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Three levels of situation awareness in driving with secondary tasks

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ABSTRACT

It is assumed that drivers are able to adapt their interaction with secondary tasks to the demands of driving. To do so, they need to be situationally aware of the current driving situation. Three levels are proposed through which drivers adapt their interaction with a secondary task to the demands of driving. On the planning level, more general strategies – like always stopping the vehicle prior to the performance of a secondary task – can be found. On the decision level, drivers decide for a given driving situation whether distraction is appropriate or not. Last, as soon as a secondary task has been started, drivers adapt their interaction with the secondary task to the demands of driving through processes on the control level. This is done for instance by adapting the distribution of attention between driving and the secondary task. Results from an experiment in the driving simulation with $N = 16$ drivers are presented that support all three proposed levels. It is concluded that there are different possibilities to adapt interaction with secondary tasks to driving in a situationally aware manner and that drivers use these possibilities to preserve driving safety.

1. Introduction

1.1. Unintended distraction vs. deliberate direction of attention towards a secondary task

To be able to preserve driving safety during performing an additional task, it is necessary that drivers attend to distracting activities in accordance with the demands of the driving situation. In driving, more complex situations like crossing intersections or overtaking and undemanding situations like travelling on a highway with low traffic density alternate. Therefore, there are driving situations in which extra load through a distracting activity is very unlikely to cause critical driving situations and there are situations in which any extra load will require attentional resources needed to solve the driving task.

In the last years, more and more publications reported how dangerous interacting with secondary tasks while driving can be. The overall result of these studies is that performance of an additional task clearly reduces driving performance and safety. Typical effects are decreases in lane keeping performance (e.g. Horrey and Wickens, 2002) or delayed reaction times to sudden events (e.g. Lee et al., 2001; Törnros and Bolling, 2005). These findings can be explained by theories that assume a limited amount of cognitive resources (e.g. Wickens, 2002) that can be spent for a certain number of tasks. If an additional secondary task has to be performed concurrent with the primary driving task, less resources can be spend for driving and if the secondary task is too demanding and is prioritized too heavily an overload situation and a performance decrease in driving may be the result (more on this topic see Section 2.3). However, an often neglected fact in typical experimental settings studying distraction is that drivers are also able to compensate for additional workload by making deliberate decisions whether to attend to a secondary task or not in a given situation. Lerner and Boyd (2005) call this the "deciding to be distracted" approach. These decisions are based on expectations about the future development of a situation and if the expected demands allow the execution of another task concurrent with the driving task. Therefore it seems necessary to make a clear distinction between unintended distraction caused by certain stimuli inside or outside the vehicle (e.g. warning messages, advertisement) vs. the deliberate direction of attention towards a secondary task (e.g. initiating a phone call, being engaged in an in-vehicle information system, IVIS) where drivers can freely choose to what extend they want to be distracted. This is often the case in naturalistic driving environments. From the widely cited 100-car-study (Dingus et al., 2006) naturalistic driving data is available on how many incidents or crashes occurred while the drivers were distracted by some kind of secondary task. In a test track experiment, Horrey and Lesch (2009) found that drivers interact with secondary tasks independently of the current driving situation although they were instructed to choose an appropriate time for attending to the secondary task. These results can be interpreted as showing that drivers are incapable to interact with distracting activities in a safe and appropriate manner.

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Besides such results, other studies exist which are more in line with the assumption that drivers are able to adapt their interaction with secondary tasks to the demands of the driving situation. In queries, drivers report that their decision to interact with secondary tasks depends on the characteristics of the driving situation. For instance, in a survey by Boyle and Vanderwolf (2005) one third of the drivers who in general do phone calls while driving reported that they dial also while driving, 41% reported dialing during short period of stopping and 23% stated that they purposefully stop before dialing (similar results see also Thulin and Gustafsson, 2004). Furthermore, drivers report that they do not only choose appropriate situations for telephoning but that they also adapt their driving behaviour to the distraction: for example 50% state that they reduce speed always or mostly always while talking on the phone (Thulin and Gustafsson, 2004).

In summary, results reported in the literature are contradictory regarding drivers' ability to adapt secondary task interaction to the demands of driving. One reason for this might be that in surveys drivers think about a wide range of different more or less demanding driving situations. In comparison to the variety of driving situations in real-life, the situations studied in the test track experiment by Horrey and Lesch (2009) were all relatively simple and for instance never involved other road users. Furthermore, the surveys indicate that besides an overall tendency to adapt secondary task interaction to driving, there is also a great variability in reported behavior across drivers.

1.2. The concept of situation awareness in the driving context

To be able to adapt interaction with a secondary task to the demands of driving, drivers have to be situationally aware of the driving situation. The concept of situation awareness was originally developed in aviation to describe a very important precondition to act safely in a complex and dynamic environment. According to the most often cited model by Endsley (1995) an operator has to perceive the relevant elements of the environment, comprehend the situation and project the future development. Also in the driving context these processes seem to be essential to reach a full understanding of the driving situation and to be able to anticipate the situational development. This implies that a cognitive representation of the current and the future situation is generated on the basis of knowledge in long term memory which guides attention to the relevant cues in the environment. Especially the point of dynamics seems to be important within the driving context. As the situation changes permanently, the mental representation has to be continuously updated. Adams et al. (1995) refer to the perceptual cycle proposed by Neisser (1976). They understand situation awareness as a repeated cyclic interaction between perceived environment, memory schema and active exploration. In a given situation, the driver knows from previous experiences how a driving situation should evolve (e.g. distance to lead vehicle should remain stable); he repeatedly and actively attends to relevant aspects in the environment (e.g. lead vehicle) and compares the perceived environment with the expected situational development. The results of that comparison guides future attention but also other aspects of behaviour.

In our model that is described later, this updating process is reflected by the so called control level where drivers distribute their attention between the driving task and a secondary task in order to permanently check the environment for potential changes during performance of the secondary task.

Smith and Hancock (1995) use a more operational definition of situation awareness that can be directly seen in an operator's behaviour: they define it as "adaptive, externally directed consciousness" (p. 138). Certain factors or dimensions in the environment restrict the operator's behavioural opportunities. An operator who correctly interprets these factors is able to behave correctly in a certain environment and can therefore be defined as situationally aware. This definition seems very suitable to directly measure a driver's situation awareness by observing his/her behaviour in the interaction with a secondary task.

2. Situation awareness in driving with secondary tasks: proposal of a three-level model

To our understanding, situation awareness is a precondition if drivers want to adapt their interaction with distracting activities to the demands of driving. Three levels are assumed on which the driver can adapt the interaction with a distracting task to driving (see also Rauch, 2009). These three levels are in dependence on hierarchical driving models, e.g. by Michon (1985) (for similar approaches see Bernotat, 1970; Rasmussen, 1983). He distinguishes three levels of driving: operational, tactical and strategical level. On the strategical level for instance the navigation task is placed. This level describes more global strategies like the choice of a certain route. The next level is called the tactical level and comprises driving maneuvers. On the tactical level, the driver has to decide when and where to perform driving maneuvers like overtaking. On the stabilization level, the vehicle is kept stable regarding longitudinal and lateral control. Here, the handling of vehicle (e.g. small corrections of lane position) takes place.

Our model also assumes three hierarchical levels with the main difference that it does not describe the driving task but the interaction with a secondary task during driving.

2.1. Planning level

On the highest level, the planning level, drivers choose purposefully situations which they believe to be most appropriate for interacting with a secondary task. If asked, drivers report that they deliberately choose appropriate – that is undemanding and stable – driving situations to attend to distracting activities. On the planning level, more global strategies can be found that are used by drivers to prevent that distracting activities might degrade driving. For instance, they perform only such tasks they perceive as less risky or they perform secondary tasks only when the car is stopped. Such global strategies can in general be communicated by drivers and they reflect a more global tendency if and when to attend to distraction. The planning level does not describe the decision to be distracted in a specific situation but more global strategies of how to deal with distracting secondary tasks in driving. It is expected that drivers' opinion regarding distraction while driving influences the behaviour at other levels of secondary task interaction. An example for such a strategy is reducing speed or only executing a task in standstill. In most cases, strategies reported on the planning level describe subjective criteria used for deciding about secondary tasks on the decision level.

2.2. Decision level

On the next level, drivers decide in a certain driving situation whether distraction is appropriate or not. Taking the affordances of the driving situation into account, drivers have to decide if they want to attend to a secondary task and for how long distraction is possible without leading to a risk in driving. On the decision level, characteristics of driving situations mentioned on the planning level are expected to play a role. But besides that there are possibly also other influencing aspects that the driver is either unaware of or that are difficult to put into words. In a specific driving situation, behaviour on the decision level can be inline or contradict strategies reported on the planning level.