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The Impact of Vehicle Appearance and Vehicle Behavior on Pedestrian Interaction with Autonomous Vehicles

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Abstract
In this paper, we present the preliminary results of a study that aims to investigate the role of an approaching vehicle's behavior and outer appearance in determining pedestrians' decisions while crossing a street. Concerning appearance, some vehicles are designed to look more assertive than others, and it is believed that vehicle appearance may reflect the driver's social behavior in traffic. In the case of autonomous vehicles, since the human driver no longer controls the vehicle's action, the question arises whether pedestrians treat autonomous and manually-driven vehicles differently when deciding to cross the street. We devised an experiment to determine the impact of the behavioral and physical attributes of a vehicle on pedestrians' road-crossing decisions, both for manually-driven and autonomous vehicles. Preliminary results show that in both cases, distance and speed play a dominant role in pedestrians' decision to cross a road when compared to the vehicle's size and appearance.

Author Keywords
Pedestrians; Vehicle appearance; Vehicle behavior; Pedestrian behavior; Autonomous vehicles; Road crossing behavior;

CCS Concepts
Human-centered computing ~ User studies

Introduction

When pedestrians want to cross the street while a vehicle is approaching, they need to decide whether to cross the street in front of the vehicle or wait until it has passed. It may be assumed that several factors influence the decision of the pedestrian: pedestrian-related factors such as mobility, assertiveness and possibly the context (being in a hurry or not, as well as location on the road), but also vehicle-related factors, both behavioral (distance, speed and acceleration) and appearance. Concerning appearance, characteristics such as size, color, design and brand may influence people's expectations about whether the vehicle is likely to give right of way or not. Vehicle appearance plays a significant role in the perception of the vehicle's sociability and power [8] and can affect the car's perceived aggression or assertiveness, or contrarily, its cuteness or friendliness. The appearance of a vehicle often lends itself to stereotypes about the kind of people who own them, and their driving behavior [3, 4]. A pedestrian may look at a vehicle and instantly make assumptions about the vehicle's assertiveness, potential to yield, etc., and consequently determine how to interact with it. If a vehicle is autonomous, irrespective of how the vehicle looks from the outside, the behavior of the vehicle is controlled by a computer algorithm and not by a human driver. When developing autonomous driving technology and designing autonomous vehicles, a relevant question is therefore whether to take appearance into consideration in order to facilitate the interaction between pedestrians and autonomous vehicles.

Auto-manufacturers and researchers in the field have chosen to follow different schools of thought in the matter of how the design of an autonomous vehicle can play a role in the conveying the subtle messages behind a car's attitude. For instance, Volvo has chosen their first test autonomous vehicles to look inconspicuous and like any other ordinary vehicle, to address the concern of invoking abusive or bullying behavior from other road users [1]. In contrast, the well-known Google self-driving car was purposefully designed to look cute in order to help pedestrians regard it as a harmless entity, as well as impart the sense that it is not a high-speed vehicle [2, 5]. Other car manufacturers employ special design techniques to help their concept vehicles stand out. Many companies highlight their autonomous vehicles to be futuristic and capable of much more than what people would expect of an ordinary car.

While auto manufacturers are eager to set themselves apart as pioneers of future technology and lifestyle solutions, it remains to be seen if designs that are remarkably different from what people are used to seeing around today will affect people's reactions in the presence of such vehicles. This research thus attempts to answer a fundamental question of the impact of vehicle design within the context of vehicle autonomy. The results can play a role in suggesting the direction of the communication paradigm that autonomous vehicles should adopt to ensure a non-disruptive acceptance into society. To this end, the current study aims to investigate the effects and contribution of vehicle appearance and vehicle behavior on pedestrians' interaction strategies with an autonomous vehicle, in comparison with their interaction strategies with manually driven vehicles. We address the following two questions:

Figure 1: Sample of images used for survey to gain insight about the perception of vehicle appearance

Figure 2: Screenshots of video stimuli of approaching cars from a pedestrian's perspective as used in the experiment

1. What is the relative contribution of behavior and appearance of an approaching vehicle on the pedestrian's decision to cross the street?
2. Is this relation different for manually driven and autonomous vehicles?

Experiment Setup

The experiment was conducted in two parts. Initially, a survey was conducted to gauge the general reaction of people on a number of existing cars based on their outer appearance (part 1). The survey presented the participants with pictures of 10 different currently existing cars next to a pedestrian (for scale of size), and asked the participants to rate the cars on a number of aspects like friendliness vs. aggressiveness of its appearance, perception of power and speed, and ordinariness vs. futuristic-ness of its physical attributes (Figure 1). Based on the responses from >100 participants, two specific cars were selected for the subsequent experiment (part 2). A Renault Twizy was chosen to represent a friendly-faced, futuristic vehicle, while a BMW 3 series sedan was chosen to represent an aggressive, ordinary vehicle. All the vehicles in the pictures used in the survey, as well as the two vehicles finally used for the experiment were specifically chosen to be white to rule out color as a confounding factor in the perception of their physical attributes as an extension of their behaviors. Subsequently, in the second part of the study, these two vehicles were used for a controlled, video-based experiment where participants were asked to make a decision regarding crossing an unmarked road with the test vehicle approaching while exhibiting different driving behaviors and driving conditions.

The participants were informed that there was no other traffic on the road. An unmarked road was chosen as opposed to a pedestrian crossing to study the vehicle-pedestrian interaction at a fundamental level where the decision takes place out of a feeling of safety and understanding the car's intention rather than out of a conviction of "right of way". The independent variables in the experiment were threefold: 1. Appearance of the vehicle (the two vehicles), 2. Driving behavior of the vehicle (assertive vs yielding behavior), 3. Driving condition of the vehicle (whether it is being driven manually, or it is driving autonomously). The dependent variable was the pedestrian's decision regarding their willingness to cross the road.

The video was captured from the pedestrian's point of view from the edge of the pavement (a normal, empty road, not at a crosswalk), showing the car approaching the pedestrian (Figure 2). Each of the vehicles (representing two different vehicle appearances) were driven to exhibit two different behaviors: 1. Driving at a constant speed of 50km/h, and 2. Gradually but purposefully braking to a complete stop before the pedestrian. The videos of the approaching car were clipped at various points (with the car being at different predetermined distances from the pedestrian), and each of these small video segments were shown in a random order to the participants (assuming the role of a pedestrian), who were asked to indicate their willingness to cross the road on a 5-point scale. The experiment was conducted as a between-subjects experiment for the manually-driven and autonomously-driven conditions, with an intended 30 participants in each condition. For the manual driving conditions, the driver wore a high-visibility jacket to make the presence of a human controller behind the steering wheel obvious. For the autonomous driving conditions, a Wizard of Oz setup was used to provide the impression that the car was driving

Figure 3: Top – the seat suit used for Wizard of Oz prototype for autonomous vehicles. **Middle and bottom** – The pedestrian's view of one of the vehicles in autonomous and manual mode respectively

itself with the use of a seat suit as demonstrated by Rothenbücher et al. [7]. In the autonomous driving conditions, the vehicles' external physical appearances were not altered in any way (Figure 3). The experiment was concluded with an assertiveness questionnaire [6] to gauge the general assertiveness of the participant and analyze how it might have played a role in their behavior, as well as a post-experiment interview to summarize their experience and the factors that influenced their decision-making while crossing the road.

Preliminary Results and Future Work

At the point of writing this report, the data-collection process is not yet complete, and we have data from 22 participants in each condition. While it is premature to run a quantitative analysis at this point and it must wait until the data collection process is complete, we noticed some emerging themes from the qualitative data (assertiveness questionnaire and post-experiment interviews). Every participant stated that the distance of the car played the most crucial role while deciding to cross the road. This is an obvious and expected behavior: if the car is still far away, they will simply cross the road; however, the situation becomes increasingly ambiguous as the car comes closer. The participant response was also unanimous across both conditions (manual vs. autonomous drive) that apart from the distance, vehicle speed and behavior played the primary role in determining their willingness to cross the road, and the movement patterns of the car (whether the car seemed to be slowing down, or continuing to drive at speed) mattered in their decision. People were divided in their opinion regarding how the appearance of the cars mattered. Some participants (38.1% and 30.5% respectively in manual and automated conditions) claimed outright that the appearance of the car did not matter at all, and their decisions were driven entirely by the behavior of the car. Others (57.1% and 69.5% respectively in manual and automated conditions) asserted that the appearance of the car made a difference, and they were mostly focused on the size of the car (there is an observable size difference between the Renault Twizy and the BMW 3 Series), and rationalized that with a smaller car, they can cross and get out of the car's way more quickly, so they were more likely to cross in front of a small car compared to a big car. However, most people (81.9% and 74% respectively in manual and automated conditions) asserted that disregarding the size of the car, its looks (friendliness/ assertiveness or ordinariness/ futuristic-ness) did not factor into their decision-making process.

Furthermore, in the autonomous condition, some participants indicated that it was easier for them to believe that the Renault was an autonomous vehicle because it was more futuristic and "robotic-looking". On the other hand, the BMW was a familiar vehicle and conformed to people's idea of an ordinary car, so it was less obvious as a self-driving car. However, everything taken into account, the appearance of the car did not matter as much as its behavior, in both the autonomous and manual driving conditions. Whether the perceived autonomous driving state of the car and the difference in the vehicles' appearances and behaviors indeed affected the pedestrians' crossing behavior remains to be investigated after a comprehensive quantitative analysis of the data. Collectively, the findings in this study contributes to the research community by informing the factors that pedestrians take into account while interacting with autonomous vehicles and giving direction to the design of autonomous vehicles.

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