Comprehension of Vibrotactile Route Guidance Cues

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Abstract. Two experiments with 24 participants each evaluated comprehension of vibrotactile route guidance instructions via a tactile seat in a driving simulator. Vibrotactile patterns were presented from an array of 8 tactors arranged in two rows of 4 tactors located in the seat pan. A faster pulse rate and a slower pulse rate as well as four distinct locations on the tactile seat (Front-Left, Front-Right, Back-Left, Back-Right) created 8 different combinations of stimuli. Across all participants, the most consistent interpretation was that the faster pulse rate played from the back two tactors was perceived as an instruction to make the next most immediate turn while a slow pulse rate from the front two tactors was interpreted as a cue directing the user to the direction of the next eventual turn. Results have direct implications for design of effective vibrotactile and multimodal route guidance systems.

1 Introduction

Vibrotactile technology for in-vehicle use has shown increasing promise and popularity of late (Scott & Gray, 2008; Mohebbi, Gray, Tan, 2009). General Motors currently offers a feature on their Cadillac XTS sedan where the seat pan vibrates if there is a potential rear-end collision while you are reversing. This is just one example among several other current production vehicles that come equipped with vibrotactile technology. The tactile modality offers a way to relay information that is privileged to only the user. Tactile collision warning systems have been shown to effectively reduce reaction time (Scott and Gray, 2008), and may be particularly effective in multimodal systems (Mohebbi, Gray, & Tan, 2009).

The tactile modality is a way to provide the user information without relying on visual or auditory attentional resources that are often in high demand in many operational settings. Recent studies investigating vibrotactile route guidance systems have shown great potential. Van Erp and Van Veen (2004) demonstrated how a tactile navigation system display can reduce a driver’s perceived workload compared to a visual display, particularly in high workload settings. Van Erp, Van Veen, Jansen, and Dobbins (2006) investigated the efficacy and feasibility of a tactile navigation waist belt and found that directional information is easy, intuitive, and requires almost no training, although their results on how to map distance were inconclusive. Vibrotactile systems for in-vehicle technology have generally been limited to collision warning
systems or lane departure warning systems and relatively few studies have investigated the use of vibrotactile systems for in-vehicle route guidance.

Garcia, Finomore, Burnett, Baldwin & Brill (2012) conducted a study to investigate waypoint navigation via a visual, auditory, tactile, or multimodal route guidance system in dismounted soldiers. Participants were lead via the various uni- or multimodal route guidance system from waypoint to waypoint and were instructed to look for certain landmarks throughout the environment. For the tactile modality, a vibrotactile belt was used, which consisted of 8 tactors equally spaced around the waist (For more information on this belt see: Merlo, Duley, & Hancock, 2010; Cholewiak, Brill, & Schwab, 2004). Overall, the unimodal geocentric visual condition was the slowest and least accurate at guiding the user from waypoint to waypoint to complete a course through a virtual environment. Additionally, every multimodal condition was as fast as its fastest unimodal condition, i.e. there was no additive effect. This experiment provides evidence for tactile navigation and its effectiveness compared to other modalities to guide dismounted soldiers. The current experiment is intended to build on this knowledge and investigate how to best design a tactile navigation for in-vehicle use.

The goal of this investigation was to determine the most intuitive mapping of different vibrotactile patterns for use as route guidance instructions. It was predicted that a redundant mapping consisting of presenting a slower pulse rate from the front two tactors to represent a preliminary cue and a faster pulse rate played from the back two tactors to represent an immediate cue, indicating to turn at the next available location would lead to the most consistent interpretation relative to formats providing information using only tacter location or pulse rate.

2 Experiment 1

Procedure. After providing written informed consent, participants sat in a high fidelity driving simulator equipped with a tactile seat pan. A schematic of how the tactors are arranged on the seat pan is available on the right side of Table 1. The driving simulator was created by RealTime Technologies, Inc. The vibrotactile seat was custom designed and constructed by Engineering Acoustics, Inc and contained an array of 8 C2 tactors. Although no motion was used for this study, the simulator is capable of yaw and pitch motion. The yaw motion allows for 180 degrees of motion, 90 left and 90 right and the pitch motion allows for 1.5 degrees of pitch motion to simulate abrupt acceleration and braking. The simulator features 3 screens that allows for 180 degree forward field of view. The cab was built from a 2002 Ford Taurus and is operated similar to a real car with an automatic transmission. Before the experiment began, a variety of vibrotactile patterns were presented to the participant to familiarize them with the seat. Participants were then shown an image of an overhead view of a street with a stationary car and six possible turn options. Each turn was labeled with a corresponding response choice (letters A-F). This can be seen in Figure 1. Eight combinations of stimuli (front or back, left or right, slow or fast pulse rate) were presented twice each in randomized order. For the two