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Technical Approaches To Increase Seat Belt Use

Report to the House and Senate Committees on Appropriations

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16. Abstract

This report to the U.S. House and Senate Appropriations Committees summarizes recent research by NHTSA's and other researchers regarding vehicle-based technologies intended to increase seat belt use. This includes four research topics: an observational evaluation of the effectiveness of current enhanced seat belt reminder systems; field operational tests to understand public reactions to prototype seat belt interlock systems (also termed "seat belt assistance systems"), particularly given the strong public pushback against seat belt ignition interlock systems in the 1970s; an evaluation of whether unbelted crash test requirements affect the optimal design of occupant restraint systems; and an investigation of whether sensor technology can detect seat belt use and misuse.

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Executive Summary

The National Highway Traffic Safety Administration has a long history of promoting vehicle technologies to increase seat belt use. In response to Congressional legislation and external petitions, NHTSA has concluded a series of research projects to better understand how vehicle systems can encourage seat belt use.

Despite high observed seat belt usage rates, unbelted occupants account for almost half of fatalities among vehicle occupants. For example, the 2018 National Occupant Protection Use Survey (NOPUS) found observed seat belt use was 90 percent; however, an estimated 47 percent of people killed in passenger vehicle crashes were unrestrained.[1]

Lap/shoulder seat belts, when used, reduce the risk of fatal injury to front-seat passenger car occupants by 45 percent and to light-truck occupants by 60 percent.[2] Among passenger vehicle occupants 5 and older, seat belts saved an estimated 14,955 lives in 2017, and if all such passenger vehicle occupants had worn seat belts, an additional 2,549 lives could have been saved in 2017.[3]

This report summarizes recent research by NHTSA's and other researchers regarding vehicle-based technologies intended to increase seat belt use. This includes four research topics:

- an observational evaluation of the effectiveness of current enhanced seat belt reminder (ESBR) systems;
- field operational tests to understand public reactions to prototype seat belt interlock systems (also termed "seat belt assistance systems"), particularly given the strong public pushback against seat belt ignition interlock systems in the 1970s;
- an evaluation of whether unbelted crash test requirements affect the optimal design of occupant restraint systems; and
- an investigation of whether sensor technology can detect seat belt use and misuse.

[1] Enriquez, J., & Pickrell, T. M. (2019, January). *Seat belt use in 2018 – Overall results* (Traffic Safety Facts Research Note. Report No. DOT HS 812 662). National Highway Traffic Safety Administration. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812662

[2] Kahane, C. J. (2015, January). *Lives saved by vehicle safety technologies and associated Federal Motor Vehicle Safety Standards, 1960 to 2012 – Passenger cars and LTVs – With reviews of 26 FMVSS and the effectiveness of their associated safety technologies in reducing fatalities, injuries, and crashes* (Report No. DOT HS 812 069). National Highway Traffic Safety Administration. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812069

[3] National Center for Statistics and Analysis. (2017, October). *Lives saved in 2017 by restraint use and minimum-drinking-age laws* (Traffic Safety Facts Crash•Stats. Report No. DOT HS 812 683). National Highway Traffic Safety Administration. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812683

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Technical Approaches to Increase Seat Belt Use

The 2018 National Occupant Protection Use Survey found nationwide daytime seat belt use to be 89.6 percent for front seat occupants.[4] The 2017 NOPUS found observed front seat belt use was 89.7 percent. Still 47 percent of people killed in passenger vehicles were unrestrained.[5] Unbelted occupants are an acute fatality concern while representing a small portion of the daytime driving population. Lap/shoulder seat belts, when used, reduce the risk of fatal injury to front-seat passenger car occupants by 45 percent and to light-truck occupants by 60 percent.[6] Among passenger vehicle occupants age 5 and older, seat belts saved an estimated 14,955 lives in 2017, and if all passenger vehicle occupants age 5 and older had worn seat belts, an additional 2,549 lives could have been saved in 2017.[7] This report will summarize recent research efforts regarding vehicle based systems intended to increase seat belt use.

Seat belt usage varies by seating position, occupant age, vehicle type, and time of day. The 2017 NOPUS Controlled Intersection Study found seat belt use continued to be lower in the rear seat (75.4%) than in the front seat (89.7%).[8] In addition, observed front seat belt use continued to be lower among 16- to 24-year-olds than other age groups. The 2018 NOPUS found observed daytime use to be 84.1 percent for pickup trucks, 90.3 percent for passenger cars, and 91.5 percent for vans and SUVs. When looking at those killed in passenger vehicles in 2017, 40 percent of those killed in crashes that occurred during the daytime were not wearing their seat belts, while 55 percent of those killed in crashes at night were not wearing their seat belts.

Background

NHTSA's technical approach to increasing seat belt use began in 1971 when NHTSA amended Federal Motor Vehicle Safety Standard (FMVSS) No. 208 to specify, as a compliance option, a seat belt warning for front outboard seats on passenger cars and some trucks.[9] In 1972 NHTSA amended the standard to specify an additional compliance option including an ignition interlock system that would prevent a passenger vehicle from starting if any of the front seat belts were not fastened.[10] This compliance option became effective in 1973 when observed seat belt use rate was between 16 percent to 18 percent.[11] The seat belt ignition interlock systems were not well received by the public and as a result of overwhelming negative public reaction, Congress adopted as part of the Motor Vehicle and School Bus Safety Amendments of 1974 a provision prohibiting NHTSA from prescribing a motor vehicle safety standard that requires, or permits as a compliance option, either ignition interlocks designed to prevent starting or operating a motor vehicle if an occupant is not using a seat belt, or a buzzer designed to indicate a seat

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[4] Enriquez, & Pickrell, 2019.
[5] National Center for Statistics and Analysis. (2018, October). *2017 fatal motor vehicle crashes: Overview* (Traffic Safety Facts Research Note. Report No. DOT HS 812 603). National Highway Traffic Safety Administration. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812603
[6] Kahane, 2015.
[7] National Center for Statistics and Analysis, 2017.
[8] Li, R., & Pickrell, T. M. (2019, February). *Occupant restraint use in 2017: Results from the NOPUS controlled intersection study* (Report No. DOT HS 812 594). National Highway Traffic Safety Administration. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812594
[9] 36 FR 4600 (Mar. 10, 1971).
[10] 37 FR 3911 (Feb. 24, 1972).
[11] Robertson, L., & Haddon, W. (1974, August). The buzzer-light reminder system and safety belt use, *American Journal of Public Health, Volume 64*, Number 8.

belt is not in use for a period of more than 8 seconds after the ignition was turned to the ''start'' or ''on" position.

NHTSA amended FMVSS No. 208, occupant crash protection, to delete the ignition interlock requirement.[12] The standard was amended to require that the driver's seating position be equipped with a seat belt warning system that activates, when the driver's seat belt is not buckled, a continuous or intermittent audible signal for a period of not less than 4 seconds and not more than 8 seconds after the ignition switch is turned on.

There was limited progress regarding vehicle systems to encourage seat belt use until the early 2000s, when NHTSA published a series of letters of interpretation indicating that a vehicle manufacturer wishing to provide a voluntary audible signal that sounds after the 8-second period specified in S7.3 of FMVSS No. 208 may do so, but must provide some means for differentiating the voluntarily provided signal from the required signal. These systems were eventually implemented in vehicles as enhanced seat belt reminder (ESBR) systems.

In 2003, in response to a Congressional request, the National Academy of Science published a study that examined the potential benefits and acceptability of technologies designed to increase seat belt use and identified any regulatory action needed to enable their installation on passenger vehicles.[13] As part of that study, interviews and focus groups were used to explore the perceived effectiveness and acceptability of ESBRs and seat belt interlock systems. The initial assessment suggested that systems perceived to be more effective were also perceived to be more intrusive or annoying. Participants reported lower tolerances for devices that affected the mobility of their vehicles (i.e., ignition, speed, and transmission seat belt interlocks). Many respondents expressed concerns about how seat belt interlock systems would affect the safety of their vehicles. Of particular concern was interlock system behavior when a seat belt is unlatched while the vehicle is in motion.

The NAS study examined perceived effectiveness and acceptance for two ESBRs (intermittent and increasing frequency with vehicle speed) and two seat belt interlock concepts (transmission and entertainment). More than 70 percent of participants rated transmission interlock systems "effective." However, less than half of the participants rated the transmission interlock "acceptable." The expert panel suggested that seat belt interlocks should only be considered for certain high-risk groups (e.g., teens and impaired drivers) due to the negative reaction and the hesitancy of industry to reintroduce seat belt interlock systems for the general public. The expert panel recommended revisiting the topic in the future to include a review of technologies and consideration for possible revisions in strategies to further increase seat belt use, including elimination of the interlock prohibition enacted by Congress in 1974.

In 2009 NHTSA published a report evaluating the effectiveness and acceptability of voluntarily installed ESBR systems.[14] The ESBRs were found to increase front occupant seat belt use by 3 to 4 percentage points compared to the base system required by FMVSS No. 208. Systems with text or icons and sound

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[12] 39 FR 38380 (Oct. 31, 1974).

[13] Committee for the Safety Belt Technology Study. (2004). *Buckling up: Technologies to increase seat belt use -- Special Report 278*. Transportation Research Board. https://doi.org/10.17226/10832

[14] Freedman, M., Lerner, N., Zador,P., Singer, J., & Levi, S. (2009, February) *Effectiveness and acceptance of enhanced seat belt reminder systems: Characteristics of optimal reminder systems* (Report No. DOT HS 811 097). Available at www.nhtsa.gov/sites/nhtsa.dot.gov/files/811097.pdf

were among those with highest belt use increases. Once again, a strong positive relationship between effectiveness and annoyance was found.

Also in 2009 NHTSA and Transport Canada tested a device that prevents drivers from shifting vehicles into gear unless occupants of front outboard seats have their seat belts fastened.[15] Unbelted participants experienced either a constant (8-second) or a variable delay. Drivers had the option of buckling, which terminated the delay, or waiting out the delay. The field study included 101 commercial drivers in the United States and Canada. The study found that gearshift delay resulted in a 37-percent to 40-percent increase in mean seat belt use relative to the baseline system. The main effect of delay type (fixed/variable) was not significant. The study also found that once drivers fastened their seat belts they tended to remain fastened for the duration of the trip. Some drivers indicated that the system was annoying because it required them to wear the seat belt for a very short trip. Some drivers thought it would be useful to have a device that required seat belt use only over certain speeds.

In 2011 NHTSA published a report on the use of haptic feedback in the accelerator pedal to increase seat belt use.[16] The device presented a sustained resistance to the accelerator pedal when the unbelted driver exceeded a predetermined speed (25 mph). The driver could override this resistance by pressing on the pedal harder. A higher seat belt use rate was expected relative to other countermeasures because a driver would find it difficult to press the pedal harder for a sustained duration. This pilot study included seven commercial vehicle drivers (carpet-cleaning fleet). The experimenter explained and demonstrated the system to drivers before the study started. The results showed that the seat belt was used for all trips during the study. Drivers buckled within less than 25 seconds of acceleration pedal force application. Participants indicated that the pre-study demonstration was an important factor in its acceptance.

The 2012 Moving Ahead for Progress in the 21st Century Act (MAP-21) provided NHTSA the authority to remove the 8-second maximum duration for the audible component of the mandatory seat belt reminder system. MAP-21 also provided NHTSA the authority to permit compliance with an FMVSS through a regulatory alternative that includes seat belt interlocks. The prohibition against NHTSA requiring seat belt interlocks remains in place.

On October 23, 2012, BMW Group (BMW of North America, LLC) petitioned NHTSA to amend the FMVSS No. 208 to permit optional certification using a seat belt interlock as an alternative to unbelted frontal crash testing. BMW cited several arguments in support of its request, including increased use of seat belts as well as the opportunity to optimize designs for belted occupants. In addition, the petition indicated that vehicles could be optimized to improve safety for belted occupants if relieved of consideration of the unbelted test conditions. BMW indicated that relief from the unbelted test requirements would enable vehicle designs that are lighter, more spacious and fuel efficient with lower emissions. NHTSA denied this petition because sufficient information was not provided to substantiate

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[15] Van Houten, R., Malenfant, J.E. , Reagan, I., Sifrit, K., & Compton, R. (2009, December). *Pilot tests of a seat belt gearshift delay on the belt use of commercial fleet drivers* (Report No. DOT HS 811 230). Available at www.nhtsa.gov/staticfiles/nti/pdf/811230.pdf

[16] Van Houten, R., Hilton, B., Schulman R., & Reagan, I. (2011, January). *Using haptic feedback to increase seat belt use of service vehicle drivers* (Traffic Tech Technology Transfer Series Report No. 403. Report No. DOT HS 811 434). National Highway Traffic Safety Administration. Available at www.nhtsa.gov/sites/nhtsa.dot.gov/files/tt403.pdf

proceeding with a rulemaking (e.g., determining the safety need, benefits, effectiveness, and acceptability of seat belt interlock systems).[17]

Recent NHTSA Research Programs

Subsequent to the denial of the BMW petition and passage of MAP-21, NHTSA initiated a series of research programs to better understand the acceptance, effectiveness, and safety consideration for vehicle technologies to increase seat belt usage. The sections below describe the major activities conducted recently to obtain this information. This discussion includes significant efforts from the Insurance Institute of Highway Safety (IIHS) that was also intended to support this effort.

Observational Study of ESBR Performance

The 2009 ESBR effectiveness report evaluated early generations of ESBR systems from a limited number of manufacturers. By 2015 ESBR systems were equipped on most new vehicles and it was desired to update this evaluation.[18] Trained data collectors observed seat belt usage for drivers and right-front seat passengers during daylight. The observers recorded age, gender, and belt use for each occupant. The vehicle type and license plate number were recorded and cooperating state motor vehicle administrations provided the Vehicle Identification Numbers (VINs) associated with each observed license plate. Observations and VINs were collected for 61,074 passenger vehicles.

Concurrently, motor vehicle manufacturers were contacted to request the characteristics of their seat belt reminder systems by make, model and year. The requests called for descriptions of the: (a) makes, models, model years, (b) trim levels for each of their systems, (c) seating positions monitored by the systems, (d) operator control of the systems, and (e) the number of stages that comprise the system. In addition, manufacturers were asked to report: (f) what initiates and terminates each stage, (g) the types and features of visual, auditory, and haptic displays, (h) whether any of the features are passenger specific, and (i) any other descriptive information. Fifteen manufacturers responded to the request, and provided information on a total of 46 ESBR systems.

The observational data was merged with the seat belt reminder system characteristics using the VINs. Statistical models were developed to assess the interaction between ESBR characteristics and observed seat belt usage. The study controlled for confounding factors such as vehicle, occupant, and location of observation. The results showed a 5-percent increase in seat belt usage for ESBR systems with combinations of sound, icon, and text elements. The results also showed increased belt usage for systems with extended warning periods. Seat belt use rate and ESBR effectiveness increased if the state had a primary seat belt use law.

Field Operational Tests of Seat Belt Interlock Systems

Due to the lack of public acceptance of the 1973 seat belt interlock mandate, the user acceptance and potential effectiveness of seat belt interlock systems requires careful study. Automotive manufacturers have adopted the term seat belt assistance systems (SBAS) to separate the current prototype systems from

[17] 78 FR 53386, August 29, 2013.

[18] Polson, A., Lerner, N., Burkhardt, E., Piesse, A., Zador, P., & Janniello, E. (in press). *Enhanced seat belt reminder systems: An observational study examining the relationship with seat belt use* (Report No. DOT HS 812 808). National Highway Traffic Safety Administration.

the ignition interlock vehicles required in 1973. The University of Michigan's Transportation Research Institute and IIHS conducted field observation studies to assess effectiveness and acceptance of two prototype vehicles.[19] [20] Both studies focused on recruiting part-time seat belt users and recorded any system-defeating behavior. The prototype vehicles were instrumented to record occupant behavior and seat belt usage. One vehicle was equipped with a transmission interlock that prevented being shifted out of park if either the driver or front seat passenger is unbelted. The second prototype vehicle had a speed limiter interlock that restricted maximum vehicle speed below 15 mph if either the driver or front seat passenger is unbelted.

NHTSA funded UMTRI for a study of 48 drivers that are part-time seat belt users. Half of the participants were randomly assigned to the speed limiter group while the other half were assigned to the transmission interlock group. Each participant was given one type of research vehicle for a total of three weeks, including one baseline week (i.e., only the baseline ESBR was turned on), and two treatment weeks (i.e., the system was fully functional). Data on participants' driving behavior and their interactions with each seat belt system were collected over the three-week period. Subjective evaluations from the drivers were also conducted.

The results showed significant effectiveness for both interlock systems such that the percentage of unbelted driving time (or trips) significantly decreased during the treatment period as compared to the baseline period. The average treatment period had a reduction in unbelted driving time of about 14.4 percent while the reduction in trips with any unbelted driving time was about 19 percent. This effectiveness was more pronounced for infrequent belt users than for frequent belt users.

Comparative differences between the two seat belt interlock systems were observed with different measures (i.e., based on unbelted trips or unbelted driving time). The decrease in the percentage of unbelted trips (between treatment and baseline driving) for the speed limiter group was much less than for the transmission interlock group, however, with the measure of unbelted driving time, similar reductions were observed for both vehicle groups. The researchers evaluated the "percentage of unbelted driving time" as an indicator of system effectiveness in order to include late-buckling, trip duration, early-unbuckling in the analysis.

Two main system-defeating or "cheating" strategies were observed, pre-buckling and then sitting on the seat belt and waiting out the 30-second transmission interlock timer. Eight of the 48 drivers cheated the systems during treatment driving and they were all infrequent seat belt users. Drivers from the transmission interlock group observed to be more likely to "cheat" the system than drivers from the speed limiter group.

Participants gave generally high levels of user-acceptance in post-test ratings of their experience with the technology. Both the perceived benefits (including resulting attitudes) and ease of interaction were rated

[19] Bao, S., Funkhouse, D., Buonarosa, M. G., Sayer, J., Ward, N., Kang, J., & Monk, C. (2019, June 10-13). *An examination of the effectiveness and user acceptance of seat belt assurance systems: A naturalistic driving study* Presented at 26th Enhanced Safety of Vehicles Conference, Eindhoven, Netherlands. Also available at *Traffic Injury Prevention 18*(S1).

[20] Kidd, D. G., Singer J., Huey, R., & Kerfoot, L. (2018). The effect of a gearshift interlock on seat belt use by drivers who do not always use a belt and its acceptance among those who do. *Journal of Safety Research, 65*, 39-51.

well. Nearly all drivers agreed or strongly agreed the technology was easy to use (95%). There was no significant difference in the reported ease of use between the two technologies.

IIHS conducted a similar series of studies looking at the same prototype vehicles and added a few others. The first IIHS study looked at the effectiveness of the gearshift interlock system. This study recruited 32 part-time seat belt users with a recent citation for seat belt non-use. The study used a two-week study period with a one-week baseline and the second week for treatment. Half of the users used the interlock vehicle for treatment and the other half drove a different vehicle with an enhanced seat belt reminder. Additionally, another 16 full-time seat belt users drove the gearshift interlock vehicle for one week.

The study demonstrated that part-time seat belt users in the gear shift interlock vehicle increased the travel time wearing the seat belt by 16 percent compared to the baseline period. All of the drivers, both full and part time belt users, reported generally positive acceptance with the gearshift interlock system. Six of the sixteen part-time belt users circumvented the gearshift interlock.

This study was augmented in 2018 to evaluate driver acceptance for a range of vehicle technologies. [21] The test vehicles were equipped with a range of ESBR characteristics, two speed limiting interlocks and the gear shift interlock. The subjects were drawn from the previous study and experienced 6 vehicle technologies on a closed course. The subjects performed a series of tasks and responded to a survey after driving each vehicle. The results indicated that interlock systems were more likely to motivate seat belt usage. However, the ESBR systems were viewed as more acceptable than the interlock systems.

IIHS conducted a third study that extended the gearshift interlock study using a similar protocol and two additional vehicles. [22] One of the vehicles was the speed interlock vehicle also used by NHTSA and the second vehicle was equipped with an aggressive ESBR. This study evaluated 49 additional drivers that had previously received a citation for not using a seat belt. Each driver drove a test vehicle for a two-week period. Relative to an intermittent reminder, seat belt use increased by 30 percent to 34 percent for aggressive seat belt reminders, 33 percent for the speed limiting interlock, and 16 percent for the gearshift interlock. Drivers completed a post study survey that indicated the seat belt reminders were more acceptable than the interlocks.

Evaluation of Belted and Unbelted Safety Requirements

The BMW petition cited potential safety benefits that could be provided by optimizing seat belt systems for belted occupants only. In order to understand how relief from the unbelted test requirements could affect seat belt designs, NHTSA sponsored a study to develop two optimized occupant restraint systems. [23] One restraint system was subject to the current test requirements and the second was subject to belted-

[21] Kidd, D. G., & Singer, J. (2018). *Consumer acceptance of enhanced seat belt reminders, a gearshift interlock, or different speed-limiting interlocks to encourage seat belt use following a brief hands-on experience*. Insurance Institute for Highway Safety. www.iihs.org/topics/bibliography/ref/2174

[22] Kidd, D. G., & Singer, J. (2019). *The effects of persistent audible seat belt reminders and a speed-limiting interlock on the seat belt use of drivers who do not always use a seat belt*. Insurance Institute for Highway Safety. www.iihs.org/topics/bibliography/ref/2185

[23] Hu, J., Klinich, K. D., Manary, M. A., Flannagan, C. A. C., Narayanaswamy, P., Reed, M. P., Andreen, M., Neal, M., & Lin, C-H. (2016, January). *Evaluation of belted and unbelted safety requirements* (Report No. DOT HS 812 232). National Highway Traffic Safety Administration. Available at www.nhtsa.gov/sites/nhtsa.dot.gov/files/812232-beltedunbeltedsafety.pdf

only requirements. Both restraint systems were evaluated in frontal crashes for the driver and front right passenger. Finite element (FE) models for two vehicles, a mid-size sedan and a mid-size SUV, were used for the study. One set of restraint systems were constrained to meet all current regulated and consumer information front impact test conditions. A second restraint design was optimized without considering unbelted test conditions. Both optimization studies evaluated a range of seat belt and air bag design parameters and selected the restraint system design that would minimize overall occupant injury risk. The optimal restraint systems for both existing and belted-only conditions were identical for three out of four vehicle/seating position combinations. Only the front right passenger in the mid-size SUV had an optimal belted-only restraint design that was not the same as the optimal restraint design under the existing requirements. Near optimal belted-only restraint designs were able to meet the unbelted test requirement. This study evaluated only frontal test conditions for selecting an optimal occupant restraint system design.

The safety implications for belted only restraint systems, from the modeling study described above, were studied using a fleet crash simulation. Each vehicle/occupant/restraint system combination was simulated in a range of frontal crash conditions and impact speeds. The occupant injury risk for each crash condition was computed and summed based on the likelihood of the crash conditions. Each crash simulation was run with the optimum restraint design. The belted-only optimized restraint designs had the knee bolsters removed from the vehicle model, as this would be a foreseeable result of a design needing only to protect belted occupants. Fifty-five frontal crash conditions were simulated to estimate occupant injury for each vehicle/restraint/occupant. The overall results indicated that occupant restraints that were optimized without unbelted test requirements generated lower injury risks for belted occupants, but increased the injury risk for unbelted occupants. The restraint systems optimized for belted only occupants tended to reduce injury risk for lower speed crashes but increase risk for the less frequent, higher injury severity causing, high speed crashes. This fleet study served to highlight the complex considerations involved in trying to develop restraint systems for a wide range of crash conditions.

Seat Belt Interlock Design to Prevent Misuse

The BMW petition did not clearly specify what the petitioner believed the relevant characteristics of a seat belt interlock are or how it should operate. Additionally, field operation testing observed a number of drivers that would habitually misuse the seat belt interlock systems in order to drive unbelted. NHTSA sponsored a project to investigate the feasibility of detecting common types of seat belt misuse.[24] The project developed a list of seat belt use and misuse scenarios. A range of sensors were implemented in a vehicle platform and evaluated individually and in combination for the ability to detect seat belt if the seat belt was not used correctly. Testing was conducted with small female and average male drivers. Seat belt misuse scenarios included buckling behind the back, using the passenger seat belt buckle, and using third party seat belt latch plates. The most feasible sensor system was implemented in a sport utility vehicle and cost estimates were developed.

[24] National Center for Manufacturing Sciences. (2018, February). *Preventing seat belt interlock misuse* (Report No. DOT HS 812 496). National Highway Traffic Safety Administration. Available at www.nhtsa.gov/document/preventing-seat-belt-interlock-misuse-final-report

The prototype vehicle with the sensor system was tested by NHTSA staff using 34 individuals in both the front driver and passenger seat systems in a range of seat belt use and misuse conditions.[25] The prototype system correctly identified seat belt misuse in 95 percent of trials and identified proper seat belt use in 97.5 percent of the trials under known types of misuse conditions. There was a minor difference in accuracy between the driver seat and front passenger seat systems. A preliminary test procedure was developed to assess the performance of a seat belt interlock system based on the use and misuse scenarios used in this test program.

Discussion

With the support of several organizations, NHTSA conducted a series of research tasks to better understand safety considerations related to the 2012 BMW petition to provide a seat belt interlock system as an alternative to meeting the unbelted occupant safety tests. Several significant concerns related to this petition were investigated in the research program. The first is the strong negative public reaction to the 1973 seatbelt mandate. The field operational tests were important to understand how public reactions to seatbelt interlock systems have changed since the 1970s when belt usage rates were below 20 percent. These studies demonstrated a reduction in unbelted driving time for this population of part time belt wearing drivers exposed to interlocks. The field operational testing also highlighted the tradeoff between increasing seatbelt usage rates and technologies that are perceived as annoying. One IIHS study demonstrated that an aggressive ESBR system can be as effective as a seat belt interlock and it was perceived as more acceptable than an interlock system. The MAP-21 legislation provided NHTSA the authority to remove the duration limit on seat belt reminders, which would allow specifying a longer audible reminder or a reminder that remains active until the driver buckles their seat belt.

The BMW petition cited the ability to improve restraint system performance for belted drivers as motivation to remove unbelted test requirements. The research project showed that the unbelted test requirements are not a primary constraint for the optimization of seatbelt and airbag designs. Unbelted frontal crash tests have a strong influence on the presence and design of knee bolsters. A belted occupant generally has limited interaction with the knee bolster in regulated crash tests, while an unbelted occupant relies on the knee bolster to control the lower body excursion. The fleet simulation predicted improved safety performance for belted occupants in the more frequent low and moderate speed crashes. However, the knee bolster plays a significant safety role in high-speed crashes for both belted and unbelted occupants. This study highlighted the considerations between reducing injury in frequent lower speed crashes and reducing fatality risk in high speed crashes.

Despite record high seat belt use in the United States, unbelted occupants remain around half of vehicle occupant fatalities. Vehicle technologies such as interlocks and ESBR have been demonstrated to help increase seat belt use. Beneficial implementations of such systems require thoughtful consideration of design elements to maximize the effect on those occupants continuing to resist buckling up while minimizing annoyance for properly belted occupants. Additional vehicle technologies designed to encourage seat belt usage are being developed and will require additional study.

[25] Mazzae, E. N., Baldwin, G. H. S., & Andrella, A. T. (2018, October). *Performance assessment of prototype seat belt misuse detection system* (Report No. DOT HS 812 593). National Highway Traffic Safety Administration. https://rosap.ntl.bts.gov/view/dot/38818

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