Proceedings Paper:

Horn, S.E., Madigan, R. orcid.org/0000-0002-9737-8012, Schulz, M. et al. (3 more authors) (2024) Smooth Rides Ahead: Integrating Chauffeur Driving Styles into HAVs. In: AutomotiveUI '24 Adjunct: Adjunct Proceedings of the 16th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. AutomotiveUI '24: 16th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 22-25 Sep 2024, Stanford, CA, USA. Association for Computing Machinery (ACM) , pp. 289-291. ISBN 979-8-4007-0520-5

https://doi.org/10.1145/3641308.3680511

Smooth Rides Ahead: Integrating Chauffeur Driving Styles into Highly Automated Vehicles

Testing Chauffeur-Inspired Deceleration for Enhanced Driving Comfort

Stefanie Horn*

Robert Bosch GmbH, Cross-Domain Computing Solutions, Abstatt, Germany, stefanie.horn@bosch.com

Institute for Transport Studies, University of Leeds, Leeds, United Kingdom, tsseh@leeds.ac.uk

Ruth Madigan

Institute for Transport Studies, University of Leeds, Leeds, United Kingdom, r.madigan@leeds.ac.uk

Michael Schulz

Robert Bosch GmbH, Cross-Domain Computing Solutions, Abstatt, Germany, michael.schulz@bosch.com

Andreas Schultz

Robert Bosch GmbH, Cross-Domain Computing Solutions, Abstatt, Germany, andreas.schultz@bosch.com

Philipp Alt

Robert Bosch GmbH, Cross-Domain Computing Solutions, Abstatt, Germany, philipp.alt@bosch.com

Natasha Merat

Institute for Transport Studies, University of Leeds, Leeds, United Kingdom, n.merat@leeds.ac.uk

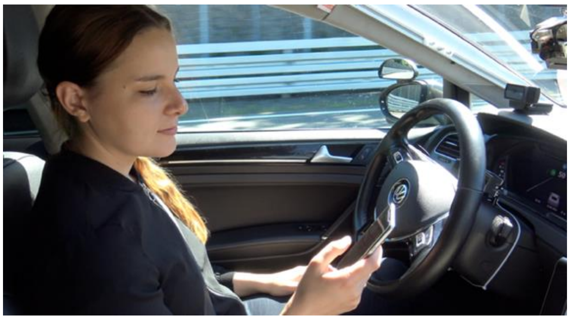

Figure 1: Passenger in the test vehicle while engaging in a non-driving-related activity. Adopted from [7].

This study investigates a novel methodology for enhancing passenger comfort in highly automated vehicles (HAVs) by deriving driving patterns from professional chauffeurs. We collected detailed driving and interview data from chauffeurs, who are known for their smooth and comfortable driving styles. A Two-Step deceleration profile was derived from this data. Two different versions of the Two-Step Profile (V1 and V2), along with a One-Step profile, were integrated into an HAV and tested in various driving scenarios with 36 participants. Participants experienced each profile twice: once while attentive and once while engaged in a non-driving activity. By transferring the chauffeur's driving style to an HAV, this study evaluates the feasibility and comfort of human-like driving patterns in automated systems. The findings provide valuable insights for designing HAVs that prioritize passenger comfort, bridging the gap between human driving expertise and automated technology.

CCS CONCEPTS • Human-centered computing • Human computer interaction (HCI) • HCI design and evaluation methods • Field studies

Additional Keywords and Phrases: highly automated vehicles, driving comfort, driving style, chauffeur-like driving, deceleration profiles, non-driving related activities

* Corresponding author.

1 INTRODUCTION

With the advancement of highly automated vehicles (HAVs) reaching SAE Level 4 automation [1], ensuring passenger comfort becomes a top priority. Driving comfort in HAVs is influenced by factors such as speed, acceleration, jerk, and overall driving style [2,3]. Traditional automated systems often rely on algorithmic decision-making, which may not always align with passenger comfort preferences [4]. Previous research indicates that passengers prefer a natural, human-like driving style [4]. However, visually distracted passengers perceive excessive movements of AVs as less comfortable than attentive ones [5]. This suggests adapting HAV driving styles based on passenger activities, raising the question of whether human-like patterns suit inattentive passengers. While human-like driving is not optimized for visually distracted passengers, professional chauffeurs are trained to transport passengers engaged in non-driving related activities (NDRAs), such as working on a laptop. The driving style of trained chauffeurs potentially can provide valuable insights for HAV development as suggested by [5].

This research aims to capture the key elements of a chauffeur's driving style, specifically focusing on deceleration patterns, and integrate them into HAV systems to create more comfortable and human-like driving experiences. Incorporating these patterns allows HAVs to better align with passenger expectations of a natural and comfortable ride [4]. A user study aims to identify the most comfortable deceleration profiles by comparing those derived from chauffeur data and state-of-the-art practices. This approach offers valuable insights into designing automated systems that prioritize passenger comfort, ultimately aiding in the broader acceptance and adoption of HAVs.

2 METHOD

This research was structured in two main phases (see Figure 2). First, driving data from professional chauffeurs were collected to understand their deceleration styles and subsequently derive deceleration profiles (see section 2.1). These profiles were then implemented into a HAV test vehicle. In the second phase, the deceleration profiles were evaluated through a user study conducted on the same test track where the chauffeur data was collected (see section 2.2). The primary objective of this evaluation was to understand and assess the driving comfort experienced by the participants, as well as their preferences for different driving profiles.

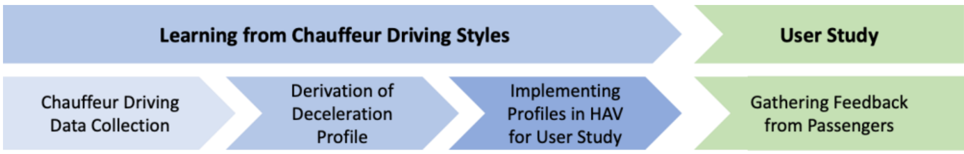

Figure 2: Structure of this research's method.

2.1 Learning from Chauffeur Driving Styles

2.1.1 Data Collection from Professional Chauffeur

The first step in our methodology involved collecting detailed driving data from a professional chauffeur. The chauffeur drove for 1.5 hours loops on a test track that included curves, straight roads, and intersections. He was instructed to drive as if transporting a person in the backseat and with no time pressure. Measurements such as acceleration, speed, and jerk were obtained using an Inertial Measurement Unit and aligned with GPS and camera data to link them with driving maneuvers. Additionally, the chauffeur's comments on the execution of decelerations were gathered to understand their conscious actions. He was asked to speak out loud during the drive, describing his actions.

2.1.2 Derivation of a Chauffeur-like Deceleration Profile

Based on the collected data from the chauffeur drives, a detailed analysis of each deceleration instance was conducted. All the decelerations were plotted together in a single plot for each individual scenario, such as deceleration in front of a curve or in front of a speed limit. We observed that all the decelerations of the chauffeur looked quite similar and consistent. The following analysis included deriving the maximum deceleration values, jerk values, and examining the shape of the deceleration profiles. A deceleration profile refers to the pattern of speed reduction over time, highlighting how gradually or abruptly a vehicle slows down.

From this, a *Two-Step deceleration profile* was identified (see Figure 3), mimicking the chauffeur's deceleration style. The key characteristic of this profile is a two-phase deceleration:

In the *first phase*, the chauffeur gradually releases the accelerator pedal, leading to a brief initial deceleration phase, with observed jerk values between -0.9 to -1.5 m/s³. This is followed by a plateau phase where acceleration remains constant, with an observed average acceleration of about -0.5 m/s², for approximately 2 seconds.

The *second phase* involves the application of the braking pedal, resulting in the main deceleration step with jerk values between -0.3 to -0.6 m/s³ and a resulting maximum deceleration value between -1.0 and -1.5 m/s².

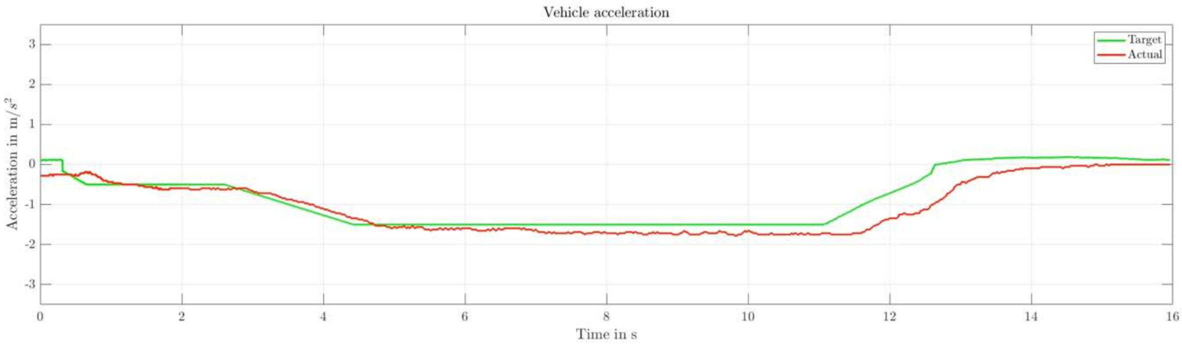

Figure 3: Implementation of Two-Step deceleration into the test vehicle. The green line represents the target acceleration implemented in the system, the red line indicates the actual acceleration profile executed by the automated test vehicle.

This Two-Step approach aims to replicate the smooth and comfortable deceleration of the chauffeur. The chauffeur's qualitative feedback further supported the identification of these conscious actions during deceleration. The chauffeur noted that by releasing the accelerator pedal, they intend to inform the passenger about the upcoming deceleration.

2.1.3 Implementation of Deceleration Profiles for User Study

Based on the chauffeur data, two versions of the Two-Step Profile (V1 and V2) were created, along with a standard One-Step profile, similar to current state-of-the-art practices [6], for comparison (see Figure 4):

One-Step Profile:

- Features a single, smooth deceleration phase with a maximum deceleration of -1.0 m/s² and a jerk rate of -0.6 m/s³.

Two-Step Profiles:

- Two-Step Version 1 (V1): Characterized by an initial deceleration plateau at -0.5 m/s² followed by a final deceleration of -1.0 m/s², with respective jerk rates of -1.0 m/s³ in step one and -0.3 m/s³ in step two.
- Two-Step Version 2 (V2): Similar to V1 but with a final deceleration phase reaching -1.5 m/s² and a second jerk rate of -0.6 m/s³.

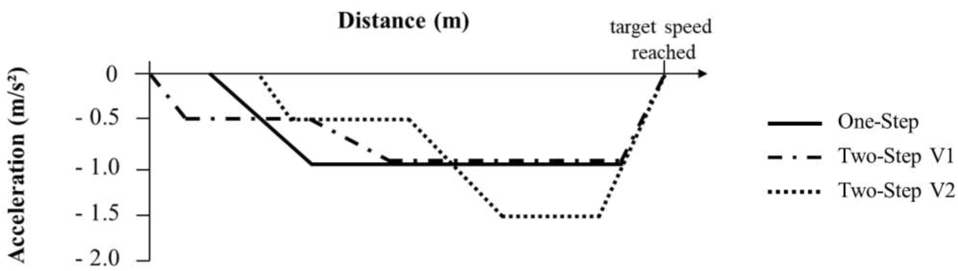

Figure 4: Deceleration Profiles tested in the user study. Adopted from [7].

These three deceleration profiles were then implemented into the test vehicle to evaluate their effectiveness in improving passenger driving comfort. A user study was conducted to test these profiles with participants, allowing us to gather valuable feedback and insights on their comfort and preferences.

2.2 User Study

2.2.1 Participants

Thirty-six participants (14 females, 22 males), aged between 19 and 63 years, participated in the study. To contextualize their comfort ratings, participants' sensitivity to motion sickness, interest in cars/technology, and usage of ADAS systems was assessed. These factors were evaluated without serving as exclusion criteria for the study. This diverse group was chosen to ensure a broad representation of potential HAV users, providing valuable insights into the general public's comfort preferences in automated driving scenarios.

2.2.2 HAV Apparatus

The study was conducted on a 3.1 km closed test track using a VW Golf 7 Variant, equipped with Level 4 [1] automated driving technology. The vehicle adhered to a pre-recorded GPS route to ensure consistent speed and maneuvers across all trials.

2.2.3 Experimental Design

Participants experienced the three deceleration profiles—One-Step, Two-Step V1, and Two-Step V2—across four driving scenarios: slowing before two different curves, approaching a speed-limit sign, and stopping at a stop sign. Each profile was tested twice per participant: once while they were attentive to the driving environment and once while they were engaged in a non-driving activity (NDRA, see Figure 1).

2.2.4 Procedure and Results

Participants initially completed practice drives to familiarize themselves with the vehicle and rating scale. The experimental drives were divided into two blocks: attentive driving and NDRA engagement. After each deceleration, participants rated their comfort using a 7-point Likert scale and provided a ranking and qualitative feedback in post-drive interviews.

Participants preferred the One-Step deceleration for its continuous and constant nature when coming to a standstill at the stop sign, while they generally found the Two-Step V1 approach gentler and calmer, making it a personal favorite. Visual distractions by an NDRA didn't affect comfort or profile preferences, though they reduced the perceived intensity of vehicle movements. More detailed results and further information about this study were reported in [7].

3 CONCLUSION

This study presents an innovative approach to enhancing passenger comfort in highly automated vehicles (HAVs) by integrating driving patterns derived from professional chauffeurs. Detailed data from a chauffeur, known for their smooth driving, was used to create Two-Step deceleration profiles, which were tested in an HAV test vehicle across various scenarios.

Our methodology demonstrates the potential of transferring chauffeur-inspired driving styles to HAVs to ensure passenger comfort. By mirroring human-like driving behaviors, we believe this approach can be particularly useful for optimizing comfort during specific driving maneuvers. This might be especially helpful for clearly observable and planned deceleration maneuvers.

Future research should continue to refine these profiles and explore additional human-like driving behaviors, such as acceleration from a standstill, deceleration when interacting with other road users, and lateral acceleration during curve driving, to further enhance the passenger experience in automated vehicles. This innovative approach provides valuable insights for designing HAVs that prioritize comfort, ultimately contributing to broader acceptance and adoption of automated driving technology.

ACKNOWLEDGEMENTS

The research was conducted as part of the RUMBA project (www.projekt-rumba.de, accessed on 29 May 2024), which is funded by the German Federal Ministry for Economic Affairs and Climate Action (grant number: 19A20007K). Additionally, support was provided by the Hi-Drive project (Grant agreement 101006664), funded by the European Union’s Horizon 2020 research and innovation programme. This project also sponsors contributions from Dr. Ruth Madigan and Prof. Natasha Merat of the University of Leeds.

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