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Analysis of compensative behavior in demanding driving situations

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ABSTRACT

Drivers usually perform a range of different activities while driving. Following a classical workload approach, additional activities are expected to increase the demand on the driver. Nevertheless, drivers can usually manage even demanding situations successfully. They seem to be able to compensate demands by behavior adaptations, mainly in the following factors: in the driving task itself, in an additional (secondary) task and in their mental workload. It is suggested that by analyzing these three factors in temporal coherence, compensative interactions between them become measurable. Additionally, a reduction of activity in the secondary task is expected to be influenced by the characteristics of this task. To analyze these effects, a driving simulator study with 33 participants was accomplished. It could be shown that if a secondary task can be interrupted without a perceived decline in performance, it is interrupted in demanding driving situations. If an interruption causes a perceived performance loss, efforts are increased, and so the workload is heightened (measured with a high resolution physiological measurement based on pupillometry). Thus, drivers compensate their current demands by behavior adaptations in different factors, depending on the characteristics of a secondary task.

1. Introduction and background

A variety of functions is implemented in modern vehicles today. Their number is constantly rising. Modern audio systems as well as route guidance systems with various options and settings can be found in most newly produced vehicles. Nearly every additional activity which is performed while driving (primary task) can be defined as a "secondary task". For example, discussing with passengers, choosing music tracks from a track list, or setting the route guidance system can be seen as demanding secondary tasks. By observing typical behavior in road traffic, or even one's own behavior, it becomes clear that most people are performing quite a range of activities while driving (Dingus et al., 2006; Huemer & Vollrath, 2011; Sacher, 2009).

It has often been discussed that performing a secondary task increases mental workload of a driver (see de Waard, 1996 for an overview). If two tasks are handled simultaneously, interferences and conflicts concerning the prioritization of these

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tasks can occur. The operation of different tasks has to be adjusted according to their relevance, their interruptibility and their time pressure (Kushleyeva, Salvucci, & Lee, 2005; Salvucci, 2005). The main problem with an increased workload is that a driver's mental resources are limited; at least in general (Kahneman, 1973). Wickens (Wickens, 1984; Wickens & Hollands, 2000) has shown that the modality in which a stimulus is perceived plays an important role for the interference of two simultaneously performed tasks: The overall workload while performing two cross-modal tasks is usually lower than operating two tasks which are presented in the same modality (i.e. the workload while performing two visually presented tasks is expected to be higher than the workload in two tasks whereby one is presented in a visual modality and one verbal). Nevertheless, conscious operations seem to use identical working memory resources (Pashler & Johnston, 1998). Such conscious operations are expected to be especially needed in new or complex driving situations. In (driving) situations, which evoke a high workload, it may happen that not all relevant stimuli are perceived (e.g. the effect tunnel vision; Williams, 1985) or that their relevance and meaning for a situation are not properly processed and/or adequately transformed into actions (e.g. Krems & Baumann, 2009). In a naturalistic driving study it could be shown that in nearly 80% of crashes driver distraction played a relevant role (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). Nevertheless, these workload theories cannot exhaustively explain why the operation of a secondary task sometimes leads to accidents and sometimes it does not. If the high number of situations in which drivers are performing a secondary task is compared to the number of accidents (NHTSA Publication 811171, 2008), it becomes obvious that accidents occur only in a fraction of those situations. An important question is how drivers manage to perform a secondary task without causing accidents or even lowering their driving performance in the wide majority of cases.

1.1. Scope

The focus of this study is the ability of drivers to compensate demands by adapting their behavior or efforts. In this resource-oriented approach, drivers are seen as active coordinators of their demands and resources. The relevant factors of a driving situation are shown and discussed in detail below. Afterwards, different ways to compensate demands between these factors are highlighted. Then, a driving simulator study performed at the BMW research facility with 33 participants is described and discussed.

To analyze a complex driving and operating situation, three central factors which describe the situation from the drivers' perspective must be considered: (1) the driving task itself, (2) the secondary task and (3) mental workload of drivers. Each of the factors influences the drivers' perceived situation and can at the same time also be influenced by the driver. From the authors' point of view, analyzing the interactions of those different factors is crucial for attaining a more holistic understanding of driving and operating behavior. Complex behavior, as driving and performing a secondary task simultaneously, can only be understood completely if the three factors and their interactions are perceived as a dynamic system. Possible interactions of the three factors are shown in Fig. 1, without claiming to be exhaustive.

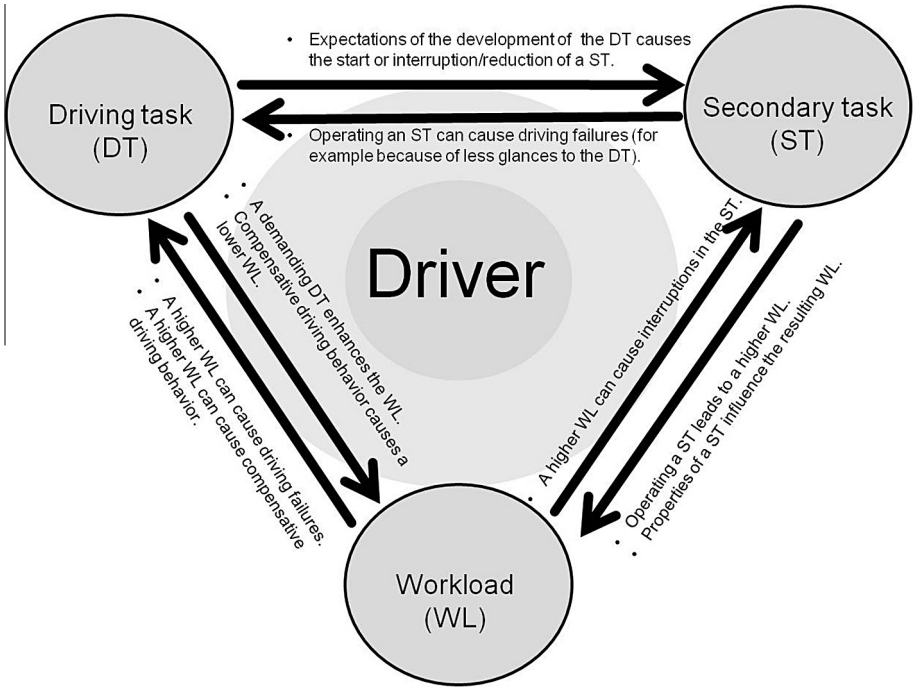

Fig. 1. Interactive effects between driving task, secondary task and mental workload (without claiming to be exhaustive).