EYE CONTACT BETWEEN PEDESTRIANS AND DRIVERS

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Summary: When asked a great number of people believe that, as pedestrians, they make eye contact with the driver of an approaching vehicle when making their crossing decisions. This work presents evidence that this widely held belief is false. We do so by showing that, in majority of cases where conflict is possible, pedestrians begin crossing long before they are able to see the driver through the windshield. In other words, we are able to circumvent the very difficult question of whether pedestrians choose to make eye contact with drivers, by showing that whether they think they do or not, they can't. Specifically, we show that over 90% of people in representative lighting conditions cannot determine the gaze of the driver at 15m and see the driver at all at 30m. This means that, for example, that given the common city speed limit of 25mph, more than 99% of pedestrians would have begun crossing before being able to see either the driver or the driver's gaze. In other words, from the perspective of the pedestrian, in most situations involving an approaching vehicle, the crossing decision is made by the pedestrian solely based on the kinematics of the vehicle without needing to determine that eye contact was made by explicitly detecting the eyes of the driver.

INTRODUCTION

When asked, most people will say that they make eye contact with the driver of an approaching vehicle before crossing the road (see Survey section). This work provides evidence that this belief is largely false, and consequently, that people misattribute the source of their crossing decisions. We focus on the subclass of pedestrian-vehicle interactions where collision is possible as a consequence of non-verbal miscommunication; specifically, situations where a vehicle is decelerating for a pedestrian and there is no crosswalk or signal. While in most road contexts, the law clearly defines who has the right of way, the reality of social-interaction in these contexts is that laws are often bent and broken. Just like many drivers partake in regularly exceeding the speed limit, many pedestrians partake in regularly crossing the street when and where they are not legally allowed to.

In this world, where formal rules of the road are not strictly followed, companies and researchers are beginning to test autonomous vehicles on public roads. The important question becomes: What are the cues that pedestrians and vehicles use in ultimately resolving these situations so that we can design autonomous vehicle control algorithms that interact successfully with pedestrians. For the pedestrian, despite the aforementioned common misconception, the crossing decision appears to be primarily based on vehicle kinematics (Brewer et al., 2006). In fact, one explanation for the findings in this work is that pedestrians form models of driver intent by observing vehicle kinematics, and because of forming such a model believe that they in-fact "see" the driver. We conduct a survey and two experiments that provide evidence that they do not see the driver.

Our work has several actionable takeaways for the design of safe human-centered autonomous vehicle control algorithms (Fridman, 2018). First, the general inability to see the presence of a driver in an approaching vehicle means that an autonomous vehicle that has no driver can still, in large part, participate in the intricate pedestrian-vehicle interaction without the pedestrian being directly aware of the driver's absence. Second, this work implies that vehicle kinematics is in fact the primary form of non-verbal cuing from vehicle to pedestrian. Acceleration and deceleration of the vehicle is something that an autonomous vehicle can control precisely and directly learn from real-world interactions.

Figure 1: Sample stimuli images of approaching vehicle in 9 different lighting conditions.

RELATED WORK

Eye contact is considered to be one of the main non-verbal cues exchanged in driver-pedestrian crossing interactions. For pedestrians, making eye contact with the driver may facilitate the assessment of drivers' awareness of their presence or serve as a signal to communicate their intent to cross (Rasouli et al., 2017). With the introduction of full autonomous cars and the elimination of driver-provided cues, a lot of effort is being directed towards the understanding of the role of non-verbal cues such as driver presence and eye contact.

Driver Presence

Testing the impact of driver absence on pedestrians' crossing decisions is so far limited to Wizard-of-Oz studies due to the limited possibility of operating driverless vehicles in urban environments. In this study (Rothenb¨ucher et al., 2016), most pedestrians managed to make crossing decisions in front of a seemingly driverless car based on vehicle cues alone. 80% of the interviewed pedestrians noticed the missing driver. It's however unclear when they noticed it and how it affected their crossing decision as the interviews were conducted after the interaction.(Lundgren et al., 2017) installed a dummy wheel in a right-hand steered vehicle, where the real steering wheel was hidden from pedestrians. In contrast to the study in (Rothenb¨ucher et al., 2016), pedestrians highlighted the necessity of driver-centric cues, as many indicated they would not cross in front of a driverless vehicle due to lack of confirmation that they were seen. Conversely, most participants were willing to cross when the driver engaged in eye contact.

Eye Contact

Eye contact has long been seen as a central component of non-verbal communication in the context of pedestrian-vehicle interaction. For example, the U.S. Department of Transportation recommends pedestrians to seek eye-contact with drivers to confirm, that they are seen. However, lost in the term "eye contact" is the distinction between (1) looking to communicate an intent and (2) looking to see. The two goals are disjoint, and the degree to which each is involved in pedestrian-vehicle communication is important to understand and what our work aims to provide insights on.

To the best of our knowledge, what is not shown in any of the above studies is the distinction between a pedestrian's behavior of "seeking eye contact" and actually being able to see the driver or the driver's eyes. We believe that the latter is not feasible in most scenarios of an approaching car, but instead, the act of seeking eye contact in itself is used as social signaling (Gobel et al., 2015). This distinction is one our work seeks to highlight as we believe it is of critical importance to the design of autonomous vehicles that safely and effectively interact with pedestrians.

Figure 2: An in-cab view of the driver's body and head position used for the two experiments.

METHODS

We conducted 2 experiments to investigate humans' ability to see inside cars. Both experiments were programmed using jsPsych, a JavaScript library for running behavioral experiments in a web browser and run on Amazon's crowdsourcing platform Mechanical Turk.

In the first experiment (DRIVER) we examined whether people are able to perceive driver's presence in the car under different lighting conditions and at different distances. The second experiment (EYES) aimed at identifying the influence of lighting conditions and vehicle's distance on pedestrians' perception of driver eye-gaze.

Stimuli
The stimuli in both experiments were 4K photos (3840×2160) of a Lincoln MKZ car that were taken using a Sony FDR-AX53. We used a tripod at adult eye level (about 165cm) and took the images from the left or the right side of the vehicle to reflect pedestrians' viewing angle on oncoming cars in a crossing interaction. The stimuli dataset includes images of the vehicle in **9 lighting conditions**: 1) sunshine (left--view), 2) sunshine (right-view), 3) sun at zenith, 4) sunset (left-view), 5) sunset (right-view), 6) shadow, 7) glare, 8) tree shadow and 9) night (see Fig. 1). For each lighting condition, images are taken at **6 distances**: 5m, 10m, 15m, 20m, 25m and 30m. And for each distance and lighting condition, images are taken featuring **3 driver states**: looking forward, looking to pedestrian, absent (see Fig. 2).

Experiments
Both experiments followed a mixed factorial design with two independent variables: Distance as the within-subjects factor and lighting as the between-groups factor. Participants were assigned to a random lighting condition and performed a repeated measurement task for all distances in that particular lighting condition.

Task. At the beginning of an experiment, we collected data on gender and age and asked 2 survey questions:

- Q1: When crossing the street as a pedestrian, when there is a crosswalk and there are no traffic lights, do you try to make eye contact with the driver?
- Q2: Do you believe pedestrians are able to see through a car's windshield and make eye contact with the driver?

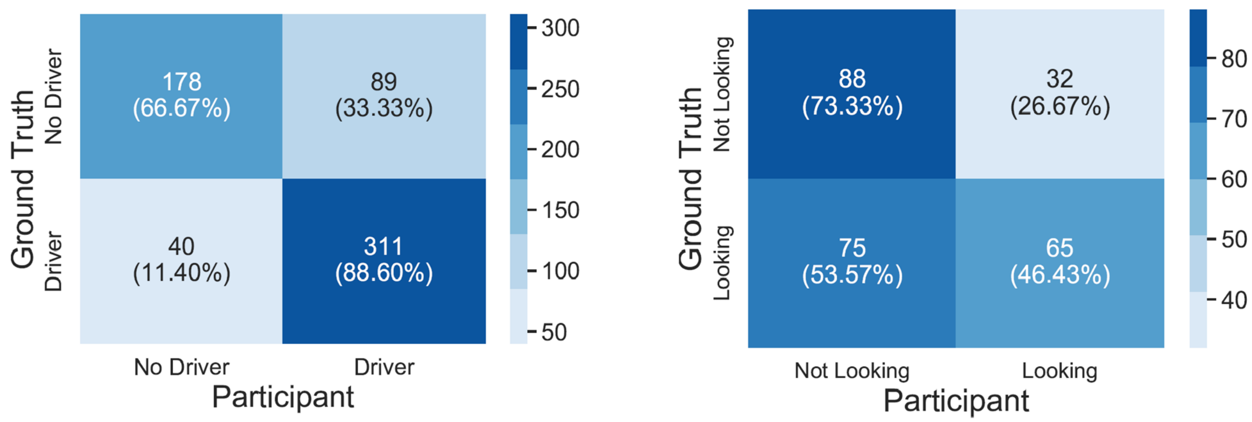
Then we showed a sample image of the stimuli dataset at a 5m distance and instructed participants to only focus on that specific car and ignore any other parked cars in the scene. The stimuli of the respective experiment were then presented to the participant in a random order accompanied by a question for each stimulus. Stimuli for one group were all in one lighting condition and 1 out of 6 distances. For each distance, 2 instances were shown of the driver states of interest to the particular experiment. After the 12 trials, we asked the participant Q2 again.

Experiment 1: DRIVER. In this experiment we included 6 distances and 2 stimuli for each distance: one where the driver is looking forward and one where the driver is absent. For each image, participants were asked to answer the question: *Can you see, if there is a driver in the car?*

Experiment 2: EYE. In this experiment we included 6 distances and 2 stimuli for each distance: one where the driver is looking forward and one where the driver is looking to the camera. For each image, participants were asked to answer the question: *Can you see where the driver's eyes are looking?*

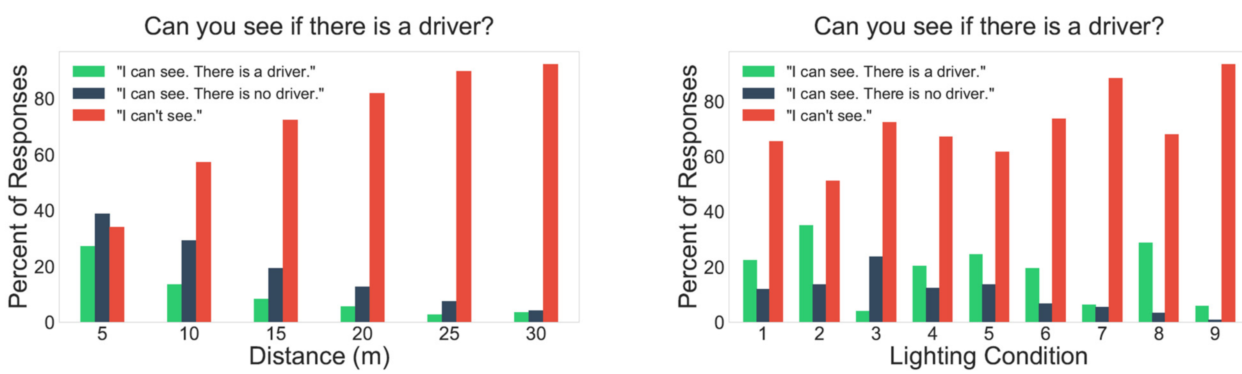
Data collection
For each experiment subjects were recruited voluntarily through Mechanical Turk. Each experiment involved 180 participants (DRIVER: 79 females and 101 males, EYES: 83 females and 97 males). Their ages ranged from 19 to 74 (M = 39, SD = 12) for the DRIVER experiment

and from 21 to 66 (M = 39, SD = 11) for the EYES experiment. Participants for each experiment were randomly assigned to one out of 9 lighting condition treatments. Hence, we had 20 participants for each lighting condition in each experiment. Subjects were rewarded 1.50 USD for participating in the EYES experiment and 0.75 USD for the DRIVER experiment. We only accepted workers who had a minimum of 1000 accepted HITs and a minimum of 98% acceptance rate. Furthermore, we measured the response times to the individual stimuli as well as the duration of the experiment and excluded data from 3 participants: 1 in the DRIVER experiment and 2 in the EYE experiment based on their very short response times (Mean response time < 400ms).



(a) Experiment 1: DRIVER (b) Experiment 2: EYES

Figure 3: Predictions of driver's presence and eye-gaze in the subset of cases where subject claimed to be able to see well enough to answer the question accurately, and then doing so erroneously a large percent of the time, especially for the eye-gaze detection experiment.

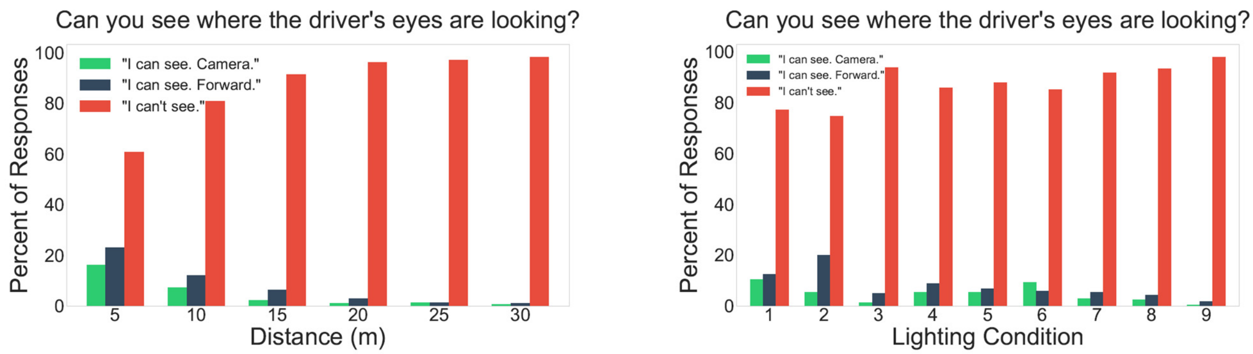


(a) DRIVER: grouped by distance (b) DRIVER: grouped by lighting

Figure 4: Effect of distance and lighting on perception of driver's presence.

RESULTS

Survey. Prior to the experiment, when asked whether the subject usually seeks eye contact with the driver when crossing the street (Q1), 122 (34%) said they don't seek eye contact while 235 (66%) indicated they do. This confirms our assumption about the relevance of eye contact as a non-verbal communication mechanism in traffic. To the question about the feasibility of such



(a) EYES: grouped by distance (b) EYES: grouped by lighting

Figure 5: Effect of distance and lighting on perception of driver's eye-gaze.

communication through the car's windshield (Q2), 282 (79%) subjects said they believe they can see through cars' windshields and engage in making eye contact with the driver whereas only 75 (21%) believed they are not able to do that. Interestingly, when asked the same question (Q2) again after the experiment, we noticed a decrease in the total number of people saying they believe they are able to see through windshields from 282 (79%) to 190 (53%). Particularly, one third of the participants (104) change their response from "Yes, I am able to see through windshields" to "No, I am not able to see through windshields" after the experiment.

Table 1. Experiment results

	Number of responses	Number of "I can't see"
DRIVER	2148	1530 (71%)
EYES	2136	1876 (87%)

Experiment. Table 1 shows that 71% of the responses to stimuli were I can't see, meaning that in all those instances subjects were unable to see whether there was a driver or not. In the EYES experiment, subjects were not able to detect the driver's eye-gaze in 87% of the instances. Decisive responses, where subjects made a prediction, had an accuracy of 0.8 for the DRIVER experiment and 0.6 for the EYES experiment (see Fig. 3).

In Fig. 4 and Fig. 5 we group the responses by the distances and lighting conditions. For all lighting conditions and all distances except at 5m distance, the highest number of responses to the stimuli is I can't see. The percentage of such uncertain responses is around 60% at 10m and increases with more distance to reach 90% of all responses at a 25m distance in the DRIVER experiment. For the perception of driver's eye-gaze, responses indicate that participants can't see whether a driver is looking at them at a 5m distance (60% I can't see). This rises up to 91%of responses at 15m distance. These results show that seeing through cars' windshields is very limited and can only occur at very short distances to the vehicle. When applied to the crossing context, this implies that crossing pedestrians don't mainly rely on driver-provided cues (eye contact) as those usually occur when the decision to cross has already been made. For example, assuming a speed of 20mph, the time to collision at 30m is 3.3s which is below pedestrians' threshold for crossing. Hence, a pedestrian must have made their decision to cross before the car reaches 30m distance at that speed. Pedestrians are therefore not necessarily basing their decision of crossing on the perception of driver-related cues.

Based on this data, we conclude that pedestrians are often unable to see through the windshield and engage in making eye contact with the driver. According to the answers to Q1 and Q2, however, a common contradicting belief exists about our ability to make eye contact. Assuming pedestrians look towards the windshield when communicating with the driver, perhaps there is something functionally similar to an eye-gaze that provides them with acknowledgment and therefore simulates engaging in eye contact with the driver.

CONCLUSION

In this paper we examine the role of eye contact and driver presence in vehicle-pedestrian interactions. We challenge the common notion that decision making in crossing interactions is largely influenced by direct human-to-human communication between pedestrians and drivers. We show that over 90% of people cannot determine the gaze of the driver at 15m and see the driver at all at 30m. This means that, for example, given the common city speed limit of 25mph, more than 99% of pedestrians would have begun crossing an unsignalized crosswalk before being able to see either the driver or the driver's gaze (Brewer et al., 2006). In other words, from the perspective of the pedestrian, in most situations involving an approaching vehicle, the crossing decision is made by the pedestrian solely based on the kinematics of the vehicle without needing to determine that eye contact was made by explicitly detecting the eyes of the driver.

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REFERENCES

M. A. Brewer, K. Fitzpatrick, J. A. Whitacre, and D. Lord. Exploration of pedestrian gap-acceptance behavior at selected locations. *Transportation research record*, 1982(1):132–140, 2006.

L. Fridman. Human-centered autonomous vehicle systems: Principles of effective shared autonomy. *CoRR*, abs/1810.01835, 2018. URL https://arxiv.org/abs/1810.01835.

M. S. Gobel, H. S. Kim, and D. C. Richardson. The dual function of social gaze. *Cognition*, 136:359–364, 2015.

V. M. Lundgren, A. Habibovic, J. Andersson, T. Lagström, M. Nilsson, A. Sirkka, J. Fagerlönn, R. Fredriksson, C. Edgren, S. Krupenia, et al. Will there be new communication needs when introducing automated vehicles to the urban context? In *Advances in Human Aspects of Transportation*, pages 485–497. Springer, 2017.

A. Rasouli, I. Kotseruba, and J. K. Tsotsos. Agreeing to cross: How drivers and pedestrians communicate. In *Intelligent Vehicles Symposium (IV), 2017 IEEE*, pages 264–269. IEEE, 2017.

D. Rothenbücher, J. Li, D. Sirkin, B. Mok, and W. Ju. Ghost driver: A field study investigating the interaction between pedestrians and driverless vehicles. In *Robot and Human Interactive Communication (RO-MAN)*, 2016 25th IEEE International Symposium on, pages 795–802. IEEE, 2016.