Feeling-of-Safety Slider: Measuring Pedestrian Willingness to Cross Roads in Field Interactions with Vehicles

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ABSTRACT

Can interactions between automated vehicles and pedestrians be evaluated in a quantifiable and standardized way? In order to answer this, we designed an input device in the form of a continuous slider that enables pedestrians to indicate their willingness to cross a road and their feeling of safety in real time in response to an approaching vehicle. In an initial field study, 71% of the participants reported

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that they were able to use the device naturally and indicate their feeling of safety satisfactorily. The feeling-of-safety slider can consequently be used to evaluate and benchmark interactions between pedestrians and vehicles, and compare communication interfaces for automated vehicles.

INTRODUCTION

In the discourse regarding the safe deployment and effectiveness of automated vehicles (AV), the safety of vulnerable road users (VRU) like pedestrians and cyclists is of utmost importance. A recurring question in the field is how VRUs can effectively interact with and understand the intention of an AV in the absence of an attentive human driver and non-verbal human-centric communications like eye-contact and gestures [11, 12]. Research on AV-VRU communication has produced some promising concepts of interfaces that allow the vehicle to communicate its intent to road users in its environment [4, 7, 9, 10]. However, there is no standardized way yet to evaluate the interaction between a vehicle and a pedestrian. Many initial tests conducted to validate novel concepts – particularly with respect to pedestrians – are done by showing the concepts to the participants in Virtual Reality (VR) or video, and asking them to evaluate the concept using standardized User Experience Questionnaires, Likert Scales, or Self-Assessment Manikins [9]. Such evaluations often call attention to their own limitations in their ecological validity. Studies have also focused on using some form of evaluation of pedestrians' 'gap-acceptance behavior', 'feeling of safety' or 'willingness to cross a road in the presence of an approaching vehicle' [1, 2, 5]. Such works also acknowledge the limitations of VR or video-based studies stressing that compared to real-world studies, given the absence of a real risk, participants may act less realistically.

In order to address this limitation, a few studies have conducted AV-VRU interaction evaluations in an outdoor setting [3, 8]. Outdoor and field experiments in this field which involve real cars and pedestrians are notoriously difficult to orchestrate because of the covariates of the setup and the difficulty in controlling the environment [6]. In these experiments, the authors either measured pedestrians' road-crossing reaction times, or asked pedestrians to observe an approaching vehicle before answering a few questions. On the one hand, asking a pedestrian to cross the road in front of an approaching vehicle in an experimental condition has twofold challenges: 1) It is difficult to ensure participant safety at all times and thus achieve ethical approval for such studies, and 2) Crossing the road is a one-time interaction – once the pedestrian has crossed the road, the interaction is over. It is then no longer possible to monitor how the interaction changes as the vehicle comes closer to the pedestrian. It is also difficult to introduce a good "starting point" for the interaction: if the vehicle is too far away, the pedestrian will just cross as the vehicle is not yet a threat to safety. This does not allow for a thorough understanding of the pedestrian's behavior. On the other hand, asking a pedestrian to answer questions *after* looking at an approaching vehicle is, by nature, not a real-time measurement. Post-hoc responses may not appropriately represent the interaction, and important

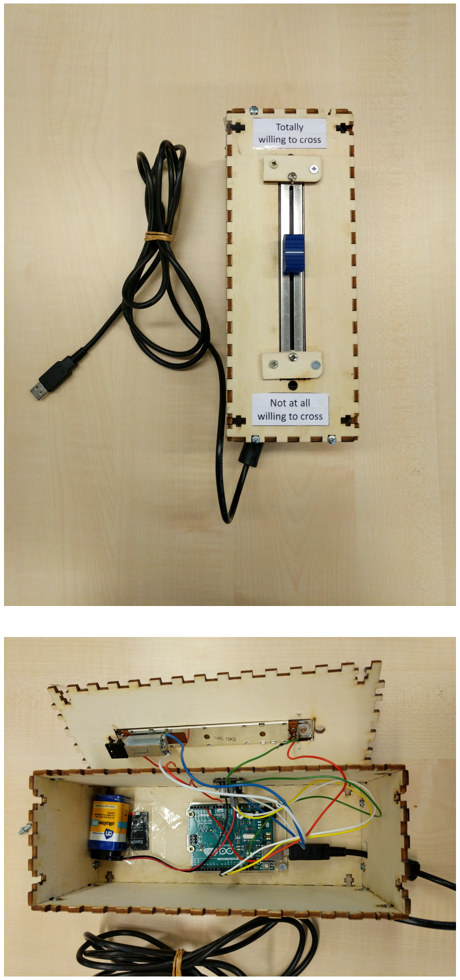

Figure 1: The input device - a continuous slider used to receive pedestrian feedback to an approaching vehicle

information may be lost. Given these limitations, a new method is needed for the assessment of pedestrians' interaction with an approaching vehicle. This should allow researchers to investigate pedestrians' behavior in a continuous, real-time manner. Such a method would provide a standardized way of measuring pedestrians' interaction with any kind of vehicle – automated or manually-driven. Data collected through this method could then be used as a benchmark, when comparing pedestrians' interactions across different vehicle interfaces and driving modalities.

CONCEPT

To effectively investigate the interaction between a vehicle and a pedestrian, we developed a device that allows pedestrians to continuously indicate in real time their feeling of safety in the presence of an approaching vehicle. We posit that the willingness of a pedestrian to cross a road follows directly from their feeling of safety. If a vehicle is far away, pedestrians are typically willing to cross as the vehicle does not breach their safety zone. As the vehicle comes closer, it enters the 'ambiguity zone', where the feeling of safety likely depends on a number of parameters including the speed of the vehicle and its motion patterns and behavior (whether it is slowing down, maintaining speed, or acting otherwise). All these factors likely influence a pedestrian's willingness to cross. It is thus interesting to monitor how the pedestrian's willingness to cross changes as a function of the car's distance, speed, and driving behavior. We therefore use pedestrians' willingness to cross as a surrogate measure for their feeling of safety. This information is gathered using an input device, which is in the form of a slider.

The device used was a motorized slide-potentiometer, connected to a tablet computer using an Arduino Uno. The Arduino was programmed to take a reading of the current value of the potentiometer every 100 milliseconds. The extremities of the potentiometer were mapped to 0 and 100, so that the values correspond to "Not at all willing to cross" (No feeling of safety) to "Totally willing to cross" (Complete feeling of safety) respectively. As opposed to a simple potentiometer, the motorized potentiometer provides the possibility to reset the starting position of the slider, and when being operated, also provides feedback with respect to the default (starting) position. The device was enclosed within laser-cut panels to form a portable and handy housing (Figure 1).

EXPERIMENT

Apparatus: To validate the effectiveness of such an input device in the real world, an outdoor experiment was set up. Initially, the feedback and reset functionality of the device was tested with a pilot. There was an argument for setting 0 (No feeling of safety/ Not at all willing to cross) as the default "home" position of the slider, so that a participant would have to exert force to show willingness to cross, and if the participant let go of the slider, it would go back to 0. This was to counter the potential situation that the participant forgets to manipulate the input in real time and leaves the

Figure 2: Experiment setup - the pedestrian stands on the pavement at the edge of the road with the input device in his hands, and manipulates the slider in real time as the vehicle approaches

slider at a certain position even though the actual feeling of safety might have changed. However, pilot runs of the study showed that the force feedback was perceived as unnecessary interference. The entire interaction took less than 12 seconds, which is not long enough to incite boredom or cause the participant to 'forget' their place on the slider and leave it unattended. As a result, the force feedback was turned off, and the slider was not configured to return to a home position.

Participants and task: The device was tested with 28 participants (N = 28, 10 male, 18 female, between ages 20 - 33, sd = 3.21). Each participant, acting as a pedestrian, was asked to stand with the input device on the edge of the pavement of a long, unmarked road (not at a crossing), and was asked to evaluate their feeling of safety about crossing the road while observing an approaching vehicle (Figure 2). The road was otherwise empty.

Procedure: The vehicle exhibited one of two behaviors: 1) Driving at a constant speed of 50 km/h (non-yielding behavior), or 2) Slowing down to a gentle, purposeful stop in front of the pedestrian from a speed of 50 km/h (yielding behavior). The vehicle started from a distance of 200 m away from the participant and accelerated to 50 km/h. In the conditions showing non-yielding behavior, the vehicle kept driving at 50 km/h until it had passed the pedestrian. In the conditions showing yielding behavior, the vehicle started braking steadily and gently at 40 m away from the pedestrian, until it came to a stop 2 m from the pedestrian. The pedestrian was asked to continuously indicate, by manipulating the slider in real time, their willingness to cross the road as the vehicle came closer. The pedestrian's response was measured with the car being 100 m away until 5 m away, at 5 m intervals. The road was prepared in advance with discreet visual markers, and a video of the approaching vehicle was captured while the pedestrian recorded their real-time response. The video and participant responses were synchronized and coded post-hoc to align the pedestrians' responses at specific vehicle distances. The experiment was run between 09:00 and 16:00 hours (daylight conditions). Participants were exposed to 4 practice trials (2 yielding and 2 non-yielding, presented in a randomized order). After this, 8 real trials were conducted (4 yielding, 4 non-yielding, also presented in a randomized order). At the beginning of each trial, the starting position of the slider was manually reset to 100 (Complete feeling of safety/ total willingness to cross), as this corresponded to the vehicle being too far away to be of concern.

RESULTS AND DISCUSSION

The participants recorded their willingness to cross, and correspondingly, their feeling of safety, using the input device. A sample of the results from one participant (P13) is shown in Figure 3. The 4 responses, each over different vehicle behaviors (yielding vs. non-yielding), are shown in the graphs. Across the trials, a clear pattern emerges. When the vehicle is yielding, the feeling of safety decreases continuously until the car is close enough (15 - 20m) and slow enough to assure the driver that the vehicle is indeed yielding. When the vehicle is not yielding, the feeling of safety continues to drop

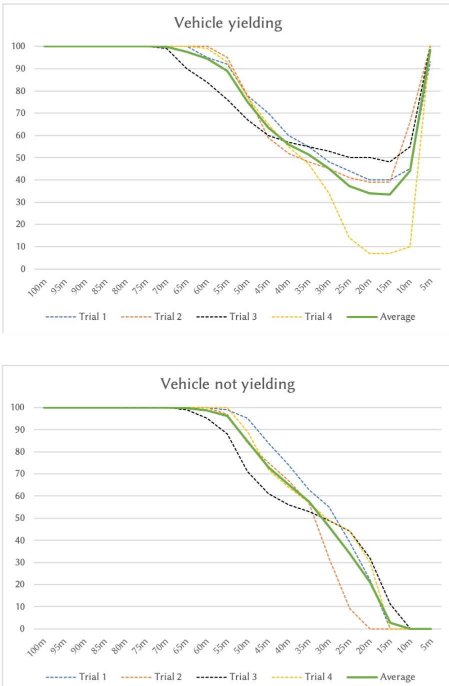

Figure 3: Results of one participant: Y axis - Feeling of safety, X axis - Distance of vehicle from pedestrian. The graph of pedestrian willingness to cross shows a general trend across 4 trials within different vehicle behaviors (yielding vs. non-yielding), and provides a good way to assess feeling of safety. The dotted lines show the individual trials, and the solid line shows the smoothed average. Extended to automated vehicles, this potentially offers a way of gauging the effectiveness of an interface in communicating with pedestrians.

sharply as the vehicle passes the pedestrian. Most participants (20/28 = 71.4%) reported that they were able to use the device naturally and felt that they were able to successfully indicate their willingness to cross using the device.

In this experiment, the vehicle was driven manually, the interior of the vehicle was dark (which made it difficult to observe the driver), and no nonverbal communication (such as eye-contact or gestures) were offered. In the future, the same form of measurement can be used to investigate interactions with an AV. This will offer the possibility to compare and contrast the interactions with manually-driven vs. automated vehicles. Furthermore, this methodology may be used as a standardized way to benchmark and compare the effectiveness of different Human-Machine Interfaces of AVs used for communication with pedestrians. The distance of the vehicle from the pedestrian at which the feeling of safety goes below a certain threshold can be easily compared for differences (e.g. when the feeling of safety drops below 50). Depending on the research question, the value of the threshold can be manipulated.

In this experiment, the vehicle was driven at a maximum speed of 50 km/h, and the data was sampled at 100 ms, which resulted in one measurement every 1.39 m at the minimum. The granularity of the data points can be adapted easily by adjusting the sampling rate if the vehicle is driven at a different speed, or if the precision requirements are higher.

An interesting point to note is that the act of crossing the road is a binary behavior - a pedestrian either decides to cross or not to cross. However, in this design, it was important to account for the ambiguity in this decision-making process. While the average ambiguity becomes clearer with an increased sample size for a binary response, the continuous nature of this input device allows the study of feeling of safety even with one participant. Therefore, the input device was particularly chosen to be a slider as opposed to a Crossing/Not-crossing button. A slider was considered specifically as opposed to other forms of linear input devices (such as a squeezing device measured by a pressure sensor) because of ease of calibration - the slider has physical 'end-points' that affords an intuitive mapping to the extremities of the scale, and is independent of a participant's physical strength.

CONCLUSION

The use of a slider as an input device towards investigating how pedestrians' feeling of safety changes during interaction with an oncoming vehicle appears to work well. This can be a valuable approach for similar research with pedestrians and automated vehicles in evaluating the efficacy of interactions. With this experimental design as a platform for further field studies, pedestrians' interactions to vehicles in real life can be examined. Such data can be used for effective evaluation and design of interfaces. This paper presents the promising results from a preliminary investigation on a continuous, real-time method of capturing interaction data. However, further research is required to validate its efficacy with respect to other approaches of evaluating AV-VRU interaction.

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