Pedestrians’ Crossing Behaviour During Car Deceleration: An Application Towards the Evaluation of eHMI for AVs

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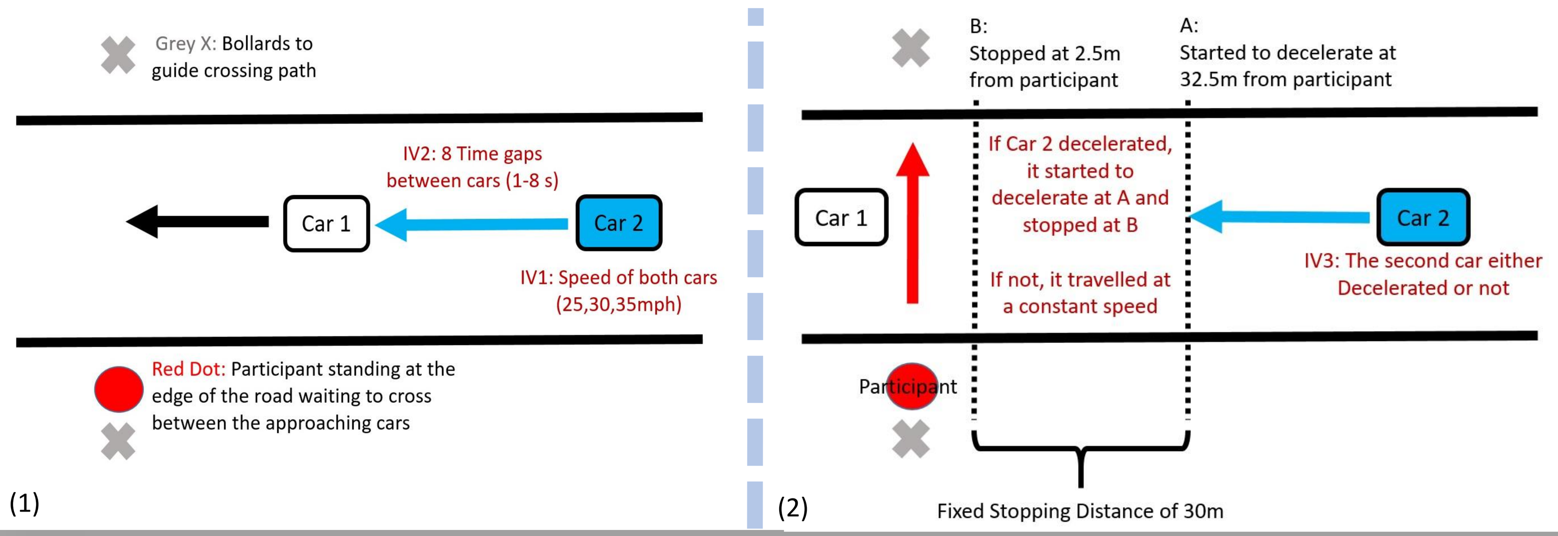
Introduction

- The AIM of this VR study was to contribute to a methodology and analysis framework that can be used in the future for evaluating the effect of externally presented Human Machine Interfaces (eHMI), on pedestrians crossing behaviour.
- Previous research has suggested the importance of eHMI for communication of information by AVs (e.g. Merat et al., 2018). It is therefore useful to observe how different eHMIs affect pedestrians’ actual crossing behaviour.
- Deb et al., (2018) used four auditory and four visual cues as eHMI, to notify pedestrians that it was safe to cross the road at an intersection. However, in this study, the vehicle always stopped at the intersection, which meant that it was always safe for participants to cross.
- Therefore, the aim of this study was understand whether pedestrians are actually able to judge the speed and deceleration behaviour of an approaching vehicle during a crossing manoeuvre, in the absence of reassurance that the vehicle will always give way.
- Research Question: Are pedestrians able to use the deceleration profile of the vehicle, its travelling speed, and the time gap between two approaching vehicles, to guide their safe crossing behaviour?

Methods

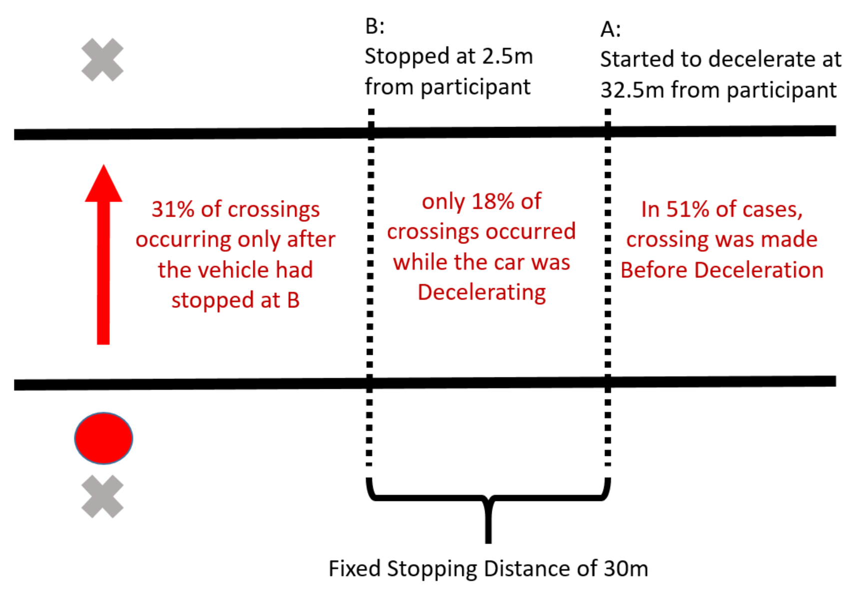
14 participants (*M* age = 27.64) wore an HTC VIVE Head-Mounted Display, and held a controller to trigger the trials. They were required to cross a 3.5m single lane road, with each trial involving two approaching saloon vehicles from the right (white vehicle, followed by blue vehicle). The participants’ task was to cross the road, between the two approaching vehicles, if they felt safe to do so. 3 blocks of 48 trials were presented to each participant (3 speeds x 8 time gaps x 2 decelerated or not).



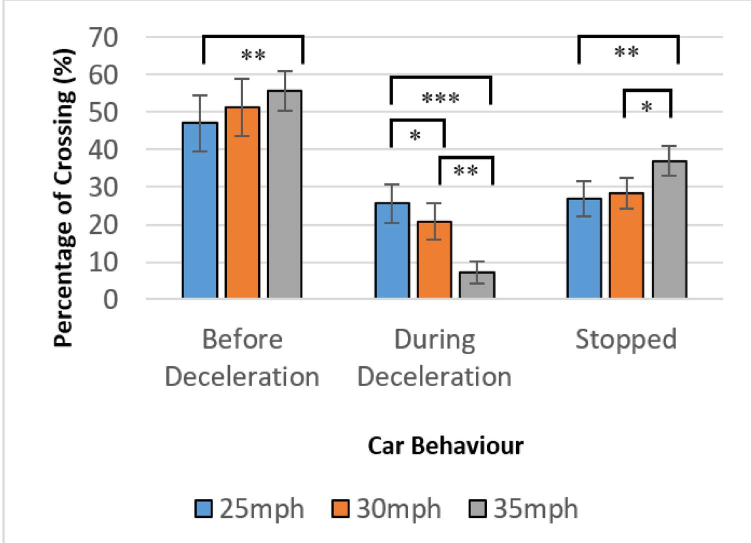
Results

- Crossing behaviour for the deceleration trials (1008 trials) was analysed, with an amalgamation of all time gap manipulations, as they were not the main interest and only used to provide variability.

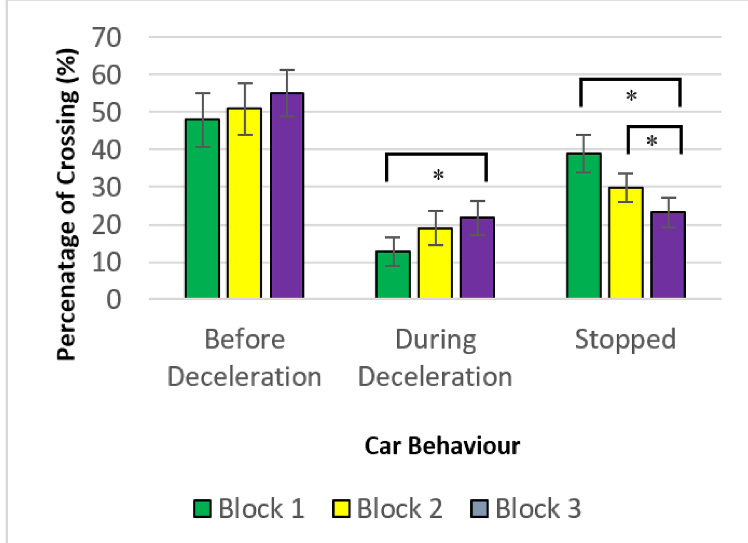
Percentage of crossings



- A 3 (25, 30, 35mph) x 3 (1st, 2nd, 3rd block) repeated measures ANOVA was conducted to investigate **the effect of speed and repeated exposure** on crossing behaviour for each segment.
- No interactions were found in any of the analyses. Therefore, the figures below provide an **overview of the main effect of speed (left) and repeated exposure (right)** on crossing behaviour.



The effect of vehicle speed on the percentage of crossings. Error bars depict S.E.M. *** $p < .001$; ** $p < .01$, * $p < .05$



The effect of repeated exposure across 3 blocks on the percentage of crossings. Error bars depict S.E.M. *** $p < .001$; ** $p < .01$, * $p < .05$

Analysing Crossing Behaviour During the Deceleration Trials

(1) Initiation time was the time taken for the pedestrian to make their first move after the rear end of the first car had crossed the crossing path.

(2) Crossing time was the time spent to cross the road.

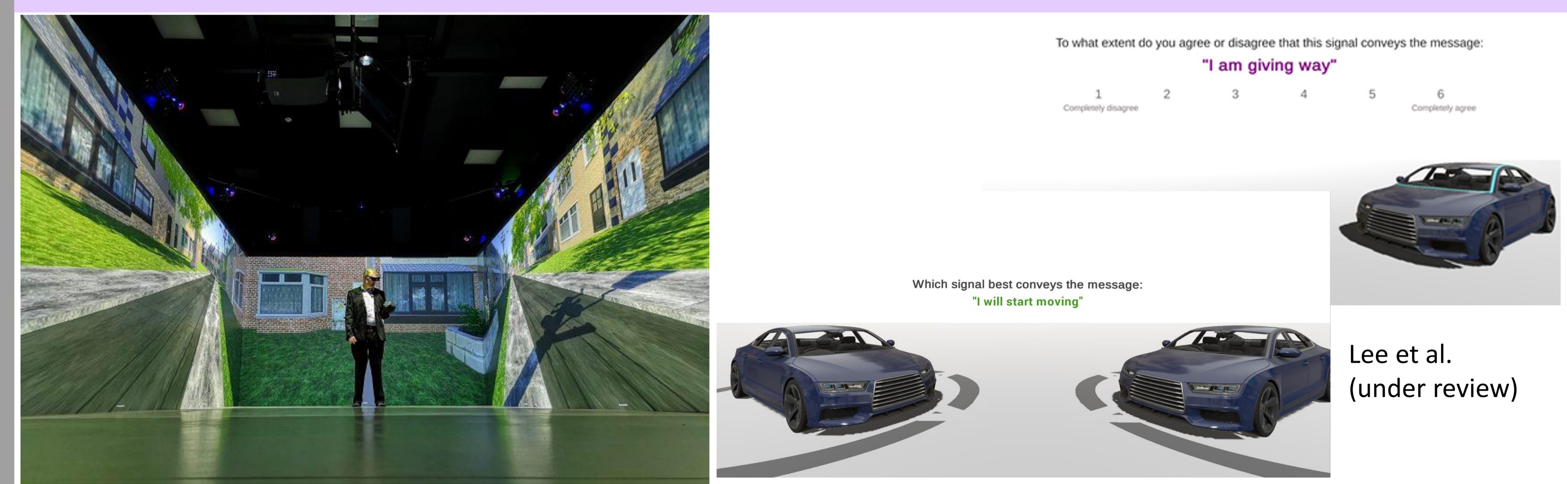
(3) Safety margin was described as the time taken for the front of the second vehicle to arrive at the crossing path after the pedestrian completed the crossing (Lobjois & Cavallo, 2007).

The effect of vehicle speed on pedestrians’ initiation time, crossing time and safety margin (s). Error bars depict S.E.M. *** $p < .001$; ** $p < .01$, * $p < .05$

Key Findings and Application

- The observed “bimodal crossing” pattern is in line with previous studies, which have used other methods to investigate pedestrian crossing. This include simulation models (Markkula et al., 2018), or test track studies (Schneemann & Gohl, 2016).
- Regarding pedestrians’ crossing behaviour, this study showed that an approaching vehicle with the highest speed produced the smallest safety margin (consistent with Lobjois & Cavallo, 2007).
- Only 18% of the crossings occurred during the deceleration trials. leaving a great margin for evaluating the effect of eHMI and changing pedestrian crossing behaviour during deceleration. Therefore, it will be interesting to see if the presence of eHMI is likely to increase crossings during deceleration, as compared to no eHMI.
- A shift of crossing decisions, and therefore a learning effect, was shown, demonstrating that pedestrians were more likely to cross early (more crossings during the decelerations, and less after the car had stopped) across blocks. This can be used to compared the **learnability** of different eHMI designs.
- This evaluation method could be applied to studying the efficiency in processing information provided by different eHMI designs, where better eHMI designs should show **a lower initiation time**, to indicate faster information processing and decision making by pedestrians, also providing **a higher safety margin**.

Future Studies



- Investigating and evaluating the effect of different eHMIs, using this methodology and analysis framework on pedestrians’ crossing behaviour in Highly Immersive Kinematic Experimental Research (HIKER) lab https://uolds.leeds.ac.uk/facility/hikerlab/
- eHMI signal designs will be chosen from Lee et al. (under review) which investigated the understanding of messages conveyed by AVs

References

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