Augmented Reality as an Advanced Driver-Assistance System: A Cognitive Approach

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ABSTRACT

AR is progressively being implemented in the automotive domain as an ADAS system. This increasingly popular technology has the potential to reduce the fatalities on the road which involve HF, however the cognitive components of AR are still being studied. This review provides a quick overview of the studies related with the cognitive mechanisms involved in AR while driving to date. Related research is varied, a taxonomy of the outcomes is provided. AR systems should follow certain criteria to avoid undesirable outcomes such as cognitive capture. Only information related with the main driving task should be shown to the driver in order to avoid occlusion of the real road by non-driving related tasks and high mental workload. However, information should not be shown at all times so it does not affect the driving skills of the users and they do not develop overreliance in the system, which may lead to risky behaviours. Some popular uses of AR in the car are navigation and as safety system (i.e. BSD or FCWS). AR cognitive outcomes should be studied in these particular contexts in the future. This article is intended as a mini-guide for manufacturers and designers in order to improve the quality and the efficiency of the systems that are currently being developed.

Keywords: Augmented Reality, Automotive, Cognitive, Review, Taxonomy.

1 INTRODUCTION

In the last years, Augmented Reality (AR) has been implemented progressively into the automotive industry in the form of Advanced Driver-Assistance Systems (ADAS). This technology is being employed in new vehicles as an aid for drivers in different circumstances such as navigation or hazard detection. It is expected it will help to reduce Human Factor (HF) related accidents on the road, but the relation between the use of AR during driving and its cognitive aspects is a relatively new topic that is still under development. This paper provides quick review of cognitive aspects of AR and a taxonomy of previous literature to date that makes special emphasis on the perceptual and cognitive aspects involved in AR while driving and its different uses. We consider that this review was necessary as a quick guide for automotive manufactures and designers: It is essential to explore the cognitive aspects involved in AR during driving in order to optimize the design of the technology, but it is even more important not to make things more difficult for drivers when developing a system. It could happen that the system offers little help to users instead of making things easier for them, adding extra risks in the form of cognitive and perceptual variables that were not taken into account during the design.

SCOPUS database was used as search motor in combination with manual web search. Used keywords were “Augmented reality” and “Automotive”. Over 173 results were displayed in the SCOPUS database after a first filter that excluded articles not related with HF. Over 50% of the results were related with the use of AR in the car manufacturing industry, but not directly with AR as an ADAS. These results were excluded, with the exception of three examples in the provided taxonomy (Kelly Villota et al., 2017; Langley, 2016; Marsh &

Merienne, 2015). In addition, technical results that involved design strategies without focusing on the cognitive aspects of AR were not used. Four additional articles were identified by examination of reference lists and other sources (Chung, Pagnini and Langer, 2016; Eriksson et al., in press; Lorenz, Kerschbaum and Schumann, 2014; Zimmermann et al., 2018). In the end, 26 publications were classified as useful for the purpose of this review.

2 COGNITIVE AND PERCEPTUAL IMPLICATIONS OF AR INSIDE THE CAR

There are many cognitive and perceptual aspects of AR that should be taken into account while driving. In this section some of them will be shown.

One of the potential drawbacks of AR inside the car is that it can lead to cognitive capture if the AR area is overloaded with information (Pauzie, 2015). This may cause the driver to respond to the offered information rather than to the driving task and a problem of overreliance, and thus, that users engage in risky driving. It is because of this reason that AR should keep a reasonable amount of essential information on display and this should not be secondary or not driving-related. A mix of important information and secondary information may cause confusion in the driver, who may not know where to look (Ng-Thow-Hing et al., 2013). In a study from 2016, Wang and Soffker suggested different Head Up Displays (HUDs) designs that displayed information related with driving efficiency. While driving efficiency information could be important for many people, it could be an example of secondary information that should not be provided in a HUD.

AR information does not have to and should not be present at all times, because this could also lead to overreliance on the system (Gabbard, Fitch and Kim, 2014). In a 2016 study related with the usefulness of AR while navigating, Chung et al. noticed that participants who had the possibility of doing punctual choices while navigating were more engaged with the task and showed less distractions. This is a complementary solution against overreliance: to offer drivers specific cues during specific manoeuvres, but never telling them exactly what to do, since that is their responsibility and could affect their driving skills in the mid-term (Ng-Thow-Hing et al., 2013). AR is a helping system, but it is not a substitute of real life signals. Even if AR allows us to keep looking to the road while looking at the information, it can receive more attention than the road, turning what is supposed to be a helping system into a distraction. Information should be presented just for certain manoeuvres and not constantly in order to increase situation awareness. Showing the relevant information for specific events makes the driver more attentive to what is happening. On the other hand, if the user had constant information, it could also occlude important visual information.

The concept of Useful Field of View (UFOV) is also important in this context. When talking about AR, UFOV refers to the visual area where information can be extracted with a simple glance without head movements (Ng-Thow-Hing et al., 2013). This UFOV is in accordance with the tendency of AR to be displayed via HUD inside the car, which do not require head movements to be seen. Using a HUD would be enough for obtaining benefits from AR and allows to reduce the potential cost of full windshield AR, so it makes sense that this is general tendency in the market. Having a full AR windshield could force drivers to move their head and thus, increase cognitive distance between two separated sources of information. Nevertheless, there have also been proposals of full windshield AR (see Charissis, 2014, Hosseini, Bacara and Lienkamp, 2014). More information and references about cognitive aspects of AR as an ADAS can be found in figure 1.

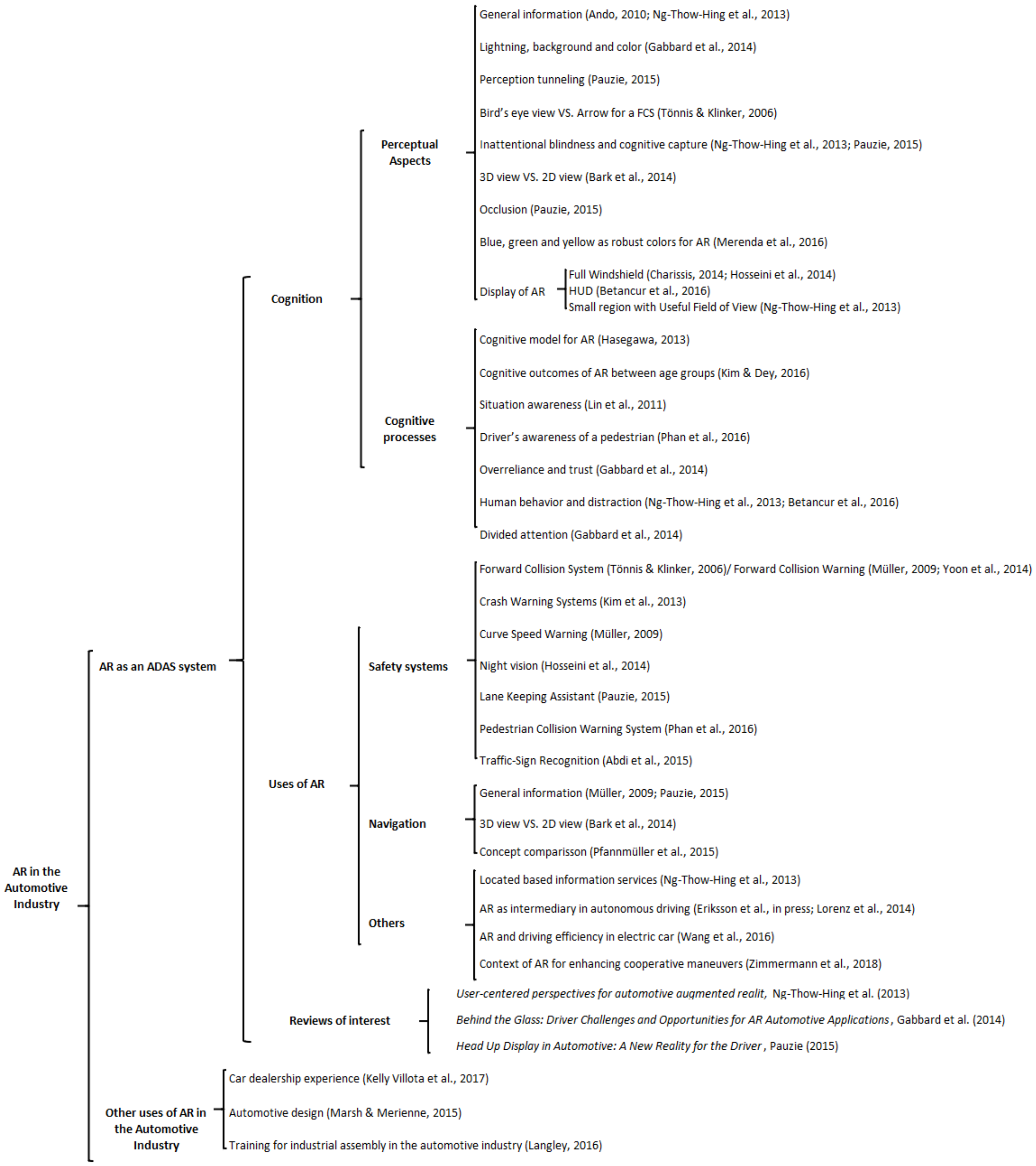

Figure 1 – Taxonomy of previous literature related with AR in the Automotive Industry

3 DIFFERENT USES OF AR INSIDE THE CAR

3.1 Safety

AR is a worthy system for providing safer driving. It can alert the driver and provide cues about the environment with enough time for them to react. Nowadays some cars include a Blind Spot Detection system (BSD), which informs the user about close cars or obstacles that they cannot see directly. Especially in these critical moments, it is crucial to remember that the way in which the information is presented to the driver can make the difference. Cognitive implications of AR in the car specially apply here in order to optimize drivers' cognitive resources and avoid fatalities. An example of safety system that have been studied in the AR domain is the Forward Collision Warning Systems (FCWS) (Yoon, Kim, Park, Park and Jung, 2014). In 2016, Phan, Thouvenin and Frémont designed an evaluated and tested a particular kind of FCWS, a Pedestrian Collision Warning System (PCWS). In their study, they found that conformal cues (adapted and in coherence to the real shape), in contrast with non-conformal cues (non-changing opaque shape), enhanced drivers awareness of the pedestrian.

3.2 Navigation

Another particular use of AR is navigation. Non-AR navigation process already requires a high cognitive workload for the user: visual attention and spatial orientation are cognitive functions that are highly involved in this context. The problem of navigation systems is that they also challenge the divided attention of the user. Divided attention is also known as multitasking, it is the ability of the person to perform two parallel activities at the same time. A straightforward way to reduce cognitive workload is offering the navigation information to the user directly in the HUD. In a study by Chung et al. (2016) it was suggested that AR helps the user to focus on while navigating. Several participants had to find a goal in a building with challenging routes. The authors showed that participants who used AR cues reached their final destination before the other group (no AR cues), supporting the use of AR for navigation. The use of AR for optimizing the navigation is also supported by the number of times the participants made mistakes (got lost), which was lower on the AR. It is important to notice that this study was done by pedestrians, and not drivers.

It has also been suggested that the AR navigational information should be provided only with 3D HUD because it allows to a better depth perception (Bark, Tran, Fujimura and Ng-Thow-Hing, 2014). In a different study (Pfannmüller, Krammer, Senner and Bengler, 2015), non-contact-analog (image not implemented over real environment) 2D screens were classified as more annoying and distractive than other 3D concepts. In that same study, the authors concluded that a pattern of small boomerang-like arrows was the ideal for navigation in contrast to a continuous arrow symbol. They argue that the second may occlude the real environment to a higher extent, and thus, lead to cognitive capture.

3.3 Take Over Request Assistant

Another promising use of AR is to assist drivers in a Take Over Request (TOR) event in the context of automated driving. Recent studies have shown that although AR does not necessarily decrease reaction times when regaining manual control, it does increase the quality of the TOR and assist drivers in decision making situations, like overtaking or braking when a car ahead is driving slower (Lorenz et al., 2014; Eriksson et al., in press). Combined, AR and autonomous driving systems could be a big step towards a much safer driving.

4 Conclusions

This paper is focused on the cognitive outcomes of interacting with AR while driving. Even though these systems are meant to help drivers, there is still work to do in order to fully understand how to make the best of them, and what is more, to not make these more dangerous than driving without them.

The information offered via AR should be essential and should make sense in the context of the real driving, this means that it should be related with the main driving task. AR information should not be present at all times, avoiding occlusion of the road elements and over trust on the system. It is recommended that AR information is related with concrete maneuvers or particular moments.

Effectively used, AR may reduce accidents on which human factor is crucial. It is critical to keep researching the interaction between the driver and the AR device in order to design systems that take into account all the possible cognitive outcomes in the most efficient way.

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