Accident Analysis and Prevention 53 (2013) 1–8

Contents lists available at SciVerse ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

# Developmental differences in auditory detection and localization of approaching vehicles

Benjamin K. Barton*, Roger Lew, Casey Kovesdi, Nicholas D. Cottrell, Thomas Ulrich

*University of Idaho, Department of Psychology and Communication Studies, United States*

ARTICLE INFO

*Article history:*
Received 22 August 2012
Received in revised form
11 December 2012
Accepted 19 December 2012

*Keywords:*
Pedestrian safety
Developmental
Auditory

ABSTRACT

Pedestrian safety is a significant problem in the United States, with thousands being injured each year. Multiple risk factors exist, but one poorly understood factor is pedestrians' ability to attend to vehicles using auditory cues. Auditory information in the pedestrian setting is increasing in importance with the growing number of quieter hybrid and all-electric vehicles on America's roadways that do not emit sound cues pedestrians expect from an approaching vehicle. Our study explored developmental differences in pedestrians' detection and localization of approaching vehicles. Fifty children ages 6–9 years, and 35 adults participated. Participants' performance varied significantly by age, and with increasing speed and direction of the vehicle's approach. Results underscore the importance of understanding children's and adults' use of auditory cues for pedestrian safety and highlight the need for further research.



## 1. Introduction

More than 13,000 children ages 5–9 are injured, and more than 100 are killed, as pedestrians each year in the United States, making pedestrian safety a significant concern during middle childhood (National Center for Injury Prevention and Control, 2012). Risk factors for pedestrian injury include environmental factors and characteristics of children themselves. For example, traffic speed and exposure to higher vehicle counts are important environmental factors (Laflamme and Diderichsen, 2000). Recent work has made progress in understanding the roles of child factors in pedestrian injury risk, suggesting younger children ages 5–7 are at greater risk partly due to developmental influences (Barton, 2006; Barton and Morrongiello, 2011).

Younger children's emerging ability to attend to the plethora of stimuli in the pedestrian setting is one way developing cognition may play a role in injury risk. Pedestrians must attend to a constantly shifting array of crossing signals, changing lights, road markings, and approaching vehicles. During middle childhood, children are still developing the perceptual capacity to efficiently gather and interpret these pedestrian safety cues.

Safety-relevant stimuli in the pedestrian setting are largely visual, which highlights the importance of children developing visual attention skills for their safety. Barton (2006) discussed the importance of children's developing visual search skills for pedestrian safety during middle childhood. The general trend in developmental research parallels children's performance in pedestrian tasks. Children younger than ages 7–8 tend to be less able to engage in efficient visual search and ignore distracting information and also perform more poorly on pedestrian crossing tasks (Barton, 2006). As children approach the end of middle childhood (i.e., ages 10–11), their developmental capability and pedestrian task performance both begin to approach adult levels (Barton, 2006; Pitcairn and Edlmann, 2000; Whitebread and Neilson, 2000).

Visual cues are important, but developing an understanding of safety-relevant auditory information in the pedestrian setting also is imperative. Vehicles emit engine and tire noise which pedestrians can use to identify safe crossing opportunities. Indeed, pedestrians use changes in sound signals at roadside to assess risk, and also experience physiological reactions to vehicle noise (Bach et al., 2009). Exactly how pedestrians use auditory information to detect and localize approaching vehicles has only recently become the focus of empirical investigation, but is increasingly becoming an important aspect of pedestrian safety. A primary reason for expanding knowledge of our use of auditory information is the greater frequency of hybrid and electric vehicles that emit different and, under certain conditions, less noise than traditional vehicles (Hanna, 2009). The importance of using vehicle noise to locate threats in the pedestrian setting is increased when auditory information is the only indicator of risk available (Guth et al., 2005). Thus, while visual cues remain important, there is increasing evidence that the auditory cues present in a roadside pedestrian setting are important for safety. The advent of new types

* Corresponding author at: Department of Psychology, and Communication Studies, University of Idaho, 875 Perimeter Drive, MS 3043, Moscow, ID 83844-3043, United States. Tel.: +1 208 885 6515/7375; fax: +1 208 885 7710.
*E-mail address:* barton@uidaho.edu (B.K. Barton).
*URL:* http://www.webpages.uidaho.edu/ barton (B.K. Barton).

0001-4575/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.aap.2012.12.040

of quiet vehicles, the existing significant problem of child pedestrian safety, and also the needs of certain populations of pedestrians have pushed the need to understand how pedestrians detect and respond to auditory information to the forefront.

Not only must we increase our understanding of pedestrians' use of auditory information, we must also consider the added difficulty presented to children by their developing auditory perception skills. Visual and auditory perception develops rapidly during infancy, allowing children to explore their environments, develop spatial perception, and localize visual and auditory stimuli. However, children's perceptual skills are still being honed during middle childhood. Auditory perception, in particular, may not reach adult levels until approximately age 10 (Johnson et al., 2005; Werner and Gray, 1998). Infants, for example, show some ability to detect and localize auditory stimuli, but may require sound intensities up to 15 dBA above that required by adults to detect the same stimulus (Johnson et al., 2005). In addition, perception of stimuli delivered at specific frequencies differs between younger and older children in middle childhood, and differs from adults. Younger children, in particular, are less able than adults to detect auditory stimuli at higher frequencies (Werner and Gray). Thus, a reasonable suspicion would be that children's ability to perceive and use the dynamic auditory stimuli present in pedestrian settings would be quite different from adults.

Some research on the role of auditory cues in the pedestrian setting has been done with visually impaired adults. One study examined gap selections made while listening to real traffic at roundabouts, but not actually crossing through traffic (Guth et al., 2005). Results indicated that visually impaired pedestrians are able to use auditory cues to make crossing decisions, but the usefulness of these cues is dependent on environmental factors. In particular, gap selection varied by road configuration and traffic volume. Another study involved crossings through real traffic at roundabouts (Ashmead et al., 2005). Visually impaired adults were able to successfully complete crossings using only auditory information but were hampered by their inability to rely on non-verbal visual communication with drivers. Visually impaired participants waited somewhat longer to cross than sighted participants, and were unable to take advantage of opportunities to cross when drivers yielded to them. A third study, again underscoring the importance of auditory cues within the larger context of other environmental factors, examined visually impaired pedestrians' use of traffic noise when aligning themselves with a crosswalk (Guth, 1989). Traffic sounds were useful for alignment when attempting a street crossing, but did not guarantee success, indicating sound localization in the pedestrian setting is imperfect even for adults.

To date, we are aware of only one published study that has examined children's use of auditory cues in the pedestrian setting. Pfeffer and Barnecutt (1996) examined perception of movement in naturalistic traffic stimuli among 60 children ages 5–11. Children were presented with sound recordings of a real automobile in four conditions: approaching, passing, moving away, and accelerating away from the listener's position. Children were asked to indicate whether they thought the car was approaching, passing, or moving away from their location. Age was related to correct determination of the automobile's condition of travel, with 5-year olds performing worse than 8- and 11-year olds. In addition, 11-year olds still made a significant number of mistakes in determining the condition of vehicle motion (i.e., approaching, moving away, etc.). Condition of the vehicle's travel did not appear to affect children's determinations. Rather, age was the dominant factor that determined whether children could correctly identify the type of vehicle motion presented.

Together, the literature demonstrates that auditory information is important for pedestrian safety and that age differences are present when children's abilities are tested. However, empirical examination of developmental differences in use of auditory cues in the pedestrian setting is lacking. In addition, comparisons to adults are needed to illustrate how children's skills are different from those of more experienced pedestrians.

### 1.1. Aims

Our goal was to examine how adults and children detect and localize vehicles using only auditory stimuli. We were interested in how participants performed once a vehicle was emitting auditory information detectable by human hearing. Our focus was on examining detection and localization, rather than providing an index of normative adult and child performance in the use of auditory cues in general. Our study enhances current knowledge of pedestrians' use of auditory cues in two ways. To our knowledge, this is only the second study to examine children's performance in response to auditory cues produced by approaching vehicles. We also examined children's performance in comparison to adults, which is otherwise absent from the literature.

## 2. Method

### 2.1. Sample

A sample of 35 adults ages 19–40 ($M = 21.34$, $SD = 4.21$; 54% male) were recruited from the undergraduate population at university in the Pacific northwest. A sample of 50 children ages 6–9 were recruited from the community through a local elementary school (age 6: 6m, 6f; age 7: 6m, 9f; age 8: 6m, 5f; age 9: 7m, 5f). Corresponding to the demographic characteristics of the local population, both adult and child samples were entirely Caucasian. The study was approved by the University's Institutional Review Board.

### 2.2. Creation of auditory stimuli

Three speeds were chosen for vehicle noise stimuli: 5, 12, and 25 mph. At 5 mph, vehicles emit only engine noise, which is very difficult to detect at such a low speed. The 12 mph speed condition represents a threshold at which some research indicates tire and engine noises begin to blend together (Japanese Automobile Standards International Centre, 2009). At 5 and 12 mph, risk for severe injury is significantly lower. Therefore, the higher speed condition of 25 mph also was included; being representative of speeds vehicles typically travel in residential areas. At 25 mph, the noise emitted by the vehicle's tires is considerably greater and may even mask engine noise.

Sound stimuli were gathered with an Edirol R-09HR digital stereo field recorder mounted on a tripod approximately 1 m above the ground. Recordings were collected of a 2009 Nissan Altima passing the recorder's location from left and right at each speed. The vehicle was driven on a two-lane asphalt road free of loose gravel, snow, ice, or rain. Recordings were collected at night in a remote area to minimize ambient background noise that might habituate participants to vehicle approach on a given trial (e.g., any distinct non-vehicle sounds or other traffic noises). No other vehicles were present on the roadway, or nearby roads, when stimuli were recorded. The resulting recordings were free of any detectable noise except tire and engine sounds, with an ambient background level of approximately 35 dBA. All sound stimuli were recorded and later presented in .wav format (i.e., Waveform Audio File Format).

Sound stimuli had the following characteristics. Three seconds of ambient noise (35 dBA) elapsed at the beginning before the vehicle was detectable, followed by a period of detectable approach during which the sound of the vehicle grew naturally against the ambient background noise from approximately 38 dBA until arriving at the listener's location at approximately 75 dBA, and finally