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Exploring user comfort in automated driving: A qualitative study with younger and older users using the Wizard-Of-Oz method

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ABSTRACT

As the introduction of automated vehicles (AVs) into road traffic accelerates, establishing user acceptance is increasingly crucial. User comfort, largely influenced by the AVs' driving styles, is one of the essential factors influencing acceptance. This video submission provides a methodological overview of a qualitative interview study, which used a Wizard-of-Oz method to investigate participants' comfort levels during automated driving on real roads. By understanding the specific comfort experiences of both older and younger users, we can inform the design process for AVs, thereby enhancing user experience and facilitating broader acceptance of technology across a more diverse and inclusive demographic spectrum.

Keywords: user comfort, qualitative study, Wizard-of-Oz, user-centric design, automated vehicles, elderly

1. INTRODUCTION

User comfort has been considered as one vital factor affecting the public's acceptance of automated vehicles (AVs) (Dichabeng et al., 2021; Nordhoff et al., 2021; Siebert et al., 2013). Comfort is generally described as a subjective and personal experience, which is affected by physical, physiological, and psychological factors, in the users' interaction with AVs (De Looze et al., 2003; Hartwich et al., 2018; Peng et al., submitted). User comfort arises from positive experiences, such as feeling relaxed, taking a smooth ride, or engaging in non-driving related activities (NDRAs), and the absence of negative experiences, such as feeling unsafe, enduring a jerky ride, or experiencing poor communication with the automation system (Peng et al., submitted).

In highly or fully automated driving (SAE level 4+), the in-vehicle users will be freed from driving or monitoring tasks and can engage in NDRAs (SAE, 2021). However, without active control of the vehicle, users might struggle to anticipate vehicle manoeuvres, leading to discomfort or carsickness, caused by a mismatch between visual input from NDRAs and vestibular input from vehicle movements (Diels & Bos, 2015).

The driving style of AVs, characterised by vehicle kinematics, such as speed and acceleration, and proxemics, such as distance kept with regards to the roadside or on-road objects, plays an important role in user comfort (Bellem et al., 2018; Hartwich et al., 2018; Peng et al., 2022). However, there is limited understanding of the factors that affect user comfort in relation to AV's driving styles, particularly in realistic, complex road environments. AVs will navigate a wide range of road and traffic conditions, from diverse road geometries (e.g., curvy, or bumpy roads), to interactions with other vehicles (e.g., merging, lane-changing, and car-following) and vulnerable road users (e.g., pedestrians, mobility-impaired users, and cyclists). Previous, simulator-based, research has focused on specific road environments in which users compare and evaluate different driving styles (Bellem et al., 2018; Haghzare et al., 2021; Peng et al., 2022). This does not allow an exploration of users' experience of more complex driving environments. In addition, for safety reasons, most current AV prototypes tested on real roads, operate at low speeds on constrained routes. These conditions are not ideal for evaluating the impact of driving styles on user comfort, because future AVs are expected to offer a smooth ride and handle normal traffic flow competently, whereas the slow speed of current AV prototypes may even cause discomfort (Nordhoff et al., 2019). Thus, it is important to explore users' experience with AVs which can drive at normal speeds and navigate diverse traffic conditions.

Previous research has used an expert workshop to conceptualise and define user comfort in relation to AVs' driving styles (Peng et al., submitted). However, it is not yet clear whether the general public will share these perspectives. Moreover, given the potential for AVs to enhance mobility for older individuals, the elderly comprise a distinctly important group (Alessandrini et al., 2015), whose needs have not yet been explored. Therefore, understanding the comfort needs and expectations of older users is of considerable value.

In this study, we aim to investigate general, and particularly older, users' insights on comfort in automated driving. Semi-structured interviews, as one useful method to assess user experience in AVs (Bhide et al., in preparation), were conducted to gather insights on how users describe comfort and discomfort, and to identify factors that affect the experience. Results from these interviews will be integrated with results from our previous expert workshop to build a comprehensive conceptual framework of user comfort. This knowledge will inform and support the design of comfortable driving styles for future AVs.

2. METHOD

2.1 Participants

In this study, interviews were conducted with 39 respondents (14 females and 25 males). Among all participants, 29 respondents were over 60 years old (M = 69, SD = 6.10), while the other 10 were younger than 33 years old (M = 28, SD = 3.33). Participants were recruited using a panel consisting of residents in Delft, who received the study invitation via calendly.com. The invitation informed participants that the purpose of the research was to gain insights into their experience as passengers in a self-driving vehicle. Upon registering on calendly.com, participants received an email from the researchers, confirming their timeslot and providing information about the meeting point. After the study, participants were entered into a draw to win one of five 25€ vouchers. The study was approved by the Human Research Ethics Committee of Delft University of Technology.

2.2 Design and procedure

1.1.1. Apparatus

The study was conducted using a Wizard-of-Oz vehicle in Delft, the Netherlands. The vehicle is a Nissan e-NV200 electric bus, provided by Leaseplan, owned by the Department of Civil Engineering at TU Delft. The vehicle had to be manually driven by a driver. However, to give participants the impression that this vehicle is self-driving, one shield between the driver's seat and the backseat, and two shields on the side windows in the back cabin were used to prevent participants from seeing the driver or looking out the windows. One large screen was fixed on the front shield and two small screens were placed on the window shields, all of which provided a live stream of the outside view (Figure 1), captured by three cameras fixed on the vehicle (Figure 2). A small monitor under the main front screen showed whether manual driving mode or automated driving mode was on. This was accompanied by a voice indicating when a mode switch took place.

Figure 1. The participants' view from the backseat of the vehicle.

Figure 2. One camera is fixed on the windshield and two cameras are attached to side mirrors.

Before the study, all drivers (four in total) received training in which they were instructed to drive in a similar way (e.g., driving as smoothly as possible, avoiding abrupt operations, accelerating quickly, not braking hard, and keeping large distances) during the automated driving mode, to ensure consistency across participants. The mode display information (automation or manual) was controlled by the driver. The drivers were introduced to participants as “safety drivers” who would take care of any emergency situations. The journey started in “manual mode”, then before and after a certain location, the driver changed the display of mode information (Figure 1) to show a “switch” of the mode between manual and automated driving.

1.1.2. Route

The vehicle travelled in a loop, starting and finishing at the same point on the TU Delft campus (Figure 3). The route included a range of road environments, such as rural areas with numerous vehicles on the road, and urban areas with road-side dense building structures, pedestrians, and cyclists. The ride took about 20 minutes to complete.

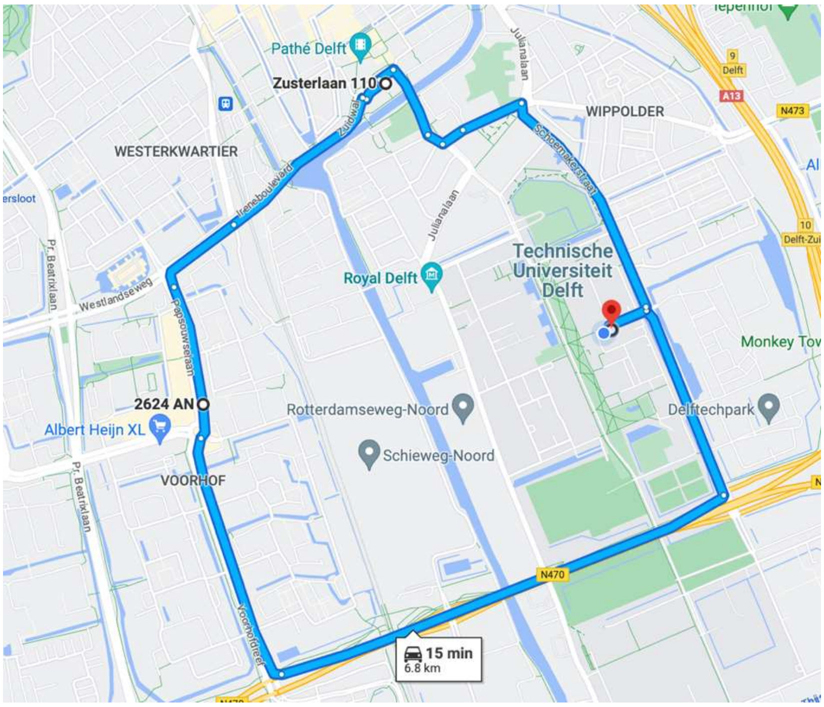

Figure 3. An overview of the driving route.

1.1.3. Procedure

Upon arrival at the starting point, the experimenter provided the information sheet, explained procedures, and asked the participant to sign the consent form.

The participant was then asked to answer three questions about previous comfortable and uncomfortable riding experiences as passengers in currently available transport modes. They were also asked about their expectations about automated driving. This pre-ride interview took about 10 minutes. Participants were then taken to the vehicle to complete the ride, during which they were instructed to observe the driving styles, and any other factors that affected their comfort or discomfort. After the ride, the participant took part in a 30-minute post-ride interview, where they were asked about their experiences in the vehicle. They then completed a demographic questionnaire, and the experimenter debriefed the participants by explaining how the Wizard-of-Oz vehicle worked (Figure 4).

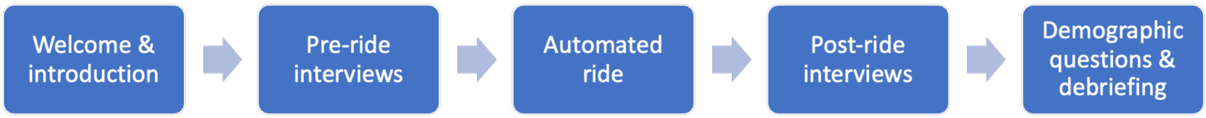

Figure 4. The procedure of the study.

3. CONCLUSIONS

In order to design appropriate and acceptable AV controllers, it is important to consider how users will experience any driving styles adopted by the AV (Hartwich et al., 2018). In this paper, we present an overview of a Wizard-of-Oz study, which aims to understand the impact of an AV's driving style on user evaluations of comfort. Our goal is to gain insights from the general population and, particularly, from elderly users.

The results of the present study will improve our understanding of user comfort in automated driving, building on a previous framework derived from experts' insights (Peng et al., submitted). The study will facilitate a comparison of comfort experiences across different age groups within a complex driving environment. The insights gained will enable us to suggest enhancements to system designers and manufacturers, thereby improving the AV experience for a broader user demographic. Furthermore, we aim to establish a measure to assess user comfort in automated driving, by combing the input from the previous expert workshop and the current study. The measure will quantify user comfort in automated driving, enabling researchers, system designers and manufacturers to systematically explore user comfort in future studies.

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