Research on Quieter Cars and the Safety of Blind Pedestrians

A Report to Congress

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EXECUTIVE SUMMARY

People who are blind have expressed concern that the proliferation of quieter cars, such as hybrid electric vehicles (HEV), may affect pedestrian safety negatively. These vehicles, when driven at slow speeds, are more likely to operate on their electric motor system, resulting in minimal engine sound when other auditory cues from tires and wind noise may also be diminished. While this may be a beneficial outcome for environmental noise reduction, it may pose a safety problem for pedestrians. Pedestrians who are blind are particularly affected because they rely even more heavily on these auditory cues to identify the presence of a vehicle. These cues are also used to determine the location of a street, to traverse the crosswalk properly and to identify a safe time to cross.

This report to the Congress briefly discusses the Quieter Cars issue, how NHTSA's research plan addresses the issue, and the status of our research in following that plan. In addition NHTSA's public outreach efforts are reported, along with some preliminary findings from a NHTSA study of hybrid crashes with pedestrians and from the research plan where appropriate.

The magnitude and detail of the impact of quieter cars on the safety of pedestrians is not well known. In an effort to quantify the problem, the National Highway Traffic Safety Administration's (NHTSA) National Center for Statistics and Analysis (NCSA) examined the incidence rates for crashes involving hybrid electric vehicles and pedestrians under different circumstances, using data from twelve states and compared the results to those for internal combustion engine (ICE) vehicles. This study, which was based on a small sample size, found an increased rate of pedestrian crashes for hybrid vehicles compared to their peer ICE vehicles.

NHTSA developed a Research Plan to (among other tasks) identify blind pedestrians' mobility needs, measure the acoustic parameters of quieter vehicles and ICE vehicles, measure blind pedestrian responses to vehicle acoustic parameters under various ambient conditions, and review possible countermeasures. In order to gather information about the issue of quieter cars, NHTSA held public meetings in 2008 and 2009 to obtain stakeholder input and to exchange information. The Volpe National Transportation Systems Center in Cambridge, Massachusetts (Volpe Center) was selected to conduct the study due to their expertise in sound measurement. The Volpe Center is approximately 5 months through the 10 month research plan and is on course to completing NHTSA's research program in mid-December 2009, and the final report at the end of January 2010.

NCSA Data Analysis

NCSA calculated the incidence rates for crashes involving pedestrians and HEVs and compared the results to similar crashes involving ICE vehicles using the State Data

System (SDS) for model years 2000 and later. Because Vehicle Identification Numbers (VINs) were used to identify HEVs, the NCSA analysis was limited to data from the twelve state files that include VINs. Crashes with pedestrians were found to be 0.9% of the HEVs and 0.6% of the ICE vehicles, which was statistically significant at the 0.05 level.

The NCSA study found that HEVs have a higher incidence rate of pedestrian crashes than do ICE vehicles for certain slower vehicle maneuvers. When a vehicle was slowing or stopping, backing up, or entering or leaving a parking space, the HEV was two times more likely to be involved in a pedestrian crash than was an ICE vehicle. The incidence rate of pedestrian crashes in scenarios when vehicles make a turn was significantly higher for HEVs when compared to ICE vehicles. The NCSA study incidence rates should be interpreted with caution due to the small sample size.

Research Plan Activities

The Research Plan outlines an approach to examine the issue of Quieter Cars and the risk they present for blind pedestrians. It includes comparing the acoustic output and auditory detectability of hybrids and non-hybrid vehicles. The work will also identify and compare the strengths and limitations of potential countermeasures. Various factors are considered that may contribute to the risk such as vehicle type, maneuver, speed, and ambient sound.

The first of seven tasks in the Research Plan, identification of the critical safety scenarios for pedestrian vehicle-conflicts, has been completed (Task 1). The elements of the critical safety scenarios were identified as pedestrian/vehicle environment, vehicle type, vehicle maneuver/speed/operating condition and background noise. The sources of risk in pedestrian-vehicle environments include vehicles approaching at a constant speed, turning into the pedestrian's path and backing up into pedestrian path. The effort to identify blind pedestrian mobility needs and the acoustic cues used for safe pedestrian travel has also been completed (Task 2). Blind pedestrians must determine the presence of the vehicle of interest, the position of the vehicle relative to the pedestrian, the direction of travel, as well as the rate of acceleration or vehicle speed. The requirement to review the Society of Automotive Engineers (SAE) test procedure for acoustic measurement of vehicles has been completed (Task 3). The SAE test procedure was reviewed and adapted for the collection of vehicle acoustic data in the critical safety scenarios identified in the first two tasks.

Acoustic recordings of vehicles and ambient sound have been completed (Task 4). HEV and ICE vehicle acoustic parameters were measured during critical safety scenarios on a test track at the Transportation Research Center (TRC) in East Liberty, Ohio, which was used because it had very low background noise. The test vehicles included three hybrid electric vehicles (Honda Civic, Toyota Prius, and Toyota Highlander) and their ICE twins (the Toyota Matrix serves as a twin for the Prius). Vehicle model years ranged from 2008 to 2010. Five of the six vehicles were new 2009-2010 vehicles. The Volpe Center acoustic team recorded vehicles approaching at low speeds (6 mph and 10 mph), backing up at 5 mph, slowing from 20 mph to 10 mph (mimicking a vehicle preparing to turn right from a parallel street), approaching at moderate to high speeds (20 mph, 30 mph, and 40 mph), accelerating from a stopped position and stationary and idling. Analysis of the acoustic characteristics of the recorded vehicles is underway. The vehicle acoustic characteristics and the ambient sounds were combined to simulate situations where a pedestrian could expect to detect vehicles using auditory cues from traffic. These recordings will be used in human-subject studies described below (Task 5).

Human subject studies will be conducted to measure pedestrian response to vehicle acoustic parameters under various ambient conditions (Task 5). This task is 25 % complete. This work will determine whether blind pedestrians have more difficulty detecting acoustic information from HEVs operating in electric mode than ICE vehicles. The test subjects will listen to audio recordings of vehicle sounds approaching at low speeds (6 mph or 10 mph), backing out at 5 mph and slowing from 20 mph to 10 mph (mimicking a vehicle preparing to turn right from parallel street). Data collection will start in September 2009.

Tasks 6 and 7, identifying and ranking potential countermeasures, are 80% and 15% complete, respectively. The current and emerging countermeasure options are being documented. Preliminary ranking criteria include suitability in critical scenarios (i.e., detection range, warning time, type of information provided), cost, barriers to implementation, and acceptability. Acceptability ranking will be obtained from blind subjects during their debriefing session after the human-subject tests.

Outreach

NHTSA, along with its selected partner in this research, the Volpe Center, has taken an active role in connecting with various public and private entities. NHTSA held its first public meeting in June 2008 and topics discussed included recent research on sound measurement and mobility, potential solutions, and concerns and perspectives of interest groups representing the blind. NHTSA established a public docket for the receipt of comments and other documents from the public pertaining to the Quieter Cars issue. NHTSA presented a draft research plan at a NHTSA public meeting at the U.S. DOT headquarters on April 15, 2009, which was attended by most of the same participants of the June 2008 meeting.

A NHTSA researcher attended a “cognitive walkthrough” on June 3, 2009 at the National Federation of the Blind (NFB)’s headquarters in Baltimore, Maryland. Sighted participants were paired with blind “guides” who acted as instructors for the sighted attendees to give the sighted participants insight into the unique problems that blind pedestrians face when trying to travel on streets and crosswalks and safely avoid vehicle traffic. NHTSA convened a meeting on the following day, June 4, to learn about the tests conducted by the Alliance of Automobile Manufacturers (Alliance) using the vehicle test procedure developed by the SAE (SAE Standard J2889-1) to determine the minimum noise emission of road vehicles and to review the cognitive walkthrough event the day before.

NHTSA held a public meeting on August 4, 2009 to provide a status update on the progress of the research plan, in which three of the seven tasks were completed. Also presented was a detailed review of the results of its recent study comparing pedestrian crashes of hybrid and ICE vehicles (MY 2000 and later). SAE representatives presented preliminary data from vehicle testing using the SAE test procedures and from the Japan Automobile Manufacturing Association's testing of HEVs including some human performance tests.

The Volpe Center has developed a working relationship with the Carroll Center for the Blind and the Perkins School for the Blind communities throughout this project. Both institutions are providing the Volpe Center with access to members of their community, including orientation and mobility specialists, students, and staff, and to their facilities for the human-subject tests.

Summary

NCSA analysis of limited data from 12 states shows that HEVs have a significantly higher incidence rate of pedestrian crashes than peer ICE vehicles for certain vehicle maneuvers, i.e., slowing or stopping, backing up, entering or leaving a parking space and making a turn but these results should be interpreted cautiously due to the small sample size.

Blind pedestrians must determine the presence of the vehicle of interest, the position of the vehicle relative to the pedestrian, the direction of travel, as well as the rate of acceleration or vehicle speed.

The critical safety scenarios for pedestrians who are blind are constructed by combining pedestrian/vehicle environment, vehicle type, vehicle maneuver/speed/operating condition and background noise. The critical safety scenarios identified are the following: approaching at low speeds (6 mph and 10 mph), backing up at 5 mph, slowing from 20 mph to 10 mph (mimicking a vehicle preparing to turn right from parallel street), approaching at moderate to high speeds (20 mph, 30 mph, and 40 mph), accelerating from stop, and stationary. Observations during acoustic measurements suggest there is a noticeable difference in vehicle sound by vehicle type and this is consistent with previous studies. The difference in sound appears to vary by vehicle maneuver or operating condition.

The scenarios selected for human subjects testing are a vehicle approaching at low speeds (6 mph or 10 mph), vehicle backing up at 5 mph and a vehicle slowing from 20 mph to 10 mph (mimicking a vehicle preparing to turn right from parallel street). The variables of interest are vehicle type/acoustic characteristics, vehicle maneuver and ambient sound level. The analysis procedure will examine detection accuracy or whether test subjects can recognize and detect vehicle maneuvers in the audio recordings and detection time will be recorded.

Current and emerging countermeasures may include infrastructure, vehicle-based and pedestrian-based options.

Many public and private organizations and interest groups have contributed to this effort. In addition there is outreach to international organizations and working groups.

This research program examines the issue of quieter cars and the risk they present for pedestrians who are blind. The first four of seven tasks have been completed. The last three tasks are in progress. The research results will be documented in a final report in January 2010.

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I. Introduction

Representatives of organizations for people who are blind have expressed concern that the proliferation of quieter cars, such as all-electric and hybrid electric vehicles (HEV), can negatively affect pedestrian safety. A safety problem may arise when these vehicles are driven at slow speeds because this is when an HEV is more likely to operate on its electric motor system, resulting in minimal engine sound, and when other auditory cues from tires and wind noise may be diminished. Preliminary data from prior laboratory studies, where test subjects listened to audio recordings, indicates that more time was required to localize an HEV than an internal combustion engine (ICE) vehicle approaching at five miles per hour. In some instances, the HEV was not detected until after it passed the pedestrian.[1] The subjects were asked to respond to auditory cues from the vehicles (a visual stimulus was not present).

The sound of traffic is often the best or the primary source of information at locations with limited sight lines such as driveways, intersections, and complex intersections where pedestrians must track potential conflicting vehicles from multiple directions. While quieter cars may have safety implications for all pedestrians, pedestrians who are blind are particularly affected because they rely heavily on auditory cues to recognize and detect vehicles. These cues are used to determine the location of a street, to traverse the crosswalk properly and to identify a safe time to cross. A recent study conducted in Japan shows that the slower the speed of the HEV the larger the difference in sound level from the ICE vehicle.[2] A reduction in or lack of auditory information may delay decision-making and/or increase the risk of a traffic navigating decision.

After holding a public meeting in 2008 to obtain input from stakeholders, the National Highway Traffic Safety Administration (NHTSA) developed a Research Plan to examine the risk to blind pedestrians from quieter cars. The goals of this Plan are to characterize the safety problem, identify the requirements for blind pedestrians' safe mobility, identify potential countermeasures and describe the strengths and weaknesses of the identified countermeasures. The NHTSA Research Plan, titled, "Quieter Cars and the Safety of Blind Pedestrians," is available in the docket NHTSA-2008-0108.[3] The Volpe Center was selected to conduct the research and was directed to initiate the plan in April 2009.

This report presents an overview of the Research Plan and a summary of the activities completed to date. The report also includes a summary of an analysis by the National Center for Statistics and Analysis (NCSA) to examine the incidence rate for crashes involving hybrid electric vehicles and pedestrians.

II. Background

In December 2007, NHTSA met with representatives of the National Federation of the Blind (NFB) to discuss the Quieter Cars issue. Since 2007, NHTSA has been monitoring the work of the Society of Automotive Engineers (SAE), Vehicle Sound for Pedestrian Subcommittee to stay abreast of developments concerning the issue. In June, 2008, NHTSA held a public meeting at which interested parties provided comments on research, potential solutions and safety issues concerning blind pedestrians and quieter cars.

Preliminary data on the audibility of HEVs was presented, suggesting that an HEV traveling at 5 mph is harder to detect when compared to internal combustion engine vehicles.[1] At this meeting NHTSA agreed to establish a docket for information on the issue and to draft a Research Plan to be shared with interested parties before it was finalized. The Research Plan includes input from personnel with expertise in human factors, acoustics, and technology assessment and also considers the input provided by interested parties at the June 2008 Public Meeting, from the docket and a follow up meeting with interested parties in April, 2009.

The Research Plan outlines a comprehensive approach to examine the auditory detectability of vehicles as well as to compare the strength and limitations of potential countermeasures. A traditional approach to examine safety risk relies on crash data analyses and crash investigations. However, the nature of this issue required a comprehensive approach because the primary factors of interest, to examine the auditory detectability of vehicles, vehicle sound and ambient sound levels, are not available in crash databases. Additional challenges in this evaluation include: the relatively small number of hybrid vehicles; the unavailability of a comprehensive crash database that categorize vehicles as HEV or ICE; limited data on crashes with blind pedestrians due in part to database categories; and limited data on exposure to potential conflicts. The approach is to examine the issue from the pedestrian perspective while considering factors that may contribute to the risk such as vehicle type, maneuver, speed, and ambient sound.

The Research Plan includes the following tasks: 1) definition of critical safety scenarios and description of the potential contributing factors; 2) description of the type of information blind pedestrians need, how they perceive this information, and how a reduction of auditory cues from traffic may impact pedestrian decisions; 3) measurement of the acoustic characteristics of vehicles operating at low speeds and reproduction of these characteristics to evaluate pedestrians' responses to these vehicle sounds; 4) data on the acoustic parameters of quieter and conventional vehicles; 5) human-subject studies to examine vehicle detectability of quieter and conventional vehicles in critical safety scenarios; 6) and 7) identify the criteria needed to evaluate potential countermeasures, as well as to document the strengths and limitations of these proposed solutions. This report describes the activities undertaken within each task. In addition, the report summarizes the results of the NCSA crash data analysis and the outreach efforts of NHTSA and the Volpe Center.

III. NCSA Data Analyses

The NCSA completed a study to identify the incidence rates for crashes involving pedestrians and HEVs under different circumstances and compares the results to similar crashes involving ICE vehicles.[4]

The purpose of this study was to compare the crash experience of two different types of vehicles; it was not to make national estimates of problem size. The small sample size for specific crash scenarios (locations, lighting conditions, weather conditions, vehicle maneuvers) was a limitation towards conducting further analysis. Incidence rates provided in this study should be interpreted with caution due to the small sample size. Future analysis using larger sample size would provide a better estimate of the problem size.

Crash files in the State Data System (SDS) were used to measure the incidence rates of pedestrian crashes involving HEVs and to compare the incidence rates with the rates for peer ICE vehicles. Since the early 1980s, NHTSA has obtained, from various States, computer data files coded from police accident reports (PARs) which describe the characteristics of the crash, vehicles, and people involved.

Table 1: States included in the analysis

State	Years Available
Alabama	2000 to 2006
Florida	2002 to 2007
Georgia	2000 to 2006
Illinois	2000 to 2005
Kansas	2001 to 2006
Maryland	2000 to 2007
Michigan	2004 to 2006
New Mexico	2001 to 2006
North Carolina	2000 to 2006
Pennsylvania	2000 to 2005
Washington	2002 to 2005
Wisconsin	2000 to 2006

This study compares HEVs and ICE passenger vehicles for model years 2000 and later. Vehicle Identification Numbers (VINs) are not provided by all States. The NCSA analysis used data from twelve state files that provided VINs. HEV were identified using the first 12 characters of the VIN. Each vehicle manufacturer has provided a unique method to identify HEVs according to certain VIN criteria. Vehicles with unknown or invalid VINs were excluded from the analysis. Incidences rates of pedestrian crashes reflect the first harmful event in the crash. The first harmful event is the first event to cause injury or damage in the crash.

Data was first analyzed for each state. The data was then aggregated using the results obtained from different States by using common data fields, such as light condition during the crash, vehicle maneuver prior to the crash, etc. Data reporting across different States is not uniform. Some States do not report certain data fields. Numbers of cases in certain data fields that have not been reported by States or reported as unknown are noted under each table.

Incidence rates were calculated as the number of vehicles of a given type involved in crashes with a pedestrian under a certain scenario divided by the total number of that type of vehicle that were in any crash under the same scenario. For example, if 56 HEVs were involved in pedestrian crashes during the daytime and the total number of HEVs that have been in any crash during daytime is 6,424; then the incidence rate of pedestrian crashes by HEVs during daytime is 56/6,424 X 100 or 0.9%.

In this analysis it was critical to control for vehicle speed. However, due to the fact that vehicle travel speed is not reliably reported in most police accident reports, the analysis used zone speed limit as a proxy for vehicle travel speed prior to the crash. A speed limit of 35 mph was used as a cut-off; pedestrian crashes were examined at speed limit less than or equal to 35 mph versus speed limit greater than 35 mph. In addition to speed limit, the vehicle maneuver prior to the crash was examined. In some cases the zone speed limit would not reflect the actual vehicle speed, for example, when a vehicle starts from a stopping position in a zone with a higher speed limit.

The characteristic of the wind noise of a passenger vehicle depends on its shape, cruising speed, wind direction towards the vehicle and the natural wind condition. Of these factors, the shape is the most important and the only controllable factor for the wind noise.[5] To control for the wind and tire noise as a function of vehicle size, two comparable groups of HEVs and ICE vehicles were selected for analysis (case vs. control). HEVs (case group) selected are the Toyota Corolla, Toyota Camry, Toyota Prius, Honda Civic and Honda Accord. The ICE vehicles (control group) selected are the Toyota Corolla, Toyota Camry, Honda Civic and Honda Accord. The analysis is limited to vehicles of model year 2000 and later. Honda Insight was considered but excluded from the analysis due to the fact that Honda Insight always operates using IC engine, even at low speed.

Certain weather conditions, e.g., rain, snow, fog, and smog, would restrict drivers' and pedestrians' ability to see. Road darkness would lead to a significant increase in the probability of a pedestrian fatal injury. To control for the variations on pedestrian crashes due to light and weather conditions, this study provides detailed analysis of light and weather conditions during the crashes.

The State Data System does not include information on pedestrian vision status. Therefore, this analysis provides data on pedestrian crashes by HEVs regardless of pedestrian vision status.

Both descriptive and inferential analyses were conducted to measure the incidence rates of pedestrian crashes by HEVs and to compare the results with counterparts' ICE vehicles. This study is exploratory in nature and aims to guide researchers when conducting human subject testing. The study also serves as a guide to future HEV pedestrian crash prevention research.

This analysis was conducted on a total of 8,387 HEVs and 559,703 ICE vehicles that met the selection criteria. A total of 77 HEVs were involved in crashes with pedestrians, accounting for 0.9% of all HEVs included in the analysis. A total of 3,578 ICE vehicles were involved in crashes with pedestrians, accounting for 0.6% of all ICE vehicles included in the analysis. The difference in the incidence rates of pedestrian crashes between HEVs and ICE vehicles was statistically significant at the 0.05 level [OR: 1.4 and p-value: 0.002] (Table 2).

Table 2: Pedestrian crashes HEVs vs. ICE vehicles						
					95% Confidence Intervals	
	HEVs	ICE Vehicles	Odds Ratio	p-value	Lower	Upper
Pedestrian Crashes (*)	77 (0.9%)	3,578 (0.6%)	1.4	0.002	1.1	1.8

(*) = Statistically significant

Zone Speed Limit

The majority of pedestrian crashes in this analysis occurred in low speed zones. Of the total of 2,609 HEVs that were involved in crashes while traveling in a 35 mph or less speed zone, 48 of these vehicles involved pedestrian crashes, an incidence rate of 1.8%. Of the 152,833 ICE vehicles that were traveling in 35 mph or less speed zone 1,836 of these vehicles involved pedestrian crashes with an incidence rate of 1.2%. The difference in incidence rate of pedestrian crashes at zone speed limit of 35 mph or less between HE and ICE vehicles was statistically significant at the 0.05 level [OR: 1.5 and p-value: 0.003].

Crash Location

The most common location where pedestrian crashes occurred for both HEVs and ICE vehicles was on the roadway. Of the 4,342 HE vehicles that were involved in crashes on roadways, 29 involved pedestrians in the first harmful event of the crash, an incidence rate of 0.7%. Of the 318,118 ICE vehicles involved in crashes on roadways, 1,413 of them involved pedestrians in the first harmful event of the crash at an incidence rate of 0.4%. The difference between the incidence rate of pedestrian crashes on roadways involving either HE vehicles or ICE vehicles was statistically significant at the 0.05 level [OR: 1.5 and p-value: 0.04] (Table 3).

Table 3: Location of pedestrian crashes				
Location of Crash	Pedestrian count-HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count-ICE vehicles	Incidence rate of pedestrian crashes -ICE vehicles
On roadway (*)	29	0.7%	1,413	0.4%
Intersection/Interchange	9	0.8%	392	0.6%
Off roadway including parking lot	7	1.2%	418	0.7%
Other	1	0.5%	80	0.5%
Total	46	0.7%	2,303	0.5%
Crash location is unknown or not reported for 31 HEVs and 1,275 ICE-vehicles				

(*) = Statistically significant

Light Conditions

Light condition at the time of the crash was examined to identify if the visibility of the HEVs in dark conditions would affect the incidence of pedestrian crashes relative to the ICE vehicles. The majority of pedestrian crashes by either HEVs or ICE vehicles occurred in daylight. Of the 6,424 HEVs that were involved in crashes during daytime, 56 of them involved pedestrians, an incidence rate of 0.9%. Of the 413,332 ICE vehicles that were involved in crashes during daytime, 2,469 involved pedestrians, an incidence rate of 0.6%. The difference between the incidence rate of pedestrian crashes by HEVs and ICE vehicles was statistically significant at the 0.05 level [OR: 1.5; p-value 0.005] (Table 4).

Table 4: Light condition during pedestrian crashes				
Light Condition	Pedestrian count-HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count-ICE vehicles	Incidence rate of pedestrian crashes -ICE vehicles
Daylight (*)	56	0.9%	2,469	0.6%
Dark—street lights on	12	1.2%	717	0.9%
Dark—no lights	6	1.1%	278	0.7%
Dawn/dusk	3	1.0%	91	0.5%
Other	0	0%	2	0.5%
Total	77	0.9%	3,557	0.6%
Light condition is unknown or not reported for 21 ICE-vehicles				

(*) = Statistically significant

Weather Condition

Pedestrian crashes occur most often during clear weather regardless of vehicle type. A total of 5,467 HEVs were involved in crashes during clear weather, 50 of these vehicles involved pedestrians, an incidence rate of 0.9%. On the other hand, of the 373,667 ICE vehicles that were involved in crashes, 2,566 involved pedestrians in the first harmful event, an incidence rate of 0.8%. The difference in incidence rate of pedestrian crashes between HEVs and ICE vehicles during clear weather was statistically significant at the 0.05 level [OR: 1.3; p-value: 0.04] (Table 5).

Table 5: Weather condition during pedestrian crashes

Weather Condition	Pedestrian count-HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count-ICE vehicles	Incidence rate of pedestrian crashes -ICE vehicles
Clear (*)	50	0.9%	2,566	0.8%
Cloudy/Foggy	7	0.7%	372	0.6%
Raining	11	1.4%	402	0.7%
Snowing	2	1.2%	58	0.7%
Other	3	1.4%	43	0.6%
Total	73	1.0%	3,441	0.7%
Weather condition is unknown or not reported for 4 HEVs and 137 ICE-vehicles				

(*) = Statistically significant

Vehicle Maneuver

Going straight is the most common vehicle maneuver prior to pedestrian crashes for both HEVs and ICE vehicles. The incidence rate for pedestrian crashes while the vehicle was going straight was 0.9% for HEVs and 0.8% for ICE vehicles with no significant difference at the 0.05 level [OR: 1.1 and p-value 0.46] (Table 6).

The second most common vehicle maneuver prior to crashes for both HEVs and ICE vehicles was making a turn. Of the 1,061 HEVs that were making turns prior to crashes, a total of 19 pedestrians were identified as involved in the first harmful event in the crash, an incidence rate of 1.8%. There was a total of 70,245 ICE vehicles included in this analysis making turns prior to crashes. Of that total, 698 involved pedestrians in the first harmful event, an incidence rate of 1.0%. The difference in incidence of pedestrian crashes between HEVs and ICE vehicles when the vehicle makes a turn prior to the crash was statistically significant at the 0.05 level [OR: 1.8 and p-value: 0.001].

Table 6: Vehicle maneuver prior to pedestrian crashes HE-vehicles vs. ICE-vehicles				
Vehicle Maneuver	Pedestrian count-HEVs	Incidence rate of pedestrian crashes – HEVs	Pedestrian count-ICE vehicles	Incidence rate of pedestrian crashes -ICE vehicles
Going straight	33	0.9%	2,069	0.8%
Making a turn (*)	19	1.8%	698	1.0%
Slowing/stopping	6	0.5%	148	0.2%
Backing	7	5.3%	261	2.9%
Entering/leaving parking space/driveway	1	1.2%	55	0.9%
Starting in traffic	3	2.9%	50	1.2%
Other	6	0.3%	238	0.2%
Total	75	0.9%	3,519	0.6%
Vehicle maneuver is unknown or not reported for 2 HEVs and 59 ICE-vehicles				

(*) = Statistically significant

The incidence rate of pedestrian crashes that potentially have occurred at very low speed such as when a vehicle is slowing or stopping, backing up and entering or leaving parking space was significantly higher among HEVs when compared to ICE vehicles. A total of 1,454 HEVs were engaged in one of these maneuvers prior to the crash and, 17 of these vehicles involved pedestrians as the first harmful event, an incidence rate of 1.2%. On the other hand, a total of 90,003 ICE vehicles were engaged in one of these maneuvers prior to the crashes, and of them 514 of these vehicles involved pedestrians as first harmful event, an incidence rate of 0.6%. The difference between pedestrian crashes involving HEVs and ICE vehicles was statistically significant at the 0.05 level as indicated by OR: 2.1 and p-value 0.003 (Table 7).

Table 7: Pedestrian crashes at potentially very low speed maneuvers				
Vehicle Maneuver	HEV Pedestrian Crashes	Total # HEVS	ICE Vehicles/ Pedestrian Crashes	Total # ICE Vehicles
Slowing/stopping	6	1,137	148	70,872
Backing	7	132	261	9,093
Entering/leaving parking space/driveway	1	83	55	5,870
Starting in traffic	3	102	50	4,168
Total (*)	17 (1.2%)	1,454	514 (0.6%)	90,003
Pedestrian crashes HEVs : ICE Vehicles OR: 2.1 p-value 0.003				

(*) = Statistically significant

Summary

This study found that pedestrian crashes involving HEVs and ICE vehicles commonly occur on roadway, in zones with low speed limits, during the daytime and in clear weather, with higher incidence rates for HEVs when compared to ICE vehicles. The exception was that there was no difference in crash incidence involving pedestrians between HEVs and ICE vehicles when both types of vehicles were going straight.

To further investigate the factors that increase the incidence rates of pedestrian crashes involving HEVs when compared to ICE vehicles, a variety of crash scenarios were examined. For one group of scenarios, those in which a vehicle is slowing or stopping, backing up, or entering or leaving a parking space, there was a statistically significant difference due to engine type. The HEV was two times more likely to be involved in a pedestrian crash in these situations than was an ICE vehicle. The incidence rate of pedestrian crashes in scenarios when vehicles make a turn was significantly higher for HEVs when compared to ICE vehicles.

The small sample size used in this study is a limitation and highlights the need for conducting more analyses. The incidence rates provided in this study should be interpreted with caution due to the small sample size. In the future, a larger sample size would permit a more detailed analysis such as limiting the entire analysis to low speed crashes and analyzing different vehicle maneuvers individually. NHTSA will continue monitoring the incidence of pedestrian crashes involving HEVs. Data findings on this study will be updated when more recent State Data System and other data sources are available.

In conclusion, this study found that HEVs have a higher incidence rate of pedestrian crashes than do ICE vehicles in certain vehicle maneuvers. These results should serve as a guide when designing future programs to prevent pedestrian crashes by HEVs.

IV. Status of Research Plan Activities

NHTSA is working with the Volpe Center to conduct the activities outlined in the Research Plan. The Volpe Center assembled an integrated project team with expertise in human factors, acoustic measurements and modeling and technology assessment to implement the technical approach described in the Research Plan. The Volpe Center began to conduct this research in April 2009 and the final report will be available at the end of January 2010. This section provides an overview of the work completed to date and currently underway.

Objectives

The Research Plan established the following objectives to meet its goals:

1. Describe the safety issue and identify critical safety scenarios to be examined
2. Identify requirements for blind pedestrians' safe mobility (emphasizing acoustic cues from vehicles and ambient conditions)

3. Identify potential countermeasures and describe their advantages and disadvantages

Key Tasks

The following Key Tasks have or are being carried out to address the objectives:

1. Identify critical safety scenarios where pedestrian vehicle-conflicts are likely to occur
2. Identify blind pedestrian mobility needs and the acoustic cues used for safe pedestrian travel
3. Review the draft test procedure for acoustic measurement of vehicles (SAE J2889-1) developed by the Society of Automotive Engineers (SAE) and adapt as needed
4. Measure acoustic parameters for a sample set of vehicles and ambient sound for critical safety scenarios
5. Measure vehicle detectability in critical safety scenarios
6. Identify potential countermeasures in addition to acoustic options
7. Review potential countermeasures to identify their strengths and limitations

Tasks 1 and 2: Critical Scenarios and Auditory Cues for Travel (Tasks completed)

Tasks 1 and 2 investigate the factors contributing to pedestrian-vehicle conflicts. The combination of key factors will define the conditions under which the vehicle's acoustic characteristics will be recorded and the detectability of vehicles evaluated (critical safety scenarios). Identifying critical safety scenarios is essential to characterize the problem, test vehicle detection performance with human subjects, identify countermeasures, and specify the conditions under which the countermeasures should be evaluated. The critical safety scenarios were created by combining pedestrian/vehicle environment, vehicle type, vehicle maneuver/speed/operating condition and background noise. The activities undertaken to identify the critical safety scenarios and the key findings are described in this section.

In Task 1, a review was performed of the NCSA crash data analysis of pedestrians and HEVs compared to ICE vehicles. The incidence of pedestrian crashes involving vehicle turning maneuvers is higher for hybrid vehicles than for non-hybrid vehicles. The incidence of pedestrian crashes during combined maneuvers (turning, slowing, backing, entering or leaving a parking space or driveway) was also higher for hybrid vehicles than for non-hybrid vehicles. This crash data helped identify vehicle maneuvers and pedestrian-vehicle environments to be considered in the evaluation of vehicle detectability

The NFB distributed a questionnaire to its members to collect subjective information from blind pedestrians involved in crashes or near crashes. The NCSA crash data analysis findings are consistent with the concerns reported on the completed NFB questionnaires. This information was used to identify elements of the critical safety scenarios such as the pedestrian-vehicle environment of interest (driveways, controlled intersections, and uncontrolled approaches) and vehicle maneuvers (vehicles turning into the pedestrian's path, vehicles backing up into pedestrian path).

It is important to describe what information blind pedestrians need, how they perceive this information, and how a reduction of auditory cues from traffic may impact pedestrian decisions (Task 2). This information is used to refine the scenarios or conditions to record vehicle acoustic profiles and evaluate vehicle detectability. This study observed how blind pedestrians are trained to navigate in the pedestrian-vehicle environments that have been identified. Researchers asked blind pedestrians and orientation and mobility specialists to describe the cues and strategies they use when they encounter walking situations at various controlled intersections and uncontrolled approaches. The results of these inquiries identified sources of risk at these pedestrian-vehicle environments. These risks include vehicles approaching at a constant speed, vehicles turning into the pedestrian's path and vehicles backing up into pedestrian path. In addition to these sources of risk, the pedestrians who are blind detailed the kinds of information that helps them to navigate. Blind pedestrians must determine the presence of the vehicle, the position of the vehicle relative to the pedestrian, the direction of travel, as well as the rate of acceleration or vehicle speed. Blind pedestrians use this information to judge how fast the vehicle is moving or how soon it may reach their position or travel path.

One of their strategies is to cross when the road is quiet. The technique assumes that a vehicle is loud enough to be heard far enough away to determine that it is safe to proceed, if no masking sounds are present and no other vehicles are detected. A quieter car approaching at low speed may not be detected until it is too close to the pedestrian. The ability to detect a vehicle approaching from a distance is affected by the background noise and roadway curvature.[6] Preliminary studies have shown that HEVs approaching at low speed (less than 20 km/h) may not be detectable.[2] The difference in perceptibility between the two vehicles that is associated with the background noise becomes smaller as the speed of the vehicle increases. It is necessary to record data for vehicles approaching at low (6 mph, 10 mph) and moderate speeds (20, 30, 40 mph) to examine how the acoustic characteristics of HEVs and ICE vehicles differ. A vehicle approaching at 6 and 10 mph can be representative of a vehicle in parking lot or coming out/into a driveway. Vehicles approaching at 20 mph could represent a vehicle approaching at low speed in a residential area. It is expected that the difference in vehicle sound will be at low speeds; acoustic data at moderate speeds are measured to document the transition.

Pedestrians who are blind use the surge of parallel traffic to identity a time to cross. The sound of accelerating vehicles in the parallel lane indicates, for example, that the perpendicular traffic does not have the right of way and thus a crossing opportunity is available. A safety concern is that quieter cars may not be heard during initial acceleration. Pedestrians may initiate their crossing as soon as they detect the surge of parallel traffic or may delay the decision to make sure traffic is moving straight through the intersection and not turning into their path. A significant delay in detecting the surge of parallel traffic may impact the blind pedestrian's ability to complete a crossing within a designated walking interval. It is necessary to record data for vehicles accelerating from a stop to examine how the acoustic characteristics of HEVs and ICE vehicles differ.

As indicated earlier, a blind pedestrian has to distinguish between a vehicle moving through the intersection and a vehicle turning into its path. The sound of decelerating vehicles in the parallel street helps pedestrians identify vehicles that may turn into their path. A quieter car slowly decelerating may not be detected. It is necessary to record data for vehicles slowing, for example from 20 to 10 mph, as if the vehicle is preparing to turn right from the parallel street. It is important to recognize that the pedestrian needs to perceive this information when the vehicle is in the parallel lane before it turns into their path.

Similarly it is important to record vehicles backing up as if they are coming out of a driveway. This task is complex for pedestrians since it is difficult to anticipate when a vehicle will move and the driver's visibility may be limited.

Finally, there is a concern that a quieter car may not be detected when it is stationary and idling. The sound of vehicles idling provides important cues for blind pedestrians. For example, in the far lane it gives cues about the width of the road (number of lanes), conveying information about the distance to walk and the time required to make it across. A quieter car may not be detected when stationary at intersections or parking lots and may start moving suddenly at the same time the pedestrian enter the conflicting path. Previous studies suggest that a stationary HEV is not detectable even when the background noise is moderate.[2] It is relevant to record data for vehicles in this operating condition. The critical safety scenarios will be used to structure the human-subject testing. Previous research on vehicle acoustics and vehicle detectability shows that most traffic sounds can be found in the lowest frequency bands (< 250 Hz). Although there is significant sound due to traffic below 250 Hz, the region between 500 and 4000 Hz may be more important due to the human auditory system's increased sensitivity in this range.[7] Frequency-specific thresholds may affect the auditory detectability of traffic sounds. In particular, sounds at the same sound level may be more or less detectable depending on their spectral shape. It is necessary to report the spectral shape (contour of the frequency spectrum) as well as the sound level. This factor is considered in the acoustic measurement test procedure (Task 3 in this report).

In summary, acoustic measurements were collected from vehicles operated in the following critical safety scenarios based on the results of Tasks 1 and 2:

1. Approaching at low speeds (6 mph and 10 mph)
2. Backing up at 5 mph
3. Slowing from 20 mph to 10 mph (mimicking a vehicle preparing to turn right from parallel street)
4. Approaching at moderate to high speeds (20 mph, 30 mph, and 40 mph)
5. Accelerating from stop
6. Stationary

Subject matter experts contacted during the work on these tasks included blind pedestrians, orientation and mobility specialists and representatives of national organizations including the NFB, the American Foundation for the Blind (AFB), U.S. Access Board, and American Council of the Blind, SAE and researchers.

Task 3: Review Test Procedure for Acoustic Measurement of Vehicles Developed by the Society of Automotive Engineers (SAE) and Adapt as Needed (Task completed)

A test procedure was needed to assure vehicles' acoustic parameters are measured consistently. The Society of Automotive Engineers (SAE) has developed a draft test procedure (SAE J2889-1) to measure the acoustic characteristics of vehicles at low speed.[8] This procedure was reviewed to assess its suitability to collect vehicle acoustic data in the critical scenarios identified in previous tasks (Tasks 1 and 2). A modified procedure was developed for the "Quieter Car and the Safety of Blind Pedestrians" study because the SAE J2889-1 draft test procedure currently does not include provisions to collect data that can be used to test pedestrian responses to vehicle acoustic parameters in critical scenarios. The "Quieter Car and the Safety of Blind Pedestrians" procedure follows the recommendations of the SAE test procedure with regard to instrumentation setting, however, it deviates from this with respect to the number of vehicle operating conditions, height, distance and orientation of the microphones because the goal of this study is to document vehicle acoustics under "critical scenarios" rather than the "minimum noise emitted". As pedestrians need to determine the direction of the vehicle, the sound will be recorded using microphones placed in position corresponding to the anatomical location of the human ears in addition to sound level meters.

The test plan for acoustic measurements of vehicles and ambient conditions for the "Quieter Car and the Safety of Blind Pedestrians" study described the test vehicles to be used, vehicle measurement test site, equipment layout, test schedule, and measurement procedure. The test plan also included provisions to measure and record ambient sounds typical for critical safety scenarios.

Task 4: Measure Acoustic Parameters for a Sample set of Vehicles and Ambient Sound for Critical Safety Scenarios (Task completed)

Vehicle sounds emitted by conventional and quieter vehicles operated under conditions simulating critical safety scenarios were recorded. Analysis of the acoustic characteristics of the recorded vehicles in various operating conditions is underway.

Test vehicles included three HEVs (Honda Civic, Toyota Prius, and Toyota Highlander) and their ICE twins (the Toyota Matrix serves as a twin for the Prius). Vehicle model years ranged from 2008 to 2010. Five of the six vehicles were new 2009-2010 vehicles. Test vehicles were in good operating condition, and did not generate sounds from a defect in the condition of the vehicle. The tires had sufficient tread for safe operation, an even wear pattern and were representative of Original Equipment Manufacturer (OEM) tires.

Significant efforts were made to locate a measurement site with very low background noise to measure the quieter vehicles at low speeds. The test site selected was NHTSA's Vehicle Research and Test Center located at the Transportation Research Center (TRC) in East Liberty, Ohio.[9] This site had low background noise (e.g., birds, insects, wind/vegetation induced noise, other distant vehicles), low wind speeds at night (e.g., less than 10 mph), a closed, nearly flat course long enough to bring the vehicle to the start of the test condition outside the audible range, and clean asphalt pavement in good condition.

The vehicle operations (corresponding to the critical safety scenarios) that were measured included vehicles approaching at a constant speed (6, 10, 30, and 40 mph); vehicles slowing from 20 to 10 mph (mimicking a vehicle preparing to turn right from the parallel street); vehicles backing up at 5 mph; vehicles accelerating from a stopped position; and stationary vehicles. Most of the data was recorded during the night (with no other vehicle operating at the test facility) to obtain the highest quality recordings possible. Two of the three hybrid electric vehicles were recorded while operating in electric mode for all runs except for those greater than 20 mph. Each measurement event (combination of vehicle and operation condition) was repeated several times to ensure that at least one good quality audio recording was obtained.

Audio recordings were made using a microphone that mimics the height and position of a pedestrian as well as the sound perceived in the left and right ears. Each event was recorded using sound level meters. Based on field observations there is a noticeable difference in vehicle sound by vehicle type and this is consistent with previous studies. The difference in sound seems to vary by vehicle maneuver or operating condition. HEVs emit sounds from their electronics that are more noticeable in some vehicles and operating conditions. Objective data will be documented in the final report due in January 2010.

Task 4 also included the recording of ambient sounds at suburban locations. Audio recordings were combined with ambient recordings to use in human subject testing, which will occur in Task 5. These recordings simulate situations where a pedestrian could expect to detect vehicles by means of auditory cues from traffic. Noisier urban sites are not included because preliminary data and previous studies suggest that the difference in detectability between quieter cars and conventional cars is small when background noise is too high.[2]

Task 5: Measure Pedestrian Response to Vehicle Acoustic Parameters under various Ambient Conditions (25% complete)

Task 5 is the current focus of work. One objective of this task is to determine when it is more difficult for blind pedestrians to detect acoustic information from vehicles and whether pedestrian performance (detection time and accuracy) differs for HEVs operating in electric mode and ICE vehicles. A second objective will examine how the ambient sound affects the ability of blind subjects to detect the acoustic characteristics of the test vehicles. The blind subjects will listen to audio recordings of vehicle sounds combined with an ambient sound. The study follows the Internal Review Board (IRB) protocol for the protection of human subjects.

The scenarios selected for the human-subject studies are:

1. Vehicle approaching at low speeds (6 mph or 10 mph)
2. Vehicle backing out at 5 mph
3. Vehicle slowing from 20 mph to 10 mph (mimicking a vehicle preparing to turn right from parallel street)

The variables of interest are: 1) vehicle type/acoustic characteristics, 2) vehicle maneuver, 3) and ambient sound level. Human-subjects test will examine detection accuracy (whether test subjects can recognize and detect vehicle maneuvers in the audio recordings and detection time will be recorded).

The participants in the study will be volunteers from the Carroll Center for the Blind (Newton, MA) and the Perkins School for the Blind (Watertown, MA) communities who are legally blind and age 18 or older. Data collection started in September 2009.

Task 6 and 7: Identify and Review Potential Countermeasures (80% and 15% complete)

The current and emerging countermeasure options are being documented (Task 6). Countermeasures categories include infrastructure, vehicle-based, and pedestrian-based. For example, infrastructure-based countermeasures include audible pedestrian signals; vehicle-based include artificial vehicle sound emitted when the vehicle operates at low speeds; pedestrian-based countermeasures include signal sent by a vehicle to a to special-purpose receiver carried by pedestrians to detect vehicles. These potential countermeasures will be ranked according to evaluation criteria which are being developed (Task 7). Preliminary criteria include: suitability in critical scenarios (i.e., detection range, warning time, type of information provided), cost, barriers to implementation, and acceptability. Subjective data on acceptability will be obtained from blind subjects during the debriefing session after the human-subject tests. A weighting scale for the different criteria will be developed to rank potential countermeasures and select those meriting further evaluation. Task 7 is underway and will incorporate inputs from Tasks 1 to 5 including subjective data to be collected during subject- debriefing at the end of the human-subject tests.

V. Outreach

NHTSA held its first public meeting on the Quieter Cars issue in June 2008 to provide a forum for the exchange of information and gather input from the public about the issue. NHTSA, along with its selected partner in this research, the Volpe Center, has taken an active role in gathering input from various public and private entities. The purpose is fivefold: 1) to obtain feedback from the blind community on their greatest concerns and goals concerning the issue and to learn their techniques and approaches to navigating streets in order to determine and study their needs in safely negotiating vehicle traffic,

2) to learn about research or other information gathering activities that public and private entities were involved in concerning the issue and what their findings were, 3) to identify potential countermeasures to aid the blind in detecting and localizing vehicles as they negotiate street crossings, 4) to gather information on industry's perspective of the issue and to learn what impact various countermeasures might have on vehicle development and cost, and 5) to promote the exchange of ideas concerning this important safety issue.

June 2008 NHTSA Meeting

NHTSA held a public meeting to bring together state and local government policy makers, stakeholders in the blind community, industry representatives and public interest groups to provide a forum for interested parties to discuss the Quieter Car issue and exchange information about it. The meeting was attended by representatives of various organizations such as the National Federation of the Blind, American Council of the Blind, Alliance of Automobile Manufacturers, Society of Automotive Engineers, Association of International Automobile Manufacturers, and the State of Maryland Task Force. Topics discussed included recent research on sound measurement and mobility, potential solutions, concerns and perspective of interest groups representing the blind, and comments from various public and industry groups, and individuals. In addition, a public docket was established for the receipt of comments and other documents from the public pertaining to the Quieter Cars issue (docket NHTSA-2008-0108).

April 15, 2009 NHTSA Meeting

Following the meeting in June 2008, and after a substantial amount of background work and revision, a draft of NHTSA'S research plan was presented at a public meeting at the U.S. DOT headquarters on April 15, 2009, which was attended by most of the same participants of the June 2008 meeting. The main purpose of this meeting was to present NHTSA's research plan and obtain feedback from the various stakeholders about its appropriateness and thoroughness. The plan was discussed in detail and comments concerning aspects of it such as which types of vehicles should be tested, what scenarios are of most concern, which types of countermeasures might be most useful, and suggested additions to the research plan were captured and considered in finalizing the document.

In addition to presenting NHTSA's research plan, time was allotted for the various organizations in attendance (for example, the National Federation of the Blind, American Council of the Blind, the Alliance of Automobile Manufacturers, and the SAE's Vehicle Sound for Pedestrians committee) to provide updates or status of activities being undertaken by them.

June 3, 2009 NFB Meeting (Cognitive Walkthrough)

A NHTSA researcher attended a "cognitive walkthrough" at the NFB's headquarters in Baltimore, Maryland. At this event, which was also attended by other groups such as the Alliance and the SAE, sighted participants were paired with blind "guides" who acted as instructors for the sighted attendees to gain experience of having to negotiate walking on sidewalks and crossing streets while not being able to see (wearing blindfolds) for the entire exercise which lasted about 90 minutes. This exercise gave the sighted participants insight into the unique problems that blind pedestrians face when trying to travel on streets and crosswalks and safely avoid vehicle traffic. During the debriefing and discussion that followed the exercise, a number of topics surfaced that were helpful in further understanding the problems that blind pedestrians face.

June 4, 2009 NHTSA Meeting

This meeting held at U.S. DOT headquarters had a two-fold purpose. The first was to hear details of and discuss the Alliance's test plan using the vehicle test developed by the SAE (SAE Standard J2889-1) to determine the minimum noise emission of road vehicles. Representatives from the Alliance of Automobile Manufacturers provided the meeting participants with a list of categories of vehicles and specific vehicle models they planned to test. The Alliance expressed a desire to work with NHTSA to produce a large combined database of tested vehicles from which to draw on for analysis. The second part of the meeting was spent reviewing the cognitive walkthrough event that took place at the NFB headquarters the day before. Participants of the walkthrough shared their experiences and insights with the attendees at this meeting who did not participate in the event.

August 4, 2009 NHTSA Meeting

At this point in time, NHTSA had completed three of the seven tasks of its Research Plan for the Quieter Cars issue. As a result, the agency was able to provide a status update on the research program. After a brief review of the previous public meetings held by NHTSA, a detailed review of the work accomplished and work remaining for each task in the Research Plan was undertaken along with details on how the research tasks were carried out. Most of the discussion concerning the research tasks focused on the testing of the selected vehicles to obtain acoustic measurements (Task 4) and also on a comparison of NHTSA's test procedure to the SAE test procedure.

In addition to the status review of the Research Plan, NHTSA presented the detailed results of its recent study comparing pedestrian crashes of hybrid and ICE vehicles (MY 2000 and later). SAE representatives also presented preliminary data from vehicle testing using the SAE test procedures and from the Japan Automobile Manufacturing Association's testing of HEVs including some human performance tests. The vehicle test results were compared to the preliminary results found in NHTSA's tests.

Other Associations and Collaborations

- SAE Vehicle Sound for Pedestrian Sub-Committee monthly meetings: NHTSA and Volpe representatives attend the monthly committee meetings as government liaison members to stay apprised of the committee's progress.

- EPA: The Environmental Protection Agency (EPA) has become involved in the issue of quieter cars and pedestrian safety and NHTSA and the EPA have begun to confer with each other.

- United Nations sound/noise regulation committee UN/WP29/GRB

- State of Maryland Task Force on Hybrid Vehicles and Blind Pedestrians: NHTSA maintains contact with the Maryland government representative to stay apprised of activities of the task force.

Blind Community

The Volpe Center has been working with The Carroll Center for the Blind and the Perkins School for the Blind communities throughout this project. The Carroll Center for the Blind, located in Newton, Massachusetts, is a private, non-profit agency which serves persons of all ages who are blind or visually impaired, and their families.[10] The Perkins School for the Blind, located in Watertown, Massachusetts was first school for the blind in the United States and continues to provide services to people of all ages who are blind, visually impaired, deaf-blind, or with multiple disabilities.[11] Both institutions are providing access to members of their community including orientation and mobility specialists, students, staff, as well as access to their facilities for the human-subject tests. Some of the activities conducted in coordination with these institutions include interviews about the tasks, techniques, and strategies used by blind pedestrians at various crossings; cognitive walkthroughs (Task 2 in this report) where researchers observed orientation and mobility specialists and blind pedestrians crossing at various intersections and followed up with discussions on the scenarios of concern.

VI. Summary and Conclusions/Status of On-going Research Effort

Prior research shows that there is a difference in the sound emitted by HEVs and ICE vehicles when they operate at constant low speeds and when they are stationary (1, 2). These differences may alter the perceivable acoustic cues used by blind pedestrians. This research program will provide information to better understand the safety risk to blind pedestrians associated with the acoustic profiles of quieter cars in various maneuvers including low speed and backing up operations. Based on preliminary observations, there is a noticeable difference in vehicle sound by vehicle type which is consistent with previous studies. The difference in sound also appears to vary by vehicle maneuver or operating condition.

Blind pedestrians must determine the presence of a vehicle of interest, the position of the vehicle, its direction of travel as well as the rate of acceleration or vehicle speed. They must assess risks from vehicles approaching at a constant speed, vehicles turning into the pedestrian's path and vehicles backing up into a pedestrian's path. Blind pedestrians use acoustic cues to monitor vehicles to avoid conflicts as well as to support crossing strategies. They acquire useful information from vehicles that are accelerating, decelerating or idling. Volpe Center researchers have recorded and will identify the acoustic characteristics of a sample of HEVs and ICE vehicles for critical operating conditions. In addition, the research will examine how the acoustic characteristics of vehicles and ambient sound affect blind pedestrians' detection of vehicles. It will also identify countermeasures that have the potential to reduce the safety risks to blind pedestrians. The promising countermeasures will be compared and rated and the evaluation metrics will be reported.

This report is a status update on NHTSA's Quieter Cars research. The research program is mid-way toward completion of its tasks and has involved extensive contact with subject matter experts including blind pedestrians, orientation and mobility specialists and representatives of national organizations including the NFB, the American Foundation for the Blind (AFB), U.S. Access Board, and American Council of the Blind, SAE and other university and independent researchers to formulate and conduct its activities. Critical safety scenarios have been identified, which include turning, slowing and backing maneuvers as well as entering or leaving a parking space or driveway. These high risk scenarios occur in proximity to driveways, controlled intersections, uncontrolled approaches and when vehicles turn into or back up into the pedestrian's path.

The research has identified the cues that blind pedestrians depend on for safe travel. Blind pedestrians have to determine the presence of a vehicle of interest, its relative position, direction of travel, as well as its rate of acceleration to judge how fast the vehicle is moving or how soon it may reach their position.

The SAE test procedure for acoustic measurement of vehicles was reviewed and adapted for use in the test plan to measure HEVs and ICE vehicles' acoustic parameters. This test plan has been implemented in recording the vehicle sounds emitted by HEVs and ICE vehicles operated under conditions simulating critical safety scenarios. The Volpe Center research team has combined the audio recordings with ambient recordings for use in the upcoming human subject testing and is currently analyzing the acoustic characteristics of the recorded vehicles in various operating conditions.

There are several areas of work which will be completed during the next few months. There will be a comparative analysis of the acoustic profiles of the six vehicles recorded at the test track. This analysis will describe each vehicle's acoustic profile when they were approaching at low speeds (6 and 10 mph), backing up at 5 mph, slowing from 20 mph to 10 mph (mimicking a right turn from a parallel street), approaching at moderate to high speeds (20, 30, and 40 mph) and idling and stationary. In addition, there will be laboratory tests carried out using blind subjects to determine whether and how quickly they can detect vehicles approaching in these low speed operating conditions. The final activity is to document, compare and rank proposed countermeasures that merit further evaluation. The results of this research program will be documented in a final report which will be completed in January 2010.

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