# Incorporating Multiple Users' Perspectives in HMI Design for Automated Vehicles: Exploration of a Role-Switching Approach

Ruolin Gao*
r.gao@tue.nl
Eindhoven University of Technology
Eindhoven, The Netherlands

Rutger Verstegen*
r.verstegen@tue.nl
Eindhoven University of Technology
Eindhoven, The Netherlands

Haoyu Dong
h.dong@tue.nl
Eindhoven University of Technology
Eindhoven, The Netherlands

Pavlo Bazilinskyy
p.bazilinskyy@tue.nl
Eindhoven University of Technology
Eindhoven, The Netherlands

Marieke Martens
m.h.martens@tue.nl
Eindhoven University of Technology
Eindhoven, The Netherlands
TNO
Helmond, The Netherlands


**Figure 1: Close-up of participants' perspectives from each role and a scenario overview. A: Manually-driven vehicle driver, B: Pedestrian, C: Cyclist, D: Automated vehicle passenger, E: Overview of the scenario.**

## ABSTRACT

Human-machine interfaces (HMIs) are important for the introduction of automated vehicles (AVs). Even though interactions can involve multiple users and modes of transportation, current research and ideation for HMIs are often directed at only one road user group. This reductionist approach goes against the principles of design, which argue for a holistic understanding. To address this gap, we conducted a novel role-switching approach where participants explored a traffic scenario from four roles: pedestrian, cyclist, driver of a manually-driven vehicle and passenger of an AV. After experiencing all roles, participants evaluated each role and generated HMI designs. Results demonstrate that the roles were perceived differently and that switching between these different perspectives contributed to participants' understanding of the traffic scenario and the generated designs. This paper reports insights on the value of a role-switching approach to promote the future development of a more holistic approach towards HMIs.

## CCS CONCEPTS

• **Human-centered computing** → **Interaction design process and methods**.

## KEYWORDS

HMI, Design, Holistic, Role-switching, Automated Vehicle

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*Both authors contributed equally to this research.


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# 1 INTRODUCTION

Human-machine interfaces (HMIs) are pivotal in facilitating effective communication between automated vehicles (AVs) and humans, including both other road users (ORUs) and in-vehicle users [3]. This paper discusses a novel approach for designing such HMIs, focusing on automation that does not require driver control (i.e. SAE level 4 and 5 [7]).

## 1.1 Design: Reductionist vs holistic approach

Current research and ideation efforts in HMIs focus predominantly on either internal or external communication, targeting in-vehicle users and ORUs separately [9]. Regarding external communication with ORUs, the scope of research is furthermore reduced by a large body concentrating on AV-pedestrian interactions [8]). Some studies examined AV interactions with cyclists (e.g. [2]) or with drivers of manually-driven vehicles (MDVs) (e.g. [15]); however, these studies are scarce and often have a limited scope of one user group.

Focusing on a single-user perspective with a reductionist approach offers effectiveness in initial research—simplifying complex problems for easier analysis and later synthesizing the solutions to a whole [1]. However, the comprehensive integration of AVs into the existing traffic ecosystem necessitates a holistic consideration of multiple user types, both internal and external [17]. Additionally, traffic interactions with multiple users and even multiple modes of transportation are not uncommon and thus require further consideration. Such a holistic approach is aligned with the principles of requirements exploration in design, where the aim is to, among other things, understand the conditions in which a product will be used, its users, and their goals and tasks [14]. The manifold in user roles and the prevalence of multi-user scenarios underscore the need to consider HMI design from a more holistic perspective.

## 1.2 Role-playing and user enactment

Role-playing and user enactment are widely used design approaches to help designers and participants better understand scenarios and experiences. As articulated by IDEO design [16]: "*With the dual properties of bringing participants into the moment and making shared activities physical rather than just mental, role-playing techniques make the process more experiential and creatively generative*". Work by Buchenau and Suri [6] and Iacucci et al. [10] describes how role-playing and enactment explorations can bridge the gap between real and prototyped situations. Odom et al. [13] describe the user enactments design approach, where users act out scenarios to envision potential futures. By doing so, they investigate these scenarios, helping reduce risks and uncover new opportunities that may not be easily identified through studies of users' current behaviour [13]. Iacucci et al. [10] developed a role-playing game and situated and participative enactment of scenarios (SPES) to address their design challenges in open-ended design, mobility, and socio-cultural influences. Such approaches enable exploring future potential scenarios by providing experienceable roles, scenarios and interactions, which we aim to leverage for the purpose of this study.

## 1.3 Aim of this study

To address the consideration of the manifold of traffic roles and HMI designs, we investigated the usage of role-switching sessions to incorporate multiple users' perspectives when exploring and ideating on HMI designs. As such, we aim to answer the following research question (RQ): *How can a role-switching approach be used to facilitate a holistic understanding for HMI design?* In this Work in Progress paper, we demonstrate the execution of a role-switching approach and report insights on its contribution to participants' understanding and HMI design ideation.

# 2 METHOD

We designed and hosted role-switching sessions to investigate its application and contribution to participants' understanding and HMI ideation in the context of automated driving. For more details on the specific questions and execution of this study, see the supplementary material. [1].

## 2.1 Design of the sessions

To stimulate rich, experienceable interactions, three sessions were performed outdoors in a controlled mock traffic setting in the Eindhoven University of Technology campus. This mock traffic setting approach bridges between the real and the fictive, using two real cars and a bicycle in an actual road setup with users enacting the scenario. The specific road setup is a T-shaped equal-level intersection at the end of a vacant parking lot that connects to the road. The roles in this scenario included a pedestrian, a cyclist, an MDV with a driver and an AV with a passenger, see Figure 1. A schematic scenario overview, including measurements (performed using a Surveyor's wheel), is shown in Figure 2.

## 2.2 Participants

We conducted three sessions, with four participants per session, resulting in a total of 12 participants (6 males and 6 females). All participants had a driver's license and normal or corrected to normal eyesight. Participants were recruited via flyers and online message distribution. As compensation for their participation, they received a €15 gift voucher.

There were 11 participants between 18 and 29 years old and 1 between 30 and 39. Origin-wise, 6 participants originated from Europe, 4 from East Asia, and 2 from South Asia. The highest education level completed was high school for 1 participant, a Bachelor's degree for 2 participants and a Master's degree for 9 participants. 4 participants had a driver's license for 1–3 years, 7 for 4–10 years and 1 for 10+ years. In the last 12 months, 2 participants reported not driving any distance, 7 reported driving 1–5.000 km, and 3 reported driving 10.001–30.000 km. Generally, participants showed a positive attitude towards wanting to take a ride in an AV (5-point Likert from -2 to +2, M=0.9, SD=0.9). Experience-wise, 4 participants selected never having used or been in an AV, 3 reported having had a ride in an AV, 2 reported having encountered AVs

[1]Supplementary material: https://doi.org/10.4121/b63a08f4-a961-4708-85af-acb384c01095

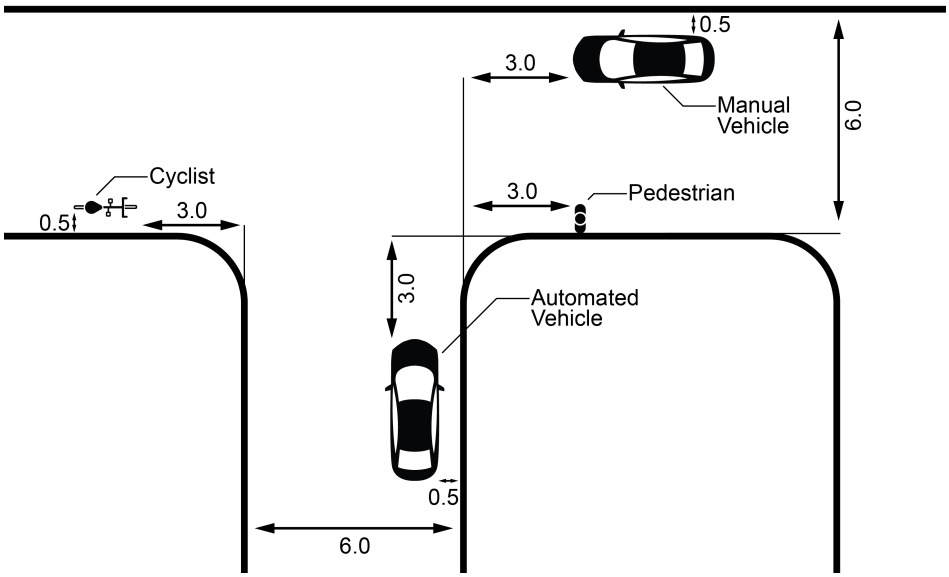


**Figure 2: Road setup, positioning of the traffic roles and measures (in meters). Figure not to scale. Icons licensed via The Noun Project.**

whilst driving, and 4 reported having experience with automated functions (e.g. Adaptive Cruise Control).

## 2.3 Procedure and apparatus

After completing an informed consent and a demographic questionnaire, each quadruplet of participants received a standardized introduction to AVs and the workshop procedure. Then, all participants were informed of their first role in the traffic scenario. To represent an AV, we used a modified Renault Grand Espace from 2011, which was equipped with special stickers and equipment (such as a 3D-printed mockup of LIDAR). We used a 2022 Skoda Fabia Combi (MK3 Facelift model) to represent an MDV. For the cyclist's perspective, we provided an Amigo Control Mountainbike (unisex model, frame size of 47,5cm, 28-inch wheels), see Figure 1.

After participants positioned themselves in their traffic role, they were orally introduced to the scenario of arriving at an intersection whilst being late for a work meeting. Participants were shown a role-specific map to demonstrate the direction in which they wanted to travel from their perspective. After the participants individually indicated everything was clear, the experimenter asked the participants to fully focus on imagining and acting out the standstill traffic scenario for 1 minute (e.g. the cyclist would grab the handlebars, look around and imagine crossing the road). During this minute, the researchers kept their distance from the traffic scenario to avoid distracting participants.

After 1 minute of acting out, participants filled out questionnaires considering their traffic role's perspective, with questions about their subjective state, their uncertainty, how they would act, what could help and how the AV specifically could help. These questionnaires aimed to give insight into the existence of differences between roles since role-switching aims to stimulate participants' understanding by experiencing multiple roles. Then, participants switched traffic roles 3 more times in a counterbalanced order (participant numbers were assigned to roles before the start of the experiment and shifted to minimise sequencing effects) and filled out the questionnaire after each role. Each round took between 5 and 10 minutes, depending on the time required for questionnaire completion.

After the role-switching session, participants were asked to ideate on how the AV could help in the given traffic setting, considering the four perspectives they had just experienced. Participants were provided with sets of markers and could walk around between the locations of the roles but were instructed not to discuss with other participants yet. Then, participants reported on the contribution of the four perspectives to their generation of ideas and their understanding of the scenario. Finally, each participant presented their favourite idea. After this, the participants discussed it with one another. Here, researchers stimulated participants to voice their opinions. These discussions were audio recorded. In total, the procedure execution for each group took approximately 90 minutes. This study was approved by the Ethical Review Board of the university.

## 2.4 Data processing and analysis

The two authors who were also present at the experiment digitalised data from written questionnaires before analysis to decrease errors. During this phase, any unclarities related to handwriting were checked with the participants. Similarly, audio recordings were first transcribed by one author and then checked by the other author.

Qualitative text-based data was analyzed using an emergent coding approach with researcher-denoted concepts, generated based

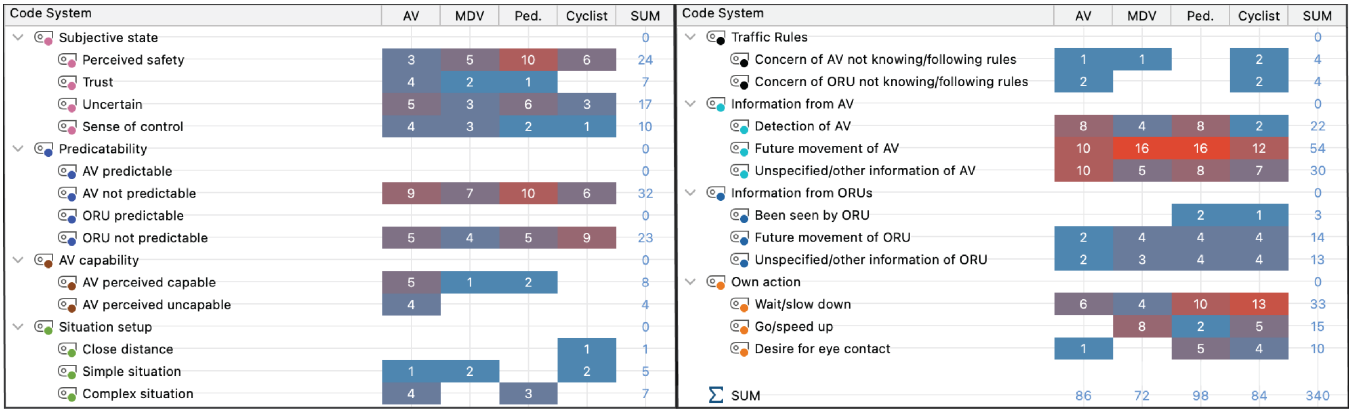


**Figure 3: Code Matrix Browser showing themes and heat mapped code count per role.**

on two authors' separate coding on a subset of the data [12]. Detailed coding definitions are provided in supplementary material. The qualitative analysis was executed using MAXQDA software [2].

## 3 RESULTS

### 3.1 Role-based written questionnaires

Iterative, emergent coding of a sample of the data lead to the development of 8 themes with 24 underlying codes. Two coders applied this code independently to the full dataset of answers from the written questionnaires. This application had an inter-rater reliability of Kappa 0.61 (Brennan and Prediger variant [5]), labelling the coding result as "very good" [11]. After this phase, coding disagreements were discussed and solved between both coders in mutual understanding, resulting in the coding outcomes, which can be seen in Figure 3.

The results from the written questionnaires highlight code outcomes comparing the four roles. Since the approach using disparate roles aimed to stimulate participants' understanding of the traffic scenario as a whole, this analysis is used to gain insight into whether each role differed for participants.

The theme of participants' own *Subjective states* (mentioned: 58 times) was used mainly by the pedestrian (19) and AV passenger roles (16) but less mentioned by the MDV driver (13) and cyclist roles (10). Under this theme, pedestrians (10), cyclists (6) and MDV drivers (5) mainly mentioned their feelings related to *Perceived safety* (24). Under the theme of *Predictability*, all roles mentioned considering the *AV not predictable* (32) and *ORU not predictable* (23), with *ORU not predictable* most frequently discussed by the cyclist role (9). The theme discussing perceived *AV capability* (12) was mainly attributed to the AV passenger role (9). Mentions of the traffic setup being a *Complex situation* came only from the AV passenger role (4) and the pedestrian role (3).

Regarding the theme *Information from AV*, participants desired to know what was being detected by the system, coded as *Detection of AV* (22). This was mainly mentioned by both the AV passenger (8) and pedestrian role (8). A desire to know about the *Future movement of AV* (54) was more frequently mentioned by both the pedestrian (16) and the MDV driver roles (16) than by the AV passenger (10) and cyclist roles (12).

*Information from AV* (106) was mentioned more than *Information from ORUs* (30), indicating a desire for information specifically related to the AV. Both MDV drivers and AV passengers didn't mention a desire for confirmation of *Been seen by ORU*. AV passengers only mentioned remarks about communication of *Future movement of ORU* twice, which was less than the other roles did.

Regarding how participants would behave in the scenario, themed as *Own action*, the pedestrian (10) and cyclist (13) roles were more willing to *Wait/slow down* (33) in the traffic scenario than MDV driver (4) and AV passenger (6) roles were. For *Go/speed up*, the MDV driver role (8) had the highest frequency, while the AV passenger role (0) had the lowest. Both the pedestrian (5) and cyclist roles (4) mentioned a *Desire for eye contact* (10) more than the MDV driver (0) and AV passenger roles (1).

### 3.2 Generated designs

In total, participants filled 13 pages with sketches; which were coded per sketched page. Emergent coding generated 3 themes with 11 codes. Independent coding achieved an inter-rater reliability of Kappa 0.71 (Brennan and Prediger [5]), demonstrating a "very good" coding outcome [11]. Disagreements were solved on a common agreement basis.

There were 12 pages with HMI designs placed on the *Exterior* of the vehicle. *Interior* designs were placed on 6 pages, and 2 pages involved HMIs *Not on a car*. Communication was mostly targeted to *ORUs generally* (11) and/or *AV passenger* (7), though there were designs for a *Pedestrian specifically* (3), *Cyclist specifically* (2) and *MDV driver specifically* (1). In total, 5 participants contributed both in the code *ORUs generally* and *AV passenger*. Information communication was mostly focused on the *Future movement of AV* (12). There were 9 pages of designs that involved *Unspecified/other information of AV*, and 8 described the *Detection of AV*.

### 3.3 Contribution of perspective switching

After design generation, 7 participants agreed with the statement that experiencing the traffic scenario from four perspectives contributed to their understanding of the traffic scenario as a whole, and

[2]https://www.maxqda.com/, last accessed: 2024-06-10

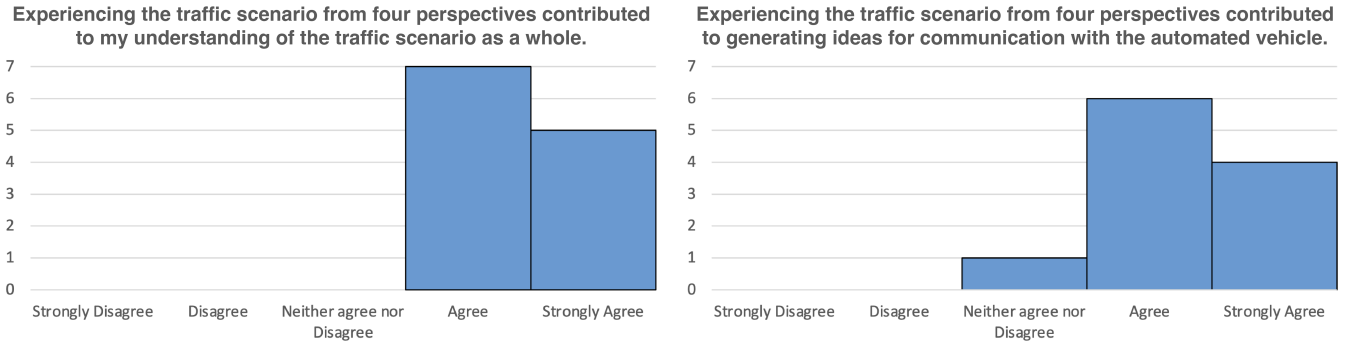


**Figure 4: Outcomes on the contribution from experiencing traffic roles from Likert question responses.**

5 participants strongly agreed (5-point Likert from -2 to +2, M=1.4, SD=0.5). Except for one participant (who selected "neither agree nor disagree"), all participants either agreed or strongly agreed that experiencing the traffic scenario from four perspectives contributed to generating ideas for communication with the AV (M=1.3, SD=0.7); see Figure 4.

### 3.4 Focus group sessions

Based on a data sample, emergent coding was applied specifically related to the topic of holistic considerations, leading to one code being developed. Two coders applied this independently on all data, with an "almost perfect" inter-rater reliability of Kappa 0.85 [5, 11]. In total, there were 27 mentions of participants *Considering needs of multiple road users*, demonstrating participants' holistic considerations. These statements were made by 10 out of 12 participants.

## 4 DISCUSSION

In this study, we designed and conducted a novel role-switching approach to gain insights into its contribution to participants' understanding and HMI ideation.

### 4.1 Role-based differences

The application of the role-switching approach is related to whether the different roles can contribute different insights from one another, allowing participants to learn from multiple roles. Analysis of the key themes per role identified from the written questionnaires offers insight into different road users' diverse experiences and perspectives and confirms the existence of differences between the roles in the traffic setting. Pedestrians' *Subjective states* are focused more on *Perceived safety* than *Trust* and *Sense of control*, and mentioned most about *AV not predictable*. The pedestrian role required information of the *Future movement of AV* and *Detection of AV*. They indicated most frequently a *Desire for eye contact* in the scenario. The cyclist role showed fewer mentions about *Perceived safety* compared to the pedestrian role. The MDV driver role contains the fewest code (72 in total) of the 4 roles, with a low focus on *ORU not predictable*, *AV capability* and *Complex situation*. However, it showed the highest focus on *Future movement of AV* and was more willing to *Go/speed up* in the scenario. This may be because the MDV driver is not a vulnerable road user and since traffic rules should allow them to drive straight without giving any priority. Similar to the MDV driver, the AV passenger role also mentioned less about their *Subjective state*; however, compared to the MDV driver role, they mentioned *Perceived safety* less, but *Trust*, *Uncertain* and *Sense of control* more. Compared to the MDV drivers, they also express their worry more about *AV perceived uncapable*, *Complex situation* and *Concern of ORU not knowing/following rules*. These findings do not demonstrate a definitive comparison between the transport modes. They rather show the different insights that can be generated from different perspectives and show the potential that a role-switching approach can contribute to building a more holistic understanding.

### 4.2 Generated designs and the contribution of role-switching

Analysis of sketched pages with designs highlights the frequent consideration of *ORUs generally*. Furthermore, five participants also created ideas for both *ORUs generally* and the *AV passenger*. The multi-user scope of these designs is also reflected by the focus group sessions, showing the participants' application of holistic considerations. Even more so, positive ratings on the evaluation questions support the contribution of the role-switching approach to both participants' designs and their understanding of the traffic scenario.

### 4.3 Conclusion

Our findings provide insights into the application of a role-switching approach for exploring HMI designs from a holistic perspective. They indicate that this approach allows participants to experience different perspectives in a daily traffic scenario, which could contribute to the generation of designs with a holistic focus. Participants perceived this approach to positively contribute to their understanding of the traffic scenario and the development of their designs.

### 4.4 Limitations and future work

Due to the sun and temperature of 23°C during the study, the windows of the AV and the trunk and windows of the MDV were kept open. For future work in the context of AV HMIs, using an even

more realistic approach with closed windows and moving vehicles might provide a more immersive experience. Next to that, the role-switching sessions were relatively controlled during this study, with set road positions and enactment duration. For further creative stimulation, more playful methods such as improvisation acting [4] should be explored. The use of a role-switching approach for evaluating HMIs from multiple perspectives could be researched as well. Based on these findings, applying role-switching approaches in HMI design in a broader sense deserves further research.

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