

Being in the Zone: Investigating the Effectiveness of In-Vehicle Multi-Sensory Affective Displays

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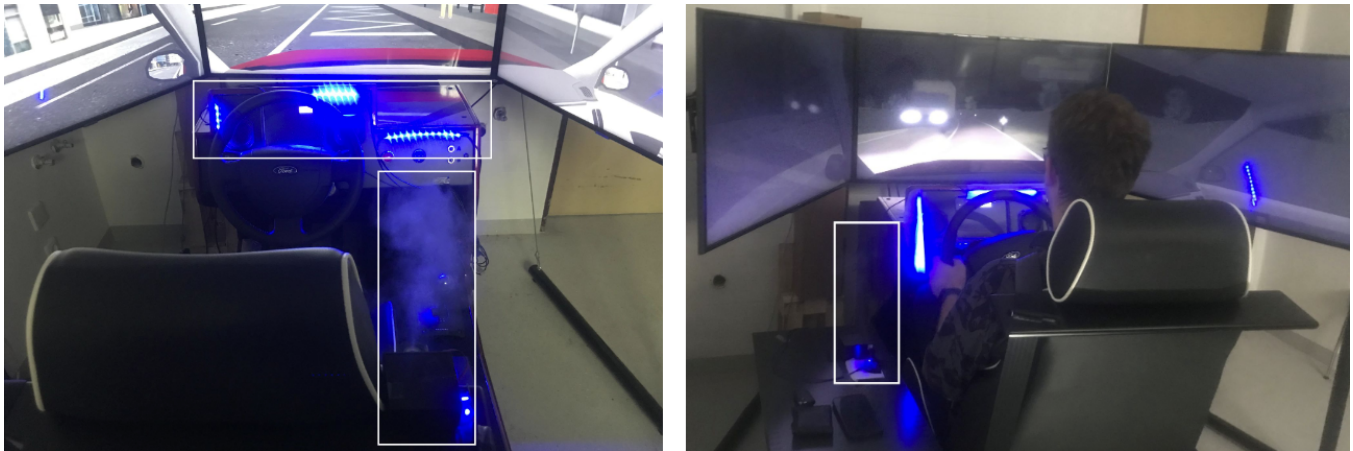


Figure 1: Study setup. Left: the ambient system setup for the easy-driving study, with the scent diffuser mounted near the headrest and the sound and visual system placed behind the steering wheel. Right: the system setup for the difficult-driving study, with the scent diffuser repositioned to a lower place on the left.

ABSTRACT

Previous research highlights the benefits of affective interfaces in improving drivers' emotional state and performance. This poster investigates the impact of a multisensory affective display, encompassing visual, auditory, and olfactory stimuli. A preliminary evaluation with eight participants in easy driving conditions informed scent intensity and placement adjustments. In a subsequent study under more challenging driving scenarios, the majority of participants (14 out of 20) reported minimal awareness of the system, while self-reported less skilled drivers perceived the system, experienced distractions and cognitive overload. Our findings suggest that the effects of multisensory affective displays on drivers vary and are influenced by driving difficulty, driver skill, and mental state, such as the state of flow. Future research is encouraged to explore novel interface designs that consider drivers' skills and cognitive states to adapt accordingly.

CCS CONCEPTS

• Human-centered computing → Empirical studies in HCI.

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AVI 2024, June 3–7, 2024, Arenzano, Genoa, Italy

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ACM ISBN 979-8-4007-1764-2/24/06.

<https://doi.org/10.1145/3656650.3656758>

KEYWORDS

Empathic Vehicles, Affective Computing, Interaction Design

ACM Reference Format:

Yu Sun. 2024. Being in the Zone: Investigating the Effectiveness of In-Vehicle Multi-Sensory Affective Displays. In *International Conference on Advanced Visual Interfaces 2024 (AVI 2024)*, June 3–7, 2024, Arenzano, Genoa, Italy. ACM, New York, NY, USA, 3 pages. <https://doi.org/10.1145/3656650.3656758>

1 INTRODUCTION & MOTIVATION

Over the past few years, in-vehicle affective display technologies have gained attention as a means to regulate driver emotions. This is particularly relevant considering negative emotions can have a detrimental effect on driver attention and performance [5, 11, 17, 20]. Adverse effects such as road rage [14], anxiety [16], fear [15] and sadness [10] can deteriorate risk perception, driver behaviour, and driving performance. As a result, empathic in-vehicle interfaces that can mitigate adverse effects by employing various stimuli, such as visual, acoustic, and olfactory modalities, have been researched to enhance driving performance. For example, using ambient light in visual displays reduces anger driving [2] and increases individual driving performance [9]. Furthermore, acoustic cues, such as music [7], and empathic speech [2] can help alleviate feelings of anger and sadness. Olfactory interfaces that release pleasant scents can further promote safer driving [6].

Building upon previous research, in this poster, we present a multisensory empathic interface incorporating visual, auditory, and

olfactory components. To assess usability and the impact of multi-sensory feedback, we conducted a preliminary evaluation involving simple (empty highway, no traffic, straight) and more difficult driving tasks (low visibility on a zigzag countryside road with numerous curves). Our findings suggest that the impact of multisensory affective displays on drivers varies, potentially going unnoticed, causing distractions, or positive effects such as alleviating boredom, depending on the difficulties of tasks, drivers' skills and mental states, such as the state of flow. We recommend future designs consider drivers' cognitive load and mental state for improved effectiveness.

2 PROTOTYPE & USER EVALUATION

Our driving simulator (see Figure 1) from Foerst [19] resembles the environment of a standard car and consists of three 43" monitors. The driving simulator consists of all necessary parts for driving, such as a steering wheel, automatic gear switch control, accelerator pedal, brake pedal, light controls, etc. The software, *Trainer Vehicle Simulator*, can simulate a range of driving environments, including varying traffic levels, road types (such as icy or bumpy), diverse landscapes (like mountainous or countryside roads), and different light conditions (day or night). We used *Govee car LED strips* [13] (two-line design, 4x30cm), which were fixed around the dashboard and we selected the blue colour to induce positive valence [9]. For the music, we used a small speaker box placed behind the steering wheel, playing "Eine kleine Nachtmusik" [8]. The 3D-printed scent container, located near the headrest, contains 7 drops of lemon [6] essential oil mixed with 40 ml of water. An atomiser, connected to a PCB module, is integrated into this container to produce the scent. To enhance ventilation, we kept the room window open.

2.1 Study 1: Preliminary Usability Evaluation

To investigate the usability of our prototype, 8 participants (2 female, 22-27 years, $M = 24.88$, $SD = 1.81$, all with driving licenses) underwent four rounds of driving with different combinations of sensory feedback (olfactory feedback is present across rounds). Participants adjusted the car seat, completed a 2-minute test drive to familiarise themselves, followed by semi-structured interviews.

In our preliminary analysis, we noticed five main factors that influenced the perception of olfactory feedback: 1) *personal preference of smell*, 2) *artificial/natural scent*, 3) *intensity*, 4) *visibility of vapour*, and 5) *noise of the scent diffuser*. Participants commented on the monotony of easy driving and the interface's emotional regulational effects. They reported feeling "deprived" when switching from multisensory conditions to zero sensory feedback, indicating potential benefits of the ambient system in alleviating boredom and increasing patience. However, concerns have been raised regarding the potential over-relaxation effect, and the system's applicability in critical driving situations. In summary, participants expressed mixed feelings about the desirability and utility of the prototype, with some acknowledging its benefits while others questioning its appropriateness in a car setting.

2.2 Study 2: Evaluation of the Effectiveness in More Complex Driving Scenarios

To explore the impact of multisensory ambient displays in challenging driving scenarios, as real-world driving conditions often

involve e.g. traffic jam, low visibility, and curvy roads, a second study was conducted under low visibility conditions (driving in fog and at night). Based on the findings from our preliminary study, we relocated the scent diffuser to reduce obtrusiveness and reduced the intensity of the smell. Two challenging simulated driving scenarios were used: 1) *Driving in fog*: Starting with good visibility, sudden fog requires adapted speed. 2) *Driving at night*: Low-visibility conditions require switching between high and low-beam lights for approaching cars on a curved country road. Overall 20 participants participated (9 female, 11 male, aged 20-34, $M = 23.6$, $SD = 3.15$, all with driving licences), with a mean self-rated driving skill of 3.5 ($SD = 0.76$) on a 5-point Likert scale. The procedure mirrored that of Study 1.

The majority of participants (14 out of 20) reported not perceiving at least one type of sensory feedback during the experiment. This was unexpected, as in Study 1, no participants reported neglecting the ambient setup. Some participants reported ignoring up to three sensory modalities. This phenomenon, that many participants became absorbed in the driving task, resembling the psychological state of "flow" [4], requires a challenging task and matching skills. This leads to deep focus on the driving and reduced awareness of the ambient system.

Alternatively, the diminished sensory perception could stem from inattentional phenomena or attentional failures, such as the "invisible gorilla" effect [3], where individuals focus on one task and fail to notice other stimuli due to inattention blindness. Notably, a "cross-modal" effect can occur, which suggests that e.g., acoustic stimuli might increase the cognitive load in visually demanding tasks and therefore be ignored [1]. In contrary to the focused participants, the unfocused, less skilled participants reported to be distracted by the ambient setup, and felt overwhelmed by the challenging conditions. This led to task execution failures, such as accidents. In these cases, ambient stimuli acted as an attention-grabbing distractor and demanded extra cognitive capacity. The effects of distractors can be cumulative, as reported by some participants, suggesting that integrating more senses into driving experiences might increase distraction levels.

3 DISCUSSION & CONCLUSION

Combining the findings from study 1 and 2, we can conclude that skill level and mental state influence the perception of ambient setup. While individuals in a flow state often did not notice the setup, less skilled drivers could be distracted by the setup in challenging tasks. Additionally, participants exhibited mixed feelings about multisensory interfaces, which may alleviate boredom but should align with individual preferences.

Our study highlights the importance of extending future intelligent ambient setups beyond detecting drivers' emotional states to also assess the cognitive load, thus enabling tailored hedonic effects. Besides, we learned that for olfactory studies, we should account for participants wearing perfume and the potential for scent-induced motion sickness, which is contrary to current research using scent to reduce motion sickness [18]. Future research could also utilise tools like EEG for quantitative measurement of flow states [12].

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