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Supporting anticipation in driving through attentional and interpretational in-vehicle displays

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ABSTRACT

Objective: This paper evaluates two different types of in-vehicle interfaces to support anticipation in driving: one aids attention allocation and the other aids interpretation of traffic in addition to attention allocation.

Background: Anticipation is a competency that has been shown to facilitate safety and eco-driving through the efficient positioning of a vehicle for probable, upcoming changes in traffic. This competency has been shown to improve with driving experience. In an earlier simulator study, we showed that compared to novice drivers, experienced drivers exhibited a greater number of timely actions to avoid upcoming traffic conflicts. In this study, we seek to facilitate anticipation in general and for novice drivers in particular, who appear to lack the competency. We hypothesize that anticipation depends on two major steps and that it can be supported by aiding each: (1) conscious perception of relevant cues, and (2) effective processing of these cues to create a situational assessment as a basis for anticipation of future developments.

Method: We conducted a simulator experiment with 24 experienced and 24 novice drivers to evaluate two interfaces that were designed to aid the two hypothesized steps of anticipation. The attentional interface was designed to direct attention toward the most relevant cue. The interpretational interface represented several cues, and in addition to directing attention also aimed to aid sense-making of these cues.

Results: The results confirmed our hypothesis that novice drivers' anticipation performance, as measured through timely actions to avoid upcoming traffic conflicts, would be improved with either interface type. However, results contradicted our expectation that novice drivers would obtain larger improvements with the interpretational interface. Experienced drivers performed better than novice drivers to begin with and did not show any statistically significant improvements with either interface.

Conclusion: Both interfaces improved anticipation performance for novice drivers. Future research should evaluate the effectiveness of these interfaces in a wider variety of driving conditions, such as when the driver is multitasking.

1. Introduction

Anticipation has been argued to play a role in driving safety, hazard perception, and eco-driving. With respect to safety, research has shown anticipatory aids to facilitate earlier deceleration prior to conflicts (Popiv et al., 2010) and better reaction times in combination with improved, smoother deceleration profiles (Laquai et al., 2011). Response priming for specific driving tasks has been studied as well, and proven to have positive impacts both in simulator (Hofmann and Rinkenauer, 2013) and real world research (Davoodi et al., 2012; Fitch et al., 2010). Hazard perception has been connected to anticipation and described as “the ability to anticipate traffic situations” (Sagberg et al., 1997, p. 407). This ability has been argued to support safety by maximizing available decision-making time (Jackson et al., 2009). Anticipation can also be used to minimize pedal use (for both braking and accelerating), and is therefore part of hypermilers' strategies to drive more economically (Hypermiling Techniques, 2011). Research into eco-driving, conducted both in driving simulators (Baer et al., 2011; Rommerskirchen et al., 2013) and on the road (Thisjen et al., 2014), suggests that aids for the anticipation of upcoming braking events can generate fuel savings of approximately 10%.

In prior publications, we have reviewed the role of anticipation in driving research and reported anticipation to be a concept

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that has not been explicitly defined or operationalized, but that is claimed to benefit both safety and eco-driving and is considered to be crucial to skilled driver behavior (Stahl et al., 2014a). We have also discussed the theory of anticipation in driving (Stahl et al., 2014b), and defined anticipatory driving as "a high level cognitive competence that describes the identification of stereotypical traffic situations on a tactical level through the perception of characteristic cues, and thereby allows for the efficient positioning of a vehicle for probable, upcoming changes in traffic" (Stahl et al., 2014b, p. 605). Thus, we see anticipation in driving as a competence to correctly interpret traffic situations and their development, akin to third level situation awareness (Endsley, 1995), and consider it to take place at the tactical level in Michon's hierarchical model of driving performance (Michon, 1985). While the strategic level allows for general planning of driving, it does not allow for anticipation of specific events due to near endless possibilities. In contrast, sudden events do not leave enough time for the perception and cognitive processing of complex cues indicative of upcoming scenarios. Thus, on the operational level, a driver can only be described as reactive. We have provided a detailed discussion on the theory of anticipatory driving in Stahl et al. (2014b).

In Stahl et al. (2014b), we have also reported the results of a driving simulator study that investigated anticipation in several simulator scenarios, and found that experienced drivers in general were able to anticipate, and take action to avoid upcoming conflicts, whereas novice drivers nearly completely lacked this competence. Currently, it is not well understood how we can facilitate anticipation in general and for novice drivers in particular, who appear to lack the competency. The current paper discusses differences between novice and experienced drivers with the aim of finding methods to aid anticipation. It then reports on a new simulator experiment conducted with novice and experienced drivers, in which we investigated two different types of interfaces designed to aid anticipation.

1.1. Anticipation in driving: perception and interpretation

In prior research (Stahl et al., 2014b), we found that experienced drivers were more likely to exhibit anticipatory competence and act to avoid potential conflicts. This finding was expected given our hypothesis that experienced drivers possess heightened skills for the timely and accurate interpretation of the local traffic situation. It was also in line with prior research in hazard perception, where experienced drivers exhibited superior visual scanning patterns (Garay-Vega and Fisher, 2005) and early recognition of hazards (Jackson et al., 2009). We argued before (Stahl et al., 2013) that anticipation in driving is rooted in the identification of stereotypical situations in traffic. In this sense, both anticipation and hazard perception rely on skilled perception and correct interpretation of the surrounding traffic situation. These mechanisms are learned competencies in large, and therefore are impacted positively by experience and repeated exposure to similar situations, as well as the abilities to access and compare the current situation to similar situations stored in memory.

The mechanism by which experience benefits anticipation should therefore be viewed as a top–down process in which established mental models and knowledge from relevant past experiences guide attention and the interpretation of sensory input from the traffic environment. This view of top–down processing in traffic has also been discussed by Hole (2007) and is an idea in the constructivist tradition, where learning takes place as an iterative, comparative process between perceived information and constructs of the world. Constructs are the reference point for interpretation of sensory information, and new information in turn continuously updates and changes our mental constructs.

In this regard, facilitating anticipatory competence can be seen as a matter of aiding in the development of a catalog of stereotypical traffic situations, their likely progression in the immediate future, and appropriate actions to position a vehicle efficiently in those situations. In post-experiment cognitive walkthroughs following our earlier experiment (Stahl et al., 2014b), experienced drivers who exhibited timely, anticipatory actions frequently referred to past experiences when explaining the perceived traffic scenario and their actions within it. They also presented more complete accounts of the experimental scenarios they had driven through, remembering more cues, connecting them causally, and drawing conclusions from those observations (Stahl et al., 2014a).

Experience can be argued to lead to a catalog of stereotypical situations that is more detailed and more extensive. Consequently, for the experienced driver, the process of interpreting the situation at hand is heavily guided through the knowledge of similar situations. Efficient and fast skill-based behavior (Rasmussen, 1983) takes over in this case. The novice driver in contrast may be unable to match the current situation to a fitting, memorized one due to an underdeveloped catalog of stereotypical situations. The novice driver will instead rely more heavily on inductive reasoning, such that more effortful processing will take place. He will still be able to interpret the current situation, but the accuracy of his interpretation will rely more on high level, knowledge-based behavior.

These theoretical considerations suggest two crucial steps for anticipation in driving, namely (1) the conscious perception of appropriate cues that serve as indicators for the traffic scenario at hand, and (2) efficient cognitive processing that leads to a quick and correct interpretation of these cues. Experienced drivers' superior performance with respect to anticipation can be argued to result from heightened skill in both. Their driving altogether has become a more automated procedure, so that more cognitive resources are available to monitor the environment for cues. Even more so, frequent exposure to a multitude of stereotypical traffic situations will result in knowledge of appropriate cues indicating those situations, such that the monitoring of surrounding traffic will become a more targeted process than for a novice driver. Thus, in line with Neisser's perceptual cycle model (Neisser, 1976), anticipation relies on a cyclical, continual process of cue perception and cue interpretation guided by mental models developed over time.

1.2. Aiding anticipation

While we cannot substitute for the heightened competencies of an experienced driver, we can attempt to mitigate lack of experience by highlighting relevant cues, and aiding the correct interpretation of these cues. Even for an experienced driver, highlighting appropriate cues may hold promise, since cues missed due to distraction can result in incomplete or incorrect situation assessments.

Different types of interfaces aiding anticipation have been proposed in prior driving research. Toennis et al. (2007) discussed the use of a head-up display that communicates the stopping distance to the driver by visualizing the distance that would be covered before a full stop. Further, Laquai et al. (2011) proposed and investigated the use of color-coded LED arrays to help drivers modulate their brake pedal control in response to other vehicles, under the assumption that car to car communication would be available in the future. With a particular focus on improving fuel consumption, prior research has investigated interfaces that suggest the optimal gear to the driver (Van der Voort and van Maarseveen, 1999), and present optimal coasting distances to minimize braking (Baer et al., 2011; Rommerskirchen et al., 2013). All of these examples aim to directly support vehicle control when the system is anticipating in place of the driver. Further, none of these interfaces support the