A Social Approach for Autonomous Vehicles: A Robotic Object to Enhance Passengers' Sense of Safety and Trust

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ABSTRACT

One of the central challenges in designing autonomous vehicles concerns passenger trust and sense of safety. This challenge is related to passengers' well-established past experience with non-autonomous vehicles, which leads to concern about the absence of a driver. We explored whether it is possible to address this challenge by designing an interaction with a simple robotic object positioned on the vehicle's dashboard. The robot greeted the passenger, indicated that the vehicle was attentive to its surroundings, and indicated that the drive was about to begin. We evaluated whether the robot's non-verbal behavior would provide the signals and social experience required to support passengers' trust and sense of safety. In an in-person (in-situ) experiment, participants were asked to enter an autonomous vehicle and decide if they were willing to go for a drive. As they entered the vehicle, the robot performed the designed behaviors. Our findings indicated that participants' trust ratings and safety-related experience were higher than those of a baseline group who did not interact with the robot. We suggest that robotic objects are a promising technology for enhancing passengers' experience in autonomous vehicles.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

Autonomous Vehicles, Trust, Sense of Safety, Greeting, Social Robots.

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1 INTRODUCTION

In recent years, great efforts have been invested in the development of autonomous vehicles (AVs). AVs can react faster than humans to potential hazards, coordinate their movements with other vehicles, and serve multiple users throughout the day. AVs therefore have the potential to reduce the number of vehicles on the road, prevent accidents, and improve traffic flow [47, 48].

The technical development of such vehicles is progressing rapidly. However, their acceptance by potential users faces several challenges related to passengers' trust in the AV and their sense of safety [4, 12]. Passengers already have strong habits in the context of going for a drive. The most important one involves the presence of a human driver controlling the vehicle. Going for a drive in an AV is therefore not an entirely novel experience. Instead, it is a familiar experience with an important missing element: the human driver. Challenging such strong habits can lead to a highly uncomfortable experience that requires the activation of cognitively demanding inhibition processes [37, 45]. In addition, passengers are expected to naturally trust an autonomous technology that is typically controlled by humans, which can be difficult [61].

Apart from generally having a driver who controls the vehicle, passenger habits also involve the observation of signals concerning the driving status. For example, the driver's non-verbal behavior can signal that the driver is confident and focused on the road [30]. Such understanding of the driving status further increases the passenger's trust and sense of safety [30]. The experience in an AV is missing these important signals, which indicate that the vehicle can "see" its environment and inform the passengers of the vehicle's future intent. The absence of these important signals in the AV can lead to a dramatic decrease in a passenger's sense of control and, as a result, in their trust [30]. Since trust is one of the main factors contributing to a sense of safety [25], the lack of informative signals that passengers usually rely on may hinder their willingness to use AVs altogether.

Figure 1: A robotic object for providing social cues and enhancing AV passengers' sense of safety and trust.

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Several solutions for increasing passenger trust and sense of safety have already been suggested by designers and researchers [17, 37]. The main method for enhancing trust has involved providing passengers with information about the vehicle's status. Previous studies indicated that it is possible to increase trust by communicating information concerning the vehicle via visual displays. A heads-up display, light bands, augmented reality, and regular screens have all been indicated as valid methods for enhancing passenger trust by providing information related to the AV and road [8, 42]. Trust was further enhanced when these displays were designed to have anthropomorphic and social features such as a name, gender, voice, and politeness [31, 58]. While these methods have various advantages, it has also been argued that they involve demanding learning processes, as they require the interpretation of unfamiliar interactions (social cues provided by a visual display) in a familiar context (a passenger in a vehicle) [37].

Recently, the AV community has also begun to explore social robots that perform non-verbal gestures as a method for indicating an AV's intent and status [29, 57]. The main advantage of this approach concerns the ability to design an interaction that is compatible with people's existing habits [29]. Passenger habits are strongly based on the social cues provided by the driver. By observing the driver's non-verbal behavior, passengers deduce the level of focus on the road, intent, and stress. Social robots can be leveraged to communicate similar cues, leading to a more familiar experience without the need to inhibit previous habits and learn novel communication methods. Research has shown that even very simple robots can easily communicate clear and consistent social information [1, 10, 19, 46]. Because of the human tendency to perceive the world through a social lens, non-verbal robotic gestures are automatically interpreted as social cues. This phenomenon is observed even when the robot has a non-humanoid appearance and cannot directly mimic human behavior [10]. Clear and consistent understanding of social cues has been documented with robots designed as a desk lamp [50], a microphone [56], a robotic arm [22], and a small ball rolling on a dome [1]. Participants naturally perceived the interaction with such robots as acknowledging their presence, greeting them [1], and caring for them [9, 11].

In the context of AVs, a non-humanoid robot was suggested as a method for communicating an AV's intent to pedestrians [29]. This work indicated that a simple social robot could be used for designing communication that is perceived as familiar and natural. The robot's gestures were adjusted to leverage existing pedestrian habits, and the interaction was perceived as clear and easy-to-understand communication with an AV. The researchers suggested that non-humanoid robots should be explored as a simple and cost-effective way to overcome communication challenges with AVs. Following this work, we suggest that the tendency to perceive non-humanoid robots as social entities, can also be leveraged for designing high-quality AV-passenger communication. By using the robot as a social entity in control of the vehicle, which provides common social cues, we could enhance passenger trust and sense of safety.

Another advantage of using social robots for AV-passenger communication concerns the sense of companionship related to social interactions with them. Previous studies indicated that even simple non-humanoid robots can provide a strong sense of companionship by performing minimal non-verbal gestures [3, 16, 18, 40, 63]. It was also found that social qualities and a sense of companionship in human-robot interaction (HRI) are closely related to trust [35]. In fact, several studies showed that when it comes to trusting the robot, companionship and social capabilities are more important than the robot's practical functioning [15].

In this work, we explore the possibility of using a robotic object to design a familiar experience in an AV and provide social signals to passengers. We focused on the initial interaction in the vehicle immediately after participants entered an AV and tested their experience when considering whether or not to go for a drive. Our focus on the beginning of the interaction allowed for an in-person (in-situ) evaluation. In addition, multiple studies have indicated that opening encounters and first impressions have a profound impact on the rest of the interaction. It is argued that the experience in the opening encounter has a long-lasting effect that shapes the nature of the interaction that follows [13, 26, 52]. This effect impacts the level of trust and the perceived competence of the autonomous technology [44, 60]. It has therefore been suggested that the opening encounter is the cornerstone for the entire relationship [2].

Accordingly, we designed an opening interaction between a passenger and a non-humanoid robot placed on the vehicle's dashboard. We used the simple non-humanoid robot designed by Chakravarthi et al. [29] for mediating an AV's communication with pedestrians (used with permission, see Figure 1). We tested whether the robot's simple non-verbal gestures could mediate the social cues required for passengers to feel that there is an entity in control of the AV and to support their trust and sense of safety. The results of a pilot study were used to design a set of robotic behaviors for the robot to perform as soon as the passenger entered the vehicle: greeting the passenger, checking the road in front of the vehicle for safety, and turning back to the passenger to indicate that the vehicle is ready to go. We compared the participants' level of trust and sense of safety to those of a baseline group who had a similar experience without the opening encounter with the robotic object.

2 RELATED WORK

Relevant previous work evaluated trust in AVs, social interpretation of non-verbal gestures by non-humanoid robots, and robots for mediating AV communication with drivers.

2.1 Trust in AVs

Previous studies investigated factors contributing to trust in AVs and their impact on AV acceptance. For example, Choi and Ji conducted a large-scale survey to map factors that contribute to acceptance and trust in AVs [7]. They found that system transparency, technical competence, and situation management had a positive impact on passengers' trust. In addition, the AV's perceived usefulness and participants' personal traits (e.g., locus of control) emerged as significant determinants of an individual's intention to use one [7].

In another study, Morra et al. investigated the factors that contribute to building trust in AVs [37]. They focused on the possibility of leveraging human-machine interfaces to enhance trust by providing information about the status of the vehicle. Participants who engaged in a VR-based driving simulation received visual cues informing them about the vehicle's sensory input and planning systems. Their findings indicated that the ability to form a mental model of the AV was crucial for establishing trust. The information concerning the vehicle's surroundings had a strongly positive impact on participants' trust and stress despite the cognitive demands to process a lot of information. The increase in participant trust increased their willingness to experience a drive in a real AV [37].

Another example was presented by Häuslschmid et al., who tested the possibility of increasing trust using the projection of visual information on the road in front of the passenger (outside the vehicle) [17]. In their video study, they indicated the vehicle's responsiveness to objects in the environment either by presenting a visualization of an animated chauffeur or by a visual representation of the vehicle and its surroundings (a world in miniature). They compared participants' trust to that of a baseline group that could only watch a display of the vehicle's indicators. They found that only the vehicle's visualization enhanced participants' trust [17].

Additional methods that have been suggested for increasing passenger trust in AVs include different methods for communicating the vehicle status (conversational agents [51], screens [42], augmented reality, a heads-up display, and light bands [8]). It was also indicated that adding anthropomorphic features to the vehicle, for instance, naming the vehicle or associating it with a specific gender, can positively impact passengers' trust [58].

In this work, we extend these previous studies and explore whether it is possible to enhance trust and a sense of safety by leveraging existing passenger habits. Our AV–passenger communication interface involved a robotic object that could provide clear and consistent social cues that passengers already use when taking a ride with a human driver.

2.2 Social Interpretation of Non-Verbal Gestures Performed by Non-Humanoid Robots

Prior research has highlighted the human tendency to perceive non-humanoid robots as social agents [11, 23, 41, 63]. Regardless of whether the robot was configured to resemble a familiar object or had a more abstract and unfamiliar form, its non-verbal gestures tended to be uniformly perceived as distinct and consistent social signals [11, 21]. It has therefore been suggested that robotic gestures can be easily designed as social cues commonly used in human-human communication, leading to clear and natural communication even with very simple robots [1].

For instance, Ju and Takayama demonstrated that the motion of an automated door could be designed to provide social cues associated with an opening encounter [21]. Participants in their study interpreted the movement of the door as a greeting behavior based on its speed and trajectory. When designed appropriately, participants perceived the movement as inviting and welcoming [21]. Another example was presented by Sirkin et al., who showed that a robotic ottoman performing non-verbal gestures could be perceived as a social agent [54]. The ottoman's movement trajectory was interpreted as indicating its willingness for interaction. Indirect, curved movements toward a participant were interpreted as social cues signaling an interest in social interaction [54]. Social experiences were also observed in interactions with a lamp-like robot that performed minimal gestures. Manor et al. designed robotic movements mimicking "lean," "gaze," and "nod" gestures [34]. In their study, the robot performed the gestures in the direction of the participants, who shared their future plans. Participants interpreted the movements as signs of the robot's interest and care [34].

Non-verbal gestures have also been interpreted as social signals when introduced by abstract, unfamiliar, non-humanoid robots. In a study by Anderson-Bashan et al. [1], participants attributed social interpretations to the gestures of a robot designed as a small ball moving on a dome. When participants faced this robot, the small ball exhibited motion either from the rear of the dome to the front or vice versa. Despite the robot's unconventional and abstract appearance, participants consistently interpreted the robot's gestures as conveying social cues pertinent to initiating an interaction. When the small ball rolled to the front of the dome (towards the participant), participants perceived it as a sign of willingness to engage in interaction. If it moved toward the back of the dome, they perceived it as an indication of reluctance to interact [1]. In the context of AVs, the non-verbal gestures of a non-humanoid robot have been used as a method for mediating the vehicle's intent to pedestrians interested in crossing the road in front of it. Chakravarthi et al. conducted an in-situ experiment in which participants were asked to cross in front of an AV [29]. The robot was placed on the vehicle's dashboard in a location where pedestrians habitually look when making a crossing decision. It performed simple non-verbal gestures indicating that it recognized the pedestrian's presence and whether or not it was safe to cross in front of the vehicle. Participants easily understood the robot's social cues and reported a strong sense of safety when crossing in front of the AV [29].

These studies indicate the strong potential of using a simple robotic object to provide clear and consistent social cues. We followed Chakravarthi et al. [29], who leveraged a social robotic object in the context of AV communication, and tested whether a robot could also enhance trust and a sense of security for passengers who are about to go for a drive in the vehicle.

2.3 Robots for mediating AV communication with drivers

Previous studies have also explored robots and avatars for communication with AVs and raised the need for social cues. These studies typically introduced a robot for mediating the communication between a driver participant and vehicles with different levels of automation [6, 24, 31, 32, 62]. The robot represented the vehicle's status and intent using social cues in order to facilitate the collaboration required for driving the vehicle. The main factors tested in these studies include embodiment, type of cues (gaze, speech), and the content of the interaction (informative conversational). For example, Zihsler et al. showed that an avatar that uses social cues and anthropomorphism could enhance drivers' trust in a highly autonomous vehicle. The avatar represented the car's state using human behavior and expressions which can be interpreted intuitively by the driver [62]. Another example was presented by Karatus et al., who presented three domes, each with a pair of digital eyes[24]. They showed that when the agent's gaze followed the driver's eye gaze, participants perceived the AV as safer and more enjoyable. In another study, Cheng at al., indicated that the impact of anthropomorphism on trust is mediated by the robot's embodiment [6]. While high anthropomorphism had a positive impact when using a virtual agent, trust ratings decreased when high anthropomorphism was applied to a robot with a physical embodiment. The importance of social cues was also demonstrated by Kraus et al. They showed that it is possible to increase drivers' trust if the vehicle's spoken-dialogue system is applied to an NAO robot that uses social behaviors [28]. Similarly, Lee et al. indicated that the embodiment and politeness of a co-driving agent are central factors determining the trust in the vehicle [32].

We extend this literature by focusing on passengers in a fully autonomous vehicle. We explore the challenging case of being a passenger (who has no control over the AV) in a vehicle with no human driver. To overcome this challenge, we designed a HRI that leverages participants' already existing habits when entering a vehicle. These habits include strictly social cues (greeting) and cues related to driving (attentiveness to the road). We explored the possibility of enhancing passengers' trust by designing a familiar experience when entering a vehicle with an unfamiliar driver.

3 GESTURE DESIGN AND TECHNICAL IMPLEMENTATION

We used, with permission, the robotic object that was designed by Chakravarthi et al. for mediating AV communication [29]. The robot is composed of two parts (see Figure 2): (1) a "body" with an organic shape for indicating directionality, that can rotate horizontally; (2) a thin top part that can perform vertical movements. The robot was attached to the vehicle's dashboard using a 3D-printed black base.

3.1 Gesture Design

The gesture design process began with a pilot study that was conducted to understand people's existing expectations when going for a drive as a passenger (10 participants; 5 women and 5 men; mean age = 23.4, SD = 3.2). In this pilot study, we mapped the passenger experience when entering vehicles in general, especially in cases where there was no previous experience with the driver. We asked participants to describe their experience when using a taxi (as they would be passengers and the driver would be unfamiliar). We further asked them to describe what would make them feel comfortable and what factors would influence their sense of safety. The thematic analysis revealed that all the participants mentioned the opening encounter with the driver and explained that being greeted and having their presence acknowledged is important. All the participants also talked about the driver's attentiveness to the environment. They stated that there is an added value when the driver checks whether they are ready to go and informs them before starting the drive.

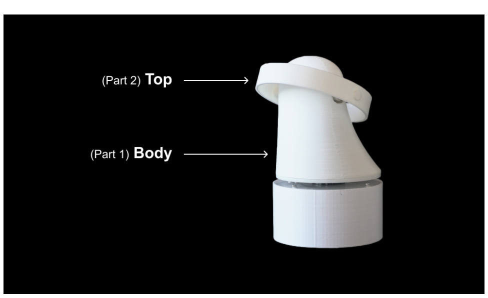

Figure 2: The robotic object, used with permission [29].

The gestures design was based on the insights from the pilot study and literature indicating the importance of non-verbal cues in this context, including eye gaze, body posture, body position, hand gestures, facial expression, and proximity [27, 53, 55]. We designed three robotic behaviors for the opening encounter with the participants after they entered the vehicle:

(1) *Greeting*: Acknowledging the passenger's presence in the vehicle and greeting him/her.
(2) *Indicating Attentiveness*: Focusing attention on the environment outside the vehicle and its surroundings. Indicating that the AV is aware of its surroundings and verifying that it is safe to start the journey.
(3) *Affirmation*: Turning toward the passenger to indicate that it is safe to go and that the drive is about to begin.

The design process included four iterations with an animator and an HRI expert, who designed gesture sequences for each robotic behavior. After each iteration, the robotic behaviors were tested with five participants and the robot's gestures were updated according to their feedback. The iterations mostly involved updating the speed, range, and number of repetitions of each gesture.

The process resulted in the following final robotic behaviors:

(1) *Greeting*: The robot turns towards the passenger from its initial position (a horizontal rotation of 155°), followed by an up-down movement of the top part (a vertical rotation of 50°), simulating a nod.
(2) *Indicating Attentiveness*: The robot turns towards the direction of the road and performs left and right movements (±60°, a horizontal rotational range of 120°). The gesture is repeated twice, simulating a head scanning the road.
(3) *Affirmation*: The robot turns towards the passenger (a horizontal rotation of 155°), followed by a vertical up-down movement of the top part (a vertical rotation of 50°). This is similar to the Greeting gesture, but twice as fast.

To validate the understanding of the robotic behaviors, we conducted another pilot study with eight additional participants. They were invited to enter a vehicle that was presented as autonomous. As they took a seat, the robot performed an opening encounter interaction that was composed of all three behaviors. All participants understood the robot's designed intent for all three gestures.

3.2 Technical Implementation

We used the Butter Robotics platform as the robot's infrastructure [36]. The robot's two degrees of freedom (i.e., Dynamixel robotic servo motors) were daisy-chained together and terminated in the Butter Robotics hardware controller. The Butter Composer directly translated Blender animations to motor movements. The robotic object was controlled wirelessly, and the vehicle's auxiliary power outlet was used to supply the robot's power.

4 METHOD

To gain insights into the potential of using robots for enhancing passenger experience in an AV, we conducted an in-person (in-situ) study with the robot installed on the vehicle's dashboard (see Figure

1). Participants were invited to enter a vehicle that was presented as autonomous and were asked to decide whether they would be willing to go for a drive in the vehicle and inform the researcher of this decision. Participants' trust in the AV and sense of safety were evaluated under two conditions: (1) the *Robot* condition, where the robot performed the designed behaviors for the opening encounter, and (2) the *No robot* condition, where the robot was placed as a stationary object that is a part of the vehicle's dashboard. The study was approved by the ethics committee of the research institute.

4.1 Participants

Forty participants were recruited either from the university or via social media (20 men, 20 women, mean age = 28.21, SD = 5.42). They received a 15 USD gift card for local stores. All participants signed a consent form and were informed that recorded material would be deleted after data analysis. We also verified that participants had no previous experience with robots or AVs.

4.2 Experimental Design

In a between-participants study, we evaluated passengers' experience in an AV. In two conditions, participants were asked to enter a vehicle that was presented as autonomous and decide if they felt comfortable enough to go for a drive (see Figure 3).

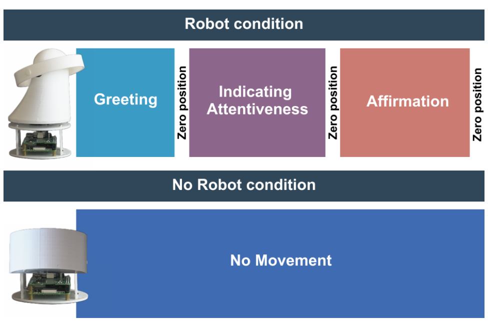

Figure 3: The experimental design included two conditions: (1) *Robot* condition; and (2) *No robot* condition.

In the *Robot* condition, the robot performed the three robotic behaviors for the opening encounter (*Greeting* > *Indicating Attentiveness* > *Affirmation*). In the *No robot* condition, participants sat in the vehicle for a similar amount of time but did not experience any interaction with the robot, which was located on the dashboard at an angle that did not indicate any directionality. The choice of this baseline was based on pilot studies. We initially tested a baseline robotic behavior involving random movements. This was interpreted by participants as a driver who is not attentive to the external environment and has increased anxiety. We then tested a robot that was not moving. The directionality of the robot's design led to two interpretations: when the robot was facing the road, it was interpreted as an unsocial and unpleasant driver; when it was facing any other direction, it was interpreted as a driver that was not attentive to the external environment. Since we aimed for a neutral baseline, we decided on a similar object without directionality.

Figure 4: The vehicle modified with objects simulating LIDAR sensors on the roof and large warning stickers

Participants were randomly assigned to one of the two conditions (order of arrival) while constantly monitoring apriori differences between the groups. When an imbalance emerged, the following participants were assigned to conditions in a way that balanced their general trust in intelligent machines [59] and gender. The final balance was validated using a Bayesian ANOVA that indicated no differences between the groups.

4.3 Experimental Settings

Following Chakravarthi et al. [29], we conducted the experiment in the university's parking lot and used a hybrid Hyundai Kona as the autonomous vehicle. To convincingly present the vehicle as autonomous, we performed the following modifications (see Figure 4): (1) We added five 3D printed objects simulating LIDAR sensors to the vehicle's roof; (2) We placed large stickers on all sides of the vehicle (on the vehicle's doors and front part) saying: *"This is an autonomous vehicle, please be cautious."*; (3) We activated the vehicle's navigation system, and a clear route was presented on the vehicle's display system. The vehicle was positioned on the far end of a road in the parking lot with the engine running.

In the *Robot* condition, the robot was placed on the center of the dashboard with a slight offset toward the driver's direction, where it could be clearly seen by the passenger. In the *No robot* condition, the robot was located at the same location but at an angle where only its base part was visible (see Figure 5). Audio and video

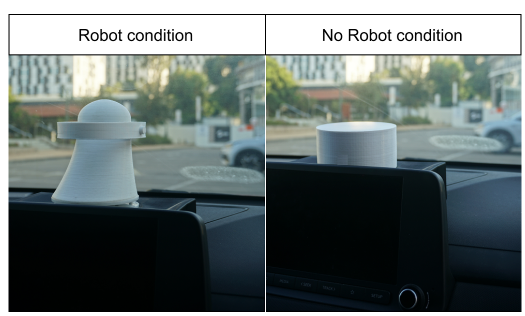

Figure 5: The robotic object placed on the dashboard.

recorders were placed in the vehicle to document each participant's responses.

4.4 Dependent Measures

To test the impact on participants' trust and sense of safety, we used four measures: (1) Trust in AVs questionnaire; (2) Trust between People and Automation questionnaire; (3) Spontaneous mentions of safe/unsafe experiences; (4) Semi-structured interview.

4.4.1 Trust in AVs questionnaire.

(1) The Trust in AVs questionnaire - designed to evaluate trust directly in AVs. It is a seven-item Likert scale ("Completely Agree" to "Completely Disagree") [33]. Cronbach's α 0.86.
(2) The Trust Between People and Automation questionnaire - designed to evaluate people's trust in autonomous systems. It is also a seven-item Likert scale ("Completely Agree" to "Completely Disagree") [20]. Cronbach's α 0.85

4.4.2 Spontaneous mentions of safe/unsafe experiences. To evaluate participants' sense of safety, we coded the frequency of participants who spontaneously described their experience in the vehicle as safe or unsafe in their immediate report of the experience.

4.4.3 Semi-structured interview. We conducted a semi-structured interview, allowing participants to freely describe their experience while remaining in line with a particular framework [14]. The interview provided an opportunity to understand participants' thoughts, emotions, and attitudes. The interview included questions concerning the overall experience, the autonomous vehicle, and the robot (e.g., "Describe the experience," "Describe your thoughts about the vehicle," and "How would you describe the robot to a friend?").

4.5 Procedure

A few days before the experiment, participants received the Trust in Intelligent Machines questionnaire [59] by email (to balance the groups in the different conditions). When participants arrived at the experiment, they were invited to the parking lot, where the vehicle was positioned as if ready to go for a drive. The researcher explained that the vehicle was autonomous and capable of self-driving. Participants were asked to enter the vehicle and take the time to decide whether they would like to go for a drive, which would begin in the neighborhoods around the campus and continue to a nearby highway. They were directed toward the passenger's seat (next to the driver's seat) and entered the vehicle. In the *Robot* condition, the robot performed the three robotic behaviors designed for the opening encounter. The robot was triggered wirelessly by a research assistant using the Wizard-of-Oz technique [38, 49]. In the *No robot* condition, the robotic object did not move, and the participant sat in the vehicle for the same amount of time (approximately two minutes). The researcher then entered the back seat and asked the participants to share their immediate experience. This was followed by a more comprehensive semi-structured interview and asking the participants to fill in the trust questionnaires on a tablet. At the final stage of the experiment, the researcher verified that the participants believed that the AV was autonomous and that they could actually go for a drive. Participants were then informed that the vehicle was not autonomous. The total time of the study was approximately 25 minutes (including a 7-minute interview).

5 ANALYSIS

We conducted a Bayesian analysis to verify the lack of differences between groups in the Trust in Intelligent Machines questionnaire. Our main analyses tested the impact of the robotic object on participants' experience when required to decide whether they were willing to go for a drive in the AV. The trust questionnaires were analyzed using a one-way ANOVA and Bayesian ANOVA (effects analysis). Sense of safety was analyzed using a chi-square test for the frequency of participants who spontaneously mentioned feeling safe or unsafe when describing the immediate experience in the AV. The qualitative analysis of the interviews was based on a thematic coding [5]: (1) Two coders transcribed the interviews to develop an initial understanding of the data. (2) Initial themes were extracted from the data and inconsistencies were resolved in a discussion with a third researcher. (3) The coders independently analyze 25% of the interviews, verifying inter-rater reliability (kappa=84%). (4) The two coders analyzed the rest of the data.

6 FINDINGS

The Bayesian analysis indicated no early differences between groups in the ratings of the Intelligent Machines questionnaire: $BF_{10} = 0.04$. The main analyses indicated an impact of the robot on the participants' trust in the AV and their sense of safety.

6.0.1 Trust in the AV. The presence of the robot had a significant influence on the trust ratings in both questionnaires. The ratings of the Trust in AVs questionnaire indicated higher trust levels in the *Robot* condition, compared to the *No robot* condition $F_{(1,38)} = 26.6$, $p < 0.001$, $\eta_p^2 = 0.51$. This was further supported by the Bayesian ANOVA, $BF_{incl} = 195.5$ (see Figure 6, Right). The ratings of the Trust Between People and Automation questionnaire indicated a similar pattern $F_{(1,38)} = 27.4$, $p < 0.001$, $\eta_p^2 = 0.67$; $BF_{incl} = 287.6$ (see Figure 6, Left).

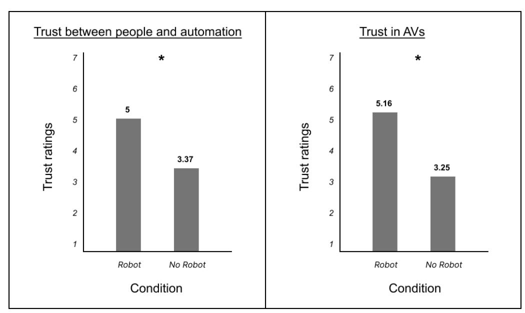

Figure 6: Trust averages: Trust Between People and Automation questionnaires (Left) and Trust in AVs (Right).

6.0.2 Sense of safety. The analysis revealed that the presence of the robot had a significant influence on the spontaneous perception of the vehicle as safe or unsafe $\chi^2_{(2)} = 19.01, p < 0.001$. Most of the participants in the *Robot* condition and none of the participants in the *No robot* condition used the word "safe" when describing their immediate experience in the AV. Moreover, a few of the participants in the *No robot* condition and none of the participants in the *Robot* condition used the word "unsafe" (see Table 1).

Table 1: Distribution of participants' use of the words "safe" and "unsafe" in different conditions.

Robot condition	Sense of safety: Safe	Sense of safety: Unsafe	Total
Robot	13	0	13
No robot	0	6	6
Total	13	6	19

6.1 Thematic Analysis of the Interviews

The thematic analysis revealed three main themes: *sense of safety*, *perception of the robotic object and its behavior*, and *social experience.*

6.1.1 Sense of safety. More than half the participants in the *Robot* condition (13/20) explicitly stated that the robot made them feel safe and increased their confidence. They associated this sense of safety with the robot's social cues and the feeling that someone in the vehicle was "watching the road" and "aware of its surroundings." (p. refers to participant number).

- *"It gave me confidence. it was aware of the space around us."* (p. 38, *Robot* condition)
- *"It made me feel safe as if everything is under control."* (p. 32, *Robot* condition)
- *"It gave me a sense of safety. It was checking what was happening around."* (p. 34, *Robot* condition)
- *"He made me feel like he's here watching over us, watching the environment and the road."* (p. 30, *Robot* condition)
- *"Without it, I would find it hard to feel that the vehicle is seeing the space around us."* (p. 22, *Robot* condition)

A sense of safety was not mentioned by any of the participants in the *No robot* condition. A few participants in this condition explicitly described the opposite experience (6/20).

- *"It's weird since there is no driver. It is a little stressful."* (p. 17, *No robot* condition)
- *"I experienced uncertainty and a lack of confidence."* (p. 11, *No robot* condition)

6.1.2 Perception of the object and its behavior. All participants in the *Robot* condition reported that they noticed the robot easily and understood its intent clearly. While the *Greeting* and *Indicating Attentiveness* robotic behaviors were consistently interpreted similarly to their intended design, the *Affirmation* behavior was perceived either as an indication that the vehicle was about to drive or as a request to get approval to begin the drive.

- *"I felt like it recognized that there was a passenger; greeting me."* (p. 6, *Robot* condition, *Greeting behavior*)
- *"Like it's recognizing me. Letting me know it's aware of my presence somehow."* (p. 18, *Robot* condition, *Greeting behavior*)
- *"It was looking and checking the surroundings."* (p. 12, *Robot* condition, *Indicating Attentiveness*)
- *"It wanted me to feel that the car knows exactly what was going on in its surroundings, everything around."* (p. 24, *Robot* condition, *Indicating Attentiveness*)
- *"It turned back towards me since it wanted my approval to start driving."* (p. 40, *Robot* condition, *Affirmation*)

Some participants also mentioned that the robotic object was a mediator between the AV and the passenger. They explicitly described it as responsible for controlling the vehicle:

- *"I think it's some kind of a driver controlling the vehicle and communicating."* (p. 14, *Robot* condition)
- *"It is something that replaces the driver; it's there for me."* (p. 36, *Robot* condition)
- *"He is like a bridge between me and this vehicle."* (p. 10, *Robot* condition)

6.1.3 Social experience. Participants in the *Robot* condition (13/20) also associated their positive experience in the AV with a sense of companionship provided by the robot. They described the robot as another entity that made them feel that they were not alone in this unfamiliar experience.

- *"I think I felt like I had company; I wasn't alone."* (p. 2, *Robot* condition)
- *"I felt like there was someone else with me – someone I can interact with."* (p. 26, *Robot* condition)
- *"It gives you confidence since there is someone else here with you."* (p. 40, *Robot* condition)

Interestingly, most participants in the *No robot* condition (17/20) stated that they felt alone and described a need for companionship and communication.

- *"I was a little anxious since I was all alone."* (p. 21, *No robot* condition)
- *"I needed someone to communicate with. Someone in the vehicle, related to the vehicle."* (p. 5, *No robot* condition)

7 DISCUSSION

In this work, we demonstrate the potential of using a non-humanoid robot to enhance the passenger experience in an AV. Our findings show that a simple robotic object can provide the social cues that passengers expect when entering a vehicle due to their vast past experience. The social interaction with the robot highly contributed to participants' trust and sense of safety. Their trust ratings were higher, and in the interview, they stated feeling "safe," "comfortable," and "confident." A very different experience was reported in the *No robot* condition. Participants provided lower trust ratings, and none of them described the vehicle as safe. A few participants explicitly stated that the vehicle was not safe and expressed their concern about going on a drive in the autonomous vehicle. They reported an emotional experience that involved stress and a lack of confidence.

Participants in the *Robot* condition directly attributed their experience in the AV to the robot (indicated by the interview). They associated their sense of safety with having "someone" who was "controlling the vehicle," "watching over them," and "making sure they know that the AV is aware of its surroundings." In the *No robot* condition, participants attributed their experience to the absence of the driver or "someone controlling the vehicle." They expressed their concern about the highly irregular experience of being a passenger in a vehicle without a driver. These results further enhance the need to consider passengers' past experiences when designing AVs. People's already well-established habits as passengers in non-autonomous vehicles create a schema of going for a drive in a vehicle. The driver who controls the vehicle is an integral part of this schema. Designing an experience that triggers this schema but misses such a central part can easily lead to negative effects.

Our findings suggest that, if designed appropriately, a social robot could assist in overcoming the challenges posed by the existing strong habits of passengers when entering an AV. The social cues provided by the robot can support the passenger's need to be noticed and greeted. They can also provide signals indicating that the vehicle is controlled and aware of the environment outside. While a robot would not replace a driver, it could minimize the gap created due to the driver's absence by preserving a somewhat familiar social experience. The advantages of using a social robot were further supported by participants' need for companionship. In the *Robot* condition, participants associated their positive experience with the robot's "friendliness" and its "communication" with them. They explicitly stated that it relieved their sense of loneliness in the AV. The opposite pattern was observed in the *No robot* condition, where participants reported feeling lonely and explained that this created a negative experience. Therefore, social robots can also be leveraged to comply with passenger expectations and the need for social interaction. Previous studies indicated that such a sense of companionship may further contribute to enhancing trust [15].

Our findings also indicate that the advantages associated with a social robot in an AV can be achieved with a simple (2-DoF) non-humanoid robot. The social experience constructed by the robot's minimal movements was sufficient to provide the signals indicating that the AV is in control and aware of the environment. Despite the lack of language, participants perceived the robot as providing companionship and mediating the AV's intent. We note that this easy-to-understand robotic behavior did not require the novel design of a robot for communication with passengers. Instead, we leveraged an existing robot that was initially designed to communicate with pedestrians [29]. By applying small adjustments to the robot's movements, it was possible to design social communication with passengers. We, therefore, suggest that using a social robot to enhance an AV experience can be accessible and cost-effective.

Taken together, this work indicates that a social robotic object can address several challenges associated with the absence of a driver in an AV. The robot's non-verbal behavior can provide the missing signals and social atmosphere required for a safe and comfortable experience that does not conflict with passengers' well-established habits. The tendency to assign social interpretations to robotic gestures and their flexible design position non-humanoid robots as great candidates for enhancing the experience in an AV.

8 LIMITATIONS

This study has several limitations. Trust in AVs is composed of several factors. This study focused on the first stages of the experience with an AV that occurs before experiencing an actual drive. This gave us the opportunity to capture participants' willingness to experience a drive as a function of their first impression when entering the AV. We acknowledge that this is also the main limitation of the study, as participants based their responses on their perception of the drive that was about to take place before experiencing it. However, this allowed us to test participants' responses in an in-person, in-situ setting where they believed that the vehicle was autonomous and that they had the opportunity to experience a drive. Due to the high impact of opening encounters on the interaction that follows [2], we decided that such an experimental setting was preferred over a more comprehensive simulator experience. Future studies should test the impact of the robotic object during an actual drive, and evaluate the effect of the robot's social behavior, attentiveness towards the road vs. the passenger, robot vs. AV errors, and the robot's communication with other road users. These studies should also verify that the interaction with the robot does not lead to overtrust in the AV. Another limitation concerns the difference between the experimental and baseline conditions. Participants in the baseline conditions interacted with an object with a different shape that did not move. This could have impacted their engagement and focus on the drive. However, participants in this condition did not simply wait for the drive to begin. They explored the vehicle's systems and speculated about the object's function, e.g., "I noticed the 'Google map' on the display and the route; I also saw the white object. I think it was a sensor collecting data from the environment". We also acknowledge that our findings cannot identify the unique contribution of the robot's sociality and attentiveness. Our goal was first to indicate the possibility that a simple robotic object would be perceived as attentive and social in a way that would enhance trust. Future studies should test the impact of these factors separately. Another limitation concerns the external environment. While participants believed that they were about to go for a drive outside the campus, the initial experience took place on the road leading to the parking lot, which had little traffic and few pedestrians. Future studies should evaluate the impact of the robot in busier environments that involve other vehicles and pedestrians. Future studies should also explore if the combined effect of the robot with other existing methods for supporting trust could further enhance passengers' experience. As these methods address somewhat different needs, it is possible that a combination of visual displays with a social robot can highly contribute to participants' sense of safety and trust. Lastly, interviews may be biased by the interviewers' expectations and the "good subject effect" [39, 43]. We minimized this risk by following a strict protocol, using neutral language, and telling participants that all answers were helpful.

9 CONCLUSION

We presented the potential of using simple robotic technology to enhance a passenger's experience in an AV. The automatic tendency to perceive non-verbal robotic gestures as social cues positions such robots as a potential solution for communicating that the AV is in control and can be trusted. Even simple robotic objects can be designed to provide the social cues that passengers expect when entering a vehicle due to their rich experience as passengers in non-autonomous vehicles. This, in turn, can provide a sense of familiarity when using an unfamiliar technology, which is likely to facilitate a positive experience, enhance passengers' sense of safety, increase trust, and assist in overcoming acceptance challenges.

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REFERENCES

[1] Lucy Anderson-Bashan, Benny Megidish, Hadas Erel, Iddo Wald, Guy Hoffman, Oren Zuckerman, and Andrey Grishko. 2018. The greeting machine: an abstract robotic object for opening encounters. In *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 595–602.

[2] João Avelino, Leonel Garcia-Marques, Rodrigo Ventura, and Alexandre Bernardino. 2021. Break the ice: a survey on socially aware engagement for human–robot first encounters. *International Journal of Social Robotics* 13, 8 (2021), 1851–1877.

[3] Gurit E Birnbaum, Moran Mizrahi, Guy Hoffman, Harry T Reis, Eli J Finkel, and Omri Sass. 2016. Machines as a source of consolation: Robot responsiveness increases human approach behavior and desire for companionship. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 165–172.

[4] Jennifer Bornholt and Margareta Heidt. 2019. To drive or not to drive-A critical review regarding the acceptance of autonomous vehicles. (2019).

[5] Richard E Boyatzis. 1998. *Transforming qualitative information: Thematic analysis and code development.* sage.

[6] Peiyao Cheng, Fangang Meng, Jie Yao, and Yiran Wang. 2022. Driving With Agents: Investigating the Influences of Anthropomorphism Level and Physicality of Agents on Drivers' Perceived Control, Trust, and Driving Performance. *Frontiers in Psychology* 13 (2022), 883417.

[7] Jong Kyu Choi and Yong Gu Ji. 2015. Investigating the importance of trust on adopting an autonomous vehicle. *International Journal of Human-Computer Interaction* 31, 10 (2015), 692–702.

[8] Mark Colley, Svenja Krauss, Mirjam Lanzer, and Enrico Rukzio. 2021. How should automated vehicles communicate critical situations? a comparative analysis of visualization concepts. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 5, 3 (2021), 1–23.

[9] Hadas Erel, Elior Carsenti, and Oren Zuckerman. 2022. A carryover effect in hri: Beyond direct social effects in human-robot interaction. In *2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 342–352.

[10] Hadas Erel, Tzachi Shem Tov, Yoav Kessler, and Oren Zuckerman. 2019. Robots are always social: robotic movements are automatically interpreted as social cues. In *Extended abstracts of the 2019 CHI conference on human factors in computing systems*. 1–6.

[11] Hadas Erel, Denis Trayman, Chen Levy, Adi Manor, Mario Mikulincer, and Oren Zuckerman. 2022. Enhancing Emotional Support: The Effect of a Robotic Object on Human–Human Support Quality. *International Journal of Social Robotics* 14, 1 (2022), 257–276.

[12] Roja Ezzati Amini, Christos Katrakazas, Andreas Riener, and Constantinos Antoniou. 2021. Interaction of automated driving systems with pedestrians: Challenges, current solutions, and recommendations for eHMIs. *Transport Reviews* 41, 6 (2021), 788–813.

[13] Raymond Firth. 1972. Verbal and bodily rituals of greeting and parting. *The interpretation of ritual* 1972 (1972), 1–38.

[14] Anne Galletta. 2013. *Mastering the semi-structured interview and beyond: From research design to analysis and publication.* Vol. 18. NYU press.

[15] Adriana Hamacher, Nadia Bianchi-Berthouze, Anthony G Pipe, and Kerstin Eder. 2016. Believing in BERT: Using expressive communication to enhance trust and counteract operational error in physical Human-robot interaction. In *2016 25th IEEE international symposium on robot and human interactive communication (RO-MAN)*. IEEE, 493–500.

[16] Ryan Hamilton, Rosellina Ferraro, Kelly L Haws, and Anirban Mukhopadhyay. 2021. Traveling with companions: The social customer journey. *Journal of Marketing* 85, 1 (2021), 68–92.

[17] Renate Häuslschmid, Max von Buelow, Bastian Pfleging, and Andreas Butz. 2017. SupportingTrust in autonomous driving. In *Proceedings of the 22nd international conference on intelligent user interfaces*. 319–329.

[18] Guy Hoffman, Shira Bauman, and Keinan Vanunu. 2016. Robotic experience companionship in music listening and video watching. *Personal and Ubiquitous Computing* 20, 1 (2016), 51–63.

[19] Guy Hoffman and Wendy Ju. 2014. Designing robots with movement in mind. *Journal of Human-Robot Interaction* 3, 1 (2014), 91–122.

[20] Jiun-Yin Jian, Ann M Bisantz, and Colin G Drury. 2000. Foundations for an empirically determined scale of trust in automated systems. *International journal of cognitive ergonomics* 4, 1 (2000), 53–71.

[21] Wendy Ju and Leila Takayama. 2009. Approachability: How people interpret automatic door movement as gesture. *International Journal of Design* 3, 2 (2009).

[22] Malte Jung and Pamela Hinds. 2018. Robots in the wild: A time for more robust theories of human-robot interaction. , 5 pages.

[23] Malte F Jung, Dominic DiFranzo, Solace Shen, Brett Stoll, Houston Claure, and Austin Lawrence. 2020. Robot-assisted tower construction—a method to study the impact of a robot's allocation behavior on interpersonal dynamics and collaboration in groups. *ACM Transactions on Human-Robot Interaction (THRI)* 10, 1 (2020), 1–23.

[24] Nihan Karatas, Shintaro Tamura, Momoko Fushiki, and Michio Okada. 2019. Improving human-autonomous car interaction through gaze following behaviors of driving agents. *Transactions of the Japanese Society for Artificial Intelligence* 34, 2 (2019), A–IA1_1.

[25] Kanwaldeep Kaur and Giselle Rampersad. 2018. Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management* 48 (2018), 87–96.

[26] Adam Kendon. 1990. *Conducting interaction: Patterns of behavior in focused encounters.* Vol. 7. CUP Archive.

[27] Satoshi Kitazaki and Matthias J Myhre. 2015. Effects of non-verbal communication cues on decisions and confidence of drivers at an uncontrolled intersection. In *Driving Assesment Conference*, Vol. 8. University of Iowa.

[28] Johannes Maria Kraus, Florian Nothdurft, Philipp Hock, David Scholz, Wolfgang Minker, and Martin Baumann. 2016. Human after all: Effects of mere presence and social interaction of a humanoid robot as a co-driver in automated driving. In *Adjunct proceedings of the 8th international conference on automotive user interfaces and interactive vehicular applications*. 129–134.

[29] Srivatsan Chakravarthi Kumaran, Agam Oberlender, Andrey Grishko, Benny Megidish, and Hadas Erel. 2023. To Cross or Not-to-Cross: A Robotic Object for Mediating Interactions Between Autonomous Vehicles and Pedestrians. In *2023 32nd IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 285–292.

[30] Jae-Gil Lee, Ki Joon Kim, Sangwon Lee, and Dong-Hee Shin. 2015. Can autonomous vehicles be safe and trustworthy? Effects of appearance and autonomy of unmanned driving systems. *International Journal of Human-Computer Interaction* 31, 10 (2015), 682–691.

[31] Jae-gil Lee and Kwan Min Lee. 2022. Polite speech strategies and their impact on drivers' trust in autonomous vehicles. *Computers in Human Behavior* 127 (2022), 107015.

[32] Seul Chan Lee, Harsh Sanghavi, Sangjin Ko, and Myounghoon Jeon. 2019. Autonomous driving with an agent: Speech style and embodiment. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings*. 209–214.

[33] Ana Mackay, Inês Fortes, Catarina Santos, Dário Machado, Patrícia Barbosa, Vera Vilas Boas, João Pedro Ferreira, Nélson Costa, Carlos Silva, and Emanuel Sousa. 2020. The impact of autonomous vehicles' active feedback on trust. In *Advances in Safety Management and Human Factors: Proceedings of the AHFE 2019 International Conference on Safety Management and Human Factors, July 24-28, 2019, Washington DC, USA 10*. Springer, 342–352.

[34] Adi Manor, Benny Megidish, Etay Todress, Mario Mikulincer, and Hadas Erel. 2022. A Non-Humanoid Robotic Object for Providing a Sense Of Security. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 1520–1527.

[35] Nikolas Martelaro, Victoria C Nneji, Wendy Ju, and Pamela Hinds. 2016. Tell me more designing hri to encourage more trust, disclosure, and companionship. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 181–188.

[36] Benny Megidish. 2017. *Butter Robotics.* https://butterrobotics.com/

[37] Lia Morra, Fabrizio Lamberti, F Gabriele Prattichó, Salvatore La Rosa, and Paolo Montuschi. 2019. Building trust in autonomous vehicles: Role of virtual reality driving simulators in HMI design. *IEEE Transactions on Vehicular Technology* 68, 10 (2019), 9438–9450.

[38] Bilge Mutlu, Takayuki Kanda, Jodi Forlizzi, Jessica Hodgins, and Hiroshi Ishiguro. 2012. Conversational gaze mechanisms for humanlike robots. *ACM Transactions on Interactive Intelligent Systems (TiiS)* 1, 2 (2012), 1–33.

[39] Austin Lee Nichols and Jon K Maner. 2008. The good-subject effect: Investigating participant demand characteristics. *The Journal of general psychology* 135, 2 (2008), 151–166.

[40] Thomas P Novak and Donna L Hoffman. 2019. Relationship journeys in the internet of things: a new framework for understanding interactions between consumers and smart objects. *Journal of the Academy of Marketing Science* 47 (2019), 216–237.

[41] Jekaterina Novikova and Leon Watts. 2014. A design model of emotional body expressions in non-humanoid robots. In *Proceedings of the second international conference on Human-agent interaction*. 353–360.

[42] Luis Oliveira, Jacob Luton, Sumeet Iyer, Chris Burns, Alexandros Mouzakitis, Paul Jennings, and Stewart Birrell. 2018. Evaluating how interfaces influence the user interaction with fully autonomous vehicles. In *Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. 320–331.

[43] RJG Opdenakker. 2006. Advantages and disadvantages of four interview techniques in qualitative research. In *Forum qualitative Sozialforschung= Forum: Qualitative Social Research*, Vol. 7. Institut fur Klinische Sychologie and Gemeindesychologie, art–11.

[44] Maike Paetzel, Giulia Perugia, and Ginevra Castellano. 2020. The persistence of first impressions: The effect of repeated interactions on the perception of a social robot. In *Proceedings of the 2020 ACM/IEEE international conference on human-robot interaction*. 73–82.

[45] Nicole Perterer, Petra Sundström, Alexander Meschtscherjakov, David Wilfinger, and Manfred Tscheligi. 2013. Come drive with me: an ethnographic study of

driver-passenger pairs to inform future in-car assistance. In *Proceedings of the 2013 conference on Computer supported cooperative work*. 1539–1548.
[46] Viva Sarah Press and Hadas Erel. 2022. Designing Non-Verbal Humorous Gestures for a Non-Humanoid Robot. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. 1–7.
[47] Solmaz Razmi Rad, Gonçalo Homem de Almeida Correia, and Marjan Hagenzieker. 2020. Pedestrians' road crossing behaviour in front of automated vehicles: Results from a pedestrian simulation experiment using agent-based modelling. *Transportation research part F: traffic psychology and behaviour* 69 (2020), 101–119.
[48] Amir Rasouli and John K Tsotsos. 2019. Autonomous vehicles that interact with pedestrians: A survey of theory and practice. *IEEE transactions on intelligent transportation systems* 21, 3 (2019), 900–918.
[49] Laurel D Riek. 2012. Wizard of oz studies in hri: a systematic review and new reporting guidelines. *Journal of Human-Robot Interaction* 1, 1 (2012), 119–136.
[50] Danielle Rifinski, Hadas Erel, Adi Feiner, Guy Hoffman, and Oren Zuckerman. 2021. Human-human-robot interaction: robotic object's responsive gestures improve interpersonal evaluation in human interaction. *Human–Computer Interaction* 36, 4 (2021), 333–359.
[51] Peter AM Ruijten, Jacques MB Terken, and Sanjeev N Chandramouli. 2018. Enhancing trust in autonomous vehicles through intelligent user interfaces that mimic human behavior. *Multimodal Technologies and Interaction* 2, 4 (2018), 62.
[52] Deborah Schiffrin. 1977. Opening encounters. *American sociological review* (1977), 679–691.
[53] Bridie Scott-Parker. 2017. Nonverbal communication during the learner lesson with a professional driving instructor: a novel investigation. *Transportation research part F: traffic psychology and behaviour* 47 (2017), 1–12.
[54] David Sirkin, Brian Mok, Stephen Yang, and Wendy Ju. 2015. Mechanical ottoman: how robotic furniture offers and withdraws support. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*. 11–18.
[55] Edward R Straub and Kristin E Schaefer. 2019. It takes two to Tango: Automated vehicles and human beings do the dance of driving–Four social considerations for policy. *Transportation research part A: policy and practice* 122 (2019), 173–183.
[56] Hamish Tennent, Solace Shen, and Malte Jung. 2019. Micbot: A peripheral robotic object to shape conversational dynamics and team performance. In *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 133–142.
[57] Yiyuan Wang, Luke Hespanhol, and Martin Tomitsch. 2021. How Can Autonomous Vehicles Convey Emotions to Pedestrians? A Review of Emotionally Expressive Non-Humanoid Robots. *Multimodal Technologies and Interaction* 5, 12 (2021), 84.
[58] Adam Waytz, Joy Heafner, and Nicholas Epley. 2014. The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle. *Journal of experimental social psychology* 52 (2014), 113–117.
[59] Min Wu, Nanxi Wang, and Kum Fai Yuen. 2023. Deep versus superficial anthropomorphism: Exploring their effects on human trust in shared autonomous vehicles. *Computers in Human Behavior* 141 (2023), 107614.
[60] Jin Xu and Ayanna Howard. 2018. The impact of first impressions on human-robot trust during problem-solving scenarios. In *2018 27th IEEE international symposium on robot and human interactive communication (RO-MAN)*. IEEE, 435–441.
[61] Siyuan Zhou, Xu Sun, Bingjian Liu, and Gary Burnett. 2021. Factors affecting pedestrians' trust in automated vehicles: Literature review and theoretical model. *IEEE Transactions on Human-Machine Systems* 52, 3 (2021), 490–500.
[62] Jens Zihsler, Philipp Hock, Marcel Walch, Kirill Dzuba, Denis Schwager, Patrick Szauer, and Enrico Rukzio. 2016. Carvatar: increasing trust in highly-automated driving through social cues. In *Adjunct proceedings of the 8th international conference on automotive user interfaces and interactive vehicular applications*. 9–14.
[63] Oren Zuckerman, Dina Walker, Andrey Grishko, Tal Moran, Chen Levy, Barak Lisak, Iddo Yehoshua Wald, and Hadas Erel. 2020. Companionship Is Not a Function: The Effect of a Novel Robotic Object on Healthy Older Adults' Feelings of" Being-Seen". In *Proceedings of the 2020 CHI conference on human factors in computing systems*. 1–14.