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Look where you have to go! A field study comparing looking behaviour at urban intersections using a navigation system or a printed route instruction

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ABSTRACT

In this study, experienced navigation system users ($N = 20$) drove a given unfamiliar route twice: once with the navigation system activated and once with a printed instruction including a route instruction. Quantitative analysis indicated that drivers passed intersections slower when they used the printed instruction than when they used the navigation system. Drivers looked more often and in proportion longer to the side scene when they used the printed instruction and made less and proportionally shorter glances away from the road scene and to the instruction than when they were supported by the navigation system. No difference was found between these two conditions in the total number of glances and the amount and duration of glances to the forward scene. A qualitative analysis provided understanding of the quantitative results: the type of route guidance was identified to influence drivers' motive for scanning the side road scene. When the navigation system was used the motive was primarily to look for potential hazards and when the printed instruction was used the motive was more focused to look for salient orientation points. The outcomes of the study are discussed in terms of looking motive and the 'look but failed to see' phenomenon.

1. Introduction

The navigation system aims to support the driver in the driving task by providing dedicated and timed route instructions. The system guides the driver verbally and/or visually through the quickest or shortest route to the chosen destination. This support aims to reduce the effort the driver has to make in order to navigate the vehicle and allows the driver to spend additional resources on the performance of the driving task. Previous research shows that the use of a navigation device is more efficient for reaching a destination compared to when a map is used (e.g. Dingus, 1995; Lee & Cheng, 2008). The navigation system provides a more efficient and convenient way to reach the destination and also saves time and fuel.

The navigation system for passenger cars was introduced to the market over 30 years ago, therefore it is not surprising that quite a substantial amount of research has already been done on this topic. A thorough literature search shows that the existing research on the use of navigation systems has focussed on two main questions:

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(1) How should a navigation system be designed optimally? (e.g. Burnett, 2000; Lee, Forlizzi, & Hudson, 2008; Lin, Wu, & Chien, 2010; Parkes & Coleman, 1990; Srinivasan, 1999).
(2) How does operating the system (e.g. typing in new destinations) while driving affect driver behaviour? (e.g. Dingus, Atin, Hulse, & Wierwille, 1989; Lee, Caven, Haake, & Brown, 2001; McCall, Achler, & Trivedi, 2004).

1.1. Behavioural effects of navigation system use

When considering the research domain on operating the system (e.g. typing in new destinations) while driving and the effects on driver behaviour, Wickens' (1984, 2002) multiple resources theory must be taken into account. Wickens aimed to predict to which extent the two concurrently performed tasks (e.g. driving and navigating) interfere with each other. He categorised four dimensions that are important when considering time-sharing tasks: (1) stages; (2) modalities; (3) codes and; (4) visual channels, each of which are further divided into different levels (see Fig. 1).

The active operation of a navigation system while driving may cause higher levels of distraction (e.g. Maciej & Vollrath, 2009) since the driver must perform two tasks simultaneously: driving and the operation of the system. This manual-interaction with the system mainly requires the drivers' visual attention and consequently may distract the driver while driving (e.g. Dingus et al., 1989; Maciej & Vollrath, 2009). Chiang, Brooks, and Weir (2004) conducted a field study in order to investigate the distraction level of a drivers' visual attention in response to entering destinations while driving. They interpreted that the visual distraction caused by entering the destination while driving is 'acceptable'. In their driving simulator study, Maciej and Vollrath (2009) found distraction to be higher when entering a destination (speech based or manually) than in the baseline driving condition.

Some studies have investigated the effects of route guidance on driver behaviour while driving (e.g. Kun, Paek, Medinica, Oppelaar, & Palinko, 2009; Lee & Cheng, 2008). In a field experiment, Lee and Cheng (2008) found that the level of route guidance significantly affected the mean driving speed. In urban areas, on average drivers drove 2.717 km/h faster when they used a portable navigation device for navigation support compared to when a printed map was employed. In addition, the drivers who used the navigation system deviated less in driving lanes and had on average a lower yaw rate than the printed map users. In a driving simulator study, Kun et al. (2009) investigated drivers' visual attention and driving performance when using a map in comparison to using a navigation system. They found that drivers who used a map had poorer visual attention and displayed poorer driving performance compared to when using a navigation system. A recent study by Christoph, van Nes, and Wesseling (2012) considered the effects of voice instructions on eye glance behaviour on motorways. They found that drivers tend to look more often and longer at the navigation system just after an instruction has been given. Drivers seem to appreciate visual information to interpret the auditory instruction. In summary, when drivers use navigation systems, three factors play an important role: the drivers' visual attention, level of workload and resources. All three factors are related to Wickens' (1984, 2002) multiple resources theory and to traffic safety issues.

1.2. Errors in visual attention allocation: The looked but failed to see phenomenon

Visual attention is not only relevant when a navigation system is employed, rather it is also required for the successful performance of the driving task: the environment has to be observed, the road scene has to be scanned for potential hazards and any relevant information (traffic signs, infrastructural information, other road users) has to be gathered. One main factor causing fatal accidents, which is linked to attention and glance behaviour, is the "*looked but failed to see*" phenomenon. In 2005,

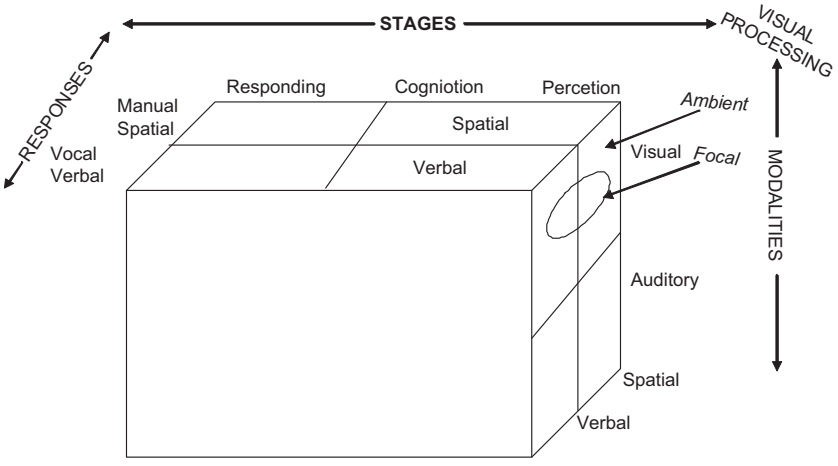

Fig. 1. Multiple resources theory model representing the three dimensions of human resources. The fourth visual processing dimension is embedded within visual resources (taken from Wickens, 2002).