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Enhancing Drivers' Awareness of Passing Pedestrians with Exocentric Digital Mirrors

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ABSTRACT

Digital mirrors are expected to feature in next generation cars. Ongoing technological developments in on-board cameras, sensors and sensor-fusing algorithms means that future drivers could be provided with novel visualisations that are not limited to traditional reflective mirror views. Comparing a traditional, egocentric, rear-view side mirror with novel, exocentric top and side views (all presented on a 'digital mirror' display inside a stationary vehicle), the study exposed 25 participants to 36 passing pedestrian scenarios to explore their ability to accurately locate the pedestrian, with the ultimate aim of reduce potential 'dooring' accidents. Overall, relative depth judgement was significantly more accurate when using the exocentric top view compared to the egocentric and side views. The top view also attracted the highest confidence and lowest ratings of workload. The study demonstrates clear benefits associated with enhanced, exocentric visualisations presented on internal digital mirrors to assist drivers in hazard detection and localisation.

KEYWORDS

Driver awareness, vulnerable road user, digital mirrors, exocentric display

Introduction

Dooring accidents are a concern for vulnerable road users (VRUs), such as pedestrians and cyclists. These occur when a vehicle occupant opens their door (normally to exit their parked vehicle), without first checking for hazards around them, and subsequently strikes a passing pedestrian or cyclist. UK Department for Transport (DfT) accident data shows that eight people died and 3,108 were injured as a result of car-dooring incidents between 2011 and 2015 (Department for Transport 2018). Although the number of reported incidents resulting from vehicle door opening is relatively low compared to other types of traffic accident (Johnson, et al. 2013), an additional concern is that the passing pedestrian or cyclist may involuntarily attempt to avoid the opening door by changing their course, and this could place them at further risk, for example, facing on-coming traffic (O'Reilly 2017). Existing reflective, rear-view mirrors provide an egocentric view, that is, one in which the first-person view is provided ("from within looking out"). This can result in poor depth perception, not least because reflected objects can appear closer than they are in the real world (Flannagan, et al. 1997). Moreover, limitations in the reflective field of view can lead to blind spots, meaning that even a vigilant motorist may miss or misjudge the precise location of a passing VRU. Existing technological solutions, such as blind spot warnings that alert drivers to a potential threat, offer some support, but may lack location-specificity and also often require that the host vehicle is moving. There is, however, a general movement towards replacing traditional reflective mirrors with camera-based digital displays ('digital mirrors') that reside inside the vehicle (see Large, et al. 2016). Digital mirrors offer improvements in aerodynamics (with associated savings in fuel consumption) and vehicle styling. Such displays are also not restricted by traditional, reflective fields of view, and can subsequently be engineered to provide a more expansive rear-view.

Figure 1: Examples of egocentric (left), top view and side view (right) used in the study

In addition, images can be dynamically augmented to highlight potential hazards, or completely re-imagined, to create previously unavailable viewpoints and new digital visualisations. For example, exocentric points of view ("from outside, looking in") can be reconstructed using vehicle-based cameras and sensors (much like current camera-based parking aids) that can provide vehicle users with a novel third-person view. The aim of this study was to compare existing egocentric ('reflected') views with novel, exocentric visualisations to help drivers locate a passing pedestrian.

Method

Twenty-five participants (17 males and 8 females) took part. Participants comprised staff and students at the University of Nottingham, with ages ranging from 20 to 50 years (median, 24). All participants had self-reported normal or corrected-to-normal vision. Participants were situated within a stationary driving simulator buck. All three visualisations (Figure 1) were presented on a 7" digital display located inside the car adjacent to the A-pillar; the existing, external reflective mirror was obscured. Passing pedestrians walked parallel to the road side at a speed of either 0.91m/s (3ft/s) or 1.52m/s (5ft/s), at a distance of 0.46m (1.5ft), 1.07m (3.5ft) or 1.68m (5.5ft) offset from the side of the vehicle. This resulted in 18 test conditions (3 views × 2 speeds × 3 distances). Participants were exposed to each condition twice, resulting in 36 scenarios, presented in random order. All visual stimuli were generated using STISIM v3 software, with subsequent editing using Final Cut Pro video editor software. During each scenario, participants were asked to make a dynamic judgement about the location of the walking pedestrian in relation to the vehicle. Specifically, they were instructed to speak aloud: "unsafe", as soon as they believed the pedestrian was close enough to the car that opening the door would hit them. If they believed there was no risk of the pedestrian being hit by the door, participants remained silent. Participants were also asked to rate how confident they were using a 5-point Likert scale (where 1 indicated no confidence, and 5 indicated complete confidence) at the end of each scenario. In addition, they completed the NASA-TLX for each configuration, as a subjective measure of workload. Responses were filmed to enable the locations of pedestrians (when declared "unsafe" by participants) to be determined.

Results and Analysis

'Unsafe' locations were calculated relative to the zero datum (marked in red in Figure 2), representing the point at which the pedestrian could be hit should the door be opened. Results show that the accuracy of these differed depending on the digital mirror configuration but were also influenced by the walking speed and distance from the car. At 0.46m, a repeated-measures ANOVA revealed significant effects for View (Ego, Top and Side) ($F(2,96) = 3.3$, $p = .004$, $\eta_p^2 = .06$) and an interaction between View and Speed ($F(2,96) = 12.0$, $p < .001$, $\eta_p^2 = .20$). Pairwise comparisons (with Bonferroni corrections) indicated that Ego was significantly different to Top and Side, but no differences were revealed between Top and Side. Similarly, at 1.07m, there were significant effects for View ($F(2,86) = 34.8$, $p = .01$, $\eta_p^2 = .10$) and an interaction between View and Speed ($F(2,86) = 9.4$, $p < .001$, $\eta_p^2 = .18$). Again, Ego was significantly different to Top and Side, but no differences were revealed between Top and Side. At 1.68m, a large proportion of participants accurately recognised that the pedestrian was not at risk from dooring (Figure 3), and thus did not declare

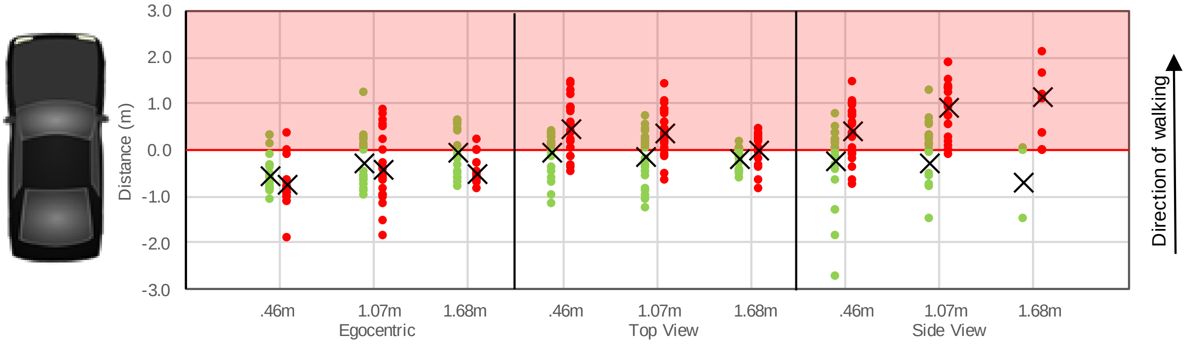

Figure 2: Locations at which participants deemed that the pedestrian was ‘unsafe’ using egocentric (left), top view and side views (right) (green = 3ft/s; red = 5ft/s; × = mean values)

“unsafe” – at this distance pedestrians were indeed outside the range of the open door. As such, there is insufficient data to make similar comparisons. However, if we assume that the zero datum point (solid red line) represents the ‘correct’ response, situations where participants accurately judged the passing pedestrian as ‘safe’ could be codified as 0. As such, there were also significant effects for View (F(2,96) = 6.0, p = .003, η_p^2 = .11) and an interaction between View and Speed (F(2,96) = 10.5, p < .001, η_p^2 = .18) at 1.68m, but the only significant difference was between Ego and Side views. It is also noteworthy that judgements made using the traditional egocentric view were largely before the pedestrian entered the critical (‘unsafe’) zone (shaded in red). For exocentric visualisations (top and side views), declarations were generally made prior to the pedestrian entering the unsafe zone at the slower walking speed, whereas declarations were made later at the higher speed – notably, when the pedestrian was already ‘unsafe’, though it is worth highlighting that only at the shortest offset would the door have actually made contact with the pedestrian. Although confidence levels were on average above the scale median of three in all situations, higher ratings were associated with the exocentric visualisations. Overall, confidence was highest for the top view and lowest for the egocentric view (F(2,598) = 44.2, p < .001, η_p^2 = .13). (Figure 3). Differences in reported confidence were significant between all three views (all p <

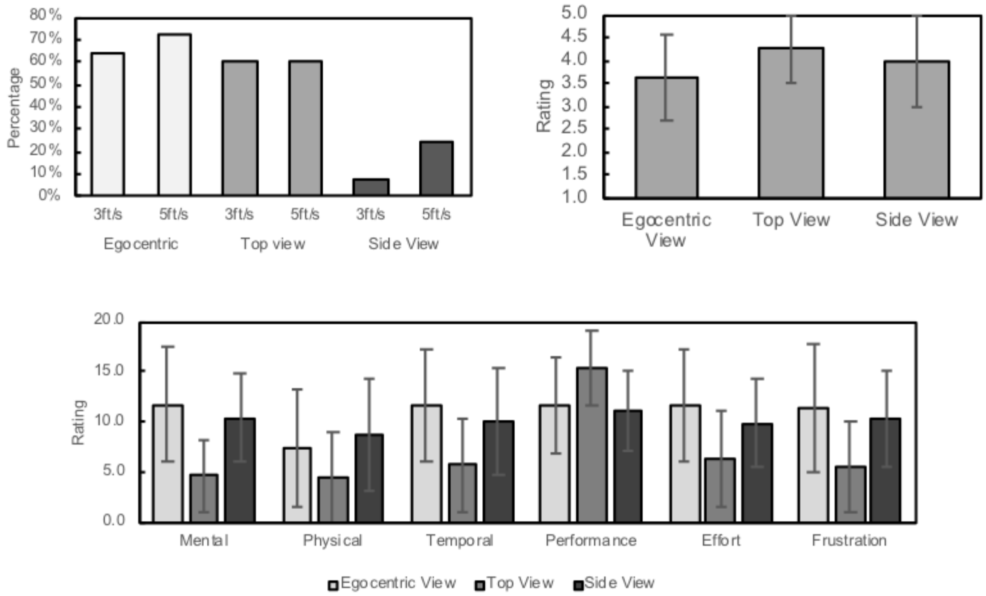

Figure 3: Percentage of participants identifying pedestrians were still at risk at 1.68m (top-left), overall confidence levels (where 1 indicated no confidence) (top-right), and NASA-TLX workload ratings (bottom), with standard deviation error bars where appropriate

.001). Results from the NASA-TLX questionnaire (Figure 3) show that the lowest Overall Workload (including the best perceived performance) was associated with the top view, whereas mean values for the other views were comparable. Differences between Overall Workload associated with the top view and the other visualisations were statistically significant ($F(2,48) = 19.3$, $p < .001$, $\eta_p^2 = .45$; all $p < .001$).

Discussion and Conclusion

Results from the study show significant differences in participants' performance (localisation/depth-judgement) between egocentric and exocentric visualisations, with the best performance associated with the exocentric top view. There was also some evidence to suggest that judgements were different depending on the walking speed of the pedestrian, particularly with the exocentric views: for higher speeds, participants often declared "unsafe" too late, indicating that the pedestrian may be struck by the door. Even though this was technically not possible, it is worth recognising that faced with such a situation, passing pedestrians (and indeed, cyclists) may change their course to reduce the threat and subsequently place themselves in further danger. During the study, 'performance accuracy' was defined as the distance from the zero datum. Therefore, although the exocentric views, and in particular, the top view enabled more accurate determination of the pedestrian's position relative to the car, it could be argued that the egocentric view might still be the most effective in reducing the number of dooring incidents due to the larger margin of safety – most judgements were made early. However, participants were specifically tasked with making an accurate judgement of the precise location of the passing pedestrian. Thus, the greater accuracy enabled by the exocentric views remains noteworthy. It is also interesting that the highest confidence and lowest workload was associated with the top view. Although further technological developments are required to support these types of representations, it is expected that such views could ultimately be reconstructed from on-board cameras and sensors integrated with 'street-view' cameras, as vehicles become increasingly connected with transportation networks and local infrastructure. Overall, the study demonstrates clear benefits associated with exocentric digital mirrors to aid the accurate localisation of passing pedestrians and offers the potential for enhanced visualisations more generally to assist drivers in hazard detection. Future work will consider additional enhancements to simplify the detection task, for example by embedding virtual 'hot' zones or targets within the images or highlighting when the pedestrian actually becomes at risk.

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