Driving Like an Experienced, Well-behaved Human Driver: Enhancing Trust in Autonomous Vehicles through Social and Spatial Interactions

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***Abstract*— "Trust" is a major challenge for autonomous vehicle (AV) adoption, as users often view AV behavior as opaque or impersonal. This paper explores how AV interfaces can reflect the qualities of experienced, well-behaved human drivers to strengthen user trust. We conducted two co-design workshops with 12 participants and generated four design strategies: (1) transparent and proactive communication, (2) anthropomorphic and expressive agents, (3) spatial and ambient responsiveness, and (4) personalization through familiarity. These strategies suggest a design space where AVs move beyond screens and voice to engage users socially and contextually through ambient and spatial expressions. Based upon these strategies, we designed a spatial and social agent embodying the role of an experienced, well-behaved human driver, and tested people's perceptions and trust of the AV equipped with this agential interface in Virtual Reality (VR). The results show significant increases in people's trust in and user experience of the AV. Alongside design contributions, our work highlights how anthropomorphism can be applied in spatial and social AV interface design to promote people's trust in AV.**

Keywords—social agent, spatial responsiveness, autonomous vehicle, human-AV trust, well-behaved human driver

I. Introduction (*Heading 1*)

Autonomous vehicles (AVs) promise benefits such as improved safety, reduced congestion, and greater accessibility [1,2]. However, public mistrust remains a major barrier to its adoption. Research on human–AV trust has highlighted the importance of trust calibration (aligning user confidence with system capabilities) and the risks of both over-trust and mistrust [3, 4, 5, 6, 7]. While prior work has explored the interaction design strategies informed by anthropomorphism [8, 9, 10], it remains unclear which specific type of human-AV social interactions may successfully enhance trust.

To address this literature gap, we propose to design the AV interface as if an "experienced, well-behaved human driver," emphasizing transparency, attentiveness, and socially considerate behaviors. After all, most people trust an "experienced, well-behaved human driver" more than an autonomous driving system [7, 12, 13]. To explore this concept, we conducted two co-design workshops with 12 designers, generating interaction ideas through sketches, prototypes, and discussions. Using Annotated Portfolios and Reflexive Thematic Analysis, we identified four design themes that informed the development of a novel AV interface prototype, named the "Experienced, Well-behaved Driving Agent" (EWDA) that is both social and spatial. The prototype (EWDA) was evaluated in VR with 20 participants, with results showing its effectiveness in significantly increasing user trust and positive perception of AVs.

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II. Co-design workshop

A. Study Procedure

To explore this design concept (designing an AV interface as if an experienced, well-behaved human driver), two workshops were conducted with a total of 12 participants who are all stakeholders of AV. The workshops began with short examples of recent AV interface developments, followed by the introduction of our design concept: positioning the AV as an "experienced, well-behaved human driver." Participants responded to open-ended prompts about trust, driver qualities, and human–AV interactions. They then engaged in hands-on activities—sketching, prototyping, and scenario-building—using low-fidelity materials to envision novel interaction concepts. Sessions concluded with presentations and group discussions, where participants explained how their designs embodied the target social role. All sessions were recorded, and outputs were documented for later analysis.

B. Data Analysis and Mixed Method Evaluation

The workshop outcomes—including sketches, prototypes, and transcripts of group discussions—were analyzed using a combined approach of Annotated Portfolios and Reflexive

Thematic Analysis (RTA). Annotated Portfolios documented pictorial artifacts with explanatory notes that captured participants' rationales, while RTA synthesized these annotations with textual data (script) to identify recurring patterns and design strategies. This process (shown in Figure 1) generated intermediate-level design knowledge, abstracted beyond individual artifacts but grounded in practice.

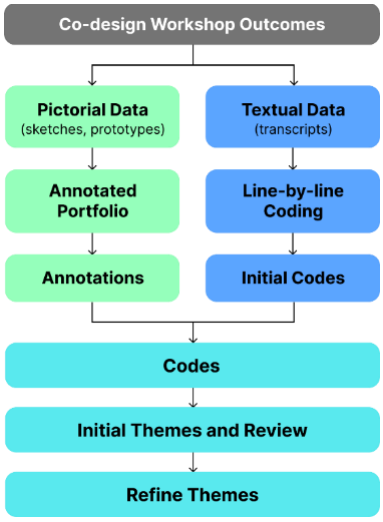

Figure 1: RTA Process Integrated with Annotated Portfolio to generate intermediate-level design knowledge

III. Key Findings of the Co-Design Workshop

The findings are organized into four themes derived from annotated portfolios and workshop transcripts, offering design insights and guidelines for AV interfaces that embody the role of an experienced, well-behaved human driver.

A. Theme 1: Building trust through transparent and proactive communication in real time

Participants emphasized the need for interfaces—whether agent- or screen-based—that provide real-time updates on the AV's decisions and environment. Transparency was seen as essential to reduce uncertainty and mirror the clarity that skilled human drivers convey through gestures or verbal cues. For example, one participant suggested that the system should announce upcoming actions, such as slowing down due to traffic ahead, while others envisioned HUD displays or voice agents to deliver information. Collectively, the designs highlight that trust can be strengthened when AVs proactively communicate precise, accessible, and context-aware information in real time.

B. Theme 2: Social and Environmental Representations of Defensive Driving

Participants also highlighted defensive driving—cautious, attentive, and smooth driving behavior—as a critical quality for building trust. Driving agents, whether robotic, virtual, or voice-based, were envisioned to embody this style through social cues such as eye movements to signal lane changes or turns. For example, one participant compared the agent to a careful taxi driver, attentive yet steady. Designs also incorporated symbolic elements, such as ambient cues or metaphors of stability, to communicate vigilance and safety. Collectively, these concepts emphasize that trust grows when AVs visibly demonstrate defensive awareness through social and environmental expressions.

C. Theme 3: Emotional Connection and Companionship

Participants emphasized that trust can be deepened when driving agents foster a sense of companionship through human-like features and social behaviors. Suggested designs included expressive cues like eyebrows or playful voice responses (e.g., saying "Oops" after hard braking), as well as greetings and farewells tied to users' names. Several concepts extended the agent beyond the vehicle—appearing on smartphones, smart home devices, or even as an ambient presence—to maintain continuity and familiarity. Others envisioned evolving or companion-like characters that "grow" with the user, or agents providing a sense of safety when entering or exiting the car at night. During the workshop, participants' ideas diverged into two distinct directions: one emphasizing cute, playful, and expressive characters that promote emotional connection and trust; the other favoring serious and professional personas that convey competence and reliability. Collectively, these designs illustrate how emotional expression and sustained social presence can make AVs feel both more trustworthy and relatable.

D. Theme 4: Personalization and Familiarity

Participants envisioned driving agents that adapt to user preferences, from transforming into familiar figures (friends, family, or pets) to adopting specific styles such as cute and playful, serious and robotic, or minimalistic and tech-savvy. These variations reflected different interpretations of what makes an "experienced, well-behaved driver" trustworthy. Personalization was seen as a way to foster familiarity, align with individual expectations, and build long-term engagement. By customizing the agent's appearance or behavior, AVs can feel less foreign and more like a trusted companion, ultimately strengthening user trust.

IV. Designing the Prototype

The prototype was developed using the four themes above: transparent communication, defensive driving, emotional connection, and personalization. Through the Research through Design (RtD) process, the proposed AV interface features were refined in VR to explore how a spatial and social agent, as the AV's interface, could embody the role of an experienced, well-behaved driver. Below, we summarize how each theme informed design decisions.

A. Transparent and proactive communication

To support transparency, the agent was placed on the dashboard where its gestures could remain visible during driving. A key feature was the agent turning its head in the direction of upcoming maneuvers, signaling attentiveness to the road and reinforcing that the vehicle was actively monitoring its surroundings. This was complemented by a Head-Up Display that projected lane-change arrows and contextual cues directly onto the windshield, ensuring that critical information stayed within the user's line of sight. Concise verbal updates and subtle auditory tones provided additional layers of communication, reducing uncertainty and enhancing situational awareness.

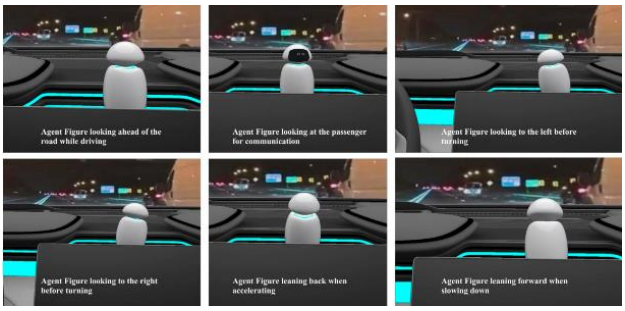

Figure 2: Dashboard-mounted agent moves and gazes in the direction of travel to convey road awareness and attentive behavior, reinforcing user trust.

B. *Embodied representation of defensive driving*

The prototype also emphasized defensive driving behaviors to convey caution and foresight. A central feature was the system's indication of lane changes, communicated through both the agent's head movements and synchronized ambient lighting. For example, the lighting shifted to yellow during a planned maneuver, reinforcing that the AV was preparing to act, while green signaled normal operation and red indicated caution. By combining expressive gestures with dynamic lighting, the system mirrored the vigilance of a careful human driver and reassured users of its attentiveness.

Figure 3: HUD projection displaying a directional arrow for lane change.

C. *Emotional connection and companionship*

To explore social presence, two distinct personas were developed on insights from the co-design workshop and benchmarking of existing automotive and conversational agent systems: one serious and professional, the other playful and expressive. Both greeted and acknowledged the user, simulating interpersonal warmth and companionship, but differed in tone and style. The serious persona communicated with polite, concise prompts, while the playful persona used lively, animated expressions. User feedback revealed that preferences varied, highlighting the importance of offering flexibility in the emotional style of interaction.

D. *Personalization*

Building on the need for familiarity, the prototype allowed users to choose between the serious and playful personas. Each was distinguished by voice style, scripted phrasing, and nonverbal animations, enabling users to align the agent with their comfort and expectations. Providing this agency helped reduce the sense of unfamiliarity often associated with AVs and supported the development of long-term trust.

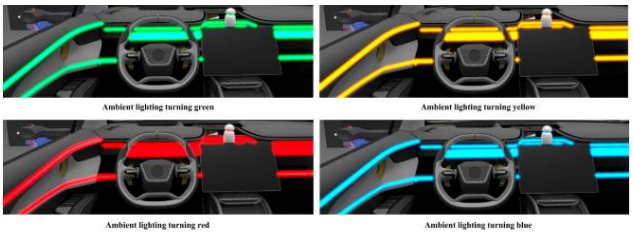

Figure 4: Ambient lighting changes according to the situation.

V. Usability Study and Design Improvement

A formative usability study with five participants was conducted to evaluate the prototype's effectiveness and identify usability issues. The goal was to assess how well the system aligned with the intended design themes: trust, transparency, emotional connection, personalization, and defensive driving.

A. *Procedure*

Participants first experienced a benchmark AV interface in VR to establish a reference point. They then interacted with two prototype variations: a serious, concise "professional" persona and a more expressive, cartoon-like persona. Each session was followed by a semi-structured interview, guided by the System Usability Scale (SUS), to gather qualitative feedback on usability, trust, and clarity.

B. *Key findings and changes*

Participants found the prototype intuitive and easy to learn, but several issues surfaced. The ambient lighting system was confusing, especially distinguishing between blue and green, leading to a simplification of color meanings and the addition of onboarding prompts. The voice agent received mixed reactions: while detailed cues built trust initially, the talkative persona was sometimes seen as intrusive, reinforcing the need for adjustable verbosity and tone. Participants also noted the lack of a navigation view, which was addressed by adding a minimal HUD route indicator, and requested more control over spatial reconfiguration features such as the retractable steering wheel. These changes were incorporated into the final prototype, named EWDA (Experienced, Well-Behaved Driving Agent).

VI. Final Evaluation

A final user study was conducted with 20 participants (late-20s to early-30s; moderate AV familiarity, limited hands-on AV experience) to evaluate how the EWDA prototype influenced perceptions of trust compared to a benchmark AV system. Our within-subject experiment design compared two conditions: a benchmark AV interface modeled after Tesla's FSD system, and the EWDA prototypes featuring different agent personas (serious & concise vs. playful & talkative). All driving scenarios and environmental conditions were held constant across conditions: took place in the same urban highway scenario with traffic, lane changes, and mix of AV and human-driven vehicles. Conditions were identical across benchmark and EWDA tests—nighttime, clear weather, and fixed routes—to ensure consistency. Below is the step-by-step experiment procedure:

Participants began the study by completing a general questionnaire assessing their prior experience with autonomous vehicles and current concerns.

Then, participants were introduced to and then experienced the benchmark AV interface. After that, participants answer a questionnaire measuring 1) people's Social Perception of this system, probing to what extent people perceive the system (that they just experienced) as if a well-behaved, experienced human driver (e.g., "Does the system seem like an experienced driver?"); 2) the adapted version of the Checklist for Trust Between People [11] and Automation to measure trust.

Next, the participants experienced the EWDA system, where each participant had the freedom to choose which mode (serious & concise vs. playful & talkative) he/she preferred to experience. After experiencing the EWDA system, participants finished the same questionnaire as described above.

Finally, we conducted semi-structured interviews to capture deeper insights into which system participants trusted more, why, and which features shaped their perceptions.

VII. Results

A. Quantitative results

Data from the 7-point Likert scales were screened (no missing/duplicate entries; reverse-coded negatives). Internal consistency was good to excellent (Social Perception: α =.80 for the benchmark, .77 for the EWDA; Trust: α =.87 for the benchmark, .88 for the EWDA). Descriptively, overall Social Perception median increased from 4.75 → 5.50 with decreased variance (.97 → .56). Overall Trust median increased from 4.17 → 5.33 with relatively consistent variances (.58 → .56).

Wilcoxon signed-rank tests showed significant gains for overall Social Perception ($p \approx .001$) and overall Trust ($p < .001$). Most individual trust items (10 out of 12 items) improved significantly. Overall, Social Perception and Trust were strongly and positively correlated (Spearman ρ=.70, $p < .001$ for the benchmark interface; Spearman ρ=.63, p=.003 for the EWDA interface; Spearman ρ=.75, $p < .001$ for both interfaces), indicating that higher perceived "experienced/well-behaving" qualities aligned with higher trust.

B. Qualitative results

We conducted Reflexive Thematic Analysis (RTA) for the semi-structured interview transcripts. Through the 5 themes we generated, participants explained that (1) clear, proactive communication via voice + HUD made the system feel "less mysterious"; (2) a social presence of the driving agent reassured them that they have a dependable driver ("felt like someone was there"), boosting dependability and reliability judgments; (3) predictable, defensive behavior of the driving agent matched expectations for an experienced human driver; and (4) multimodal feedback (voice, HUD, ambient light) improved their awareness of road conditions—though overly intense cues could feel intrusive, underscoring the need for calibration. Finally, (5) persona tone/maturity mattered: professional expressions signaled driving competence, while overly casual styles sometimes undercut perceived expertise.

VIII. Discussion

The evaluation showed that the EWDA system was perceived as more human-like, courteous, and skilled than the benchmark AV, with significant improvements in both social perception and trust. Participants described the system as dependable, confident, and socially aware, reflecting qualities associated with an experienced, well-behaved driver.

Qualitative feedback reinforced these findings. The voice agent and multimodal communication style created a sense of presence and reassurance, reducing feelings of isolation and making the system feel more companion-like. Participants emphasized that how the system communicated was as important as what it did, highlighting the value of real-time explanations, ambient cues, and embodied behaviors. These results closely aligned with themes generated in the co-design workshops, demonstrating how early annotated sketches and prototypes could be translated into concrete system features that positively shaped perception and trust.

While some participants preferred a serious, professional persona, others responded better to a playful, expressive character, confirming the importance of personalization in socially intelligent AV interface design. Together, the results show that combining transparency, defensive driving cues, emotional connection, and customization can meaningfully enhance user trust when grounded in participatory design and iterative prototyping.

IX. Conclusion

This study examined how the novel AV interface design following the concept of "an AV as if a well-behaved, experienced human driver" can enhance trust in autonomous vehicles. Insights from co-design workshops informed the EWDA prototype, which combined multimodal communication with customizable voice-based personas. In comparison to a benchmark AV interface, EWDA significantly improved users' perceptions of the system as experienced and well-behaved, while also increasing overall trust. Qualitative feedback highlighted the importance of clear communication, emotional and social presence, and defensive driving styles. Together, the findings show that framing AVs as experienced, socially aware drivers offers a promising design strategy for strengthening user trust in AVs.

X. Future work and limitations

This study was limited by its sample size and controlled VR environment, which may not fully capture the complexity of real-world driving contexts. Future work should be conducted in real vehicles and driving scenarios, examine long-term trust calibration across diverse demographics and driving conditions, and explore adaptive persona systems that dynamically adjust tone, communication style, and emotional expressiveness based on user preferences and situational context. Expanding quantitative analyses and incorporating other trust measures could also provide deeper insight into how anthropomorphic design impacts sustained user confidence in AVs.

REFERENCES

[1] Moneim Massar, Imran Reza, Syed Masiur Rahman, and Muhammad Abdullah Habib. 2021. Impacts of Autonomous Vehicles on Greenhouse Gas Emissions -Positive or Negative? Int. J. Environ. Res. Public Health 18, 5567 (May 2021). DOI:https://doi.org/10.3390/ijerph18115567.

[2] Valentas Gruzauskas, Saulius Baskutis, and Valentinas Navickas. 2018. Minimizing the trade-off between sustainability and cost-effective performance by using autonomous vehicles. J. Clean. Prod. 184 (March 2018). DOI: https://doi.org/10.1016/j.jclepro.2018.02.302.

[3] Johannes Kraus, David Scholz, Dina Stiegemeier, and Martin Baumann. 2020. The More You Know: Trust Dynamics and Calibration in Highly Automated Driving and the Effects of Take-Overs, System Malfunction, and System Transparency. Hum. Factors 62, 5 (Aug. 2020), 718-736. DOI:https://doi.org/10.1177/0018720819853686.

[4] Tove Helldin, Gran Falkman, Maria Riveiro, and Staffan Davidsson. 2013. Presenting system uncertainty in automotive UIs for supporting trust calibration in autonomous driving. In Proc. 5th Int. Conf. on Automotive User Interfa

[5] K. Hollnder, P. Wintersberger, and A. Butz. 2019. Overtrust in External Cues of Automated Vehicles: An Experimental Investigation. In Proc. 11th Int. Conf. on Automotive User Interfaces and Interactive Vehicular Applications. ACM, 211-221. DOI: https://doi.org/10.1145/3342197.3344528.

[6] M. Naiseh, J. Clark, T. Akarsu, Y. Hanoch, M. Brito, M. Wald, T. Webster, and P.Shukla. 2024. Trust, risk perception, and intention to use autonomous vehicles: An interdisciplinary bibliometric review. AI & Society (2024). DOI: https://doi.org/10.1007/s00146-024-01895-2.

[7] L. Lohaus, M. Woide, N. Damm, Z. Demiral, H. Friedrich, A. Petkov, and F. Walker. 2024. Automated or human: Which driver wins the race for the passengers' trust? Examining passenger trust in human-driven and automated vehicles following a dangerous situation. Comput. Hum. Behav. 161 (2024), 108387. DOI:https://doi.org/10.1016/j.chb.2024.108387.

[8] P. Kapoor, S. Chu, and A. Chen. 2023. "Do it my way!": Impact of Customizations on Trust Perceptions in Human-Robot Collaboration. arXiv preprint arXiv:2310.18791. Retrieved from https://arxiv.org/abs/2310.18791v1.

[9] P. Cheng, F. Meng, J. Yao, and Y. Wang. 2022. Driving With Agents: Investigating the Influences of Anthropomorphism Level and Physicality of Agents on Drivers' Perceived Control, Trust, and Driving Performance. Front. Psychol. 13 (2022), 883417. DOI: https://doi.org/10.3389/fpsyg.2022.883417.

[10] Y. Forster, F. Naujoks, and A. Neukum. 2017. Increasing Anthropomorphism and Trust in Automated Driving Functions by Adding Speech Output. In Proceedings of the 2017 IEEE Intelligent Vehicles Symposium (IVS 2017). IEEE, 12 June 2017. DOI: https://doi.org/10.1109/IVS.2017.7995746.

[11] Jian, J.-Y., Bisantz, A., & Drury, C. (2000). Foundations for an Empirically Determined Scale of Trust in Automated Systems. *International Journal of* Cognitive Ergonomics, 4, 53–71. https://doi.org/10.1207/S15327566IJCE0401_04

[12] Strayer, D. L., Turrill, J., Cooper, J. M., Coleman, J. R., Medeiros-Ward, N., &Biondi, F. (2015). Assessing Cognitive Distraction in the Automobile. Human Factors, 57(8), 1187–1197. https://doi.org/10.1177/0018720815575149.

[13] Verberne, F. M. F., Ham, J., & Midden, C. J. H. (2012). Trust in smart systems:Sharing driving goals and giving information to increase trustworthiness andacceptability of smart systems in cars. Human Factors, 54(5), 799–810.https://doi.org/10.1177/0018720812443825.