Children's Views on Identification and Intention Communication of Self-driving Vehicles

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Abstract
One of the major reasons behind traffic accidents is misinterpretation among road users. Self-driving vehicles are expected to reduce these accidents, given that they are designed with all road users in mind. Recently, research on the design of vehicle-pedestrian communication has emerged, but to our knowledge, there is no research published that investigates the design of interfaces for intent communication towards child pedestrians. This paper reports the initial steps towards the examination of children's views and understandings about the appearance and intention communication of self-driving vehicles. It adopts a design inclusive methodological approach for the development of a prototype for the communication of two basic intentions: "I am going to stop" and "I am going to proceed". The initial results indicate children's need to be aware about the autonomy of the vehicle and the use of their previous experience with traffic signs for the interpretation of communicative signs of the vehicle.

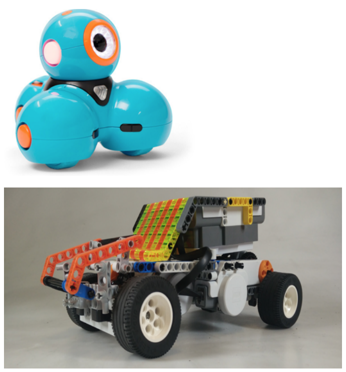


Figure 1: Materials for the focus group session with children

Author Keywords

Self-driving vehicles; child pedestrians; intention communication; interface design; inclusive design research.

ACM Classification Keywords

H.5.2 Information interfaces and presentation: user interfaces (D.2.2, H.1.2, I.3.6) Subjects: Interaction Styles; H.1.2 User/Machine Systems: Human Factors

Introduction

Children are one of our most vulnerable categories of road users. The World Health Organization (WHO) estimates that about 500 children die in accidents with motorized road vehicles each day, and that nearly two thirds of these fatalities occur outside the vehicle [17]. Child pedestrians' vulnerability stems from two key factors: (i) their physical vulnerability (they are small and are still developing physically), and, (ii) their functional vulnerability, which refers to their stages of cognitive and perceptual development, with many skills that are considered essential for safe traffic participation not fully developed until young adulthood [12]. In particular, child pedestrian safety is of concern during middle childhood when children venture farther from home, but have not yet fully developed cognitive skills needed to negotiate pedestrian environments (e.g., [1]).

Automated vehicles (AVs) that assume either partial or full authority from vehicle drivers are one of the currently most promising countermeasures being developed. Eliminating the "driver error" is expected to improve general traffic safety. However, to facilitate benefits for child pedestrians, such vehicles need to be designed with children in mind. That is, the design of AVs needs to ensure that children can easily detect, perceive and interpret intentions and actions of such vehicles, and that the risk of miscommunication between them is eliminated.

Recently, research on the design of vehicle-pedestrian communication has emerged (e.g., [3,6,9]), however the idionscratic nature of child-pedestrian might need different approaches and design principles to ensure sematically valid intent communication towards children. Since, to our knowledge, there is no research published that investigates the design of interfaces for intent communication towards child pedestrians, this topic is addressed in the study reported in this paper.

Related Work

Vehicle-pedestrian communication

Pedestrians interact with vehicles by interpreting vehicle-centric cues (e.g., velocity) and driver-centric cues (e.g., eye contact) [15]. Recent studies suggest that the introduction of AVs in the urban context may lead to a notable change on how pedestrians experience AVs compared to today's vehicles [3,8,9,14]. With the transfer of control from the driver to the vehicle, pedestrians will not be able to rely on driver-centric cues anymore. This could, in turn, lead to misinterpretation of AVs' intent and increase the risk of unpleasant encounters and accidents.

Design solutions for intent communication

To aid communication between AVs and pedestrians, communication solutions featuring external vehicle interfaces with primary visual cues have been suggested. A biomimetic interface for automated vehicles called AEVITA has been suggested that uses light, sound and mechanical actuators [13]. Researchers from Sweden suggested an interface concept called AVIP that informs pedestrians about

Figure 2: Pictures for intention communication examined with the interactive questionnaire

- Emulate human hand
- Emulate eye contact
- Projections on the ground
- Front window display
- Display in the grill
- Wearable warning device
- Audible warnings
- Pulsating icons

Table 1: Results from the brainstorming

vehicle's intentions via a LED-list on the windshield without explicitly inviting pedestrians to act [6]. Mercedes demonstrated a concept vehicle that projects a zebra crossing in front of the pedestrian and issues auditory signal to cross the road [10], while Nissan messages in the front windshield such as "after you" [11]. Google uses a flashing stop sign on the door of an AV to inform pedestrians not to cross the street and sound signals that mimic characteristics of conventional vehicles to alert pedestrians about their presence [5]. All these interfaces feature different modalities and appearances, but little is known about which interfaces are most legible to children.

Children's construction of mental models

One of the basic prerequisites in designing new interactive technologies for children is the use of their existing mental models as a basis for the construction of meaningful metaphors that support the underlying functionality of technology. Successful interface metaphors should draw on children's previous experiences in order to establish connotations that allow them to predict the results of their action in advance [16]. Previous research (e.g., [4]) indicates the necessity of including children in the design process at each stage of development, as a design partner, tester or user and iterate based on their feedback.

Current Work

This paper presents a design-based study of the development of a prototype and the extraction of preliminary design principles for the intention communication of an AV towards child pedestrians. The aim is to examine the impact of certain modalities on the legibility and interpretation of signals by children aged 7-10 years old, which may have an influence on children's safety and the social acceptance of AVs in urban environments. Therefore, open research questions (RQ) are as follows:

RQ1: What components in behavior and appearance do children use to identify autonomous vehicles?

RQ2: Which form factor of visual intention communication do children most consistently understand?

We focus on two traffic situations: (i) the vehicle intends to stop and let the pedestrian cross the road, (ii) The vehicle intends to continue moving and warns the pedestrian to stop. We assume humans inside the vehicle do not communicate with child pedestrians.

Method

The RQ are addressed by exploring children's views. Due of its exploratory nature, we apply a design inclusive research methodological approach that considers a dual manifestation of the design: as a process for a product development and as a research means [7].

Participants

Children aged 7 to 10 years were selected as children at this age start walk to school without close supervision. In total, 41 children participated. We gained the approval from one of the author's university department ethical committee and informed consent from participants' parents/carers.

Development of the prototype

To answer the research question RQ1, two sessions were designed: (1) a brainstorming with adults for the

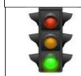
Signal	Description	Correctly decoded
	Green light	90%
	Walking figure	67%
	Red light	100%
	Stop sign	100%
	Light signals on car	90%
	"Child-walk" signal	100%
	Green flickering lights	67 %
	Projected zebra cross.	63 %
	"Child-stop" signal	97%
	Red flickering lights	93%
	Anthro. animation	40%
	Red projected zebra cross.	87%

Table 2: Results from the questionnaire (n=30)

aggregation of existing knowledge, identification of the problem, definition of goals and generation of solutions, and (2) a focus group and a drawing session with children, for the specification of the design criteria that define children's perceptions aiming to address the first research question of this study.

Brainstorming

To construct a theoretical platform, we drew on the existing research and on the results of a brainstorming session. This included a set of design goals and possible solutions which were translated in detailed sub-solutions (e.g., animated signs, projected crosswalk etc.) and then categorized as visual, audio or tactile (see Table 1).

Focus Group and Drawing Session

We organized a focus group and drawing session with 11 children aged 7 to 10 years. Probe questions and interactive materials (Figure 1) were used to ensure children's understanding of the concept of self-driving vehicles. Children's drawings were used as a means to reveal how children perceive and interpret concepts [2]. The analysis of the drawings and the conversations revealed that the main modality used to identify an autonomous vehicle is visual. The features they used included displays, projections, cameras, visible sensors and sound systems. Interestingly, 6 children mentioned visual features that relate to the recognition that the vehicle is automated (e.g., visible cameras on the top of the vehicle).

In sum, the results from the focus group session indicate that children most commonly use visual cues in the vehicle apperance to identify wheather the vehicle is autonomous or not.

Survey

This study aimed to address the second research question (RQ2). That is, it examined children's current knowledge and perceptions on the use of new visual signs for the communication of the stop / go strategies. We developed a survey consisting of an interactive questionnaire and a video study (Figure 2). These were inspired by the results from the focus groups and drawing sessions (Table 1). In total, 30 children took part, 12 boys (9.92y, SD=0.29) and 18 girls (9.89y, SD=0.47).

Questionnaire

The questionnaire consisted of 19 items, which were discplayed on personal computers. For each question, the children had to choose between two options: The human figure / the vehicle will Stop or Go. Three adult facilitators were present and provide procedural clarifications if needed. The results shown in Table 2 imply that children are familiar with existing go/stop signals and interpret them correctly. The new signals that were inspired by existing signals were also easily recognizable. However, in the case of an anthropomorphic animation, the results did not show consistency. We conducted a binomial logistic regression on the number of successful and unsuccessful interpretations as the response variable and intent, and found an interaction effect ($z = 2.86$, $p = 0.004$) as well as main effects for novelty ($z = -3.44$, $p < 0.001$), and walking ($z = -3.13$, $p = 0.002$). We conducted pairwise Tukey comparisons, specifically comparing the novel symbols for walking with one another and the novel symbols for stopping with one another. For walking, no significant differences were found. For stopping, all symbols except the orange

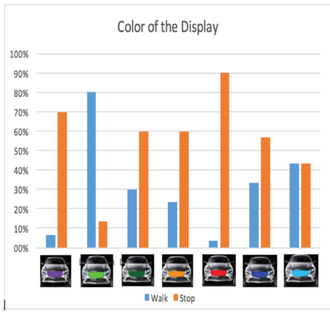


Figure 3: Results from the color of display questions in the questionnaire (n=30)

color were recognized significantly better than the anthropomorphic symbol.
For the investigation of the effects of colors, we designed a display to a vehicle grille showing different colors and we asked the children if they would stop or cross the road. The colors that were read in a more consistent way were: red (90%), green (80%), and orange (60%), see Figure 3.
The children could also explain the reason of their choice and a qualitative content analysis was carried out. Most interestingly, some of the children noted that they were not sure whether the displayed signs represented the intention of the vehicle or a command for the pedestrian. However, they did not mention any uncertainty regarding this point of confusion when the "child-signs" were displayed, which was a clear indication that this was a message for the pedestrian.

Video-based survey
We designed 3 video-clips, in which we displayed an autonomous vehicle and a (child pedestrian) figure who had to take a stop/go decision. The clips were used to investigate three affordances of communication: an already known signal displayed on the vehicle, a set of expressive eyes displayed on the vehicler, and a zebra crossing projected by the vehicle on the road. Data analysis showed that all children understood the display of an already known signal. The answers of the children about the display of the eyes on the vehicle and the projected cross road were not consistent.

In sum, the results from the survey indicate that the stop/go cues built on conventional traffic signals were more consistently recognized by children than new cues based on anthropomorphic animations. This is in accordance to the relevant literature on the ways in which children develop new constructs based on their existing mental models.

Discussion and next steps
This late breaking paper presents the first results of an ongoing research which aims to explore features that children use for the identification of an AV and the interpretation of communicative signals of its intentions. We adopted an inclusive design research methodology that proved to be an efficient and developmentally appropriate way to gain knowledge about childrens's views about non-existing AVs.
Overall, our preliminary findings indicate children's need to know whether the vehicle they are encountering is autonomous. This may create the basis for the development of the trust towards self-driving vehicles. Also, the results revealed a consistency in terms of colors used for the indication of a stop/go strategy. Green, red and orange where the best legible for children. This result can be explained by the constructivist theoretical approaches of children's development regarding the construction of mental models within a new situation. Children's need for concrete and easily read messages was also revealed. The "child-sign" that holds the stop or go sign was among the best understood.
Given the limited number of children in the study, it is difficult to generalize our results. However, the results can be used to inform design and select direction for further research. This study is only the first step towards the investigation of interaction between child pedestrians and self-driving vehicles. Next steps include the development of prototypes with additional comparisons and field studies with a larger sample of children. In addition, design issues, such as the color of signals, luminance, form and placement need to be

investigated further to ensure that the proposed signals are in line with the legislation. An important step that will be taken is to explore interaction between child pedestrians and automated vehicles without any external signals, and compare with the corresponding interactions with selected signals.

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