Autonomous Vehicle-Pedestrian Interaction Across Cultures: Towards Designing Better External Human Machine Interfaces (eHMIs)

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Abstract

Drivers and pedestrians use various culturally-based non-verbal cues such as head movements, hand gestures, and eye contact when crossing roads. With the absence of a human driver, this communication becomes challenging in autonomous vehicle (AV)- pedestrian interaction. External human-machine interfaces (eHMIs) for AV-pedestrian interaction are being developed based on the research conducted mainly in North America and Europe, where the traffic and pedestrian behavior are very structured and follow the rules. In other cultures (e.g., South Asia), this can be very unstructured (e.g., pedestrians spontaneously crossing the road at non-cross walks is not very uncommon). However, research on investigating cross-cultural differences in AV-Pedestrian interaction is scarce. This research focuses on investigating cross-cultural differences in AV-Pedestrian interaction to gain insights useful for designing better eHMIs. This paper details three cross-cultural studies designed for this purpose, and that will be deployed in two different cultural settings: Sri Lanka and Germany.

Author Keywords

Autonomous Vehicle - Pedestrian interaction; external human machine interfaces (eHMIs); cultural differences; cross-cultural comparison; intent communication

CCS Concepts

•Human-centered computing → User interface programming; Interactive systems and tools;

Introduction

Autonomous vehicles (AVs) will provide many benefits such as enhanced mobility for an aging society and increased levels of comfort for drivers [14, 24, 8]. Despite being very close to becoming a reality, AVs still need further research and development to enable practical deployment and integration into society. One of the challenges faced in practical deployment of AVs is handling of differences in cultural and social norms in detecting pedestrians' intent and communication of the vehicle's intent to pedestrians [19].However, research on AV-pedestrian interaction, gained attention only very recently.

Autonomous driving is different to traditional driving in the context of vehicle-pedestrian interaction. In traditional driving, the driver plays a central role in controlling and decision making when it comes to the vehicle's interaction with pedestrians. For example, drivers change the speed of the vehicle when they see a pedestrian trying to cross the road and use culturally-based, human-centric non verbal cues such as head movements, hand gestures, and eye contact to communicate their intent with pedestrians [7, 15, 21, 18]. With autonomous driving, vehicle-pedestrian interaction becomes challenging especially when it comes to communicating vehicle's awareness of the pedestrian's intent and communicating vehicle's intent to pedestrians [22]. Current research shows that communication of AVs awareness and intent is beneficial to users [17]. For example, Mahadevan et al. [10] found that the explicit communication of AV's awareness and intent to pedestrians using interfaces (in-vehicle, road infrastructure) are helpful to pedestrians in a road crossing scenario [10]. A lot of research is ongoing to find out how to communicate AV's awareness and intent to pedestrians [22]. For example, Chang et al. [3] compared five modalities to communicate between AVs and pedestrians [3]. Despite these existing research on communication between AVs and pedestrians, intent communication is still challenging in multiple dimensions such as catering for a range of users (eg. people with impairments, school children, elderly), addressing complexities arising from cultural and social differences, infrastructure support and development of standards and protocols [14, 19, 13, 4]. Thus, more research is needed to find exactly how to communicate the AV's awareness and intent to pedestrians [14, 22, 19, 13, 4].

On the other hand, research in this domain is nowadays mainly conducted in Europe and North America. Novel cars are designed based on the results of research conducted within these regions. Particularly research involving pedestrian-car interaction is mainly informed based on the behavior of users in these regions. In a global perspective, however, such behavior widely differs from region to region. While traffic in the currently researched areas is very structured and follows official rules imposed by governments, traffic in other parts of the world evolved more naturally and formed its own rules and regulations. For example, the number of lanes used on a road is defined by the lanes drawn on the street in North American and European countries whereas countries in Asia and Africa rather extend that suggestion to fit more cars next to each other (cf., Figure 1). Similarly, pedestrians in American and European countries crossing the street outside traffic lights and crosswalks is not very common whereas, in Sri Lanka for example, pedestrians cross the streets wherever possible and also expect cars to slow down and drive around them. It is very common in Sri Lanka that the pedestrians cross

Figure 1: Traffic in Sri Lanka and pedestrians crossing the road in the traffic (Image credit: [1, 20, 6, 12]). A video of the actual traffic can be found in [6].

the road while the signal light in the crosswalk signals "Do Not Cross" (RED).

Pedestrians intending to cross the road in these countries use various non verbal cues and behaviors that the drivers detect and understand. Pedestrians cross the road even at non-crosswalks and in very congested and busy roads using this mutual non verbal communication (cf., Figure 1). For example, the video in [6] shows how pedestrians cross a busy, congested road in Kandy in Sri Lanka using this mutual communication. Drivers know the intentions of the pedestrians from their behavior and posture. On the other hand, pedestrian behavior in these countries can also be very spontaneous and unpredictable leading to traffic accidents. For example, in Sri Lanka, a majority of pedestrian traffic injuries happen while crossing the road. For example, in Kurunegala, Sri Lanka, majority of traffic accident related pedestrian injuries (82%) happens while crossing the road, out of which 34% are on a pedestrian crossing [2]. In 2012 only, 110 pedestrian fatalities in Sri Lanka happened at pedestrian crosswalks [11]. One reason for this is that the pedestrians assume crosswalks to be safe and presume vehicles would stop at any instance thus cross the road without assessing the traffic or giving any clue to the drivers. [11]. Furthermore, in the context of developing countries, it is very unlikely that the normal vehicles be fully replaced by driverless vehicles in the near future. This transition will gradually happen meaning that both normal vehicles and driverless cars will share the roads for a long time. This, intern can lead to more confusion or even more fatalities at pedestrian crosswalks in countries like Sri Lanka if propeer means to facilitate effective communication between autonomous vehicles and pedestrians were not de-

Figure 2: Ghost Driver: special car seat costume introduced by Rothenbücher et al. [16, 5] to facilitate Wizard-of-OZ field studies involving autonomous vehicles (Image credit: [16, 5]).

veloped. Thus it is sensible to investigate how pedestrians interact with vehicles in different cultural settings, in different regions of the world to better understand the communication needs between AVs and pedestrians [19]. Such cross cultural studies could provide insights on how to tackle the AV-pedestrian communication and on designing better interfaces for AV-pedestrian interaction. However, only a very little is known about such cultural differences and systematic cross cultural studies on how pedestrians interact with an approaching autonomous vehicle are very rare.

Though not very common, there exists some research that investigate cross-cultural aspects related to AV-pedestrian interaction. For example, Weber et al. [23] studied the potential of external human machine interfaces (eHMIs) across three cultures, Germany, United States and China. Based on the results, the authors suggest that eHMIs should not be used in different cultures without considering necessary cultural adaptations. They further recommend to take habitual behavioral patterns, traffic behavior and what users expect to happen in such situations into account when introducing eHMIs in different cultural settings. [23].

Currano et al. [5] studied how pedestrians from two regions: Mexico City (metropolitan) and Colima (a smaller regional coastal city) interact with an approaching AV and found that pedestrians in Mexico City kept their pace and more often crossed in front of the vehicle whereas pedestrians in Colima stopped before crossing in front of the vehicle more often [5]. Li et al. [9] compared pedestrian behavior to an approaching autonomous vehicle in California, USA and, the Netherlands[9]. They discovered that pedestrian crossing and looking times increased when the pedestrians were in groups (compared to singletons) or saw an autonomous vehicle (compared to a normal vehicle) [9].

In summary, this work is motivated by the fact that much of the current research on autonomous vehicle- pedestrian interaction has so far happened mainly in Europe and in North America and there is a lack of similar research across cultures. The overarching goal of this research is therefore to investigate cross cultural differences (and similarities) of AV-pedestrian interaction with respect to the communication between AVs and pedestrians. For this purpose, we designed three experiments based on previous research. These experiments try to systematically compare how pedestrians from two different cultures (Sri Lanka and Germany) cross the road, their behavioral responses to an approaching normal or autonomous vehicle as well as potential interface designs. The overall objective is to gain insights that can be used to design better eHMIs to facilitate AV-Pedestrian interaction. In particular we aim to find out:

- the main cultural differences with regard to the communication between cars and pedestrians,
- ways to apply cultural differences or similarities in the design of autonomous cars (e.g., do we need specific cars for every culture or can we base our guidelines on the commonalities between cultures and how?).

In summary, the main contribution of this research is a systematic investigation of how cultural differences influence the communication between autonomous cars and pedestrians.

Cross Cultural Studies

This section briefly details the experiments we designed for the cross-cultural comparison of AV-Pedestrian interaction in the context of the two chosen cultures: Sri Lanka and Germany. There are two main reasons for selecting

Sri Lanka and Germany for this research. First, their differences in cultural backgrounds: Germany, a developed country with more western culture and more structured traffic that follows the rules and regulations; Sri Lanka, a developing country with Asian culture and where the traffic is more unstructured. Second, they were chosen for convenience sampling due to the researchers involved come from these two countries. However, technically, any two countries with different traffic cultures could be used for these studies.

Study 1: Pedestrians and Autonomous Vehicles: The objective of this study is to compare the behavioral response of pedestrians from two different cultures (Sri Lanka, a developing South Asian country with an Asian culture and Germany, a developed European country with a western culture) to an approaching autonomous vehicle in a road crossing scenario.

Method: A breaching experiment similar to the one conducted by Currano et al. [5] to investigate the behavioral response of pedestrians trying to cross a road (at a crosswalk or at a non-crosswalk) to an approaching AV will be conducted. To simulate autonomous driving, the Ghost Driver protocol introduced by Rothenbücher et al. [16] will be used. In the Ghost Driver protocol, a manually-driven car with a driver hidden in a special car seat costume (Figure 2) will be used to evoke an automated driving scenario [16]. Multiple cameras installed inside the car, on top of the car and across the street will be used to video record the pedestrian's reactions from multiple perspectives. Pedestrians will be interviewed to gain further feedback on their experience with the AV. Videos will be analysed using a coding scheme to categorize different behavioral responses and the interviews will be transcribed and analysed using a coding scheme. This study also will be replicated in Sri Lanka and in Germany and the results will be analysed for cross cultural differences and similarities.

Study 2: Pedestrians and Normal (non-autonomous) Vehicles: This experiment will investigate how pedestrians will interact with a normal car (driven by a human driver) in a road crossing scenario.

Method: A manually driven normal car will be used to video record how pedestrians from the two cultures (Germany and Sri Lanka) interact with vehicles in a road crossing scenario. A camera installed inside the car will be used to video record the pedestrian's behavior in a road crossing scenario. Videos will be analysed using a coding scheme to categorize different behavioral responses. The results will be analysed for cross cultural differences and similarities.

Study 3: Design study on interfaces for communication between AVs and pedestrians: A cross cultural design study: The objective of this study is to compare interface (to communicate AVs awareness and intent) design insights from people from two different cultures (Sri Lanka, a developing South Asian country with an asian culture AND Germany, a developed European country with a western culture).

Method: A participatory design method where participants will design interfaces for AV's intent and awareness communication for a road-crossing scenario for two conditions (in a pedestrian crosswalk and when there is no crosswalk) for a set of predefined situations. These situations will include for example, the vehicle decides to stop and allow the pedestrian to cross, the vehicle decides not to stop, pedestrians trying to cross in a school zone, pedestrians with various impairments trying to cross the road, etc.). Participants will be provided a list of potential design elements such as for example, LED panels and WiFi (based on existing literature on interfaces for AV-pedestrian interaction) but they are encouraged to use any element they think is appropriate even if they are not listed in the list. Participants will be provided with required stationary such as drawing boards, markers, sticky notes etc. The study will take in three phases. In the first phase, participants will design alone and in the second phase they will work in groups. In the third phase, a focus group (with participants) will be conducted to discuss the designs. All the sessions will be video-recorded. The study will be replicated in Sri Lanka and in Germany and the results will be analysed for cross cultural differences and similarities. The findings will be used afterwards to create a design space for intent and awareness communication in AV-pedestrian interaction.

Study 1 and study 2 will investigate how pedestrians from two different cultures communicate with a car (normal/ autonomous) in a road crossing scenario (in crosswalks and non-crosswalks). For example, whether (how often) they use eye contact, look at the driver/ approaching car, and various gestures they use. These two studies will also look at other behavioral responses such as stopping and waiting time, percentage of spontaneous crossings (and their nature), and violations of traffic signals in crossing the road. Through the interviews, these studies will also investigate other factors relevant to road-crossing decisions such as vehicle speed, type of vehicle, and vehicle appearance. These studies will then compare the above factors between the two cultures involved to see if there are differences (or similarities) thus aim to address the first research question. On the other hand, the outcomes of these studies could provide insights valuable for pedestrian intent detection in road crossing scenarios and to see if there are cultural differences. These findings could also provide insights on when and how to trigger autonomous vehicle to pedestrian communication. Thus study 1 and 2 also contribute towards research question 2. Study 3 mainly focuses on revealing different interface concepts from two different cultural perspectives. The similarities or differences in the interface concepts and elements together with findings from study 1 and study 2 could provide insights to answer research question 2.

The Way Forward

This paper presented only a minimalist set of experiments as an initiative to raise the need for cross-cultural research related to AV-Pedestrian interaction. We are currently organizing the deployment of these experiments in Sri Lanka and in Germany. This research can be extended in several dimensions. For example, we can extend the type and the number of the experiments to cover different aspects related to AV-Pedestrian interaction such as for example, cross cultural evaluation of eHMI concepts that have been developed. Another way of extending is to replicate the experiments in other cultures such as South America, Eastern Asia, Africa and Eastern Europe. Developing a benchmark set of experiments for cross-cultural evaluation of AV-Pedestrian interaction could also be an interesting long term goal.

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