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Driver distraction, crosstalk, and spatial reasoning

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ABSTRACT

The hypothesis is explored that the precise influence of a secondary, unrelated, spatial reasoning task on driving performance also depends on the specific spatial cues used in this task, compared to those currently emphasized by the primary driving task. In a laboratory experiment, participants were presented with questions about spoken (familiar) city names while driving. The questions either required them to reason spatially about the cities or to process the same city names only acoustically (i.e., remembering and repeating one of the names). Amount of driver distraction was measured by means of a standardized tool called the Lane-Change Task (LCT) using a PC-based driving simulator. Results of the experiment showed that the spatial reasoning secondary task was more distracting than the acoustic one. In addition, participants performed worse on the LCT when switching to a right lane than when switching to a left lane. It is concluded that the results confirm an interpretation in terms of (in)compatible spatial cues emphasized simultaneously by primary and secondary task, but that alternative interpretations are also possible. The moderating influences of two cognitive ability variables on, and potential practical applications of, these findings are also addressed.

1. Introduction and problem statement

An increasing number of automobile accidents is attributed to distracted driving. The percentage of accidents with such origin varies from 5 to over 25%, depending on the type of study (traditional crash studies or naturalistic driving studies) and the definition of distraction utilized by the study (Gordon, 2009; Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005). Naturalistic studies arrive at percentages as high as 23% for crashes due to the performance of non-driving related secondary activities a few moments before the crash. These activities include personal grooming, and reaching for some object in the car. Moreover, there is evidence this percentage would be even higher if inattention-based crashes were included in the crash statistics (i.e., paying insufficient attention to the forward roadway due to daydreaming or other internal, but invisible activities).

Obviously, when driving, not all sources of distraction can be avoided. However, knowledge about the human driver can help reduce the size of the distraction problem, for example by appropriately designing car-based equipment and procedures for its usage, but also by training and reinforcing drivers to behave prudently and responsibly with respect to the use of distracting equipment or activities.

Though driver distraction can usefully be attributed to some kind of interference between a secondary task (driving-related or not) and the primary driving task, there are multiple sources of such dual-task interference in the driving

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context. Moreover, many psychological mechanisms have been proposed for explaining the nature and size of the interference. In an attempt to clarify these issues, we start by distinguishing structural interference from cognitive interference. *Structural interference* is based in the physiology of the sense organs. It refers to the influence of physiological limits on the ability of people to perform two or more tasks simultaneously (Pashler & Johnston, 1998). *Cognitive interference*, on the other hand, refers to those types of interference that are observed when some or all subtasks of the time-shared tasks require information processing (Kujala, 2010). Cognitive interference, in turn, can be divided into task-independent interference and task-dependent interference. The latter type of interference usually refers to the interference caused by task similarity.

One particular type of similarity-based interference is also known as *crosstalk* (Navon & Miller, 1987): performing two tasks simultaneously becomes difficult if they contain stimuli which generate conflicting response tendencies (e.g., a right-pointing arrow appears in one task, and an unrelated left-pointing arrow appears in the other (Hommel, 1998; Lien & Proctor, 2002; Pashler, Johnston, & Ruthruff, 2001). This is similar to the Stroop task (Stroop, 1935) and the Simon effect (Simon, 1990) in single-task conditions.

Though the empirical evidence for crosstalk is rather robust, disagreement exists in the literature with regard to the generality of, and the theoretical explanation for, this phenomenon. Explanations are based in theories varying from *limited capacity models* (Pashler et al., 2001), to *multiple-resources theory* (Wickens, 2002), to the concept of *attention sharing* (Navon, 1984, 1985), and to the *theory of multimodal spatial attention*. According to the latter account, shifts of spatial attention in one sensory modality (e.g., vision) tend to be accompanied by corresponding covert shifts in other modalities (e.g., audition) (Driver & Spence, 1998; Spence & Driver, 2004). These attentional shifts may be triggered by external events (exogenous attention shifts) or by internal events (e.g., intentions or thoughts: endogenous attention shifts). Therefore, this theory may explain crosstalk to the extent that the stimulus attributes causing crosstalk are spatial in nature.

Regarding the empirical conditions necessary for crosstalk to be observed, there is evidence that time-shared tasks are less vulnerable to crosstalk with certain types of display design and task configuration (Carlson & Sohn, 2000; Elio, 1986). Under some circumstances, task similarity also results in *improved*, rather than reduced, dual-task performance. Specifically, time-sharing efficiency may improve if tasks share some common display property, processing routine, mental set, or timing mechanism (Duncan, 1979; Fracker & Wickens, 1989). These findings probably reflect the fact that task reconfiguration becomes simpler, going from task to task, when the tasks are structurally identical or similar.

This article describes a laboratory experiment in which one particular type of crosstalk was studied in the context of driver distraction. Specifically, the effect on driving performance was studied of having simultaneous activation in working memory of semantically related spatial codes, these codes either being invoked by a spatial reasoning auditory secondary task or a concurrently performed primary (driving) task. In addition to a spatial reasoning version, an acoustic version of an otherwise identical secondary task was employed. This acoustic version served as a baseline against which to assess the distracting effect of the spatial reasoning part of the first version, as the two versions only differed with respect to the amount of spatial reasoning they imposed on the participants. Driver distraction was measured by means of a standardized tool, called the Lane-Change Task (LCT).

The rationale for studying this particular spatial reasoning task as a secondary task was that, though cognitive interference of a spatial nature has already been studied before in a driving context (Patrick & Elias, 2009), the distracting effect of semantically related spatial memory codes on driving performance has not. Moreover, there was an interest to test the generality of the observation that not only physically related items, but also items belonging to the same semantic category may cause crosstalk (Hirst & Kalmar, 1987). Specifically, in this experiment the hypothesis was tested that cardinal spatial cues such as "east" and "west" belong to the same semantic category as (and, therefore, may interfere with) egocentric spatial cues, such as "left" and "right". The moderating influence of two cognitive ability variables (i.e., *useful field of view, or UFOV*, and *task-switching ability, or TSA*) was also investigated in this study.

From a practical point of view, spatial reasoning can be considered an ecologically valid secondary task, because it can be linked to the use of in-car GPS-devices, to navigational conversations, or to reading a map while driving. Therefore, the results of this experiment may also have practical applications.

2. Hypotheses

From the multiple-resources theory (Wickens, 2002) and from the functional distance theory (Kinsbourne & Hicks, 1978) it follows that spatial reasoning about familiar city names must be a more distracting secondary task to drivers than acoustically processing the same stimuli (i.e., remembering and repeating the first of two spoken city names). This hypothesis is also consistent with the outcomes of another study (Patrick & Elias, 2009) showing the distracting effect of performing an irrelevant mental navigation task while driving. Functional distance theory states that the longer the distance between the brain parts that are involved in unrelated information processing tasks, the smaller the amount of interference to be observed among the tasks. This theory is also supported by recent neurological evidence (Newman, Keller, & Just, 2007). Therefore:

Hypothesis 1. The spatial reasoning version of the secondary task interferes more with the driving task than the acoustic version of the same task.