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Interaction autonomous vehicle - pedestrian: dynamic vehicle behaviour as a function of subjective safety perception

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Abstract— **In this work we propose to change the dynamic of an autonomous vehicle as the main form of giving a reassuring feedback to a would-be crossing pedestrian. The subjective perception of the safeness of a crossing should be always taken into consideration, and we propose to associate it to the different classes of pedestrian vulnerability. In order to define a dynamic for each class of pedestrians, we propose to assess their safety perception while crossing in the presence of a self-driving vehicle. Besides more conventional self-assessment questionnaires, we here propose to also rely on physiological responses to evaluate the emotional and affective state of pedestrians during the interaction with an autonomous vehicle. To this end we have designed an experiment in a controlled urban-like crossing environment and we have prepared a proper self-driving vehicle.**

I. INTRODUCTION

The vehicle-pedestrian interaction while crossing a road is a crucial aspect in the perception of safe walking, and subjective perceptions must be considered, due to the different degrees of vulnerability (age, gender, disabilities) of pedestrians. In future scenarios, self-driving vehicles will circulate in urban environments, and will need to adapt to the feelings of pedestrians, and to be able to give them effective feedback, especially when dealing with the most vulnerable ones, such as elderly and impaired people [1]. In case of traditional vehicles, the establishment of eye contact between pedestrians and drivers is one of the important clues to provide a perception of safety, for a crossing pedestrian. In this research we investigate whether another form of communication, *i.e.,* the change of dynamic, can be established between the subject and the vehicle, in order to increase the subject perception of safety. As introduced by Franzoni et al. in [2], the new era of information society has produced a significant revolution related to the creation of strong interactions between humans and machines. In particular, there is no field related to robotics and AI that is not, directly or indirectly, related to the implementation of emotional values. Emotion recognition represents a fruitful research direction for the *safe walking perception* field, to assess and introduce quantitative evaluation tools for the measurement of *affective walkability* [3]. Thus we here propose to rely on physiological responses to assess the subjective perception of safe crossing, measuring and recognizing the affective state of pedestrians of various age, with respect to different vehicle dynamic behaviours. The final goal of this investigation is to define adaptive dynamic behaviours of self-driving cars, with respect to different classes of pedestrians, characterized in terms of their safety perception.

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II. SAFETY PERCEPTION ASSESSMENT THROUGH AFFECTIVE STATE RECOGNITION

In this work we present the experimental protocol designed to assess the safety perception of different categories of pedestrians while crossing a road in the presence of a self-driving vehicle. We have been encouraged to perform this research, by having obtained positive results in a previous experiment on the pedestrian interaction with traditional vehicles, whose aim was to collect movement and physiological data as reliable indicators of stress, during safe walking and road crossing [4]. Physiological responses, which are uncontrolled and autonomous reactions of our nervous system, can be considered honest indicators of our emotions and mood, and are nowadays widely adopted to recognize affective states [5]. Thanks to the development of the technology, several sensors can be easily integrated into smartphones or wearable devices [6], making them more comfortable and usable even in case of elderly people. In our investigation we consider Plethysmogram (PPG) and Galvanic Skin Response (GSR), as they are both well indicated to detect emotional arousal. Arousal is a physiological and psychological state that can be related to sensory alertness, mobility, and readiness to respond, activated as a defensive reaction to preserve safety. Moreover, motion data both physiological, measuring the muscle activity with Electromyogram (EMG), and inertial will be adopted, in an integrated approach to the study of pedestrian walkability.

III. EXPERIMENTAL DESIGN

To analyze the affective state of people when crossings with an approaching autonomous vehicle, we designed a controlled experiment. The hypotheses we want to verify are:

1) whether the perceived safety of a pedestrian is inversely proportional to the perceived degree of autonomy of the vehicle;
2) whether the perceived safety of a pedestrian is directly proportional to the *safety gap*. We define the safety gap as the distance between the pedestrian and the vehicle, after the vehicle has changed its dynamics, *i.e.,* completed a steep reduction of its speed, to notify the pedestrian of having been perceived;

3) whether the perceived safety of a pedestrian is inversely proportional to her/his age.

The experiments will take place in an area closed to public traffic, where we will reproduce a pedestrian crossing. A vehicle will approach the crossing area, starting stationary and rapidly accelerating up to a top speed of about $30km/h$. After reaching that speed, the vehicle will keep it, until a strong reduction will take place at the predefined safety gap. While in the safety gap, the vehicle will keep a very low speed, so as to invite the pedestrian to cross, and will completely stop whenever it detects a crossing subject.

The path of the vehicle, before reaching the crossing area, is 45 meters long (including the safety gap); we will test different safety gaps, to verify hypothesis 2.

Even tough the vehicle will move autonomously, a passenger on-board will be in charge of operating an emergency stop button, that will rapidly stop the vehicle, so to be redundant *w.r.t.* the obstacle detection subsystem, and doubly-avoid to harm the participants to the experiment. The operator will be sitting on the passenger side, and apparently reading. The video from a forward-looking camera will be displayed on a monitor. Both the safety button and this monitor will be hidden to the pedestrian, so that the vehicle will be perceived as being autonomous, *i.e.,* not supervised by a human operator.

Two groups of people will participate in the experiments: young adults (age between 18 and 35 years) and elderly people (aged beyond 65 years). Participants of both groups will try to perform the crossing, one at a time, while the vehicle will be approaching. The variables of our experiments are: the safety gap, the degree of autonomy of the vehicle (we will test also a variant where the operator will be seated at the driver side, hands on the wheel, and looking at the pedestrian), and the age of the pedestrian. The pedestrians will wear the sensors for collecting physiological responses.

IV. THE VEHICLE

The autonomous vehicle used for the experiment is a prototype, equipped with a complex sensor suite. Relevant for this experiment are the two front-corner-mounted one-scanning-plane Light Detection And Rangings (LiDARs), to detect obstacles (including pedestrians), and one of the front cameras, displayed to the operator in the passenger seat, to introduce the above mentioned redundancy in obstacle detection. Specifically for this experiment, we will also use an external fixed camera, to record the crossing area. These recordings will be useful to analyze the behaviour of the pedestrians. All these sensors will be synchronized and their relative pose calibrated.

The software architecture of the vehicle base on ROS [7], to ease the communication between the different components. For the localization of the vehicle, we will use a Montecarlo localization algorithm [8], which base on LiDAR scans and wheel encoders. Of course, we will also need a map, which will be built using GMapping [9].

Since we want the vehicle to follow a fixed path, with a fixed velocity pattern, we developed two ROS nodes: one to record a path while manually driving the vehicle (to be done during the experiment's setup), the other to send the recorded path to the ROS navigation stack. To make the vehicle follow the path, we use our own implementation of a sample based motion planner, based on Schwesinger *et al.* [10].

V. CONCLUSIONS

With this experiment we aim at profiling pedestrians *w.r.t.* their safety perception. Furthermore, *w.r.t.* the profiles, we would like to define specific safety gaps, *i.e.,* dynamic behaviours of the vehicle, as a reassuring feedback for a would-be crossing subject. The adaptation of the safety gap to the class of pedestrian is technically possible, as it requires the sensing suite of the vehicle to be able to classify the pedestrians nearby the crossing, while the corresponding dynamic behaviour is just executed. The success of the physiological data collection is related to the significant improvements in sensor technology, that allow to easily integrate several sensors into smartphones or wearable devices and in the new frontiers that the advent of 5G will open in the context of continuous and ubiquitous communication connecting anybody to anything [11]. The results of this experiment can also provide hints about the effectiveness of CAVE Automatic Virtual Environment (CAVE) for experimentation in this area.

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