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Navigational conversation impairs concurrent distance judgments

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ABSTRACT

Dual-task performance as it relates to driving, such as tuning a radio or manipulating a cellular phone, forces drivers to divide their attention between the traffic demands and the in-car task. The present study investigated how concurrent spatial or non-spatial cognitive distractions mediated proximity judgments using vehicular stimuli. Utilizing a modified version of the task employed by [Elias, L.J., Robinson, B. in press. Drive on the right side of the road: perceptual asymmetries for judgments of automobile proximity. International Journal of Neuroscience.] the current study examined how mental navigation (spatial distraction) affected accuracy and response time for depth judgments on vehicular stimuli in each visual field. These were compared to a control condition in which no distraction was present, as well as when a semantic (non-spatial) distraction was present. We found that conversation of a navigational nature (i.e., spatial distraction) most negatively impacted accuracy and response time when processing dynamically changing vehicle proximity. Further, these deleterious effects appeared to be uniform throughout the visual field. Findings are related to driving while being distracted, with particular emphasis on the role of cerebral lateralization in dual-task performance.

1. Introduction

Performing two tasks simultaneously is disproportionately more difficult than performing the same two tasks individually (Hiscock, 1986). Humans, none the less, do have the capacity for dual-task performance with some degree of success depending on the specific parameters and demands of each task. Several theories have been put forth to explain the attentional mechanism mediating dual-task interference. Welford (1952) reasoned that attention is indivisible, though it may be switched rapidly. This suggests that attention to one activity will always impair performance of a concurrent attention-demanding activity, regardless of the modality and nature of the two tasks. An alternate concept proposes that multiple cognitive resource pools may be used simultaneously when performing concurrent tasks (Allport et al., 1972). This implies that under certain conditions, two activities can be performed in parallel as well as they would be separately.

Kinsbourne and Cook (1971) were the first to relate dual-task performance to cerebral lateralization. They observed that speaking affected concurrent right- and left-hand performance differentially. Left-hand performance for balancing a small wooden dowel was enhanced whereas right-hand performance was not. This effect was attributed to interference between the two tasks in the left hemisphere. Because speaking and motor-control of the right hand are left hemisphere functions, greater interference occurs when both activities are done at the same time. This reflects the central assumption underlying the interpretation of asymmetric interference: when two activities are performed concurrently, considerable interference should occur when both tasks require resources from the same hemisphere, but there should be much less interference when different hemispheres are involved (Pashler and O'Brien, 1993).

Kinsbourne and Hicks (1978) extended this argument by claiming dual-task interference was a function of cerebral space. They proposed that the two cerebral hemispheres act as separate cognitive resource reservoirs by virtue of their functional and spatial separation. That is, there is an inverse relationship between the degree to which competing tasks affect each other and the functional distance that separates the active cerebral regions (Hiscock, 1986). According to this principle, the degree of interference between tasks increases as tasks begin to parallel to one another, in turn, lessening functional distance. Recent neuroimaging research has offered support for this idea by demonstrating there is "interdependence among cortical regions in how much activation they can sustain at a given time, probably because of the resource demands that they conjointly make during the performance of a cognitive task" (Newman et al., 2007, p. 114).

Dual-task performance as it relates to driving, such as tuning a radio or manipulating a cellular phone, forces drivers to divide their attention between the traffic demands and the in-car task. Prior

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literature has drawn attention to the fact that cognitive, not motor, distraction leads to greater dual-task interference and decreased driver performance (e.g., McKnight and McKnight, 1993; Lamble et al., 1999; Shinar et al., 2005). McKnight and McKnight (1993) demonstrated this by investigating the effects of casual and intense conversation, as well as manual phone manipulation, on driver's responses to simulated highway traffic situations. Performance deficits were most significant when participants were engaged in emotionally intense conversation than for any other type of distraction. Furthermore, according to the National Highway Traffic Safety Administration (1997) the majority of cellular phone related crashes in the United States occur during conversation.

Lamble et al. (1999) further supported this by conducting a study in which drivers had to maintain constant headway to a leading vehicle while engaging in a simulated cellular phone conversation. Driver's brake reaction times to the lead vehicle decelerating were delayed by approximately 0.5 s when compared to drivers not distracted by any sort of cognitive interference. What is particularly disconcerting is that this effect was seen when drivers had their feet positioned immediately over the brake; this does not reflect the additional time required to move the right foot from the accelerator to the brake pedal when reacting. These results suggest that proximity assessment was in some way hindered by the cognitive interference introduced by the concurrent tasks.

There is a problem, however, in simply claiming cognitive distractions are a significant detriment to driver performance. One must specify the nature of the distraction in order to effectively determine the associated effects. Simultaneous performance of two tasks may result in deficient performance of either or both, depending on the nature of each task and their allocated priorities (Haigney and Westerman, 2001). For example, a spatial-based cognitive task, such as mental navigation, may lead to increased interference on spatially oriented driving activities, such as making distance judgments. Given that these tasks draw on similar cognitive resources, it logically follows that they may activate similar regions of the cortex. Indeed, prior neuroimaging studies have found that a variety of spatial cognitions (including mental navigation and depth judgment tasks) elicit right hemisphere activation (e.g., Grön et al., 2000; Nishida et al., 2001; Zacks et al., 2003, 2002). On the basis of the functional distance theory, because depth processing and mental navigation are both spatial cognitions that activate similar areas of the cortex, significant interference should occur when they are performed concomitantly. In contrast, non-spatial tasks that do not draw on resources from the right hemisphere should result in relatively modest interference due to increased functional distance of the active cerebral regions.

In addition to investigating the effects of specific cognitive interferences on proximity judgments, the current study examines how accuracy and response time for these judgments may be mediated by side of presentation. That is, do accuracy and response time for proximity judgments vary when images are presented to the left or right side of space? Prior research has found a left-side advantage for accuracy when making depth judgments using both monocular and binocular cues (Grabowska, 1983; Kogure and Hatta, 1999). For example, Kogure and Hatta (1999) observed that depth judgments based on occlusion (using two-dimensional images of layered rectangles) resulted in reduced error rates for images presented to the left side of space when compared to the right. Furthermore, Grabowska (1983) observed a higher amount of correct depth detections for images in the left side of space when laterally presenting random dot stereograms. Given that depth processing draws on resources from the right hemisphere, it is not surprising that accuracy when making distance judgments is enhanced for images presented to the left. It is interesting to note, however, that no such effect has been observed with respect to response time, suggesting that temporal processing is not mediated by side of presentation when performing distance judgments (Kogure and Hatta, 1999).

Although the topic of driving while being cognitively distracted has been examined extensively, a number of methodological flaws have been recognized. One of the major flaws identified by Shinar et al. (2005) is that commonly used interference tasks tend to have weak ecological validity. The issue of using distracters that are not ecologically valid illustrates the problem of generalizability to real-world situations. For example, some researchers have used the math operations task as the primary cognitive distraction while conducting dual-task driving research (see McKnight and McKnight, 1993). The value, however, of this task as an ecologically valid distraction is disputed (Shinar et al., 2005). Distractions with enhanced external validity should be utilized when investigating the effects of cognitive interference on certain aspects of driver performance. It is proposed that a mental navigation task may be a valid cognitive distraction in the context of driving as it can be linked to the use of in-car GPS devices, conversation of a navigational nature, or something as simple as reading a map. Hence, the current study utilizes mental navigation as one of the distracter tasks.

Using a modified version of the task (i.e., lateralized distance judgments) employed by Elias and Robinson (in press), the current study examines how two different forms of cognitive interference (spatial and non-spatial distraction) affects two separate dependent variables: response time and accuracy for assessing proximity using vehicular stimuli in each hemispace. The within-subjects independent variables are distraction condition (baseline, mental navigation – spatial, and noun/verb discrimination – non-spatial) and side of presentation (left, right). Results are discussed in relation to driving while being cognitively distracted in an effort to determine specific aspects of cognitive interference that may affect depth processing whilst driving.

It is predicted that accuracy will vary across the three distraction conditions. Overall, the baseline condition will produce the most correct responses and the mental navigation condition will produce the fewest. This, as stated above, relates to how cognitive resources are accessed and the regions of the cortex that will be most active. A left-side advantage is also expected for accuracy in the baseline condition. As the processing of spatial tasks is localized to the right hemisphere, accuracy for distance judgments in the left hemispace should be enhanced when compared to the right (see Grabowska, 1983; Kogure and Hatta, 1999). It is further hypothesized that the time required to make vehicle proximity judgments will also vary across the three distraction conditions. Given that similar areas of the cortex will presumably be used, greater interference will occur during mental navigation, leading to greater processing times.

2. Methods

2.1. Participants

Data was collected from 36 participants (17 male, 19 female, mean age = 20.9, S.D. = 3.1, 34 right-handed). They were either acquaintances of the researcher (5 of 36), or students from an undergraduate psychology participant pool. Those participants who signed up from the undergraduate pool received bonus credit towards their final mark in an introductory psychology course. Acquaintances were unaware of the incentives offered to participating undergraduate students, and all participants were blind to the purpose and rationale of the study prior to data collection. Two strict eligibility requirements were in place for all participants: (a) they must have resided in Saskatoon for a minimum