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The effect of ambient light condition on road traffic collisions involving pedestrians on pedestrian crossings

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ABSTRACT

Previous research suggests darkness increases the risk of a collision involving a pedestrian and the severity of any injury suffered. Pedestrian crossings are intended to make it safer to cross the road, but it is not clear whether they are effective at doing this after-dark, compared with during daylight. Biannual clock changes resulting from transitions to and from daylight saving time were used to compare RTCs in the UK during daylight and darkness but at the same time of day, thus controlling for potential influences on RTC numbers not related to the ambient light condition. Odds ratios and regression discontinuity analysis suggested there was a significantly greater risk of a pedestrian RTC at a crossing after-dark than during daylight. Results also suggested the risk of an RTC after-dark was greater at a pedestrian crossing than at a location at least 50 m away from a crossing. Whilst these results show the increased danger to pedestrians using a designated crossing after-dark, this increased risk is not due to a lack of lighting at these locations as 98% of RTCs at pedestrian crossings after-dark were lit by road lighting. This raises questions about the adequacy and effectiveness of the lighting used at pedestrian crossings.

1. Introduction

Road traffic incidents account for 1.25 million deaths across the world each year, making them one of the leading global causes of death (World Health Organisation, 2015). Road safety is a key priority for the UK Government, due not only to the public health implications of the injuries and deaths caused but also because of the economic costs of road traffic collisions, which is estimated to be in excess of £16.3 billion per year (Department for Transport, 2015a). Vulnerable road users, which includes pedestrians, cyclists, motorcyclists and horse riders, have much higher casualty and fatality rates relative to the distances travelled, compared with other road users. For example, in 2014 in the UK there were 2108 pedestrian casualties and 36 pedestrian fatalities per billion miles travelled, compared with 273 casualties and 2 fatalities per billion miles travelled by car users (Department for Transport, 2016a). The perceived danger on roads can discourage walking and act as a barrier to active travel (Jacobsen et al., 2009), particularly for children (Lorenc et al., 2008). Reducing pedestrian casualties on the road is therefore both a direct and indirect benefit to public health.

There is a range of evidence that suggests road traffic collisions (RTCs) are more likely to occur after-dark than during daylight, and more likely to lead to a severe or fatal injury if they occur after-dark. This includes RTCs that involve a pedestrian. For example, Jensen (1998) analysed Danish pedestrian casualty data from police-recorded incidents between 1993 and 1995, and found that walking one km in darkness was 2.7 times more dangerous than in daylight in urban areas, and 7.4 times more dangerous in rural areas. Pedestrian injury records from Florida in the US between 1986 and 2003 also suggested that the odds of a fatal injury reduced by 75% at midblock locations and 83% at intersections during daylight, compared with darkness and no road lighting (Siddiqui et al., 2006). Other data has also shown that conditions of darkness are more likely to lead to severe or fatal injury compared with daylight (Tay et al., 2011; Mohamed et al., 2013; Wang et al., 2013). It is also likely that conditions tending towards darkness, not just darkness itself, can lead to increased risk of an RTC. For example, daylight running lights (DRLs) can reduce the risk of daytime RTCs (Elvik, 1996). They were introduced and have been legally required in Scandinavian countries for decades, as these North European countries receive longer periods of twilight and generally lower levels of ambient light than other countries. Such conditions can lead to increased benefit of using DRLs, compared with countries at lower latitudes (Koornstra et al., 1997). Further evidence of the impact transitions to darkness can have on RTCs is provided by the regular debate over the safety impacts of biannual transitions to and from daylight saving time. One-hour changes to clock times in Spring and Autumn can lead to abrupt changes in ambient light conditions, particularly around morning and evening rush hour times, and this has been associated with increases in RTCs (e.g. Broughton et al., 1999).

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Table 1
Key features of different types of pedestrian crossing in the UK.

Feature	Type of crossing				
	Zebra	Pelican	Puffin	Toucan/ Pegasus	Traffic signal pedestrian phase
Road surface marking	✓	x	x	x	x
Pedestrian-controlled traffic signal	x	✓	✓	✓	x
Pedestrian sensor	x	x	✓	✓	✓
Provisions for non-pedestrian road-users	x	x	x	✓	✓
Traffic signal junction	x	x	x	x	✓

According to UK data, 77% of road collisions that kill or seriously injure a pedestrian occur when the pedestrian is crossing the road (Department for Transport, 2015b). Designated road crossing locations (referred to here as pedestrian crossings, but also known as crosswalks) are a design feature of transport infrastructure in most developed countries that aims to reduce the frequency of pedestrian collisions. These aim to enhance safety by alerting the driver to the presence of a pedestrian crossing and making the pedestrian more visible to allow corrective action to be taken, using a combination of road surface markings and supplementary lighting. In the UK there are four main types of pedestrian crossing, and their key features are highlighted in Table 1. Example photographs of a typical puffin crossing during daylight and after-dark are shown in Fig. 1.

Table 2 shows past studies of pedestrian risk of accident when using road crossings. There are three limitations evident from this overview of past literature. First, findings are mixed about the effect of designated crossing facilities on the risk to pedestrians – some studies (e.g. Keall, 1995; AA Foundation, 1994; Ghee et al., 1998; Al-Ghamdi, 2002) suggest crossings have a beneficial effect on pedestrian road safety, whilst others (e.g. Zegeer et al., 2005, see Table 3; Koepsell et al., 2002; Tay et al., 2011) suggest there is no effect or even a negative effect. Second, not all studies adequately control for exposure to risk, for example by accounting for the number of crossings made by pedestrians or the traffic volumes. Such data about risk exposure is difficult to obtain, and most studies that do include measures of exposure base these on estimates from a sample time period or sample of survey respondents (e.g. Koepsell et al., 2002; Zegeer et al., 2005; Keall, 1995). Third, most studies examining collisions at pedestrian crossings can say little about whether the apparent increase in risk to pedestrians during hours of darkness applies to pedestrians using designated crossings, and whether the risk after-dark is reduced at crossing locations. This is relevant not only to the design of pedestrian crossings, but also to how they are lit.

One of the purposes of a pedestrian crossing is to make the presence of a pedestrian and the likelihood of them crossing the road more conspicuous to the driver. This requires not only alerting the driver to the fact they are approaching a designated crossing, but also making any pedestrian stood at or on the crossing visible to the driver. Supplementary road lighting is widely used to increase the visibility and conspicuity of the crossing and anything on it. Local design guides specify how a crossing should be lit, for example ILP TR12:2012 (Institute of Lighting Professionals, 2012) in the UK, AS/NZS 1158.4:2015 (Standards New Zealand, 2015) in Australasia, and IESNA RP-8:2014 (IESNA, 2014) in North America. These guides do not agree however on the type and amount of light that should be used; the UK guide for example specifies ratios for horizontal and vertical illuminances (e.g. minimum horizontal illuminance on the crossing surface is 3.5 times that of the road surface illuminance), whereas the Australasian guide suggests horizontal illuminances of 16 lx for local roads and 32 lx for arterial roads. The guidance for North America instead suggests vertical illuminances of 10 lx and 2 lx for areas of high and medium pedestrian conflict. This variation in the recommendations of different guidance documents indicates a lack of consensus on what is good lighting for pedestrian crossings. A first step in resolving this lack of consensus is understanding what impact ambient light conditions have on the risk of an RTC involving a pedestrian.

Previous research on this topic is limited (see Table 3). Zegeer et al. (2005) found little difference in the proportion of crashes occurring in darkness rather than daylight at marked compared with unmarked crossings. These proportions do not reveal anything about the risk after-dark however, as although crash frequency was compared against pedestrian volumes, these volumes were derived from sample hours that were not systematically recorded during both daylight and after-dark conditions. Olszewski (2015) found that the probability of being killed on a zebra crossing in Poland was increased by 1.95 when it was dark with road lighting on, and by 4.08 when it was dark with no road lighting. Although this data appears to show an increased risk after-dark at pedestrian crossings it does not take account of exposure rates, and it may be that the relative number of pedestrians crossing the road at a designated crossing rather than another location increases after-dark. There may also be a range of confounding variables that are associated with darkness and an increased RTC risk, and these limit what we can conclude about the impact of darkness on pedestrian injuries and RTCs based on past research. For example, reduced traffic volumes after-dark lead to increased vehicle speeds (Department for Transport, 2016b), and these are likely to increase the risk of a collision and the severity of injury to a pedestrian (Elvik et al., 2004; Rosén and Sander, 2009; Tefft, 2013). Drivers are also more likely to be intoxicated when driving after-dark, and may also feel more sleepy and drowsy due to effects of circadian rhythm, increasing the risk of their involvement in an RTC (Summala and Mikkola, 1994). Furthermore, as hours of darkness are associated with colder temperatures and wetter weather (both from a daily and a seasonal perspective), the road conditions may be more likely to lead to an RTC than they would during daylight hours. Darkness may also be associated with differences in pedestrian behaviour compared with daylight, for example pedestrians may be more likely to be intoxicated. This is largely due to the association between

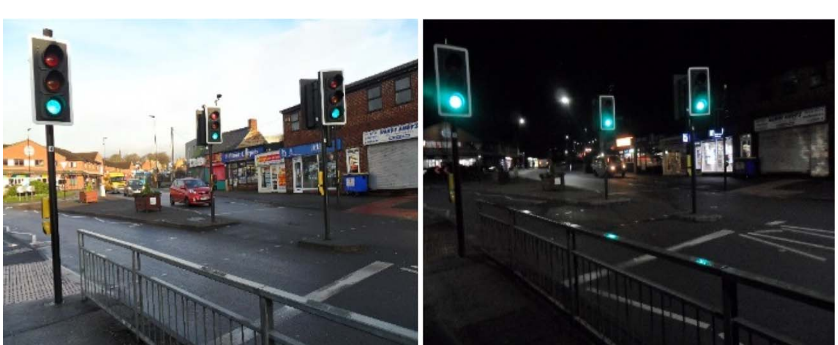

Fig. 1. Example images of a puffin crossing during daylight (left) and after-dark (right).