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Detection and localization of approaching vehicles in the presence of competing vehicle noise

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ABSTRACT

Recent research indicated that auditory detection and localization of approaching vehicles play roles in pedestrian safety. The present study examined detection and localization of recorded sounds of approaching target vehicles in the presence of competing noise from a second vehicle. Forty-one adults completed an auditory vehicle detection task comprising competing and non-competing vehicle noise conditions. Auditory vehicle detection performance was significantly better in the non-competing condition than the competing condition. Specifically, participants performance in the non-competing condition included larger detection distances, and more accurate localizations. We conclude that auditory perception of vehicles suffers significantly when competing noise from a second vehicle is present, and we discuss implications for pedestrian safety.

Introduction

Each year between 55,000 and 100,000 adult pedestrians are injured in the United States and approximately 4000 more are killed (National center for injury prevention, 2012; National highway traffic safety administration, 2010). Several risk factors have been identified, facets of the environment (e.g., Roberts, Norton, Jackson, Dunn, & Hassall, 1995) and also various factors within the individual pedestrian (e.g., Barton & Morrongiello, 2011; Barton, Ulrich, & Lew, 2012; Schwebel, Stavrinos, & Kongable, 2009). Though some predictors of pedestrian injury risk have been identified, further examination of pedestrian injury is critical. One aspect of pedestrian behavior that has yet to receive adequate attention is the role of auditory perception at roadside. Our goal was to examine detection and localization of approaching vehicles within the context of competing noise produced by other vehicles.

Pedestrians use both visual and auditory perception when making decisions. Although visual perception has received much attention in the realm of pedestrian safety, the role of auditory perception also is important to consider. The use of the two senses is somewhat dependent on variations between pedestrian setting. For example, the locations of street accidents involving children suggests that many accidents occur where visibility is obstructed such as bends, crossroads, the crests of hills (Ampofo-Boateng & Thompson, 1989). Streets with large volumes of parked vehicles (Roberts et al., 1995) and higher traffic volume (LaScala, Gerber, & Gruenewald, 2000) also are problematic. Research also points to the importance of variation in roadway design for adults, noting that decision making is difficult when auditory information must be relied on Emerson and Sauerburger (2008) and Guth, Ashmead, Long, Wall, and Ponchillia (2005). Pedestrians face great difficulty when they must use auditory perception to make judgments about where and when to cross a street when visibility of

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approaching vehicles is obstructed or environmental demands are high. In short, environmental demands are widely varied and create a demand for the use of auditory skills in pedestrians.

A small, but growing body of research has begun to examine the relevant auditory perceptual skills required for detecting approaching vehicles in the traffic environment. One recent study examined pedestrians' detection and localization of approaching vehicles and noted significant influences of vehicle speed (Barton et al., 2012). Slower moving vehicles were detectable at smaller distances from the listener, while detection of vehicles occurred at significantly greater distances as speed increased. Changes in the sound signatures emitted by the engine, tires, and wind resistance, in addition to variations in sound intensity were likely responsible for variation of detection distance by speed. One factor not examined, however, was detection of vehicles in the presence of other traffic sounds; most notably the noise produced by a second vehicle approaching the listener on the same road. Such interference should complicate auditory perception when making crossing decisions, especially when approaching traffic is occluded by visual obstacles (Emerson and Sauerburger, 2008).

Auditory perception used for detecting approaching vehicles requires psychophysical calculations to derive point of origin in the traffic environment. In this regard, auditory perception is analogous to perceptual skills required for visual detection of approaching vehicles. The interaural level difference (ILD) and interaural time difference (ITD) play significant roles in determining the direction of the sound source (Hartmann, 1983). The pedestrian setting contains sounds at both high and low frequencies, necessitating the utilization of both ILD and ITD when detecting and localizing approaching vehicles. In addition to ILD and ITD, pedestrians also use the Doppler Effect to localize the sound of moving vehicles (Rosenblum, Carello, & Pastore, 1987).

Situations which require the pedestrian to detect and localize multiple stimuli in the environment point to the relevance of our study. Detecting multiple stimuli requires auditory grouping mechanisms that create a sound object based on harmonicity and common onset time (Darwin & Hukin, 1999), a process which occurs separately and prior to localization. Once two distinct sound objects (e.g., vehicle sounds) are detected, the localization of those two sounds are then based on their ILD's and ITD's much the same as a single vehicle. However, with the exception that the ILD of one vehicle sound could mask the ILD of the other vehicle sound and reduce the accuracy of localization judgments.

Although relatively few studies have examined the use of auditory information by pedestrians, existing research suggests ambient noise plays an important role in pedestrian safety when auditory cues must be used to detect approaching vehicles. Emerson and Sauerburger (2008), for example, found ambient background noise competed significantly with noise from approaching vehicles and led many pedestrian participants to hear the vehicle with an insufficient margin of safety. In addition, slower vehicles provided larger margins of safety simply because the slower speeds allowed the pedestrian more time to cross the street. Also noted by Emerson and Sauerburger (2008) was the potential for a passing vehicle to obscure or perceptually interfere with detection of another vehicle following close behind (i.e., forward masking). However, ambient noise in the pedestrian environment is important not only for detecting a vehicle, but also for determining a vehicle's path of travel. Pedestrians' ability to determine the travel path of a vehicle is greatly diminished in the presence of background traffic noise (Ashmead et al., 2012), preventing accurate determination of the direction of travel and alterations in travel path. Thus, ambient background noise has the potential for greatly hindering not only detection, but determination of direction of motion.

The background noise present in any pedestrian setting comprises many factors. The noises from passing vehicles, sounds reflected from nearby architecture, perhaps even conversations occurring at roadside and wind disturbances may be among the stimuli encountered by a pedestrian. For example, recent research has specifically identified effects of road surface variations and individual difference characteristics (i.e., age) within the pedestrian (Mendonca, Freitas, Ferreira, Raimundo, & Santos, 2013). The mixture of such stimuli forms a context in which we must understand vehicle detection and use of auditory stimuli by the pedestrian. The primary focus of our study, however, was to examine one element found among the various stimuli in pedestrian settings: the role of competing noise produced by a second vehicle.

Aims and hypotheses

Our study adds to knowledge of pedestrians' use of auditory cues by examining detection and localization of approaching vehicles within the context of noise produced by another, "competing" vehicle. Barton et al. (2012) used sound stimuli from several vehicles, each presented alone, to examine use of auditory cues. We incorporated a second non-target competing vehicle traveling at the same speed as the target vehicle. We hypothesized that detection and localization of target vehicles would be significantly impaired by the presence of a competing vehicle sound. Specifically, the target vehicle would be more difficult to detect and would draw significantly nearer to the participant's position when the sound of a competing vehicle was present. We also hypothesized that participants would have greater difficulty determining when the target vehicle had arrived at their location when in the presence of sound from a competing vehicle. Variation in perceptual judgment degradation was expected across levels of speed due to louder sound signatures, and thus more competing noise, produced by faster-moving vehicles.

Method

Sample

The sample comprised 41 primarily young adults (M = 22.15 years, SD = 7.33; 34% male) recruited from the undergraduate population at a university in the Pacific Northwest. Participant ages ranged from 18 years to 55 years, with 85% of the