Developing Preliminary Heuristics for In-Vehicle Ambient Intelligence Systems

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SUMMARY

This study aimed to develop heuristics for designing and evaluating in-vehicle Ambient Intelligence (AmI) systems. Utilising an expert focus group (n=3) and a user study (n=8), 15 preliminary heuristics were derived. These aim to ensure that in-vehicle AmI enhances the driving experience by fostering driver wellbeing and a positive user experience, whilst minimising distraction.

KEYWORDS

Ambient Intelligence, In-Vehicle, Driving, Heuristics

Introduction

Ambient Intelligence (AmI) describes, *“the application and embedding of artificial intelligence into everyday environments to seamlessly provide assistive and predictive support in a multitude of scenarios via an invisible user interface”* (Dunne et al., 2021). AmI systems have been integrated into many everyday settings, including homes, classrooms, hospitals etc., where they monitor and detect users’ behaviour and intervene autonomously to enhance wellbeing, reduce cognitive load, increase engagement/enjoyment, etc. (Augusto et al., 2013). However, as the contexts of use become more complex, it is increasingly difficult to articulate users’ needs and expectations and to determine how to address these (Stephanidis et al., 2021). Moreover, as technology develops, new experiences become possible, such as ‘phygital’ devices that bridge the digital and physical worlds.

In a driving context, there is also complexity in that AmI systems must enhance the in-vehicle user experience while not interrupting or disrupting the primary driving task and this may present a conflict. For example, evocative lighting or music may be used to enhance the driver’s mood or their kinematic perception of the vehicle’s performance but could inadvertently direct their attention away from the road situation or encourage riskier driving behaviour. Further complications arise because each experience should be individually tailored to the driver’s preferences and lifestyle choices, which can change based on various factors, such as the journey type, presence of passengers etc. Nevertheless, recent examples suggest that the automotive industry is committed to creating user-centred ‘intelligent’ vehicle environments, with a focus on enhancing drivers’ wellbeing, in particular. Concepts include the Audi Urbansphere, which uses facial recognition to determine the driver’s stress level and reclines their seat to *“maximise comfort and restoration”*, and JLR’s Body and Soul Seat (BASS), which is described as an *“AI tactile audio device”* embedded in the driver’s seat that aims to enhance drivers’ wellness using ‘vibroacoustic therapy’ (Fortune, 2024). However, these concepts generally lack user-centred testing and validation in a driving context, and it is therefore unclear whether the proposed AmI solutions deliver what they purport to without compromising the driving task or the driver’s role within it. Traditional user experience and usability techniques, and indeed traditional ‘driver distraction’ guidelines, lack the scope or specificity to evaluate the nuances of in-vehicle AmI, and new or enhanced methods are subsequently required to define bespoke user requirements and appropriate evaluation metrics.

A common approach in user-centred design and evaluation is to apply 'heuristics' (or 'rules-of-thumb') to identify issues with a system or interface (Nielsen and Molich, 1990). Heuristic evaluation is a cost-effective method as it requires minimal training; by definition, heuristics should be easy to understand and apply, and the technique itself is intended to be intuitive and easy to accomplish. It is particularly effective as a formative, 'discount' method applied early in the design cycle, as it does not require systems to be complete or fully functional, but the method can also be applied as a summative evaluation of more mature systems. Nielsen's '10 Usability Heuristics' (Nielsen, 2024) have been applied in countless situations, but as they are targeted at direct interactions with a system, they are difficult to interpret and apply in the unique and nuanced context of in-vehicle AmI where only passive interaction is intended.

Overview of Study

The study aimed to develop domain-specific heuristics for in-vehicle AmI, with a particular focus on driver wellbeing. Firstly, a focus group was conducted with 3 experts in the field of automotive HF, HMI design and AmI. In addition to providing specific insights, this also informed the design of a user study that took place in a driving simulator, in which 8 participants (3M, 5F) experienced a simulated journey in which a prototypical AmI interface provided immersive sensory stimuli (dynamic images, sound, lighting) using Wizard-of-Oz, and were interviewed afterwards. Finally, inductive thematic analysis was conducted on all transcribed data to derive relevant themes and terms around which to define the heuristics. Fifteen heuristics were subsequently derived (Table 1).

Table 1: Preliminary AmI Heuristics

1. Stimuli must be balanced to prioritise safety and enhance the driving experience of occupants without causing distractions that hinder the primary task of driving. 2. The system should be subtle and non-explicit in nature by blending into the background to support the driving task without causing distractions. 3. The system should have situational awareness. (i.e. time, speed, traffic conditions, weather etc.). 4. The system output methods should be in sync with each other to complement the vehicle settings and user-state 5. The system should enhance the multi-sensory ambient interaction by incorporating any/all of visual, auditory, haptic and/or olfactory stimuli to create the in-vehicle environment. 6. A balance between comfort and alertness should be maintained in the vehicle. 7. The system should be adaptive in response to different users (i.e. offer personalisation without user input). 8. The system should be integrated with driver monitoring technology allowing it to adapt to occupant's current state and intervene accordingly, whenever necessary. 9. System integration should complement driving information outputs (e.g. speed) rather than replace it, without overwhelming the occupant with unnecessary information.	10. The system should avoid complicated and over-saturated stimuli for extended periods of time to prevent mental overload and reduced driver alertness. 11. The system should preserve user privacy by ensuring data collection and usage is transparent. It should be able to make occupants feel comfortable and calm, without being invasive or critical about the occupants' behaviours. 12. The location and quality of stimuli should be clear and designed to meet occupants' needs based on their role in the vehicle (i.e. driver, front passenger, rear passenger). 13. System stimuli should be designed as per individual needs, ensuring that the experience of one occupant does not cause hindrance to the experience of others. 14. The system should be congruent with a user's mental model of an in-vehicle experience, as an unexpected response from the system can lead to mistrust and reduced user interaction. 15. The system should provide limited but sufficient information about its status to avoid any confusion and maintain a balance between occupant safety and experience.

Conclusions

The proposed heuristics are intended to support driver wellbeing but can also be applied as a discount method to evaluate in-vehicle AmI, more generally, and may be adapted to other situations in which AmI supports a critical primary task. Further work will seek to refine/validate the heuristics and explore other novel methods to evaluate the impact of in-car AmI and inform design.

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