



## Driving with navigational instructions: Investigating user behaviour and performance

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### ABSTRACT

This paper reports the results of an inter-disciplinary study investigating user preferences and performance in relation to spoken in-car route guidance. In-car navigation systems are becoming increasingly popular. However, despite large amounts of research assessing the presentation of spatial information, and the usability and interaction issues surrounding the interfaces, there has been much less investigation of the impacts of auditory presentation of route information. We addressed this issue using a multi-disciplinary approach to collect both qualitative and quantitative data through questionnaires and user experiments. Our research identified a user preference for auditory presentation of route information, as well as a memory advantage for auditory over visual presentation. We also found that simple auditory route instructions could be followed without significant interference to a simulated driving task, whereas more complex auditory instructions did cause interference. Taken together, this research highlights the importance of the design of spoken route guidance instructions in minimising the cognitive demands that they impose.

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### 1. Overview

Over the last decade, researchers have become increasingly interested in the levels of driver distraction caused by a range of in-car devices (see Young and Regan, 2007, for a review). Much of this research has focused on the effects of in-car mobile phone use. However, a recent rise in the popularity of in-car navigation systems has also sparked research into the distraction that these devices might cause. Whereas many studies have compared different visual presentations of route information, substantially less research has examined the presentation of auditory navigation instructions. More specifically, although a number of studies have investigated the optimal timing for presentation of auditory route information (e.g. Green and George, 1995; Ross et al., 1997; Wu et al., 2009) as well as the most effective types of informational content for these instructions (e.g. Burnett, 2000), there is much less research on the cognitive demands imposed by the act of processing auditory instructions of any kind, and on the impact that these cognitive demands might have on the task of driving.

Here, we present a multi-disciplinary study examining people's preference and performance during the use of auditory route

information while driving new and unfamiliar routes. We address this issue using several different research methods (including questionnaires, a laboratory study of abstract memory and a simulator experiment) with the aim of providing a wider perspective on the question than is possible using a single research method alone. Our preliminary questionnaire investigates people's reported use of the auditory instructions available from their in-car navigation devices. Experiment 1 then asks whether spoken route information is remembered more effectively than the same information presented in other forms. Finally, in Experiment 2 we examine whether increasing the levels of complexity in the spoken instructions can lead to reductions in performance in a simulated driving task. Our study is novel in bringing together these relatively disparate approaches to address a single research question, so each of the approaches that we use draws on a different background literature. For this reason, we describe the research background separately for each section of the study, before integrating the findings in the final conclusion section.

### 2. Questionnaire

We began our research with a preliminary questionnaire designed to extract information about people's everyday use of in-car navigation systems and their preferences. Navigation systems are designed to be flexible, such that users can engage with them in different ways, according to their own preferences (e.g. Svahn,

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2004). It is, therefore, important to undertake an initial assessment to establish whether users have specific preferences in terms of how the route information is presented. We investigated this issue using a questionnaire consisting of nine items in total. Here, we focus on the two items that related most closely to the use of auditory instructions. Sixteen participants (nine male, aged 18–50, all regular users of in-car navigation devices by self-report) gave free-form responses which we then categorised and coded.

*Item 1: Do you ever turn off the spoken directions on your in-car navigation device? If so, why?*

In response to this item, only 25% of participants reported ever using the visual display for full navigation, in the absence of auditory instructions. This number corresponds closely with a recent online survey on a much larger scale, which found that only 21% of respondents reported using either the only visual display or mainly the visual display, with the remaining participants making substantial use of the auditory instructions (Forbes, 2006). The correspondence between the results of the two studies is striking, given that participants in our questionnaire gave detailed free-form written responses whereas the online survey required check-box responses from a restricted set of options. Together, these converging findings indicate that the vast majority of users of in-car navigation devices choose to receive auditory instructions from their devices while driving.

However, many respondents report making use of both the auditory and the visual information simultaneously. For example, 71% of respondents to the online survey mentioned above indicated that they preferred to receive route guidance information in both spoken and visual forms (Forbes, 2006). It is, therefore, also important to investigate the relative priority that users assign to the different presentation modalities and this was the aim of the next item.

*Item 2: Under what circumstances do you look at the visual display of your in-car navigation device? What information do you typically seek from the visual display?*

In response to this item, 75% of participants reported that they only used the visual display for clarification, elaboration or reminders of the auditory instructions. This finding confirms the central importance of the auditory instructions to the majority of users.

Overall, our preliminary questionnaire investigation indicates that the majority of users of in-car navigation devices elect to receive ongoing spoken route guidance information and that they give this information a relatively high priority. This reinforces the importance of research into the ways in which auditory instructions might be processed and the demands that such processing might impose. In line with this aim, our first experiment examined the possibility that auditory route guidance information might be remembered more effectively than information presented through other modalities.

### 3. Experiment 1: route memory

A range of laboratory studies have demonstrated an advantage for spoken rather than written presentation, in tasks of short term-memory (e.g. see Penney, 1975 for a review), long-term memory (e.g. Carroll and Korukina, 1999; Conway and Gathercole, 1987) and comprehension and reasoning (e.g. Jakimik and Glenberg, 1990; Markman et al., 2007). These results have often been interpreted as indicating that auditory presentation might afford better representations of the temporal order of information (e.g. Glenberg and Swanson, 1986), and might also encourage a greater focus on

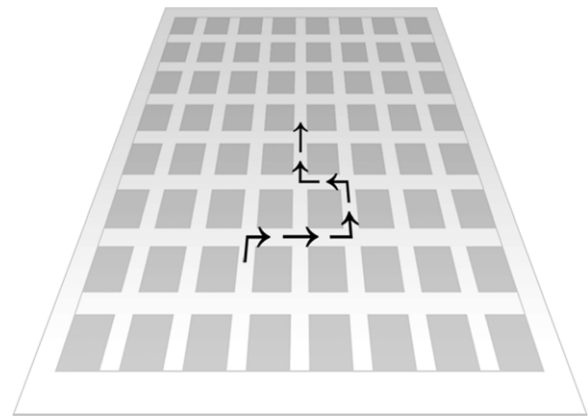


Fig. 1. Example of map route used in Experiment 1.

relational information (e.g. Markman et al., 2007). Given that the successful use of navigational instructions requires both memory for temporal order and some degree of relational processing, these studies might suggest that auditory presentation would be better than written presentation for delivery of navigational instructions.

However, the fact that driving involves continual visual demands in itself suggests that written presentation might present more problems than auditory presentation, regardless of the direction of any memory advantages. Instead, when navigational information must be presented visually, it is more conventional to use map-based, rather than written, presentation. However, none of these earlier studies considered navigational information per se and this research has therefore not typically investigated memory performance for directions presented in the form of a map. Here we compare memory for navigational information presented in map, written and spoken formats, with the aim of identifying which presentational format leads to the best memory performance.

#### 3.1. Methods

##### 3.1.1. Participants

Twenty participants aged between 18 and 34 (mean age 23) gave informed consent before taking part in the experiment. All were regular users of in-car navigation devices by self-report. Participants were paid a single fee for participating in this and another, unrelated experiment. To avoid introducing any systematic bias, the order in which they took part in the two experiments was alternated so for half the participants this was the first experiment, while for the others it was the second.

##### 3.1.2. Stimuli and apparatus

The experiment ran on a laptop PC and was programmed using PST's E-Prime 2.0. Stimuli consisted of 10 test routes and two example routes. Each route consisted of six steps: two left turns, two right turns, and two straights. The routes were generated by randomising the order of these six steps, though the same 12 routes were then used with all participants. We used routes involving six steps because this constituted enough information to present a reasonably challenging memory task while not exceeding the amount of information that can typically be stored in working memory.

Each route was presented once in each of three forms: Map, Spoken, and Written. Fig. 1 illustrates an example of a map stimulus. The spoken routes used three recordings of a woman's voice saying "left", "right", and "straight", stored as three separate audio files, each exactly 1 s in length, which were played in sequence and repeated as necessary for each route. Written instructions were also generated by E-Prime, and presented in two rows of three words in order to avoid simple shape or contour of the written text being

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