Interacting with automated vehicles and why less might be more

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Abstract

Effective interaction design for automated vehicles is a challenging matter. Be it interacting *with* the vehicle from a driver/operator position or being interacted with *by* the vehicle as a part of its road environment, the challenge lies with how to integrate the new contents or address the novel challenges brought about by the vehicle being (partially) automated. This typically takes the form of additional indicators (e.g., external displays) or exploration into different interaction modalities. In this paper, I want to share my view on how many automation challenges might be better addressed using minimal additional indicators or re-using already existing indicators and techniques as much as possible. Based on experiences from recent studies(specifically, one study on external HMI designs and one on an in-vehicle HMI), I argue for a more frugal approach to automation interaction design.

Keywords

automated vehicles, interfaces, lessons learned, frugal approach

1. Introduction

The transition from fully manual to automated transport is a continuous process and will persist as such for quite some time to come. Within this transitional period, humans are confronted with a wide range of automation functions or automated subsystems across an equally wide range of means of transportation. Even when limited to only the road environment, there are passenger vehicles, shuttles, buses, and drones of varying sizes, which all look different depending on who manufactured them and can differ in their degree of automation and other related constraints (e.g., maximum velocity or braking behaviour). Taking this into consideration, there is not so much a situation of "interacting with automation" in the singular sense but rather a field of interactions between humans and many different (partially) automated agents.

It is this complex interaction space that appears to call for a need for additional information and clarification on how this space is to be navigated by the human user This user can either someone who is at the controls of an automated vehicle and might have to perform partial tasks, (de-)activate systems, or intervene or it might be someone who is simply a part of the vehicle's driving environment and needs to have an avenue to communicate the vehicle in order to navigate traffic safely and effectively - just as with non-automated vehicles. The underlying assumption is that the automation brings with it new requirements that need to be satisfied with additional information, which manifest in additional indicators in existing interfaces or entirely novel interaction designs. This assumption is not unfounded, as numerous challenges and requirements in relation to interacting with automated vehicles have been identified [1], [2] across a wide spectrum of interaction solutions. However, what I intend to argue With this position paper is that while the need for additional information to interact with automated systems might be true, the need for novel interaction solutions might not be as high and that, especially long-term, simple standard indicators might be the primary way to go both in terms of effectiveness and efficiency.

2. How much is too much?

One question that should always be in the back of one's mind when designing an interface – especially in a safety-critical context – is that of distraction or workload [3], [4]. The interface should enable the user to perform the needed tasks without negative impact on their (physical or mental) workload or add as an additional distractor [5]. Thus, with the adding of additional information flow to a context there is the risk of that new information drawing attention from what had previously been the focus of attention. Visual indicators in particular run the risk of overloading users who, especially in driving and traffic contexts, already need to pay attention to a wide variety of visual cues and indicators. One strategy is then to pursue other modalities, such as haptics [6] or auditory [7] in order to distribute the load across sensory

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channels. Another strategy is to ask the question: "Is it really necessary?" and potentially reduce the amount of additional indicators used, reduce the complexity of the communicated content, re-use already existing interfaces, cues, or indicators, or similar strategies.

Over several studies and instances, I have now had experiences from which I went away with a strong tendency towards the latter, i.e., trying to reduce the communication down to what is strictly necessary and steering away from additional indicators, modalities as the exploratory default. Here, I would like to share the experiences from three such studies across two cases to exemplify the idea.

2.1. Case 1: External on-vehicle indicators

The first instance was a study on a closed test track in which we investigated eHMI (external Human-Machine Interface) designs for automated shuttles to communicate with manual vehicles and other road users [8]. It was a comparison study with several different visualisations on a front-mounted display as well as two side-mounted displays towards the front. The designs themselves were based on an online-questionnaire, from which we had already extracted what we thought were the most suitable colours, icons, and animation patterns. In the study, we had the shuttle circulate around the track and then interact with manually driven vehicles and pedestrians crossing the road across several interaction scenarios and different visualization conditions.

As far as the eHMI comparison went, we stopped the study before we got to the double digits in terms of participant numbers, as we had learned what we needed by then: There would be little to no usable data for comparison regardless of the number of participants due to a clearly visible *lack of willingness to engage* with the eHMIs. The reasons for this ranged from the participants not even noticing the indicators to them noticing but deciding to not make use of them as the interaction went along. In the post-interaction interviews, we learned that the participants were very quick to revert back to what they knew when interacting with the shuttle and its unknown or hard to expect driving behavior. This means that they would look at the standard lights and turn indicators and, when in doubt, simply wait and see what happens, as they were never in any real danger. When the participants did look at the indicators, we learned that many of the designs that seemed to work on paper (and according to the questionnaire results) did not work as well in context, especially in light of how drivers apportioned their attention while driving: Anything that required sustained attention (short animations in particular) was difficult to process, leading the participants to again go with their usual gaze and action patterns for interaction with manually driven vehicles.

Still, the participants from this study had all mentioned a strong preference for additional information and indicators, despite their reliance on "traditional" indicators during the interactions. Thus, our take-away from this study was that we needed to reduce the complexity, use only very simple animations (e.g., blinking) and to not use images or verbal content that needs additional mental processing. In a field study later in the project [9], [10], we did a performance assessment of the eHMIs, which had finally been realized as one-dimensional LED-strips. The lessons we had learned previously were well-learned as it appeared, as we finally did see interaction success when the indicators were active as opposed to the control condition. While the effects were noticeable, they were not major and it was clear that the shuttle was able to navigate traffic also in the control condition – just not *quite* as well. In this study in particular, we noticed that vehicle position (e.g., stopped further into an intersection vs. with greater distance as well as the fact whether the shuttle was visibly accelerating or decelerating were by far the most used indicators by the other traffic participants.

2.2. Case 2: In-cabin indicators

In another study from a different project, we made similar experiences, this time regarding in-vehicle indicators [11]: For the purpose of exploring the suitability of (ambient) light displays to signal driving modes and control transitions in highly automated vehicles, we had installed lights below the windshield, on the steering wheel, and in the footwell. These would then emit light signals in two conditions (static and dynamic (e.g., pulsing, blinking), with the colours having been informed by a previous online questionnaire. Among the results from this study were the findings that the steering wheel light was too distracting and needed to be used more sparingly. The light in the footwell, despite having been the largest in terms of illuminated surface, was not found to have any noticeable effect or even be noticed by most participants while driving. The other lights were found to have an effect, though it was not very large overall when compared to the control condition without lights. By itself, this is about what one should expect when running a study: In practice, some things work other than intended and some not at all.

What was interesting, however, was an observation that was rather minor in the grander scheme of things and, thus, not included in the original publication but is something which I would like to share here: The results from the post-interaction interviews yielded more positive comments towards the light interfaces and also a strongly expressed need for additional indicators in automated vehicles, which was not reflected in the quantitative data. When looking at the data more closely, we

found this discrepancy to occur within-participants as well, i.e., a single participant would speak highly of the lights and express a need for additional HMIs or indicators, yet that same participant would rate light and baseline conditions similarly in the questionnaires. Just like with the first eHMI study, it seemed that the indicators the participants expressed to require, were not actually that necessary in the actual interaction and quickly too much. This can then result in participants interacting with what they would be used to normally in such cases, i.e., interacting just as they would in the baseline, thus explaining the lack of differences in actual performance.

3. Frugally forward

So what do we take away from this? On the one hand, there is a component of uncertainty when interacting with automated vehicles and that component needs to be addressed. On the other hand, users are quick to fall back to what they are used to from interacting with manually driven vehicles and the success rate in this "interaction baseline" is already rather good. A part of this is certainly related to the fact that controlled field study conditions cannot be high risk conditions, so the measurable effects of a safety-critical technology should be expected to be more limited in field trial condition. Another aspect is certainly that just because *an* interface was developed, does not mean that it was the ideal interface for the purpose, so a smaller than expected success over the control condition may just as well be a hint towards improvability of the interface.

Another take-away, however, is the observation of "what works" and how users are easily able to reapply that which worked before to the novel context, despite explicitly expressing to require additional information or indicators (as it was the case in eHMI study 1 or the in-vehicle HMI). There is a difference between the transition phase, in which we are right now, where the automation technologies are novel, manifold, and to many unknown in detail, to a phase in which the technology has been in use for some time and is largely known to most in terms of capabilities and limitations. In such a context, explanatory indications are not necessary, as users already know what to expect. Users need to know if a machine or device is on or off (status indicator), need rudimentary information regarding the planned actions (see: turn indicators, braking light) and take the rest from the information present in the context.

In all the provided examples but especially the mixed traffic experiments in eHMI study 2, we have had a glimpse of users falling back into these for them safe and established interaction behaviours, despite interacting with a novel technology – and for the most part, it worked out just fine. From this, I believe that the communication of additional, automation-specific information, is still important but perhaps not as vital as we might have additionally assumed. Furthermore, I would like to use this as a motivation to explore even simpler indicators to communicate automation-relevant information, to even re-use as many of the existing indicators as we can. If, to only provide an illustrative example, turn indicators suffice, why use something else? The resulting HMIs and interfaces will certainly be less fancy or futuristic, perhaps a bit boring even, and less attractive for the often brilliant and creative minds that explore interface and interaction design. This is why I would like to put explicitly put this direction forward, discuss with and encourage others to explore frugal interaction design, employing existing designs and interaction channels to solve novel challenges. It might not look that exciting in practice, though the long-term interaction results might outdo the short-term excitement gained by a nice looking HMI that nobody else had done before.

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