Ghost Busting: A Novel On-Road Exploration of External HMIs for Autonomous Vehicles

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SUMMARY

The absence of a human driver in future autonomous vehicles means that explicit pedestrian-driver communication is not possible. Building on the novel 'Ghost Driver' methodology to emulate an autonomous vehicle, we developed prototype external human-machine interfaces to replace existing cues, and report preliminary, qualitative findings captured from a sample of pedestrians (n=64) who encountered the vehicle when crossing the road, as well as reflecting on the method.

KEYWORDS

Autonomous vehicles, external HMI, Ghost Driver

Introduction

There has been considerable interest amongst behavioural scientists in the potential impact of highly and fully autonomous 'self-driving' vehicles (AVs) on the behaviour of pedestrians. These vehicles, operating at SAE level 4 or 5, are unlikely to have a human driver present, and as such, explicit visual cues (head, eye, hand/arm gestures etc.) that are traditionally exchanged between a driver and a pedestrian, will be absent. Typically, these aim to establish a mutual understanding of perception (*Have you seen me?*) and intent (*Will you give way?*) (Merat et al., 2018), and are important to overall traffic safety especially in low-speed crossing scenarios in complex urban settings (Lee et al., 2020). However, studying genuine, naturalistic behaviours of people responding to AVs presents a number of challenges (limited public trials, requirement to have a 'safety driver' present etc.). A novel solution is to use a Wizard-of-Oz (WoZ) approach to give the appearance that the car is driving on its own, even when it is not. This can be achieved by hiding the driver using a bespoke seat cover (aka 'Ghost Driver' method) (Rothenbücher et al., 2016). To date, no such studies have been reported in the UK. In addition, the Ghost Driver method has not been employed specifically to evaluate external human-machine interfaces (eHMIs).

Method

A 'Ghost Driver' WoZ study was devised in which the driver was hidden in a bespoke seat-suit, thereby giving the appearance that the vehicle (Nissan Leaf) was driving by itself (Figure 1). The seat-suit was designed and fabricated to enable the driver to maintain safe control of the vehicle, whilst ensuring that they could not be seen by a passing pedestrian glancing into the vehicle. Three eHMIs were created. These were informed by the literature and prototyped using an individually addressable RGB-LED matrix and strip attached to the outside of the vehicle (front of bonnet and at top of windscreen, respectively). The eHMIs were programmed using an Arduino Mega board and manipulated with push-button controls from inside the vehicle. The eHMI designs employed varying degrees of anthropomorphism (implicit, explicit, low) to aid interpretation and build trust. The first (implicit) utilised the LED strip only and mimicked the pupillary response of an eye: lateral movement demonstrated scanning/awareness, and blinking provided an implicit cue of the

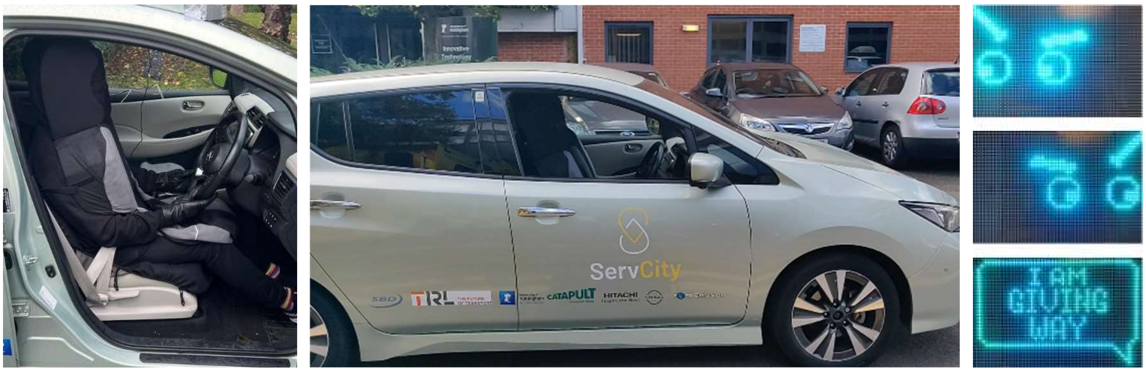

Figure 1: Driver in seat-suit (left); hidden driver operating car (centre); example eHMIs (right)

vehicle's intention to give way. The second (explicit) presented a face and eyes on the LED matrix to scan the road and used humanlike language to 'talk' to the pedestrians (Figure 1). The third (low) used a vehicle icon and vehicle-centric language on the LED matrix. For each eHMI design, four modes were created: scanning, giving way (pedestrian on right), giving way (pedestrian on left) and giving way (pedestrians on both sides of road). A second researcher, seated in the back seat of the ego-vehicle, controlled the current state of the eHMI in response to the observable pedestrians in the vicinity of the vehicle. The study took place on the extensive University of Nottingham campus and a circuitous route was selected that included several marked and unmarked crossings. Over 10 hours of video data were captured using a dashcam and GoPro recorder to document pedestrians' responses to the 'driverless' vehicle and eHMIs. In addition, researchers were located at specific crossing points, and invited pedestrians who encountered the vehicle to complete a survey.

Results and Discussion

Video analysis is ongoing. Here, we report qualitative findings, including illustrative comments and responses related to the vehicle and eHMI concepts. Results show that over eighty percent of respondents believed that the car was driving on its own ("*There was no driver, just a passenger in the back passenger seat*"), and this surprised many people ("*I was mostly just shocked, so I stopped and observed*"). Nevertheless, many people still appeared to interact with the vehicle as if a driver were present (e.g. waving to thank the vehicle for stopping), highlighting the value of an eHMI to replace interactions with a driver, and supporting the inclusion of 'human' elements. Comments suggest the eHMIs impacted the trust relationship ("*I was a bit curious about why the car stopped...when I saw the screen that explained a lot*"), with most comments suggesting support for the concepts ("*I quickly became aware that it was helping me to cross*", "*[the eHMI] matched observed behaviour of vehicle*", "*I understood that the eyes were looking out for people*"), whereas others were more cautious towards the technology ("*Would need to encounter it more before I fully trusted it*"), and a few respondents admitted being confused by the messages ("*I wasn't entirely sure what the message was conveying*"). This did not necessarily change pedestrians' crossing behaviour, with most respondents still stating that they crossed in front of the vehicle as they normally would. It did, however, inspire some additional curiosity: "*Had seen it…earlier and was curious to see if it would stop or not.*" The different eHMIs appeared to inspire different emotional responses. For example, the explicit anthropomorphism encouraged positivity – smiling, laughing etc., whereas responses to the low anthropomorphism were more perfunctory; survey ratings indicated that the latter provided the highest clarity in conveying its intended messages. Overall, initial findings support the use of a hidden 'ghost driver' to explore pedestrians' interactions with an AV, with observed behaviour suggesting high ecological validity. In addition, explicit communication using eHMIs (employing elements of anthropomorphism) appears to encourage safe crossing behaviours, help pedestrians interpret vehicle behaviour and intent, and increase their confidence and build appropriate trust when interacting with a driverless vehicle.

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