# Vehicle's Driving Mode and External Appearance:

### Effects on Pedestrians' Road-Crossing Behavior

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### Public perception of Automated Driving



#### **Macnbc**

KEY

POINTS

#### MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV

#### Self-driving cars are scaring more people

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> More Americans say they wouldn't ride in a self-driving car than those surveyed in 2017, according to AAA.

 The report attributes the increased concern to highly publicized accidents involving self-driving cars.



A Field Study of Pedestrians and Autonomous Vehicles SEARCH QUOTES Carnegie Mellon University Pittsburgh, PA, USA Cecilia G. Morales stnorman@andrew.cmu.edu Samadrita Das Carnegie Mellon University Carnegie Mellon University Pittsburgh, PA, USA Pittsburgh, PA, USA cgmorale@andrew.cmu.edu Aaron Steinfeld samadrid@cs.cmu.edu Carnegie Mellon University SHARE f 🔰 in 🖂 Pittsburgh, PA, USA ABSTRACT Jodi Forlizzi Autonomous vehicles have been in development for nearly steinfeld@cmu.edu Carnegie Mellon University Autonomous venicies nave been in development for nearly thirty years and recently have begun to operate in real-world Pittsburgh, PA, USA intry years and recently have begun to operate in real-world, uncontrolled settings. With such advances, more widespread incomotion settings, with storig auvances, more wincospicate research and evaluation of human interaction with forlizzi@cs.cmu.edu developing AVs; these companies ranged from automobile research and evaluation of numan interaction with autonomous vehicles (AV) is necessary. Here, we present and eeveloping Avs; taese companies ranged irom automount manufacturers such as General Motors to leading technology automotions ventries (A V) is necessary. Here, we present at interview study of 32 pedestrians who have interacted with a subsection of the statement of subsection and accounting and companies such as Apple [26]. interview study of 34 percessions who have interacted while Uber AVs, Our findings are focused on understanding and AVs and avticulat interlineation While a number of research and design techniques have been Uper Avs. Our innames are tocused on understanding and itust of AVs, perceptions of AVs and artificial intelligence. itus oi Avs, perceptions or Avs and artificial intelligence, and how the perception of a brand affects these constructs, was count on inhomost substantia, hortowas forwards accurate a material in experience or increasing with AVs in simulated settings [36], little opportunity has been constant to observe human interaction with annual broand now the perception of a brand attects these constructs. We found an inherent relationship between favorable Avs in simulated settings (36), inter opportunity has been afforded to observe human interaction with actual Avs We found an innerent relationship between favorable perceptions of feedball of the field of the found  $AV_{3}$ attoraged to observe numan interaction with actual Avs operating in real-world settings. This study is one of the first perceptions of technology and teerings of trust toward Avs. Trust in AVs was also influenced by a favorable Iruss in Avs was also innuenced by a favorable interpretation of the company's brand and facilitated by interpretation of the company's brand facilitated by interpretation or the company's transition incutation by knowledge about what AV technology is and how it might as the state of the sta Furthermore, most of the attention in the space of human knowiedge about what AV technology is and now it might fit into everyday life. To our knowledge, this paper is the Furthermore, most or the attention in the space or human interaction with  $AV_s$  has been focused on driver-vehicle in mine everyonsy me. To our knowledge, mis paper is me first to surface AV-related interview data from pedestrians in interaction with AVs has been locused on driver-venicle interaction, which is only part of the equation. Pedestrian househards are a convict class of interactants due to their interaction, which is only part of the equation. Pedestrian pysanders are a special class of interactants due to their relative lack of physical partners and took of these bystanters are a special class of interactants due to liter relative lack of physical protection and lack of direct interactions of vehicle interact 155 261 Techenters understand Author Keywords retative fack of physical protection and fack of direct knowledge of vehicle intent [25, 36]. To better understand how nedestrians and AVs will interact and many states knowledge of vehicle intent [25, 36]. To better understand how pedestrians and AVs will interact and ensure safe mous vehicles; field study; trust; human-vehicle interaction. interactions overweich peuesn tans and Avis, more knowled about how pedestrian bystanders perceive AVs is needed. CCS Concepts In this paper, we present an intervi-Human-centered computing ~ Field str INTRODUCTION mous vehicles (AVs nearly thirty years [30] and h realistic settings since 200 Awareness of AVs transport is of great interest in domains and has also game Rating "AVs are important for me" Rating "AVs are trustworthy" example, in 2018, TechWorld r Rating "AVs are important for society" Rating "I am interested in AVs" take digital or hard de or distributed for profit or e use is granted w r this notice and the full citation 4.5 sents of this work owned by other 5 sting with credit is permitted. T nd/or a fee. Rec 20 3.5 C 2018 Association for Computing Machine ACM ISBN 978-1-4503-5946-7/18/09815.00 R 13

Little to no awareness

Some awareness

### Missing Driver-centric communication



**Source:** Lundgren, V. M. et al. (2015). AVIP : An Interface for Communicating Intent of Automated Vehicles to Pedestrians.







### Vehicle appearance













### AV appearance









### **Research Questions**

Effects of:

- Perceived driving mode (normal vs. automated vehicle)
- External appearance
  - Friendly vs. aggressive
  - Ordinary vs. futuristic







### **Experiment Setup**



#### **Renault Twizy**

Friendly Small Low-power Novel Futuristic

#### BMW 3 series sedan

Aggressive Large High-power Ordinary Commonplace







### **Experiment Setup**









### **Experiment Setup**



#### Independent variables:

Vehicle type (appearance) Vehicle behavior (Yielding/ non-yielding) Vehicle driving mode (automated/ non-automated) – Between subjects

#### Measurement points:

45m, 30m, 15m, 5m, 1.5m Car started to brake gently at 54m away (1.8m/s<sup>2</sup>)







### How does Willingness to Cross change?



5.0 Autonomous Manual 2.0 1.0 45m 30m 15m 5m 1.5m Vehicle Distance

Renault Twizy, non-yielding behavior. Error Bars: 95% CI



i-CAVE



1.5m

Driving

Mode

Driving

Mode

Autonomous Manual





Driving behavior is the most important determinant of crossing decision (implicit communication of intent)

Driving mode (automated/manual) had no statistically significant impact on crossing behavior

External appearance had a significant impact in the "ambiguous zone" (neither to far away, nor too near)

- Pedestrians were less willing to cross in front of the Twizy
- Futuristic and novel appearance caused hesitance. < *Experimental vehicle*?>







### Follow-up: Appearing like an AV



- How effective is a sensor system make a vehicle look more "self-driving"?
- Will a "self-driving capable" appearance have a positive effect on willingness to cross?
- How does an external HMI (eHMI) as an explicit intention indicator affect willingness to cross?







### **Experiment setup**



Baseline







eHMI+Appearance

i-CAVE





## Findings



Both sensors and eHMI made the car look more like a "self-driving car"

Even when such cars are not popularly seen in The Netherlands







Findings





- Sensors had no detrimental effect on pedestrian behavior.
- eHMI had a positive effect







- Sensors seem to make people think that a car is "self-driving"
- Despite that, people are not necessarily 'afraid' to cross the road
- eHMI appears to aid crossing decisions

When AVs behave in an expected manner, people seem to behave around them just as around ordinary cars

Putting the previous findings together: a highly futuristic design can cause hesitation by breaking mental models. But sensor systems do not.

For future AV introduction: design choices are important. It may be beneficial to not make AVs stand out as too futuristic to ease social acceptance in the early stages







### Let's talk!



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