Attentive User Interfaces to Improve Multitasking and Take-Over Performance in Automated Driving: The Auto-Net of Things

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ABSTRACT

Automated vehicles promise engagement in side activities, but demand drivers to resume vehicle control in Take-Over situations. This pattern of alternating tasks thus becomes an issue of sequential multitasking, and it is evident that random interruptions result in a performance drop and are further a source of stress/anxiety. To counteract such drawbacks, this article presents an attention-aware architecture for the integration of consumer devices in level-3/4 vehicles and traffic systems. The proposed solution can increase the lead time for transitions, which is useful to determine suitable timings (e.g., between tasks/subtasks) for interruptions in vehicles. Further, it allows responding to Take-Over-Requests directly on handheld devices in emergencies. Different aspects of the Attentive User Interface (AUI) concept were evaluated in two driving simulator studies. Results, mainly based on Take-Over performance and physiological measurements, confirm the positive effect of AUIs on safety and comfort. Consequently, AUIs should be implemented in future automated vehicles.

KEYWORDS
Automated Driving, Device Integration, Non-Driving Related Tasks, Pervasive Computing, SAE J3016, SAE J3114, Take-Over Request

INTRODUCTION

From all the advantages associated with automated vehicles (AVs), engagement in non-driving related tasks (NDRTs) might be among the promises most relevant from consumers’ perspective (Pfleging, Rang, & Broy, 2016). Due to the general availability of the internet and smart devices - on average, each smartphone receives 63.5 notifications per day (Pielot, Curch, & de Oliveira, 2014) - people nowadays incline to permanently “divide their attention”, and expose themselves to multiple conversations or media content, following a mindset also called “always on mentality” (Vorderer, Hefner, & Klimmt, 2017). This has already become a major safety issue in manual driving. Distraction

DOI: 10.4018/IJMHCI.2019070103

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is connected to every 10th fatal injury, and 47% (often young and novice driver) state to frequently use their smartphone while driving, whereas 25% state to read, and even 15% to reply to messages (Easternmeier & Kubitzki, 2016). Recently, legislators issued new laws to prohibit device usage in vehicles (except for hands free equipment), what is important as publicly available automated driving technology only operates up to level-2 (SAE, 2016), where drivers must monitor vehicle behavior anytime, and without distraction. The next step in the evolution of AVs are level-3 systems that, by definition, allow drivers to engage in NDRTs until interrupted by so-called “Take-Over Requests” (TORs). Such a transfer of control back to the driver is, in case of an emergency (“imminent” TOR), the most critical issue of level-3 driving. Despite researchers working hard to improve transition quality and safety, some vehicle manufacturers even stated to skip level-3 because of safety issues (M14 Ingelligence, 2018). However, even level-4 vehicles would not fully eliminate these problems. Here, not responding to TORs might not be safety-critical, as the vehicle is capable of reaching a safe state (“Minimal Risk Condition”), but transitions will still be relevant. First, drivers have to resume control when the automation leaves its operational design domain (“scheduled” TOR), for example at highway exits (Wintersberger, Green, & Riener, 2017). Second, even in an emergency situation, interception by the human driver is preferable over a stand still.

Summarizing, as long as AVs provide driving controls (such as steering wheels/pedals), transitions will happen, and in phases of automated driving, drivers will demand to engage in NDRTs. Thus, to implement level-3/4 AVs successfully, it will be essential to support side activities in the safest way possible. One potential strategy in this regard is to integrate or mirror content from consumer devices at in-vehicle information systems (IVIS), such as Apple CarPlay or Android Auto. This approach also increases safety, for example by suppressing notifications while driving. In AVs however, engaging in NDRTs on consumer devices could be favored over such systems. First, they are mainly designed to support manual driving, whereas level-3/4 driving will be characterized by alternating phases of driving and NDRT engagement. Second, due to familiarization, it might be more convenient to use private devices as in any other situation (Diwald, Möller, Roalter, & Kranz, 2011) – it even has been shown that humans react anxious when being separated from them (Clayton, Leshner, & Almon, 2015). Third, some tasks might be performed faster using nomadic devices, for example typing with a well-trained “Swype keyboard” (rather than using input options currently present in vehicles). Consequently, it is realistic that drivers want to use nomadic devices in AVs and the authors of this article claim that this does not necessarily impede safety when supported properly. A major principle of pervasive/ubiquitous computing is to “seamlessly integrate” one’s devices/technologies and thereby “automatically adjust behavior to fit circumstances” (Mahadev, 2001). Since users already perceive vehicles as intelligent agents (Thill, Riveiro, & Nilsson, 2015), future users may want AVs to integrate into their digital ecosystem as any other “Internet of Things”-device.

This work extends these principles to the domain of automated driving and demonstrates with two driving simulator studies (see Figure 1) how the integration of nomadic devices, AVs and cooperative, intelligent transportation systems (C-ITS), can increase safety in level-3/4 driving, while allowing drivers to seamlessly switch between activities. The here presented system is able to transform some imminent TORs into scheduled transitions by help of C2X communication – the application of “Attentive User Interfaces” (AUIs) principles eliminates negative effects of unplanned interruptions, while allowing drivers to respond to the remaining set of emergency transitions directly on nomadic devices.

**MULTITASKING IN HIGHLY AUTOMATED VEHICLES**

While in manual driving multitasking is a problem of shared attention (“concurrent multitasking”), in AVs the established definition of primary (driving) and secondary (NDRTs) tasks might change (Wintersberger & Riener, 2016). Drivers will be able to concentrate at only one activity at a given time, while sequentially switching between NDRTs and the driving task (“sequential multitasking”)
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