Safe to Approach: Insights on Autonomous Vehicle Interaction Protocols with First Responders

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ABSTRACT

As autonomous vehicles (AV) become increasingly common on our roads, it is important for first responders - police officers, firefighters, and emergency medical services to learn new interaction protocols as they can no longer rely on those applied to human-driven vehicles. This study identifies critical pain points and concerns of first responders interacting with AVs on the road. We explore 7 different designs that communicate that an AV is in park and is safe to approach and analyze how first responders perceive these designs in terms of clarity and safety. We conducted qualitative interviews with 9 first responders and gained insights on how the needs of first responders can be integrated within the AV design process. As a result, we identify an AV safe park state communication protocol that would be ideal for first responders. Additionally, we derive a guideline for effective communication methods that can be used in the design of these vehicles establishing research methods that involve emergency responders within the loop.

CCS CONCEPTS

• **Human-centered computing → Interaction design process and methods**; • **Security and privacy → Social aspects of security and privacy**;

KEYWORDS

Autonomous Vehicles, Human Robot Interaction, First responders, AV Interaction, Qualitative Study

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1 INTRODUCTION

First Responders are facing an increasing number of incidents that involve autonomous vehicles (AVs). While the AV industry has recognized the need to address AV interaction protocols at emergency incident scenes, there are no generalizable first responder interaction protocols that have been adopted across the industry. This research attempts to fill in the gap of knowledge in understanding the pain points of first responders when interacting with an AV. Additionally, we identify effective communication designs for providing information to first responders about a vehicle's state.

2 BACKGROUND

A number of organizations and industries have started to conduct research on first responder interactions with AVs. Current research has been done by the Autonomous Vehicle Safety Consortium (AVSC) and Crash Avoidance Metrics Partners (CAMP) [2][3]. These reports identify interaction plan frameworks as well as an outline of first responder and AV interaction use cases. Current autonomous vehicles deployed on roads provide different protocols on how to interact with an AV [8][4][1]. Many of these methods include screen interfaces within cars and contact information in compartments that can only be accessed when the first responder steps inside the vehicle [6][9][8]. Procedures on how to immobilize the vehicle, ensure safe park, and identify combustible components are different for each company vehicle making it difficult for first responders to know how to safely interact with the vehicle [7][5]. Additionally, there is a lack of methods that communicate to first responders on how to handle the vehicle without stepping inside it which can cause additional accidents. This research looks into

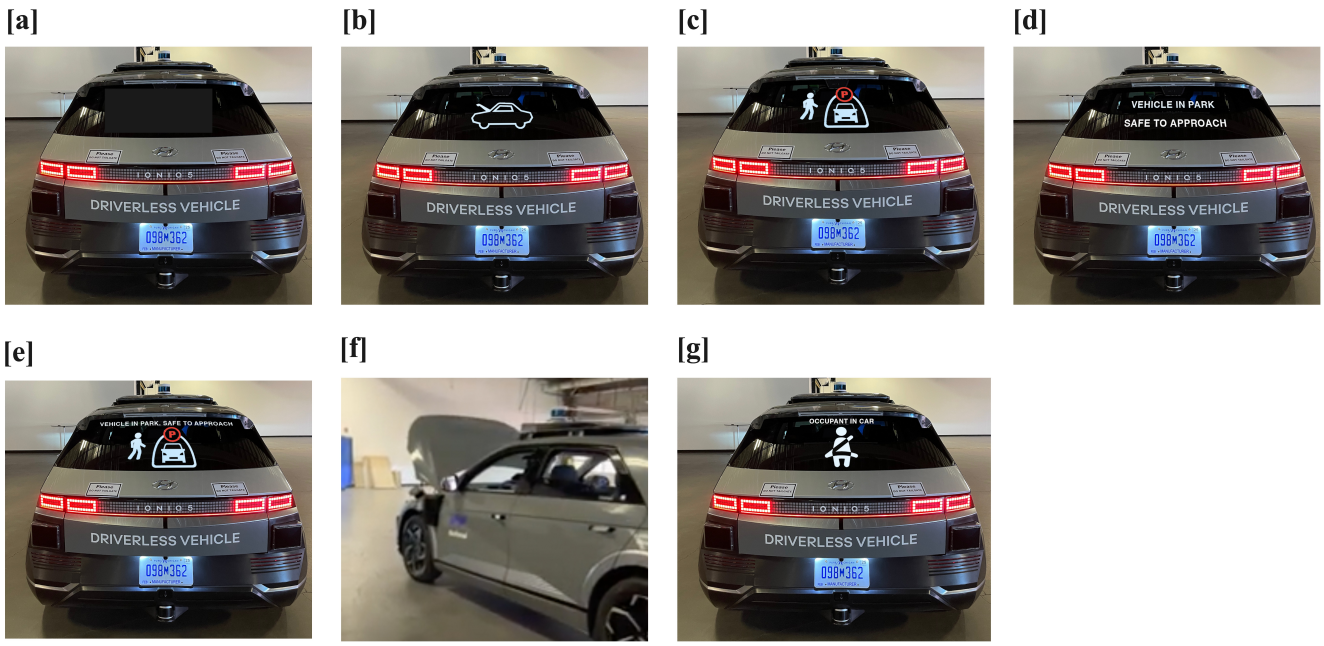

Figure 1: Study Design Conditions, [a] No additional design on the car, [b] Hood up icon on the car, [c] safe to approach the car icons, [d] text display of vehicle state, [e] text and icon display, [f] hood up movement of the car, [g] occupant information on the vehicle.

understanding the gap of knowledge in how first responders will interact with a problematic vehicle and what necessary information must be communicated by the AV.

3 METHODOLOGY

We conducted an interview study with 9 first responders to identify pain points and derive guidelines for first responder interaction protocols with Autonomous Vehicles. We used an open ended interview protocol to build initial understanding about past protocols of interacting with problematic vehicles. Additionally we used a set of images that depicted a range of vehicle breakdown state indicators to elicit feedback and gain insights about how an autonomous vehicle might effectively communicate that it needs assistance.

3.1 Breakdown State Indicators

We developed a set of seven breakdown state indicator designs that were designed to indicate that an autonomous car is malfunctioning and has entered a state of being parked (Figure 1). Our goal was to create indicator designs that are intuitively understandable and that clearly communicate that the AV is securely parked and is safe to approach.

We created the designs using an exploratory design process with five first responders. A pilot study revealed that direct communication of the vehicle's state through a text and a hood-up motion was most effective in communicating a safe parked state of an AV to first responders. To communicate a safe parked state, we created 7 designs based on the insights gained from the exploratory design process. Additionally, a design that communicates the number of occupants in the vehicle were added. The icons were sourced from open source websites and the designs added on the back of Motional's driverless vehicle. Through the results of the exploratory analysis, we focused on icons that could communicate the state of the vehicle through an easily identifiable and learnable indicator. Additional designed communication methods were a direct textual display and hood up movement from the vehicle. The final design options for the interview study included (1) No display (2) Icon of a person approaching a parked vehicle (3) Icon of the vehicle with a hood raised up (4) Direct text communicating the vehicle's state (5) Combination option 2 and 4 (6) Hood-up movement of the vehicle (7) Icon alongside text that displayed there were occupants in the vehicle.

3.2 Participants

Using email and in-person contacts we recruited a total of 4 police officers, 5 firefighters, and one emergency medical services member across areas ranging from New York, Pittsburgh, Boston, and Santa Monica. Participants had an average of 25 years of first responder experience in the field. All participants reported having had experience encountering problematic vehicle situations such as a vehicle crash, a vehicle with a mechanical issue, or an abandoned vehicle.

3.3 Procedures

Each interview was conducted online through zoom and had a total of 3 parts that took a total of 40 minutes. The first part of the interview focused on gaining basic understanding about first responders' experiences, the second part focused on eliciting responses to the vehicle breakdown state indicators and the third part focused on the identification of future design protocols. We received consent from participants to record the interviews via zoom.. The recordings were then analyzed to generate design insights.

3.3.1 Part 1: Understanding Experiences of First Responders. First, to understand first responder's experiences, we asked participants to explain their duties on a daily basis. From there, we narrowed down to ask about concrete examples of how they have interacted with a problematic vehicle (car crashes, drunk driving, abandoned vehicles, vehicles with mechanical issues) and what protocols they were required to go through in such situations. After current protocols were identified, we asked questions on what concerns first responders would have when interacting with a self-driving vehicle in a similar situation where no driver was present. Through this discussion, we identified the concerns of first responders in interacting with an autonomous vehicle alongside the safety and training that might be required of them in the future.

3.3.2 Part 2: Identification of Effective Breakdown State Indicators. Following the first part of the study, we moved on to identify effective communication methods with first responders. We presented 7 different designs of an Autonomous Vehicle communicating its safe park state through static images and videos. After viewing each design, first responders were asked to give feedback on what they believed the design communicated along with responding to two questions on clarity and safety. Three questions were asked for each design. (1) What is the vehicle trying to communicate? (2) It is clear what the vehicle is trying to communicate (3) I feel safe to approach the vehicle. Questions 2 and 3 were answered on a 7-point Likert scale ranging from completely disagree (1) to completely agree (7). We additionally collected comments from first responders on their reasonings behind the ratings as well as notes on what elements were confusing to them. After interacting with the 7 designs participants were asked to report their favorite communication method of the ones seen in-combination or individually. Participants were also asked if there were additional communication methods beyond the ones that they have seen in the presented designs that they preferred.

3.3.3 Part 3: Envisioning Future Design Protocols. In the last part of the study, we asked first responders about future design considerations of AV communication with first responders. Here, we specifically asked about the following state after this part of the study was done to identify preferred design methods for communication with first responders beyond the initial step of communicating a vehicle's safe state.

4 FINDINGS

4.1 First Responder Roles and Pain Points

4.1.1 Police Officers. We found that police officers tended to focus on problematic situations that could be happening inside the vehicle along with checking for the security of passengers inside the vehicle. The protocols of police officers interacting with a problematic vehicle started by approaching the vehicle from the driver side of the vehicle from a 45 degree angle. As they approach the vehicle security checks such as touching the trunk to make sure it is closed - preventing situations where hazardous materials are placed in the trunk. Once approaching the vehicle, police officers monitor people inside the vehicle using a flashlight in dark places and illuminating the interior of the car. If no one is in the vehicle, steps such as running the license plate are conducted to identify the owner of the vehicle. As police officers tended to deal with situations where problematic situations occurring inside the vehicle, they tended to be concerned with checking inside the vehicle to check if there is a person. They main concerns were about knowing information about occupants in the car, concerned about criminal activities inside the vehicle

4.1.2 Firefighters and Emergency Medical Services. Firefighters are called into vehicle emergency situations where the vehicle has been involved in a serious crash. Firefighters go out in a SOS situation when there is a problem with the car beyond just being parked such as situations involving a compromised vehicle (accident , running car, still in drive). Firefights focus on a process called vehicle extrication, where they go through mechanical, chemical, and electrical procedures of ensuring that the vehicle is safely disabled. Once firefighters approached the situation, they started off by ensuring that the traffic was controlled. Following safe approaching procedures, they started off by rendering the scene safe enough to start working. Only after the scene has been rendered safe, paramedics and other officers start to enter the scene. Following vehicle disabling procedures and vehicle disengagement processes, firefighters start by ensuring the vehicle is unmovable by flattening the tires and de-energizing the vehicle. The de-energizing process of the vehicle follows after this which includes protocols such as disabling fuel systems, batteries, and combustible components of the car. Firefighters were usually concerned about knowing how to disable the vehicle. As electric and self-driving cars require knowledge of new disabling systems, first responders wished to know how to interact with these new vehicles.

4.2 Preferred Communication Methods

4.2.1 Direct Text Communication over Icons. For both responses to the questions "It is clear what the vehicle is trying to communicate" and "I feel safe to approach the vehicle" option 4, direct text received the highest score in clarity and safety. "Plain text is the most clear and can avoid confusion". We found that communicating the vehicle's state through icons was subject to multiple interpretations. 4 officers confused the approaching person as a pedestrian or occupants in the vehicle. In general first responders responded that universal traffic icons should be used and recommended refraining from using icons as communication signals to avoid subjective interpretations and confusion. Considering that there will be no language barriers among first responders it is questionable whether having icons will be necessary

4.2.2 Hood up Communication. All first responders identified the hood up movement as a universal signal that communicated that

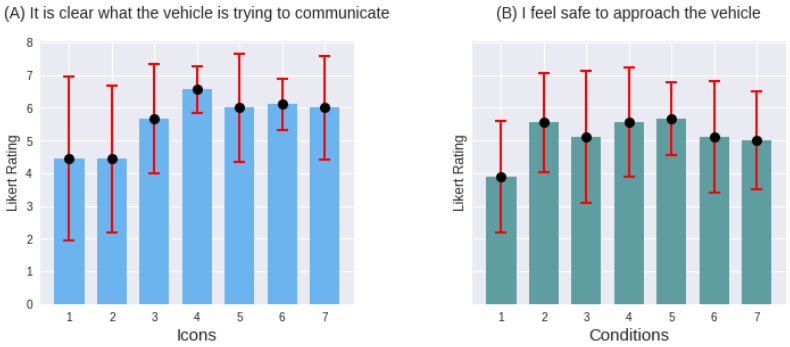

Figure 2: Likert Ratings on the Prototypes : (A) It is clear what the vehicle is trying to communicate. (B) I feel safe approaching the vehicle.

there was a mechanical error with the car and that the car was disabled. As a result, the hood up movement of the car received an average Likert score of 6.28 (ranked 2nd out of 7 designs) in "It is clear what the vehicle is trying to communicate." However, first responders also indicated that the hood up movement of the vehicle was not enough to indicate that the vehicle was parked and safe to approach. The hood up movement of the vehicle received a Likert score of 5.42 (ranked 5th out of 7 designs) in conveying the message to first responders that the vehicle was safe to approach. Compared to other methods such as using direct text and icons that indicated the vehicle in park, the hood up movement scored lower in terms of communicating that the vehicle was safe to approach. 3 out of 9 first responders preferred using option 3, icon of the hood up movement alongside the actual hood up movement of the vehicle. 1 out of 9 first responders responded that the icon alone was sufficient to communicate that the vehicle was experiencing a mechanical error.

5 DISCUSSION

From our findings we propose a safe park communication system of using universal signals such as the hood up movement and the hazard lights to signal the initial state that there is a problem with the vehicle. Following these movements, having a flashing text communication that signals the internal state of the car. As identified from concerns that first responders will have when interacting with an autonomous vehicle, generalizable training procedures need to be established outlining procedures for how first responders should interact with an AV. For police officers, main concerns are about how they should approach the vehicle from what angle and what occupants are doing inside the vehicle. Measures that clarify to officers information such as the number of occupants in the vehicle, what purpose the vehicle is being used for and additional information on who to contact should be available. Concerns of police officers include transporting hazardous things through autonomous vehicles, weaponization of the vehicle. For firefighters who mainly perform vehicle extrication tasks, knowing how to render the vehicle safe and inoperable is important. Questions surrounding the AV include how to unlock the vehicle and how to disable the vehicle mechanically.

6 CONCLUSION

One of the most discussed concerns of first responders was in understanding how the vehicle could be disabled. Officers mentioned the usefulness of "Having a big red button" that would let the system be entirely turned off. One phrase that was often mentioned was the need to have something like a "Big Button" to just be able to turn the system off from outside the vehicle without having to step in. First responders preferred to have the vehicle disengagement process accessible outside the vehicle to prevent any additional accidents occuring with the sudden movement of the vehicle. Additionally, things such as illuminating the interior of the car to ensure safety inside the vehicle and displaying the number of occupants in the vehicle was also mentioned. First responders mentioned that displaying how to approach the vehicle with an arrow and additional steps they should be aware of were important information to know. Finally, efforts that look into training first responders through collaboration with AV industries and police and fire departments by identifying actionable scenarios are needed.

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