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The Effectiveness of Enhanced Seat Belt Reminder Systems

Observational Field Data Collection Methodology and Findings

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16. Abstract

Enhanced seat belt reminder systems (ESBRs) provide a more conspicuous warning to fasten seat belts than the Federal Motor Vehicle Safety Standard (FMVSS) currently requires. The effect of ESBRs on driver and front passenger seat belt use was examined in a field observational study of seat belt use of unalerted front seat occupants in nearly 40,000 passenger vehicles in eight States with and without primary seat belt laws. License tag numbers were matched to State motor vehicle registration records to determine Vehicle Identification Number (VIN), manufacturer, model, and year. ESBR features (e.g., sound, icon, text, duration, cycle, etc.) were determined by matching make, model, and year to a features database compiled by NHTSA and Westat. A propensity analysis was conducted using stepwise logistic regression models to estimate the probability of seatbelt use while controlling for the influence of key vehicle, occupant and geographic location factors. ESBRs were found to increase front occupant seat belt use by 3-4 percentage points compared to vehicles without ESBRs. Significant positive effects of ESBRs were more often found among the lowest belt use propensity groups. ESBR features were found individually and in combinations to have significant effects on driver seat belt use. The findings suggest that ESBRs may be most effective in converting belt use resistors if they incorporate the features found to have positive effects among lowest belt use propensity groups.

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1. Summary

The objective of this study was to determine the effect of Enhanced Seat Belt Reminder Systems (ESBRs) in non-commercial passenger cars, pickups, SUVs, and passenger vans on seat belt use rates relative to the same vehicles without ESBRs. An observational study measuring seat belt use by drivers and right front seat passengers of these vehicles was conducted in eight urban centers across the United States to determine the effect. ESBRs provide a more conspicuous or persistent seat belt reminder display than systems that meet only the Federally-mandated minimum requirements to alert passenger vehicle occupants when they are not belted. The analysis assessed the overall effects of each of the various ESBR systems on seat belt use, relative to the base 4-8 second system required by the Federal Motor Vehicle Safety Standard (FMVSS). A secondary research objective was to examine the relative effectiveness of different ESBR system characteristics, such as warning sound duration, interval between displays, change in amplitude and icon versus text.

Controlling for a number of characteristics of the occupants and vehicles that tend to influence seat belt use in general, the study found that belt use rates of drivers in vehicles with most types of ESBR systems was about 3-4 percentage points higher than drivers in vehicles without ESBRs (whose observed belt use rate of 85% in the present study is similar to the national average reported by NHTSA[1]).

The following are estimated effects of ESBR on belt use among drivers and right front seat passengers. There are estimates for ESBR effects overall, and for groupings of largely similar ESBR systems. The estimates were controlled for the potentially confounding effects of observed characteristics that could, in principle, have influenced both ESBR availability in the car, and driver belt use. Potential confounders included age of vehicle, site type, weather, occupant age and sex, State belt use law, etc. We used propensity-based statistical methods to achieve this control.

Front seat occupants

- The overall effect of ESBRs was to increase front seat occupant seat belt use by 3.3 percentage points compared to vehicles without ESBRs. Most ESBRs increased the rate of belt use by about 3-4 percentage points over the non-ESBR rate of belt use. Depending on ESBR system, the increases ranged from 2.6 to 4.1 percentage points.

Drivers:

- The overall effect of ESBRs was to increase driver seat belt use by 3.2 percentage points compared to vehicles without ESBRs. Depending on ESBR system, the increases ranged from 2.5 to 3.9 percentage points.

Front right passengers:

- The overall effect of ESBRs was to increase front passenger seat belt use by 3 percentage points compared to vehicles without ESBRs. Depending on the ESBR system, the increases ranged from 1.8 to 4.1 percentage points.

ESBR system characteristics

Relative to vehicles without ESBRs

- ESBR features (icon, sound, text) and the characteristics of each feature (e.g., interval between displays, change in amplitude, etc.) were found individually and in various

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[1] Glassbrenner, Donna**.** *Safety Belt Use in 2005 ─ Overall Results*. (DOT HS 809 932, NHTSA 2005.

combinations to have significant ($p<.05$) effects on driver seat belt use (not examined for passengers due to relatively small sample size).

- Positive significant effects were more often found among the lowest belt use propensity groups, suggesting that ESBRs help increase belt use among people who are relatively more resistant to wearing them.
- Relatively larger significant positive effects were found for systems having at least icon and sound (Sound and Icon) and icon and sound with no other component (Sound and Icon Only).
- Significant negative effects were found for the combination of sound and text only (Sound and Text Only).

Relative to vehicles with other ESBR system characteristics

- All significant ($p<.05$) effects on driver seat belt use occured in the lowest three belt use propensity groups.
- Sound and icon together, complete duration of sound, maximum frequency (rate) of the sound, and icon appearance had significant positive effects thus were associated with higher belt use relative to other ESBR characteristics in the lowest belt use propensity group.
- Sound and text together, sound density (proportion of time sound is emitted), and maximum frequency of icon display had significant negative effects, thus were associated with lower seat belt use relative to other ESBR characteristics in the lowest belt use propensity group.

Explanatory comments

- Some component of the positive or negative effects may be due to additional confounding of ESBR characteristics with other aspects of the design of those vehicles that also influence belt use but were not accounted for in the analysis, such as vehicle type or size. For example, ESBRs with the combination of sound and text may have been predominantly in SUVs and pickups, which typically have lower belt use rates independent of their seat belt reminder systems.
- Additional research is suggested to further examine the contributions of the presence and characteristics of each ESBR attribute to improved belt use.

2. Introduction and background

The use of a seat belt increases survivability and reduces injury severity for motor vehicle occupants involved in traffic crashes. Although studies have shown that the vast majority of drivers are using seat belts, with observed usage rates as high as 83 percent in 2005[2], those who do not wear their seat belts are overrepresented in fatal crashes. In 2004, of the 20,446 passenger vehicle driver fatalities for which restraint use was known, an estimated 11,031 (54%) were unrestrained[3]. The reasons drivers indicate most often as to why they do not use a seat belt include short trips, forgetfulness, in a rush, and discomfort.[4]

Congress and the National Highway Traffic Safety Administration (NHTSA) have initiated a number of activities to develop in-vehicle technologies to increase belt use. One method to increase seat belt use is installation of various types of seat belt reminders in vehicles to prompt occupants to use their belts. Currently, Federal standards require all new vehicles be equipped

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[2] Glassbrenner, Donna**.** *Safety Belt Use in 2005 ─ Overall Results*. (DOT HS 809 932, NHTSA 2005.

[3] *Occupant Protection*, Traffic Safety Facts, DOT HS 809 909, NHTSA 2005.

[4] Boyle, John M. and Vanderwolf, Patricia. *2003 Motor Vehicle Occupant Safety Survey*. DOT HS 809 789, NHTSA 2004.

with a "basic" seat belt reminder system – a warning light and a tone activated immediately after the vehicle is started and continues for 4 to 8 seconds if a driver is not belted, with the light persisting for at least 60 seconds.

The extent to which the basic seat belt reminder increases seat belt use is unknown. However, the basic belt reminder is believed to be relatively ineffective because motorists tend to ignore the brief system display. With the goal of further increasing seat belt use, a number of automobile manufacturers have designed enhanced seat belt reminders (ESBR) that exceed the Federally-mandated basic system by providing a more persistent warning to alert drivers when they are not belted. These ESBR systems have proven to be effective and are an important tool in the campaign to increase seat belt use.[5 6 7] Public attitudes towards the ESBR are generally positive, as those drivers whose main reasons for non-use of seat belts relate to forgetfulness or trip type say that the ESBR alerts are beneficial.[8 9]

In order to further develop and increase the penetration of ESBR in motor vehicles, NHTSA has contacted all the major vehicle manufacturers encouraging the installation of systems that extend beyond the basic four- to eight-second requirement. NHTSA also continues to compile information on each ESBR system since each manufacturer has designed a unique system with distinctive acoustic and or visual displays.

The observational belt use study described in this preliminary report was undertaken to investigate the effectiveness and acceptability of all known ESBR systems and to better understand which ESBR characteristics are the most effective in influencing occupants to use seat belts. Additional related studies of ESBR acceptability and effectiveness presently being conducted by Westat include a field study of driver acceptance and potential effectiveness of different reminder system design features, and a study focused specifically on teen drivers. This report summarizes only the findings of the observational survey of seat belt use; the other reports will be released at the conclusion of those studies. A synthesis report for this task and the acceptability task is also underway.

The observational survey of seat belt use was conducted in September to October 2005. The study was limited to occupants of privately owned passenger cars, pickups, vans, and SUVs only – vehicles that appeared to be commercial vehicles and medium-large trucks were not included. The survey was conducted in eight cities at public locations where drivers' and front seat passengers' seat belt use were observed unobtrusively. Vehicle plate numbers were recorded and the corresponding vehicle identification numbers (VIN), make, model, and year were then identified from data supplied by State Departments of Motor Vehicles (DMV). The VIN, model year, make, and model were used to match the vehicles with their corresponding ESBR characteristics. With the cooperation of many of the vehicle manufacturers, NHTSA has compiled the ESBR characteristics of the majority of vehicles in the fleet for each make/model/year since ESBR systems were introduced in 1998. The preliminary analysis reported here focused on determining the effect of major ESBR types on seat belt use rates.

3. Methods

The observational survey of seat belt use was designed to efficiently obtain a relatively large number of observations of vehicles with ESBR systems as well as comparison vehicles. The

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[5] Krafft, Maria, Kullgren, Anders, Lie, Anders and Tingvall, Claes. *The Use of Seat Belts in Cars with Smart Seat Belt Reminders—Results of an Observational Study*. Traffic Injury Prevention, Vol 7: No. 2, June 2006.

[6] *Buckling Up: Technologies to Increase Seat Belt Use*, TRB Special Report 278, 2003.

[7] Williams, Allan F., Wells, JoAnn K., and Farmer, C.M. *Effectiveness of Ford's Enhanced Belt Reminder System in Increasing Seat Belt Use*, Injury Prevention 2002, 8:293-296.

[8] Eby, David W., Molnar, Lisa J., Kostyniuk, Lidia P. and Shope, Jean T. *Developing an Effective and Acceptable Safety Belt Reminder System*, Proceedings of the 19th International Technical Conference on the Enhanced Safety of Vehicles, June 2005.

[9] Harrison, Warren A., Senserrik, Teresa M. and Tingvall, Claes. *Development and Trial of a Method to Investigate the Acceptability of Seat Belt Reminder Systems*, MUARC and Vagverket Swedish National Road Administration, July 2000.

survey was conducted in 8 cities for up to 12 days in each of the locations. Nearly 55,000 vehicles were initially observed; 39,013 were included in the final analysis. Table 1 shows the impact of various stages of data cleaning and matching to VINs on the sample data ultimately available for analysis.

Table 1. Observation Records

Raw Observations	N= 54,554 Vehicles
Cleaned and Matched to VINS	N= 45,253 Vehicles
Matched to ESBR systems and No Missing Values for Key Predictor Variables	N= 39,013 Vehicles

3.1 Sample design and selection

The ideal population for this study would be all drivers and front seat occupants (not in child safety seats) of passenger cars, pickups, SUVs, and passenger vans in the United States and subject to the applicable FMVSS for seat belt warnings. For practical reasons such as cost and time, a more convenient sample frame was defined that would enable many observations of drivers and passengers in the targeted types of late-model vehicles with and without ESBRs while still enabling evaluation of ESBRs. Such an environment exists at centers of business and shopping in cities and their suburbs, where relatively high traffic volumes exist.

The survey was conducted in eight States, representing four geographical quadrants of the United States, with one primary and one secondary belt use law State in each quadrant. The four study quadrants were populated by assigning 2-4 of the 10 NHTSA regions in the continental United States to each quadrant. Within each quadrant, survey data collection sites were concentrated in one large urban area in each primary belt use law State and one secondary belt use law State, as follows:

- Northeastern Quadrant – New England, Eastern, Mid Atlantic, and Great Lakes NHTSA regions

  Primary: Greater Washington, DC, area and Maryland

  Secondary: Norfolk, Virginia

- Southern Quadrant – Southeast and South Central NHTSA regions

  Primary: San Antonio, Texas

  Secondary: Jacksonville, Florida

- Central Quadrant – Central and Rocky Mountain NHTSA regions

  Primary: Des Moines, Iowa

  Secondary: Kansas City, Missouri

- Western Quadrant – Northwest and Western NHTSA regions

  Primary: San Diego, California

  Secondary: Phoenix, Arizona

Data collection sites included shopping malls and centers, parking lots, office parks, and other commercial and business activity centers with high volumes of traffic. These sites enabled unbiased observations of large numbers of late-model vehicles according to the natural distribution in traffic that entered the selected facilities, and the presence or absence of belt reminder systems was not known in advance by the observers. Consequently, the survey population consisted of drivers and front seat passengers and the light vehicles they occupied while observed driving into the parking areas of office parks, shopping malls, shopping centers, other commercial activity centers and public parking lots in the Metropolitan Statistical Areas associated with the eight targeted cities. It is recognized that this focused sample would be considered somewhat biased if estimates were to be generalized to all vehicles and front seat occupants in the United States, in that it excluded vehicles operated in other environments, such as rural areas. Therefore, estimated effects apply only to the studied population.

Candidate sites were researched and selected using information from Internet research and conversations with local Chambers of Commerce. A list of primary and alternate sites was compiled for each city. All of the sites were mapped by Westat GIS staff, and Site Assignment Sheets with schedules were used by each data collection team. The daily schedule included up to four sites in close proximity to one another to minimize travel time between sites.

3.2 Data collection instrument

Paper forms were used to collect seat belt use and vehicle license plate numbers at the various assigned sites. Data collectors completed two types of forms: a site description form and the primary data collection form. The site description forms contained basic site data (e.g., weather, site name, site type, start time, end time, etc.). Data collectors completed a site description form each time they began data collection at a site for the first time that day. The site description forms were attached to the data collection forms.

The primary data collection form included the following data elements:

- driver and right front passenger seat belt use,
- driver and right front passenger age and gender, and
- vehicle license plate number and registration State.

The format of the form was one line per vehicle, eight vehicles per form. The forms were stapled in packets of 20, and each line in the packet was numbered from 1 to 160. The forms were mailed back on a daily basis.

3.3 Electronic logging of data collection

Each team was provided with a personal digital assistant (PDA) that provided an electronic log of the visits to all of the data collection sites. The PDA tracked the amount of time spent at each site and the team's exact location and was used to assist in the site logging and quality assurance procedures for each team.

3.4 Recruiting and training data collectors

Data collection was conducted in teams made up of a site coordinator, who served both as an observer and quality control (QC) monitor, plus an additional observer. Experienced field personnel were recruited from areas local to the data collection sites. All of the field staff had some experience in survey data collection and most of them had experience conducting occupant restraint surveys in the National Occupant Protection Use Survey (NOPUS) conducted annually by Westat for NHTSA.

The training sessions were held at the Westat office complex in Rockville, Maryland, for all of the data collectors. A training manual was provided to each observer. The training covered the following topics:

- required procedures,
- selection of appropriate observation locations,
- seat belt use observations,

- identification of vehicle types (private versus commercial),
- PDA applications,
- safety, and
- procedures for daily data submission.

Tips on how to observe seat belts through tinted windows or on difficult terrain were included. Trainees were also provided with booklets presenting detailed colored photos of license plates from their respective State and neighboring States to assist them in recognizing license plates. Information on how to record license plates correctly was discussed in depth. Data collectors were trained to observe only private vehicles.

The data collectors were trained to work together as a team. One of the team members served as the observer, who quietly communicated the observed items of information to the other team member, who recorded the observations on the data collection form. The data collectors were trained to divide the work prior to beginning data collection at each site.

The training emphasized how to select a suitable location at the data collection site for conducting observations. Criteria included:

- Ability to observe incoming traffic traveling at a slow speed or stopping prior to entering the site;
- Ability to stand at an angle that allowed for a plain view of the front seat occupants and the license plate from either the front, or the back of the vehicle; and
- A location allowing the observer and the recorder to be in proximity so that the recorder was able to hear the observer.

Trainees were provided with Site Assignment Sheets that listed and described each of the multiple sites within their State with a schedule of dates and times for data collection at each site. A list of alternative sites was also provided. Sites were scheduled in close proximity to minimize travel time. Teams were provided with detailed maps developed by GIS staff with each of the scheduled and alternate sites clearly marked. Teams were given time during training to review the maps.

The training also included a field training component at several local Rockville, Maryland, area malls and shopping centers. This gave the data collectors an opportunity to experience data collection in the field and to practice working together as a team.

3.5 Collecting data

Data collection took place in each of the 8 metropolitan areas for up to 12 days. The study was conducted while the teams stood at an entrance to the locations indicated on their Site Assignment sheets. The observations included driver and right front seat passenger restraint use, age, and gender, as well as the vehicle license plate number. The data was recorded on a paper form. A total of 54,554 observations were collected during the survey period.

At each site the data collectors began by identifying the location with the best possible vantage point to observe and record driver and right front passenger belt use and license plate number of each vehicle as it entered the premises. On arrival at each data collection site the QC monitor entered the site on the team's PDA.

Generally, data collection took place between 8 a.m. and 4 p.m. with approximately three sites visited each day. Sites were clustered on a daily basis in close geographic proximity in order to minimize travel time between sites throughout the day. If the team arrived at a site but was unable to collect data at that site, they were required to select an alternate site from the list provided to them.

Data collectors were provided with an authorization letter detailing the purpose of the study that they could show to individuals with questions. Data collectors were required to wear name badges and traffic vests at all times.

The QC monitors supervised team performance, answered questions, and responded to problems in the field. QC monitors were in contact with Westat project managers on a daily basis. At the end of each day QC monitors were responsible for reviewing the forms' legibility and to ship the forms via FedEx to Westat. The QC monitors also were responsible for transmitting data from the PDAs to Westat.

3.6 Data quality assurance procedures

The data were reviewed manually and processed on a daily basis at Westat. Data were entered by experienced data keyers using double entry verification. All data items and site description information were formatted into electronic files. The verification process validated that the data were collected in the correct place, at the right time, and for the correct amount of time. Westat applied various manual and electronic quality assurance procedures (e.g., range checks) to assess completeness, accuracy, and consistency of the data. These quality control procedures ensured that the statistical team was provided a clean data set for the preparation of weights and for data analysis.

3.7 Obtaining records from State DMVs

Prior to the data collection period, Westat staff contacted State agencies to gather information on the States' requirements and process to obtain vehicle records for the ESBR observational study. A letter from NHTSA was provided identifying the contractor performing the study and the objectives of the project. A data sharing agreement was established with each of the States.

Once the observational data from the field were compiled into State files Westat coordinated with the State agencies (e.g. DMVs) to acquire records for each of the vehicles observed including the make, model, year, and VIN. Wherever possible, license plate information was matched to State files whose creation date closely followed the end of the observation period.

3.8 Use of VIN decoder

Once the license plate data were verified by the State DMVs and a corresponding list of VIN numbers were provided the files were sent to NHTSA. Using a VIN decoder program, PC VINA, NHTSA provided the make, model, and year needed to establish which of the observed vehicles are equipped with ESBR and which are not.

3.9 Details of ESBRs

NHTSA and Westat staff compiled original equipment manufacturer's (OEM) information on the ESBR equipment installed in recent year (since 1998) makes and models of vehicles. ESBRs did not exist in the United States prior to 1998. Details on the unique ESBR characteristics are shown in Appendix A, Table A1. The ESBR characteristics of interest include information on:

- presence of ESBR by make, model, and year;
- activation onset threshold for vehicle speed, time, and travel distance;
- auditory display including sound type, cadence, and duration;
- visual display including icon type, appearance, and duration;
- text display including content and duration;

- duration of the system until timeout;
- post ESBR display state; and
- ability to permanently deactivate the system.

The table of ESBR attributes was matched with the data compiled on the observed vehicles using the VIN, make, model, and year to determine which vehicles are equipped with ESBRs, the type of ESBR installed, and the corresponding ESBR characteristics in each vehicle. Comparison vehicles with the NHTSA-required base system were also identified.

4. Data and methods

4.1 Data

The data collected for each vehicle in this study included both driver and front-seat passenger belt use, age and gender of driver and front-seat passenger, the day of week of the observation, and physical descriptors of the location where the observation was taken (type of site, weather conditions, urban/suburban/rural indicator). In addition, we know the State in which the observation was taken, and whether the State has a primary or secondary seat belt law. Table 2 describes the variables used in this analysis.

Some collapsing of categories was necessary, in order to make variables more useful**,** or due to the small number of observations falling into some categories. For example, for Year of Vehicle Manufacture, all vehicles of model year 1994 and earlier were combined in a single value. Note that even though the first ESBR was introduced in 1998, earlier model year observations were valuable to improve the modeling of the effect of vehicle age on belt use. As Table D1 in Appendix D shows, the percentage of vehicles with an ESBR system increased from 1998 with a concurrent drop in the percentage of vehicles without an ESBR system. Large numbers of vehicles both with and without an ESBR were present only for a few years. Restricting the analyses to model years in which there were large numbers of vehicles with and without ESBRs and ignoring other model years would have substantially cut the sample size of ESBR vehicles and eliminated about 80 percent of the non-ESBR vehicles. Instead of eliminating model years in which both vehicles with and without ESBRs were common, we chose to explicitly model the effect of vehicle age on belt use by including model year as one of the potential predictors of belt use in the logistic regression models for estimating belt use probability (see Appendix D). We grouped pre-1994 vehicles because they were relatively uncommon, and also because among these older vehicles belt use rates depended little on the precise age of the vehicle.

The type of seat belt reminder system installed in the vehicle, and the details of each system, in terms of sound, text, and icon features, were obtained by combining records of each observed vehicle's make, model and year obtained from DMV license plate matches with the records of ESBR system characteristics by make, model and model year obtained from manufacturers and other sources. Table 2 shows the frequencies of occurrence of each seat belt reminder system in the sample. Several manufacturers have multiple systems, each with different characteristics, so the systems must be considered separately. Each system has its own designation in Table 3. Note that although manufacturer's names are encoded in keeping with confidentiality agreements, system characteristics are shown in Appendix A.

Table 2. List of Variables Used for Analysis

VARIABLE	VALUES	TYPE
Driver Restraint Use	1= Yes 2= No	Outcome
Passenger Restraint Use	1= Yes 2= No	
Presence of an ESBR	1= Yes 2= No	
Type of ESBR System	(collapsed – see Table 4)	
Day of Week	Day	Potential Confounder
Type of Site (collapsed)	1,2 = Shopping Mall, Shopping Center 3 = Office Park 4 = Parking Lot 5, 6 = Sports Arena & Other	Potential Confounder
Weather Conditions (collapsed)	1,2= Light Precipitation, Light Fog 3= Clear	Potential Confounder
Type of Area (collapsed)	1= Urban 2, 3= Suburban, Rural	Potential Confounder
Driver Sex	1= Male 2= Female	Potential Confounder
Driver Age	1= Young (16-24) 2= Adult (25-69) 3= Senior (70+)	Potential Confounder
Presence of Front Seat Passenger	1= Yes 2= No	Potential Confounder
Passenger Sex	1= Male 2= Female	Potential Confounder
Passenger Age	1= Young (16-24) 2= Adult (25-69) 3= Senior (70+)	Potential Confounder
State	CA, FL, IA, KS, MD, MO, TX, VA	Potential Confounder
Seat Belt Use Law in State	1= Primary 2= Secondary	Potential Confounder
Year of Vehicle Manufacture	1994 and earlier were collapsed into one group*	Potential Confounder

* Assumed there was little change on effect of age on belt use for vehicles more than 10 years old at time of observation

Table 3. Frequency of ESBR in the Sample

SYSTEM NAME	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Base System	27,477	70.43	27,477	70.43
Manuf. A System 1	56*	0.14	27,533	70.57
Manuf. A System 2	73*	0.19	27,606	70.76
Manuf. B System 1	1,005	2.58	28,611	73.34
Manuf. C System 1	3,107	7.96	31,718	81.30
Manuf. D System 1	443	1.14	32,161	82.44
Manuf. D System 2	386	0.99	32,547	83.43
Manuf. D System 3	51*	0.13	32,598	83.56
Manuf. D System 4	23*	0.06	32,621	83.62
Manuf. E System 1	953	2.44	33,574	86.06
Manuf. E System 2	88*	0.23	33,662	86.28
Manuf. F System 1	49*	0.13	33,711	86.41
Manuf. F System 2	45*	0.12	33,756	86.53
Manuf. G System 1	1,683	4.31	35,439	90.84
Manuf. G System 2	6*	0.02	35,445	90.85
Manuf. H System 1	20*	0.05	35,465	90.91
Manuf. H System 2	9*	0.02	35,474	90.93
Manuf. I System 1	3,356	8.60	38,830	99.53
Manuf. I System 2	47*	0.12	38,877	99.65
Manuf. J System 1	83*	0.21	38,960	99.86
Manuf. J System 2	53*	0.14	39,013	100.00

* Belt use rates can’t be reliably estimated because of small sample size

As can be seen in Table 3, many of the systems occur only rarely in the sample. For the purposes of this analysis, collapsing was done to form one set of 6 simple grouping that are relatively homogeneous with respect to their features, and a second set of 12 more detailed groupings. The basis for the collapsed groupings is shown in Table 4. Table 5 shows which systems are represented in each collapsed grouping and the frequency of the systems. Specific characteristics for each ESBR system are shown in Appendix A.

Table 4. Collapsed System Groupings Details

SYSTEM GROUP NAME	BASIC CHARACTERISTICS
SIMP1	Base System
SIMP2	Enhanced Icon Only
SIMP5	Enhanced Icon and Sound Only
SIMP6	Enhanced Icon and Text Only
SIMP7	Enhanced Sound and Text Only
SIMP8	Enhanced Icon, Sound and Text
DETL1	Base System
DETL2	Enhanced Icon Only • Icon is Continuous
DETL3	Enhanced Icon Only • Icon is Flashing
DETL4	Enhanced Icon and Sound Only • Icon is Continuous • Sound is Chime
DETL5	Enhanced Icon and Sound Only • Icon is Flashing • Sound is Chime
DETL6	Enhanced Icon and Sound Only • Icon is Flashing • Sound is Buzzer
DETL7	Enhanced Icon and Sound Only • Icon is Continuous and Flashing • Sound is Chime
DETL8	Enhanced Icon and Text Only • Icon is Continuous • Passenger Text
DETL9	Enhanced Sound and Text Only • Sound is Chime • Driver and Passenger Text
DETL10	Enhanced Icon , Sound and Text • Icon is Continuous • Sound is Chime • Driver and Passenger Text
DETL11	Enhanced Icon , Sound and Text • Icon is Flashing • Sound is Chime • Driver Text
DETL12	Enhanced Icon , Sound and Text • Icon is Flashing • Sound is Buzzer • Passenger Text

Table 5. Frequency of Collapsed System Groupings

SIMPLE GROUP	DETAILED GROUP	Systems in Group	Frequency	Percent	Cumulative Frequency	Cumulative Percent
SIMP1	**DETL1**	Base System	27,477	70.43	27,477	70.43
SIMP2	**DETL2**	Manuf. D System 4, Manuf. G System 1, Manuf. G System 2, Manuf. H System 2	1,721	4.41	29,198	74.84
SIMP2	**DETL3**	Manuf. I System 1	3,356	8.60	32,554	83.44
SIMP5	**DETL4**	**Manuf. A System 1***	**56**	**0.14**	**32,610**	**83.59**
SIMP5	**DETL5**	Manuf. C System 1, Manuf. E System 1	4,060	10.41	36,670	93.99
SIMP5	**DETL6**	**Manuf. F System* 1, Manuf. I System 2***	**96**	**0.25**	**36,766**	**94.24**
SIMP5	**DETL7**	Manuf. B System 1, Manuf. D System 3	1,056	2.71	37,822	96.95
SIMP6	**DETL8**	**Manuf. H System 1***	**20**	**0.05**	**37,842**	**97.00**
SIMP7	**DETL9**	Manuf. D System 1, Manuf. D System 2	829	2.12	38,671	99.12
SIMP8	**DETL10**	Manuf. A System 2, Manuf. J System 1, Manuf. J System 2	209	0.54	38,880	99.66
SIMP8	**DETL11**	**Manuf. E System 2***	**88**	**0.23**	**38,968**	**99.88**
SIMP8	**DETL12**	**Manuf. F System 2***	**45**	**0.12**	**39,013**	**100.00**

* Belt use rates can't be reliably estimated because of small sample size

The initial dataset consisted of 54,554 observations, of which 45,253 vehicle records were matched to VINs (see Table 1). The final dataset for analysis contained 39,013 vehicle observations, after removing 6,240 observations (4,657 with unknown seat belt reminder system, 157 where the driver or passenger belt use was not ascertained, and 1,426 were missing values for key predictor variables (Site Type, Weather, Driver Age and Gender, and Passenger Age and Gender)).

4.2 Methods

There are two research questions addressed in this analysis:

1. What is the effect on seat belt use of having an ESBR system, relative to the base system? Analysis is done for ESBR systems overall, and for individual groupings of ESBR systems.
2. What is the effect of individual ESBR system characteristics (sound, icon, and text features) on belt use?

The first question has been addressed with respect to the effects on both driver and passenger belt use, and overall. Given the much smaller passenger sample sizes, we have not attempted to investigate the individual ESBR characteristics for passengers.

4.2.1 Controlling for confounding factors

A key challenge in estimating the effect of ESBRs on belt use was to control for the effect of factors that could have influenced both driver belt use *and* choice of vehicle by drivers. Failing to control for the effect of such factors could have biased the estimated effect of ESBRs. For example, if young drivers drove a disproportionate share of vehicles with a certain type of ESBR and also had a tendency to buckle up less frequently than older drivers, an analysis that failed to account for driver age might mistakenly conclude that the system which young drivers 'preferred' was less effective than other systems. To avoid such *confounding* of the *treatment* effect (i.e., type of ESBR) with the effect of one or more *covariates* (e.g., driver age) on the outcome (i.e., belt use), the effect of the potential confounders needs to be statistically controlled. When there are many potential confounders, explicitly including all of them in a regression model may not be practical for a variety of reasons.[10]

An alternative strategy for controlling for the effect of confounders is to group the observations on their *propensity* for having the treatment.[11] The propensity for belt use was defined as the probability that the driver or passenger of the observed vehicle wore a seat belt. The propensity scoring methodology makes it possible to control for observed factors related seat belt use. With this approach, the propensity for wearing a seat belt was estimated as a function of the potential confounders of the effect of ESBRs on belt use. The approach is described below.

Step 1. Stepwise logistic regression was used to estimate the probability of seat belt use, in terms of the potential confounders identified previously in Table 2. The selected variables included in the final model are presented in Table 6. This procedure was repeated separately for drivers, passengers, and all occupants. The full details of the logistic regression model are presented in Appendix B.

Step 2. Observations were grouped into five groups, or *quintiles,* using predicted seat belt use propensities. This was done separately for drivers, right front passengers, and all occupants (drivers and front seat passenger combined).

Step 3. The propensity models were tested for the property of *balance*. As explained by Rosenbaum and Rubin (1983), if a partition of observations possesses the balance property, treatment assignment within quintiles can be treated as if treatment had been randomly assigned. By definition, balance is achieved when realized treatment assignment (i.e., wearing or not wearing a seat belt) is statistically independent of the potential confounders. Quintiles were tested for balance and, when needed, the initial models were enriched by interactions among the more important characteristics. *After balance was achieved, seat belt use was treated as if it had been randomly assigned within quintiles.*

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[10] Two of the more important among these are that the functional form of the confounder's effect on the outcome may not be known, and sample size may be inadequate for accounting for all variables. Note that if there are 6 covariates with 3 levels each, a table that included all combinations of the 6 variables would have $3^6 = 729$ cells.

[11] Details of this method are described in Rosenbaum, O. and Rubin, D. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70, 41-55.

Table 6. Seat Belt Use Model Variables

Predictor Variables	Modeled group		
	Overall	Driver	Passenger
Year of Manufacture	X	X	X
Age (Driver)	X	X	X
Gender (Driver)	X	X	X
Law	X		X
State (AZ)	X		X
State (CA)	X		
State (FL)	X	X	X
State (IA)	X	X	X
State (KS)		X	
State (MD)		X	
State (MO)		X	
State (TX)	X	X	X
State (VA)		X	
Area	X	X	
Site Type	X	X	
Passenger Present	X	X	
Driver (Yes/No)	X		

4.2.2 Estimating ESBR effect on seat belt use

A major concern is that any association between driver belt use and ESBR system may be due, in part, to occupant/observation characteristics that affect both belt use and vehicle choice. For instance, if young people tend to drive small cars and are less likely to wear their belts than other drivers, then it may appear that restraint system reminders in small cars are relatively poor. This bias is reduced, or perhaps avoided, if the analyses are performed controlling for seat belt propensity quintile.

Analyses were performed to estimate the effect of ESBR relative to the base system, controlling for quintile. For details on how these effects were determined, see Appendix C.

4.2.3 Estimating effect of individual ESBR features on seat belt use

ESBR systems represent various combinations of sound, icon, and text features. The analysis compared the effects on belt use of different combinations of these three features. It also estimated the effects of individual characteristics of these features, such as the complete duration of the sound, icon and text features, the type of sound, and the icon appearance. Table 7 below outlines the full list of individual ESBR characteristics considered in this analysis.

Table 7. Definitions of Variables Related to Individual ESBR Features

Variable	Description	Values
Any ESBR	Indicator of whether the vehicle has any ESBR system installed	1= ESBR vehicle 0= Otherwise
Icon	Indicator of whether the vehicle has an ESBR system with Icon	1= ESBR vehicle with Icon 0= Otherwise
Sound	Indicator of whether the vehicle has an ESBR system with Sound	1= ESBR vehicle with Sound 0= Otherwise
Text	Indicator of whether the vehicle has an ESBR system with Text	1= ESBR vehicle with Text 0= Otherwise
Icon Only	Indicator of whether the vehicle has an ESBR system with Icon but no Sound or Text	1= ESBR vehicle with Icon **only** 0= Otherwise
Sound and Icon	Indicator of whether the vehicle has an ESBR system with both Sound and Icon	1=ESBR vehicle with Sound **and** Icon 0=Otherwise
Sound and Icon Only	Indicator of whether the vehicle has an ESBR system with both Sound and Icon, but no Text	1=ESBR vehicle with Sound **and** Icon, but no Text 0=Otherwise
Sound and Text	Indicator of whether the vehicle has an ESBR system with both Sound and Text	1=ESBR vehicle with Sound **and** Text 0=Otherwise
Sound and Text Only	Indicator of whether the vehicle has an ESBR system with both Sound and Text, but no Icon	1=ESBR vehicle with Sound **and** Text, but no Icon 0=Otherwise
Sound, Icon and Text	Indicator of whether the vehicle has an ESBR system with Sound, Icon, and Text	1=ESBR vehicle with Sound, Icon, **and** Text 0=Otherwise
Complete Sound Duration	Complete Sound Duration – for the enhanced system phase	Number of seconds
Interval between Sound Cycles	Interval between Sound Cycles – during the enhanced system phase	Number of seconds
Single Cycle Sound Duration	Single Cycle Sound Duration – during the enhanced system phase	Number of seconds
Sound Cadence	Sound Cadence – for the enhanced system	0 = NA 1= Uniform 2= Rise 3= Uniform or Intermittent

Variable	Description	Values
Sound Type	Sound Type – for the enhanced system	0= NA 1= Chime 2= Buzzer 3= Chime or Buzzer
Total Number of Sound Cycles	The number of sound cycles occurring during the complete sound duration (SNDDURAT)	The smallest integer at least as large as the ratio: SNDDURAT/(SCSNDDUR+IBSNDCYL)
Proportion of Time Sound is Emitted	The proportion of the complete sound duration (SNDDURAT) in which sound is emitted	SNDMaxFreq*SCSNDDUR/SNDDURAT
Complete Icon Duration	Complete Icon Duration – for the enhanced system phase	Number of seconds
Interval between Icon Cycles	Interval between Icon Cycles – during the enhanced system phase	Number of seconds
Single Cycle Icon Duration	Single Cycle Icon Duration – during the enhanced system phase	Number of seconds
Icon Appearance	Icon Appearance – for the enhanced system phase	0= NA 1= Continuous 2= Flashing 3= Continuous and Flashing
Total Number of Icon Cycles	The number of icon cycles occurring during the complete icon duration (ICNDURAT)	The smallest integer at least as large as the ratio: ICNDURAT/(SCICNDUR+IBICNCYL)
Proportion of Time Icon is Displayed	The proportion of the complete icon duration (ICNDURAT) with an icon displayed	ICNMaxFreq*SCICNDUR/ICNDURAT
Complete Text Duration	Complete Text Duration – for the enhanced system phase	Number of seconds
Interval between Text Cycles	Interval between Text Cycles – during the enhanced system phase	Number of seconds
Single Cycle Text Duration	Single Cycle Text Duration – during the enhanced system phase	Number of seconds
Total Number of Text Cycles	The number of text cycles occurring during the complete text duration (TXTDURAT)	The smallest integer at least as large as the ratio: TXTDURAT/(SCTXTDUR+IBTXTCYL)
Proportion of Time Text is Displayed	The proportion of the complete text duration (TXTDURAT) with text displayed	TXTMaxFreq*SCTXTDUR/TXTDURAT

5. Results

5.1 ESBR systems

Table 8 presents the sample sizes and observed percentage of driver seat belt use for all observations, for base system (non-ESBR) vehicles and for each of the ESBR system groups, for all front seat occupants, and separately for drivers and passengers. The system names in Table 8 correspond to the system groupings in Tables 4 and 5. Overall belt use was 86.2 percent, which is slightly higher than the national average of 82-83 percent but not unexpected since half of the sites had primary belt use laws and only one site was in a rural area where low belt use pulls down the national average. Occupants of vehicles without ESBRs (base system) were belted in 84.9 percent of observations, while belt use in ESBR vehicles was in the 85-94 percent range depending on system type.

Table 8. Observed Percentage Belt Use by ESBR System and Occupant Group (All, Driver, Passenger)

	Drivers (1)		Passengers (2)		All (1+2)	
System	%	N	%	N	%	N
Overall	86.5	39,013	84.9	8,784	86.2	47,797
Base System	85.3	27,477	83.3	6,118	84.9	33,595
DETL2	87.0	1,721	82.9	340	86.4	2,061
DETL3	90.9	3,356	91.5	739	91.0	4,095
DETL4	*98.2	56	*100	10	*98.5	66
DETL5	89.6	4,060	87.7	980	89.2	5,040
DETL6	*93.8	96	*100	14	94.5	110
DETL7	91.6	1,056	89.0	301	91.0	1,357
DETL8	*90.0	20	.	.	*90.0	20
DETL9	84.3	829	85.9	206	84.6	1,035
DETL10	91.4	209	*93.5	46	91.8	255
DETL11	*90.9	88	*95.0	20	91.7	108
DETL12	*91.1	45	*80.0	10	*89.1	55
SIMP2	89.6	5,077	88.8	1,079	89.5	6,156
SIMP5	90.1	5,268	88.2	1,305	89.8	6,573
SIMP6	*90.0	20	.	.	*90.0	20
SIMP7	84.3	829	85.9	206	84.6	1,035
SIMP8	91.2	342	*92.1	76	91.4	418

* Estimates are not reliable because of the small sample size.

Table 9 presents the estimated effects of each ESBR system on seat belt use. The numbers in the table represent the estimated increase in the proportion of seat belt users if all vehicles had an ESBR system, compared to the case where none of the vehicles had an ESBR system. A three-step procedure was used to estimate the seat belt use rate assuming all vehicles had an ESBR.

Step 1. We estimated belt use probability as a function of the predictor variables in Table 6 using the procedure described in Section 4.2.1, and used the seat belt use probability estimates to partition each of the occupant groups, drivers, passengers, and all occupants, into five approximately equal-sized groups, or quintiles. Assuming that having an ESBR in a vehicle has no effect on seat belt use, the proportion of vehicles with an ESBR would be the same in each quintile as the proportion of vehicles with a base system.

Step 2. To estimate seat belt use proportions assuming all vehicles had an ESBR (p2), we calculated the weighted average of belt use rates in quintiles 1, 2, 3, 4, and 5 using the proportions of vehicles with an ESBR in these quintiles. To estimate seat belt use proportions assuming all vehicles had a base system (p1), we calculated the weighted average of belt use rates in quintiles 1, 2, 3, 4, and 5 using the proportions of vehicles with a base system in these quintiles (For details, see Appendix C).

Step 3. We calculated the difference between the two proportions, p2-p1, to estimate the effect of having an ESBR in every vehicle relative to having a base system in every vehicle. For each cell in Table 9, we calculated a chi-square statistic with 4 degrees of freedom to test the statistical hypothesis that the distribution by quintile of vehicles with an ESBR was not different from the corresponding distribution by quintile of vehicles with a base system. The chi-square test statistics and associated p-values were calculated to assess statistical significance for ESBRs in Table 9. All p-values were small (<0.001), indicating that the ESBR and non-ESBR vehicles had different distributions across the quintiles

Each of the ESBR systems has a positive and statistically significant ($p<0.001$) effect on seat belt use, for both drivers and passengers. For example, the presence of ESBR systems would increase driver seat belt use by an estimated 3.2 percentage points, and passenger seat belt use by 3 percentage points. Thus, if driver seat belt use assuming no ESBR vehicles was 85.3 percent, we would expect this to increase to 88.5 percent if all vehicles had an ESBR system.

Note that ESBR system groups with small sample sizes have not been analyzed separately, but have been included in the Overall figure. Note also that SIMP7 and DETL9 refer to the same ESBR system group.

Table 9. Effect of ESBR Systems on Seat Belt Use by ESBR System and Occupant Group (Driver, Passenger, Overall)

System	Driver Effect	Passenger Effect	Occupant Effect
SIMP2	3.2%	2.8%	3.3%
SIMP5	3.1%	3.0%	3.2%
SIMP7	3.9%	4.1%	4.1%
DETL2	2.5%	1.8%	2.6%
DETL3	3.6%	3.2%	3.7%
DETL5	2.9%	2.8%	2.9%
DETL7	3.9%	3.6%	4.1%
DETL9	3.9%	4.1%	4.1%
Overall	3.2%	3.0%	3.3%

5.2 ESBR system characteristics

The effects of specific ESBR system characteristics and combinations of system characteristics on belt use were investigated three different ways. All comparisons were performed within quintile, and all comparisons were implemented using logistic regression. Tables 10 and 11 provide the details of the various ESBR features or characteristics that were analyzed. Tables 12 and 13 present the results of this analysis. First, ESBRs with nine specific feature combinations, and with any of the nine combinations, (see Table 12) were compared to the base system. Second, we compared ESBR systems with four characteristic combinations (ICON_ONLY, SOUND_ICON, SOUND_ICON_TEXT, and SOUND_TEXT) to the rest of the vehicles with all other combination of ESBRs. For instance we compared vehicles with SOUND_ICON to vehicles that had ESBRs other than just SOUND_ICON (see Group '1. Overall' in Table 12). Third, we compared vehicles by the levels of ESBR features within the categories of sound, icon, and text (see Table 13). For instance we compared ESBRs with sound by the duration of the sound.

Tables 10 and 11 present the distributions of the various ESBR characteristics. For characteristics with six or more levels, the mean, standard deviation, and range are presented (Table 10). For those characteristics with less than 6 levels, the frequency counts for each level are presented (Table 11).

Table 10. Distribution of Individual Characteristics Among Vehicles With the Corresponding Feature (Sound, Icon, or Text) For Characteristics With Six or More Levels

Variable (See Table 6 for Description)	N	Mean	Std Dev	Minimum	Maximum
Complete Sound Duration (sec)	6,439	271.98	152.28	3.00	540.00
Single Cycle Sound Duration (sec)	6,439	21.51	34.21	3.00	96.00
Interval between Sound Cycles (sec)	6,439	35.88	51.53	0.00	248.00
Proportion of Time Sound is Emitted (decimal fraction)	6,439	0.37	0.36	0.03	1.00
Total Number of Sound Cycles	6,439	7.50	4.82	1.00	15.00
Complete Icon Duration (sec)	10,707	634.91	364.92	90.00	999.00
Single Cycle Icon Duration (sec)	10,707	5.05	10.93	1.00	90.00
Proportion of Time Icon is Displayed (decimal fraction)	10,707	0.42	0.23	0.17	1.00
Total Number of Icon Cycles (integer)	10,707	246.91	243.72	1.00	500.00
Complete Text Duration (sec)	1,191	162.18	182.92	6.00	999.00

Table 11. Distribution of Individual Characteristics Among Vehicles With Corresponding Feature (Sound, Icon, or Text) For Characteristics With Less Than Six Levels

Sound Cadence	All ESBRs With SOUND	Sound Cadence	
		1=Uniform	2=Rise
Frequency	6,439	6,392	47

Sound Type	All ESBRs With SOUND	Sound Type	
		1=Chime	2=Buzzer
Frequency	6,439	6,298	141

Interval Between Icon Cycles	All ESBRs With ICON	Interval between Icon Cycles			
		1 sec	3 sec	30 sec	180 sec
Frequency	10,707	6,414	94	4,148	51

Icon Appearance	All ESBRs With ICON	Icon Appearance		
		1=Continuous	2=Flashing	3=Continuous and Flashing
Frequency	10,707	2,006	7,645	1,056

Interval Between Text Cycles	All ESBRs With TEXT	Interval between Text Cycles			
		No interval	3 sec	30 sec	180 sec
Frequency	1,191	615	45	88	443

Single Cycle Text Duration	All ESBRs With TEXT	Single Cycle Text Duration				
		1 sec	5 sec	6 sec	27 sec	90 sec
Frequency	1,191	20	133	136	829	73

Proportion of Time Text is Displayed	All ESBRs With TEXT	Proportion of Time Text is Displayed			
		0.15	0.23	0.65	1.00
Frequency	1,191	88	443	45	615

Total Number of Text Cycles	All ESBRs With TEXT	Total Number of Text Cycles				
		1	2	12	16	999*
Frequency	1,191	595	443	45	88	20

* 999 indicates display continues until seat belt is buckled.

5.2.1 Effects of ESBR feature relative to Non-ESBR vehicles

Table 12 presents the estimated effects of individual ESBR system features on seat belt use. The effects are analyzed by propensity quintile (P-group). Table 12 compares driver seat belt use in ESBR vehicles having a particular characteristic to non-ESBR (base system) vehicles. The 'Estimate' value refers to the coefficient of that feature in the model. If the value is positive, it indicates that the presence of the feature has a positive effect on driver seat belt use. More importantly, this effect is only considered statistically significant if the P-Value is less than a given value (typically 0.05). The statistically significant results are shaded in the table.

What is most evident from the table is that the greatest effects on driver seat belt use are in P-Group=1, which is the group of vehicles with the lowest percentage of seat belt use, and therefore has the most potential for improvement. Seven of the ten ESBR feature groups showed significant effects in P-Group 1, with six of the effects positive relative to drivers in non-ESBR vehicles (SOUND_TEXT_ONLY had a negative effect). In P-Group 2, there were four ESBR feature groups with significant effects (again SOUND_TEXT_ONLY was negative). P-Group 3 had three ESBR feature groups with significant effects (TEXT, SOUND_TEXT, and SOUND_TEXT_ONLY), all of which were negative. In P-Groups 1 and 2, TEXT and SOUND_TEXT had not had significant effects.

A somewhat puzzling result is that the presence of an ESBR text feature has a negative effect on seat belt use. However, text was a feature on certain full-size pickup trucks, which are known to have lower belt use rates, thus the vehicle type may have confounded the results.

5.2.2 Effects of ESBR Features relative to other ESBR vehicles

In Table 13, base system vehicles are excluded from the analysis, and the effect on driver seat belt use of individual ESBR characteristics is compared to that of all other ESBR vehicles. The statistically significant results are shaded in the table. As with the previous table, all of the significant effects on driver seat belt use occur in the lower P-Groups.

For the 'Overall' group, all ESBR vehicles are included in the analysis. So, for example, the Sound and Icon row compares the effectiveness of ESBR systems with Sound **and** Icon features to ESBR systems that do not have both Sound and Icon features. In the lowest P-group, the Estimate is positive, and the P-value is less than 0.05, which indicates that ESBR vehicles with both Sound and Icon features more effectively increase seat belt use than other ESBR vehicles.

For the 'Sound', 'Icon', and 'Text' groups, only vehicles with that particular feature (sound, icon, or text) are included in the analysis. So, for example, the Complete Sound Duration row compares the effectiveness of different levels of Complete Sound Duration on seat belt use, among all ESBR vehicles with a Sound feature. In the lowest P-group, the Estimate is positive, and the P-value is less than 0.05, so we can say that in that P-group, there is a positive correlation between the complete sound duration (Complete Sound Duration), and driver seat belt use.

Note that in Group 1-OVERALL in Table 13, it would appear that 7,123 vehicles had at least a "Sound" feature, 11,029 had at least an "Icon" feature, and 1,513 had at least a "Text" feature. These numbers do not match the "Frequency of vehicles with feature" for Groups 2, 3 and 4 because the categories in the OVERALL Group are not mutually exclusive. For example, SOUND_ICON and SOUND_TEXT both include vehicles with sound, icon, and text. To calculate the number of vehicles with at least sound, we need to add SOUND_ICON (5,610) and SOUND_TEXT (1,171) and subtract SOUND_ICON_TEXT (342). The various combinations of individual features are tabulated below:

SOUND	TEXT	ICON	Frequency	Cum Freq
0	0	1	5,077	5,077
0	1	1	20	5,097
1	0	1	5,268	10,365
1	1	0	829	11,194
1	1	1	342	11,536

Effects shown in Tables 12 and 13 often differ. This is because the effects in Table 12 are relative to vehicles without ESBR features (base system), and those in Table 13 are relative to vehicles with other ESBRs. For instance, in Quintile 1, ESBRs with ICON_ONLY had a significant positive effect (increased belt use) relative to the base system, but they were associated with a non-significant effect in belt use relative to vehicles with other types of ESBRs. This merely demonstrates that some ESBR features or sets of features perform better than others.

Note that there is no a priori reason to conclude that increased values of a variable are associated with increased belt use. For instance, one might reasonably believe that as a beeping warning becomes more of a continuous tone, sound effectiveness decreases, at least to a certain extent. In terms of the values of the variable *Proportion of time sound is emitted* increases, it is reasonable to speculate that, other things being equal, uninterrupted sound (e. g. Proportion = 1) is less effective than repeatedly interrupted sound (Proportion less than 1).

Table 12. Individual Characteristic Effects on Driver Seat Belt Use Within Propensity Stratum, Compared to Base Systems

	Freq of Vehicles With Feature	Quintile (Driver Belt Use Percentage for ALL vehicles)														
		1 (73.6%)			**2** (83.1%)			**3** (88.5%)			**4** (92.1%)			**5** (95.4%)		
		Est	**P-Val**	**n**	**Est**	**P-Val**	**n**	**Est**	**P-Val**	**n**	**Est**	**P-Val**	**n**	**Est**	**P-Val**	**n**
ESBR features																
0. esbrANY	11,536	0.29	<.05	1325	0.13	>.05	1988	0.01	>.05	2304	0.02	>.05	2240	-0.04	>.05	3679
1. ICON	10,707	0.35	<.05	1258	0.18	<.05	1846	0.09	>.05	2109	0.06	>.05	2091	-0.05	>.05	3403
2. SOUND	6,439	0.36	<.05	651	0.14	>.05	1171	0.01	>.05	1439	-0.04	>.05	1224	-0.13	>.05	1954
3. TEXT	1,191	-0.27	>.05	100	-0.21	>.05	210	-0.48	<.05	248	-0.26	>.05	218	-0.13	>.05	415
4. ICON_ONLY	5,077	0.22	<.05	672	0.11	>.05	814	0.02	>.05	859	0.11	>.05	1011	0.07	>.05	1721
5. SOUND_ICON	5,610	0.52	<.05	584	0.24	<.05	1029	0.14	>.05	1244	0.03	>.05	1075	-0.16	>.05	1678
6. SOUND_ICON_ONLY	5,268	0.51	<.05	553	0.23	<.05	964	0.14	>.05	1197	0.01	>.05	1011	-0.13	>.05	1543
7. SOUND_TEXT	1,171	-0.30	>.05	98	-0.22	>.05	207	-0.48	<.05	242	-0.23	>.05	213	-0.14	>.05	411
8. SOUND_TEXT_ONLY	829	-0.64	<.05	67	-0.41	<.05	142	-0.62	<.05	195	-0.46	>.05	149	0.03	>.05	276
9. SOUND_ICON_TEXT	342	0.67	>.05	31	0.27	>.05	65	0.34	0.5224	47	0.57	>.05	64	-0.43	>.05	135

Table 13. Individual Characteristic Effects on Driver Seat Belt Use within Propensity Stratum, EXCLUDING Base Systems from the Comparison

		Freq of Vehicles With Feature	Quintile (Driver Belt Use Percentage for ESBR vehicles)														
			1 (78.0%)			2 (84.5%)			3 (88.6%)			4 (92.2%)			5 (95.4%)		
			Est	P-Val	n	Est	P-Val	n	Est	P-Val	n	Est	P-Val	n	Est	P-Val	n
Group	Variable																
1. OVERALL	ICON_ONLY	5,077	-0.15	>.05	672	-0.04	>.05	814	0.01	>.05	859	0.15	>.05	1011	0.20	>.05	1721
	SOUND_ICON	5,610	0.39	<.05	584	0.21	>.05	1029	0.27	<.05	1244	0.02	>.05	1075	-0.22	>.05	1678
	SOUND_ICON_TEXT	342	0.39	>.05	31	0.14	>.05	65	0.33	>.05	47	0.56	>.05	64	-0.40	>.05	135
	SOUND_TEXT	1,171	-0.65	<.05	98	-0.40	<.05	207	-0.56	<.05	242	-0.29	>.05	213	-0.11	>.05	411
2. SOUND	IBSNDCYL	6,439	-0.001	>.05	651	-0.003	<.05	1171	-0.004	<.05	1439	-0.003	>.05	1224	-0.0001	>.05	1954
	SCSNDDUR	6,439	-0.001	>.05	651	0.01	<.05	1171	0.004	>.05	1439	0.005	>.05	1224	0.003	>.05	1954
	SNDDURAT	6,439	0.002	<.05	651	0.0003	>.05	1171	0.001	>.05	1439	0.0002	>.05	1224	-0.001	>.05	1954
	SNDDensity	6,439	-0.72	<.05	651	0.20	>.05	1171	0.01	>.05	1439	0.39	>.05	1224	0.48	>.05	1954
	SNDMaxFreq	6,439	0.07	<.05	651	0.01	>.05	1171	0.03	>.05	1439	0.01	>.05	1224	-0.03	>.05	1954
	SND_CAD	6,439	10.98	>.05	651	-0.61	>.05	1171	-0.11	>.05	1439	9.92	>.05	1224	9.40	>.05	1954
	SND_TYP	6,439	10.99	>.05	651	0.50	>.05	1171	-0.39	>.05	1439	0.31	>.05	1224	9.41	>.05	1954
3. ICON	IBICNCYL	10,707	0.01	>.05	1258	-0.005	>.05	1846	0.001	>.05	2109	-0.002	>.05	2091	-0.002	>.05	3403
	ICNDURAT	10,707	-0.0004	>.05	1258	-0.0002	>.05	1846	-0.0001	>.05	2109	0.0001	>.05	2091	0.0002	>.05	3403
	ICNDensity	10,707	-0.55	>.05	1258	0.38	>.05	1846	0.01	>.05	2109	0.48	>.05	2091	0.62	>.05	3403
	ICNMaxFreq	10,707	-0.001	<.05	1258	-0.0003	>.05	1846	-0.0003	>.05	2109	0.0002	>.05	2091	0.001	>.05	3403
	ICONAPPR	10,707	0.31	<.05	1258	0.22	>.05	1846	0.17	>.05	2109	0.04	>.05	2091	0.17	>.05	3403
	SCICNDUR	10,707	-0.004	>.05	1258	0.001	>.05	1846	0.01	>.05	2109	0.02	>.05	2091	-0.001	>.05	3403

		Freq of Vehicles With Feature	Quintile (Driver Belt Use Percentage for ESBR vehicles)														
			1 (78.0%)			**2** (84.5%)			**3** (88.6%)			**4** (92.2%)			**5** (95.4%)		
			Est	**P-Val**	**n**	**Est**	**P-Val**	**n**	**Est**	**P-Val**	**n**	**Est**	**P-Val**	**n**	**Est**	**P-Val**	**n**
4. TEXT	**IBTXTCYL**	1,191	0.002	>.05	100	-0.001	>.05	210	-0.002	>.05	248	-0.004	>.05	218	-0.001	>.05	415
	SCTXTDUR	1,191	-0.02	>.05	100	-0.003	>.05	210	0.002	>.05	248	0.004	>.05	218	-0.01	>.05	415
	TXTDURAT	1,191	0.002	>.05	100	0.001	>.05	210	0.0002	>.05	248	-0.001	>.05	218	-0.0002	>.05	415
	TXTDensity	1,191	-0.77	>.05	100	-0.05	>.05	210	0.26	>.05	248	0.61	>.05	218	0.16	>.05	415
	TXTMaxFreq	1,191	0.08	>.05	100	0.03	>.05	210	0.0001	>.05	248	-0.001	>.05	218	0.01	>.05	415

6. Conclusions

ESBR systems are associated with increased seat belt use of about 2-4 percentage points above usage rates for vehicles with the required seat belt display (the base system consisting of a seat belt icon and brief warning sound). The effects differed somewhat in magnitude among various ESBR system configurations and for drivers and right front seat passengers, but were always positive. The tendency for individual ESBR features (e.g., visual icon or sound display duration, sound type, presence of text, etc.) to create positive effects varied considerably, but a number of characteristics were more often significant among the population with the lowest propensity to wear seat belts. This finding suggests that ESBRs may be most effective in converting belt use resistors if they incorporate the characteristics that showed significant effects among the lower propensity groups. Additional research is needed to better understand these effects.

A summary of the most important findings follows.

Front seat occupants

- The overall effect of ESBRs was to increase front seat occupant seat belt use by 3.3 percentage points compared to vehicles without ESBRs. Most ESBRs increased the rate of belt use by about 3-4 percentage points over the non-ESBR rate of belt use. Depending on ESBR system, the increases ranged from 2.6 to 4.1 percentage points.

Drivers:

- The overall effect of ESBRs was to increase driver seat belt use by 3.2 percentage points compared to vehicles without ESBRs. Depending on ESBR system, the increases ranged from 2.5 to 3.9 percentage points.

Front right passengers:

- The overall effect of ESBRs was to increase front passenger seat belt use by 3.0 percentage points compared to vehicles without ESBRs. Depending on ESBR system, the increases ranged from 1.8 to 4.1 percentage points.

ESBR system characteristics

Relative to vehicles without ESBRs

- ESBR features (icon, sound, text) and the characteristics of each feature (e.g., interval between displays, change in amplitude, etc.) were found individually and in various combinations to have significant ($p<.05$) effects on driver seat belt use (not examined for passengers due to relatively small sample size).
- Positive significant effects were more often found among the lowest belt use propensity groups, suggesting that ESBRs help increase belt use among people who are relatively more resistant to wearing them.
- Relatively larger significant positive effects were found for systems having at least icon and sound (Sound and Icon) and icon and sound with no other component (Sound and Icon Only).
- Significant negative effects were found for the combination of sound and text only (Sound and Text Only).

Relative to vehicles with other ESBR system characteristics

- All significant ($p<.05$) effects on driver seat belt use occur in the lowest three belt use propensity groups.

- Sound and icon together, complete duration of sound, maximum frequency (rate) of the sound, and icon appearance had significant positive effects thus were associated with higher belt use relative to other ESBR characteristics in the lowest belt use propensity group.
- Sound and text together, sound density (proportion of time sound is emitted), and maximum frequency of icon display had significant negative effects thus were associated with lower seat belt use relative to other ESBR characteristics in the lowest belt use propensity group.

Explanatory comments

- Some component of the positive or negative effects may be due to additional confounding of ESBR characteristics with other aspects of the design of those vehicles that also influence belt use but were not accounted for in the analysis, such as vehicle type or size. For example, ESBRs with the combination of sound and text may have been predominantly in SUVs and pickups, which typically have lower belt use rates independently of their belt reminder systems.
- Additional research is suggested to further examine the contributions of the presence and characteristics of each ESBR attribute to improved belt use.

While we did make an attempt in this study to estimate the effects of specific of ESBR system characteristics on belt use, we are forced to view the resulting estimates as tentative. We were unable to reach definitive conclusions about the contribution of specific ESBR system components to increased belt use for three major reasons. First, the typical ESBR system included a range of components, and this made it impossible to separate the features that might have had an effect on belt use from the set of coupled features that might not have had such an effect. Second, some of the ESBR features were present in only few makes and models, and relevant sample sizes were often very small. And third, since many unique ESBR feature combinations were included in certain makes and models only, it was impossible to separate the effect of those combinations from the effect of other coupled vehicle design features on belt use (e.g. user-friendliness of belt system design, type of driver driving the vehicle). Another weakness of these analyses is that within each quintile, the range of variation of an effective ESBR system might be somewhat compressed. For instance, if increased sound duration also increased belt use, then some of this effect would be reflected by the quintile distribution of vehicles that had sound-based ESBRs, and less so within each quintile: those with long durations might be primarily assigned to high quintiles and those with short durations primarily to low quintiles.

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Appendix A.

Table A1. ESBR System Characteristics

Variable	System Name	Base System	Manuf. A System 1	Manuf. A System 2	Manuf. B System 1	Manuf. C System 1	Manuf. D System 1	Manuf. D System 2	Manuf. D System 3	Manuf. D System 4	Manuf. E System 1	Manuf. E System 2
	Simple Grouping Name	SIMP1	SIMP5	SIMP8	SIMP5	SIMP5	SIMP7	SIMP7	SIMP5	SIMP2	SIMP5	SIMP8
	Detailed Grouping Name	DETL1	DETL4	DETL10	DETL7	DETL5	DETL9	DETL9	DETL7	DETL2	DETL5	DETL11
Driver Belt Use	1=Yes 2=No	1	1	1	1	1	1	1	1	1	1	1
Passenger Belt Use	1=Yes, 2=No	2	1	1	2	2	1	1	2	1	2	2
Activation Speed	MPH 0= Not Applicable	0	0	0	5.6	3	4.97	4.97	4.97	4.97	4.35	4.35
Activation Time	1= Start of Ignition 2= Immediately after base system N= Seconds after base system	1	15	15	30	30	2	2	30	2	30	30
Activation Distance	Feet 0= Not Applicable	0	656	656	0	0	0	0	0	0	0	0
Sound Type	1= Chime 2= Buzzer 3= Chime or Buzzer 0= Not Applicable	0	1	1	1	1	1	1	1	0	1	1
Sound Cadence	1= Uniform 2= Rise 3= Uniform or Intermittent 0= Not Applicable	0	1	1	1	1	1	1	1	0	1	1
Single Cycle Sound Duration	Seconds 0= Not Applicable	0	90	90	96	6	3	3	7	0	6	6

Table A1. ESBR System Characteristics (Continued)

Variable	System Name	Base System	Manuf. A System 1	Manuf. A System 2	Manuf. B System 1	Manuf. C System 1	Manuf. D System 1	Manuf. D System 2	Manuf. D System 3	Manuf. D System 4	Manuf. E System 1	Manuf. E System 2
	Simple Grouping Name	SIMP1	SIMP5	SIMP8	SIMP5	SIMP5	SIMP7	SIMP7	SIMP5	SIMP2	SIMP5	SIMP8
	Detailed Grouping Name	DETL1	DETL4	DETL10	DETL7	DETL5	DETL9	DETL9	DETL7	DETL2	DETL5	DETL11
Interval Between Sound Cycles	Seconds 0=Not Applicable	0	0	0	0	30	204	0	248	0	30	30
Complete Sound Duration	Seconds 0=Not Applicable	0	90	90	96	300	210	3	262	0	540	540
Sound Cessation	1= Time Out 2=Buckle 0=Not Applicable	0	1	1	1	1	1	1	1	0	1	1
Icon Type	1= Standard ISO 0= None	1	1	1	1	1	1	1	1	1	1	1
Icon Appearance	1= Continuous 2= Flashing 3= Continuous and Flashing 0= Not Applicable	0	1	1	3	2	0	0	3	1	2	2
Single Cycle Icon Duration	1= Continuous N= Seconds 0= Not Applicable	0	90	90	8	6	0	0	75	1	6	6
Interval Between Icon Cycles	1= No Interval N= Seconds 0=Not Applicable	0	1	1	1	30	0	0	180	1	30	30
Complete Icon Duration	Number of Seconds 999= Continuous until Buckle Up	0	90	90	96	300	0	0	330	999	540	540
Driver Text Content	0=Not Applicable	0	0	Fasten Safety Belt	0	0	Buckle Seatbelt	Buckle Seatbelt	0	0	0	Fasten Seatbelt

Table A1. ESBR System Characteristics (Continued)

Variable	System Name	Base System	Manuf. A System 1	Manuf. A System 2	Manuf. B System 1	Manuf. C System 1	Manuf. D System 1	Manuf. D System 2	Manuf. D System 3	Manuf. D System 4	Manuf. E System 1	Manuf. E System 2
	Simple Grouping Name	**SIMP1**	**SIMP5**	**SIMP8**	**SIMP5**	**SIMP5**	**SIMP7**	**SIMP7**	**SIMP5**	**SIMP2**	**SIMP5**	**SIMP8**
	Detailed Grouping Name	**DETL1**	**DETL4**	**DETL10**	**DETL7**	**DETL5**	**DETL9**	**DETL9**	**DETL7**	**DETL2**	**DETL5**	**DETL11**
Passenger Text Content	0=Not Applicable	0	0	Fasten Safety Belt	0	0	Buckle Passenger	Buckle Passenger	0	0	0	0
Single Cycle Text Duration	1= Continuous N= Seconds 0=Not Applicable	0	0	90	0	0	27	27	0	0	0	5
Interval Between Text Cycles	Seconds 0=Not Applicable	0	0	0	0	0	180	0	0	0	0	30
Complete Text Duration	Seconds 999= Continuous until Buckle Up	0	0	90	0	0	234	27	0	0	0	540
Post ESBR State	1= Continuous Icon 2= Flashing Icon 3= Nothing	3	1	1	1	3	3	3	3	1	1	1
Post ESBR Same as ESBR	0= NA 1= Same 2= Different	0	1	1	2	0	0	0	0	1	2	2
Permanent Deactivation	1=Yes 2=No	2	2	2	1	1	2	2	2	2	2	2

Table A1. ESBR System Characteristics (Continued)

Variable	System Name	Manuf. F System 1	Manuf. F System 2	Manuf. G System 1	Manuf. G System 2	Manuf. H System 1	Manuf. H System 2	Manuf. I System 1	Manuf. I System 2	Manuf. J System 1	Manuf. J System 2
	Simple Grouping Name	SIMP5	SIMP8	SIMP2	SIMP2	SIMP6	SIMP2	SIMP2	SIMP5	SIMP8	SIMP8
	Detailed Grouping Name	DETL6	DETL12	DETL2	DETL2	DETL8	DETL2	DETL3	DETL6	DETL10	DETL10
Driver Belt Use	1=Yes 2=No	1	1	1	1	1	1	1	1	1	1
Passenger Belt Use	1=Yes, 2=No	2	1	2	1	1	2	1	2	1	1
Activation Speed	MPH 0= Not Applicable	4.97	4.97	0	0	0	0	0	9	0	15
Activation Time	1= Start of Ignition 2= Immediately after base system N= Seconds after base system	60	60	2	2	2	2	2	2	24	24
Activation Distance	Feet 0= Not Applicable	0	0	0	0	0	0	0	0	0	0
Sound Type	1= Chime 2= Buzzer 3= Chime or Buzzer 0= Not Applicable	2	2	0	0	0	0	0	2	1	1
Sound Cadence	1= Uniform 2= Rise 3= Uniform or Intermittent 0= Not Applicable	1	1	0	0	0	0	0	2	1	1
Single Cycle Sound Duration	Seconds 0= Not Applicable	5	5	0	0	0	0	0	30	6	6

Table A1. ESBR System Characteristics (Continued)

Variable	System Name	Manuf. F System 1	Manuf. F System 2	Manuf. G System 1	Manuf. G System 2	Manuf. H System 1	Manuf. H System 2	Manuf. I System 1	Manuf. I System 2	Manuf. J System 1	Manuf. J System 2
	Simple Grouping Name	**SIMP5**	**SIMP8**	**SIMP2**	**SIMP2**	**SIMP6**	**SIMP2**	**SIMP2**	**SIMP5**	**SIMP8**	**SIMP8**
	Detailed Grouping Name	**DETL6**	**DETL12**	**DETL2**	**DETL2**	**DETL8**	**DETL2**	**DETL3**	**DETL6**	**DETL10**	**DETL10**
Interval Between Sound Cycles	Seconds 0=Not Applicable	3	3	0	0	0	0	0	0	24	24
Complete Sound Duration	Seconds 0=Not Applicable	93	93	0	0	0	0	0	30	300	120
Sound Cessation	1= Time Out 2=Buckle 0=Not Applicable	1	1	0	0	0	0	0	1	1	1
Icon Type	1= Standard ISO 0= None	1	1	1	1	1	1	1	1	1	1
Icon Appearance	1= Continuous 2= Flashing 3= Continuous and Flashing 0= Not Applicable	2	2	1	1	1	1	2	2	1	1
Single Cycle Icon Duration	1= Continuous N= Seconds 0= Not Applicable	5	5	1	1	1	1	1	1	1	1
Interval Between Icon Cycles	1= No Interval N= Seconds 0=Not Applicable	3	3	1	1	1	1	1	1	1	1
Complete Icon Duration	Number of Seconds 999= Continuous until Buckle Up	93	93	999	999	999	999	999	999	300	120
Driver Text Content	0=Not Applicable	0	0	0	0	0	0	0	0	Driver Fasten Seatbelt	Driver Fasten Seatbelt

Table A1. ESBR System Characteristics (Continued)

Variable	System Name	Manuf. F System 1	Manuf. F System 2	Manuf. G System 1	Manuf. G System 2	Manuf. H System 1	Manuf. H System 2	Manuf. I System 1	Manuf. I System 2	Manuf. J System 1	Manuf. J System 2
	Simple Grouping Name	SIMP5	SIMP8	SIMP2	SIMP2	SIMP6	SIMP2	SIMP2	SIMP5	SIMP8	SIMP8
	Detailed Grouping Name	DETL6	DETL12	DETL2	DETL2	DETL8	DETL2	DETL3	DETL6	DETL10	DETL10
Passenger Text Content	0=Not Applicable	0	Passenger	0	0	Passenger	0	0	0	Fasten Seatbelt	Fasten Seatbelt
Single Cycle Text Duration	1= Continuous N= Seconds 0=Not Applicable	0	5	0	0	1	0	0	0	6	6
Interval Between Text Cycles	Seconds 0=Not Applicable	0	3	0	0	0	0	0	0	0	0
Complete Text Duration	Seconds 999= Continuous until Buckle Up	0	93	0	0	999	0	0	0	6	6
Post ESBR State	1= Continuous Icon 2= Flashing Icon 3= Nothing	1	1	1	1	1	1	2	2	1	1
Post ESBR Same as ESBR	0= NA 1= Same 2= Different	2	2	1	1	1	1	1	1	1	1
Permanent Deactivation	1=Yes 2=No	2	2					1	1		

Appendix B. Logistic Regression Model

In order to be able to estimate the causal effect of the presence of an ESBR system on seat belt use, it was necessary to control for potential confounders. To achieve this, stepwise logistic regression models were fitted to estimate the probability of seatbelt use as a function of other variables that were known about the location, the vehicle, the driver, and the front seat passenger, where present. This procedure was repeated separately for drivers, passengers, and all occupants.

For binary response models, the response, *Y*, of an individual can take on one of two possible values (for example, *Y*=1 if a seatbelt is worn, otherwise *Y*=0). Suppose ***x*** is a vector of explanatory variables and $\pi = \Pr(Y = 1 \mid x)$ is the response probability to be modeled. The linear logistic model has the form

$$\log it(\pi) \equiv \log(\frac{\pi}{1-\pi}) = \alpha + \beta' x$$

where α is the intercept parameter and β is the vector of parameters, or coefficients.

In this study, ***x*** is the set of potential confounder variables, the β are the coefficients of each of these variables that is included in the model, and π is the probability that a seatbelt is worn, modeled on these confounder variables. Table B1 below presents results from the each of the three models, for all of the potential confounder variables that were included in the model. The p-values in the table indicate the level of significance of each of the confounder (or predictor) variables included in the models. Also included in the tables are the odds ratios, and their 95-percent confidence intervals. By definition, the odds for belt use are the probability of belt use divided by the probability of no belt use. The effect on belt use odds of a dichotomous component of the predictor vector, say the first component of $\boldsymbol{x}$, $\boldsymbol{x_1}$, is calculated by exponentiating the corresponding regression coefficient:

$$OR(x) = e^{\beta_1}, \quad \text{where } \beta_1 \text{ is the coefficient for x1 from the logistic regression.}$$

Most of the variables in table B1 are dichotomous, that is, they can take on only two values. For these variables, the first column lists the two values in order. Note that odds ratios computed from regression coefficients are adjusted odds ratios: they are adjusted for the effects of the other variables in the logistic regression model of belt use. To illustrate the interpretation of the odds ratio, take, for example, the seat belt law variable (Law). The odds ratio for ‘All Occupants’ is 3.00 = exp(1.0998), which means that the odds of wearing a seat belt are three times greater in States with primary seat belt laws than in States with secondary seat belt laws. (The raw odds are 2.02 =9.50/4.71. As usual, raw odds ratios differ from adjusted odds ratios computed from the regression coefficients.) Similarly, the odds of young drivers (ages 16-24 years) wearing seat belts are one-half of the odds that older drivers wear seat belts.

The Year1 and Year2 variables are not dichotomous – they take on several different values. For these variables, the odds ratio can be interpreted as the change in the odds for any increase of one unit in Year1 or Year2. So for example, as Year1 (the model year) increases by 1, the odds of the driver wearing a seat belt increase by about 7 percent.

Table B1 Parameter Estimates (Coefficients) from Logistic Regression Models

Predictor Variables	Modeled group											
	All Occupants				Driver				Passenger			
	Odds Ratio	Lower 95% CI limit	Upper 95% CI limit	P-value	Odds Ratio	Lower 95% CI limit	Upper 95% CI limit	P-value	Odds Ratio	Lower 95% CI limit	Upper 95% CI limit	P-value
Year1[12]	1.07	1.06	1.08	<.0001	1.07	1.06	1.08	<.0001	1.06	1.05	1.08	<.0001
Year2[13]	1.006	1.004	1.008	<.0001	1.007	1.004	1.010	<.0001				
Age1 (Occupant) *(16-24 yrs versus other)*	0.68	0.63	0.75	<.0001								
Age1 (Driver) *(16-24 yrs versus other)*					0.49	0.39	0.61	<.0001	0.69	0.57	0.82	<.0001
Age2 (Driver) *(25-69 yrs versus other)*					0.77	0.62	0.95	0.013				
Gender (Occupant) *(male versus female)*	0.63	0.60	0.67	<.0001								
Gender (Driver) *(male versus female)*					0.65	0.61	0.69	<.0001				
Gender (Passenger) *(male versus female)*									0.57	0.50	0.65	<.0001
Law *(Primary versus Secondary)*	3.00	2.68	3.37	<.0001					2.75	2.28	3.32	<.0001
States With Primary Seat Belt Law												
State (CA versus non-CA)	1.27	1.09	1.49	0.0023								
State (IA versus non-IA)	0.60	0.53	0.68	<.0001	0.43	0.38	0.49	<.0001	0.69	0.55	0.87	0.0012
State (MD versus non-MD)					0.74	0.64	0.86	<.0001				
State (TX versus non-TX)	0.80	0.69	0.92	0.0017	0.52	0.45	0.59	<.0001	2.03	1.48	2.78	<.0001
States With Secondary Seat Belt Law												
State (AZ versus non-AZ)	4.11	3.63	4.64	<.0001					3.99	2.75	5.79	<.0001
State (FL versus non-FL)	0.61	0.57	0.66	<.0001	0.16	0.14	0.18	<.0001	0.49	0.42	0.58	<.0001
State (KS versus non-KS)					0.27	0.23	0.31	<.0001				
State (MO versus non-MO)					0.24	0.20	0.27	<.0001				
State (VA versus non-VA)					0.24	0.22	0.27	<.0001				
Area *(Urban versus Other)*	0.87	0.82	0.93	<.0001	0.86	0.78	0.94	0.0008				
Site Type *(Office Park versus Other)*	1.20	1.09	1.31	<.0001	1.18	1.07	1.29	0.0005				
Passenger Present *(Yes/ No)*					1.25	1.16	1.35	<.0001				

[12] Year1 is calculated as follows: if Year of Manufacture is 1994 or earlier, then Year1=-7, otherwise Year1= (Year of Manufacture – 2001).

[13] Year2=(Year1*Year1)

Appendix C. Method for calculating effect of ESBR systems on seat belt use, using probability quintiles.

Table. C1. Belted and unbelted frequency counts by belt-use probability quintile and system type.

	Belted			Unbelted			All		
Quintile	ESBR	Base System	All	ESBR	Base System	All	ESBR	Base System	All
1	N11	N12	N1+	M11	M12	M1+	S11	S12	S1+
2	N21	N22	N2+	M21	M22	M2+	S21	S22	S2+
3	N31	N32	N3+	M31	M32	M3+	S31	S32	S3+
4	N41	N42	N4+	M41	M42	M4+	S41	S42	S4+
5	N51	N52	N5+	M51	M52	M5+	S51	S52	S5+
All	N+1	N+2	N++	M+1	M+2	M++	S+1	S+2	S++

We generated one such table for each occupant group pair and ESBR system group.

In propensity quintile k, the overall belt-use probability is

$$p_k = \frac{N_{k+}}{S_{k+}}, k = 1,...5.$$

The proportions of ESBR and base system cars in quintile k are, respectively:

Cars with an ESBR:

$$f_{1k} = \frac{S_{k1}}{S_{+1}}, k = 1,...5.$$

cars with the base system:

$$f_{2k} = \frac{S_{k2}}{S_{+2}}, k = 1,...5.$$

We note that if (1) ESBRs increase belt use and (2) quintiles are ordered so that belt use rate increases with quintile index k, then

(1) the proportion of ESBR cars will increase with k,

(2) the proportion of base system cars will decrease with k, and

(3) overall belt-use probability will increase with k.

For any group of T vehicles that follows the distribution of the observed quintile distribution of *ESBR vehicles* and has the observed belt use probability in each quintile, the number of belt users is estimated by:

$$T_{1,Belted} = T \sum_{k=1,...,5} p_k f_{1k}$$

For any group of T vehicles that follows the distribution of the observed quintile distribution of *base system vehicles*, and has the observed belt use probability in each quintile, the number of belt users is estimated by:

$$T_{2,Belted} = T \sum_{k=1,\ldots,5} p_k f_{2k}$$

The percent difference between ESBR and base system vehicles, each of size T, is

$$P_{Diff} = 100(T_{1,Belted} - T_{2,Belted}) / T = \sum_{k=1,\ldots,5} p_k (f_{1k} - f_{2,k})$$

Appendix D

Table D1. Frequency and percentage of ESBR system vehicles in Sample, by Vehicle Year

Vehicle Year	Sample Size	ESBR System	
		Yes	No
1980-1994	4,948	0 0.00	4,948 100.00
1995	1,613	0 0.00	1,613 100.00
1996	1,724	0 0.00	1,724 100.00
1997	2,237	0 0.00	2,237 100.00
1998	2,737	365 13.34	2,372 86.66
1999	3,447	735 21.32	2,712 78.68
2000	4,690	1,601 34.14	3,089 65.86
2001	3,698	599 16.20	3,099 83.80
2002	5,739	3,323 57.90	2,416 42.10
2003	3,190	822 25.77	2,368 74.23
2004	2,873	2,005 69.79	868 30.21
2005	2,033	2,002 98.48	31 1.52
2006	79	79 100.00	0 0.00
2007	5	5 100.00	0 0.00
Total	39,013	11,536	27,477

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