

USING ACCELERATOR PEDAL FORCE TO INCREASE SEAT BELT USE
OF SERVICE VEHICLE DRIVERS

RON VAN HOUTEN AND BRYAN HILTON

WESTERN MICHIGAN UNIVERSITY

RICHARD SCHULMAN

THE DEACCELERATOR CORPORATION

AND

IAN REAGAN

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

This study evaluated a device that applied a sustained increase in accelerator pedal back force whenever drivers exceeded a preset speed criterion without buckling their seat belts. This force was removed once the belt was fastened. Participants were 6 commercial drivers who operated carpet-cleaning vans. During baseline, no contingency was in place for unbuckled trips. The pedal resistance was introduced via a multiple baseline design across groups. On the first day of treatment, the device was explained and demonstrated for all drivers of the vehicle. The treatment was associated with an immediate sustained increase in seat belt compliance to 100%. Occasionally, drivers initially did not buckle during a trip and encountered the force. In all instances, they buckled within less than 25 s. These results suggest that the increased force was sufficient to set up an establishing operation to reinforce seat belt buckling negatively. Drivers indicated that they were impressed with the device and would not drive very long unbelted with the pedal force in place.

Key words: seat belt use, accelerator pedal resistance, accelerator pedal force, automated consequences, negative reinforcement

Seat belt use decreases serious injury in crashes (Tison et al., 2008). Research on increasing seat belt use has focused on public education, high-visibility police enforcement, and seat belt reminder systems. Although these measures have proven to be effective, they have not increased U.S. seat belt use to 100% (National Highway Traffic Safety Administration [NHTSA], 2009).

We thank Modernistic Carpet Cleaning and Restoration Company management and their affiliated drivers who generously agreed to participate in this research. This research was supported by a contract from the U.S. Department of Transportation, National Highway Traffic Safety Administration.

Address correspondence to Ron Van Houten, Psychology Department, 3700 Wood Hall, Western Michigan University, Kalamazoo, Michigan (e-mail: ron.vanhouten@wmich.edu).

doi: 10.1901/jaba.2011.44-41

Several contingency-based programs have produced large sustained increases in seat belt use, and some of these techniques have been employed on a communitywide basis. For example, highly publicized enforcement techniques (e.g., Click It or Ticket) influence behavior via a direct punishment contingency and rule-governed behavior (e.g., “If I don’t wear my seat belt, I may get stopped by the police, get a ticket, and lose points”; Cox & Geller, 2010). These programs have raised levels of seat belt use to an estimated 83% across the U.S. (NHTSA, 2009). Innovative technologies may add to the success of the high-visibility enforcement model and elevate this rate further (possibly to 100%).

One innovative technology that has shown promise is the application of a gearshift delay when the driver is unbuckled (Van Houten,

Malenfant, Austin, & Lebbon, 2005; Van Houten, Malenfant, Reagan, Sifrit, & Compton, 2010). Van Houten *et al.* (2005) demonstrated that imposing a short delay before allowing a driver to shift from park when his or her seat belt was not fastened effectively increased seat belt use. Specifically, fixed delays of 5 to 20 s produced increased average belt use from 45% to 81%. However, feedback from the drivers indicated that a 20-s fixed delay was aversive and frustrating to the point that some of the drivers attempted to circumvent the system. A follow-up study with 101 U.S. and Canadian fleet drivers (Van Houten *et al.*, 2010) evaluated the use of an 8-s delay if the seat belt was not buckled. Drivers could escape or avoid the delay by fastening their seat belts before attempting to shift out of park. United States drivers' belt use increased from 48% to 67% (a 40% increase), and Canadian drivers' use rose from 54% to 74% (a 37% increase). The result of focus group interviews conducted at the end of both studies indicated that many drivers felt the system would be more acceptable to drivers of fleet vehicles if it did not force drivers to buckle when backing and moving vehicles at a slow speed for a short distance, behaviors that drivers of fleet vehicles need to engage in frequently.

An alternative technology would provide a substantial increase in accelerator pedal resistance to drivers who are unbuckled. Specifically, this system would impose increased resistance of the accelerator pedal (a potential aversive stimulus) when the driver is unbuckled and a predetermined speed is exceeded. Although drivers could easily override this system when highly motivated to do so (e.g., to avoid a crash), they would find it effortful to do so for sustained periods of time. Returning the pedal resistance to the normal level could be used to reinforce negatively buckling the seat belt. This concept offers several potential advantages over other technologies. First, the system would not affect drivers who always buckle but do so after

motion. (Data collected on 1,600 drivers indicated that many drivers who wear their seat belts currently do so after placing the vehicle in motion; Malenfant & Van Houten, 2008.) It also would not affect drivers who do not buckle in very low-risk situations, such as backing a vehicle to a loading dock or moving a vehicle. Second, this system would remain in effect until drivers fasten their seat belts. Finally, the system would not require anyone to monitor driver seat belt use and apply consequences for not wearing the belt. Previous field research indicates that imposed pedal resistance can successfully eliminate highway speeding (Schulman, 2005). This technology may result in increased seat belt use, particularly for part-time bucklers or drivers who forget to buckle because of distraction. The purposes of this study were to evaluate the effect of this device on seat belt compliance and driver acceptance of the device. We hypothesized that the device activation would lead to significantly increased belt use on trips longer than 1 min relative to baseline and that drivers would find the system to be acceptable.

METHOD

Participants

The efficiency of the imposed pedal resistance system was field tested on seven drivers of a carpet-cleaning fleet. Drivers from this sample were men ranging in age from 24 to 35 years who averaged about nine trips above the criterion speed per day.

We assured the drivers and the participating company, a carpet-cleaning and restoration business in Plainwell, Michigan, with a fleet of 48 vans, that individual seat belt use data would be kept anonymous and confidential and would not be divulged to supervisors or anyone else. The employer fully agreed and supported this commitment.

Apparatus

The apparatus was designed for this study and included a microprocessor installed under

the driver's seat and connected to six functions of the vehicles via a specially designed harness, as well as two weight sensors located under the driver's seat. The microprocessor recorded all data. These data included time, date, vehicle speed, presence of weight on the driver seat, ignition on or off, brake on or off, seat belt closure switch on or off, pedal force stepper motor on or off, start of trip, end of trip, and trip history in both baseline and the experimental condition. In addition, the microprocessor was capable of analyzing the recorded data and downloading data into a spreadsheet. We downloaded the data wirelessly using a modem that allowed frequent downloads without requiring direct access to the vehicle. Data could be remotely downloaded at any time.

The pedal force contingency was controlled by a separate circuit that activated a stepper motor that applied the force that manipulated the accelerator pedal. A potentiometer was used to measure the motor's piston position. The motor was bracketed under the dashboard in such a manner that the motor's piston head was capable of contact with a flat metal disk that was affixed to the linkage arm that had the pedal attached. The piston could remain in contact with the affixed disk across the full travel of the accelerator pedal, from fully up to fully depressed. The device could not be seen without looking under the dashboard. The system operated in two modes, a position control mode and a force control mode.

Position control mode. The position control mode was critical to maintaining a preset speed in that it sustained smooth, comfortable, and accurate speed regulation. This system operated across a 2-mph speed range, from 1 mph below the preset speed to 1 mph above the preset speed, and was designed to provide the driver with a comfortable foot rest, via the pedal, when traveling at the preset speed. For example, if the device was set for a 40-kph (25-mph) speed limit, the device's piston began to rise as speed exceeded 24 mph. The piston stopped upward

travel when the accelerator pedal (due to driver depression of the pedal member) was in contact with the piston and the vehicle was traveling at 25 mph. At this point, the system was quite comfortable. The driver could simply rest the foot on the pedal. As long as the driver was depressing the pedal far enough to contact the piston, travel was always at the preset speed. As the driver encountered a downhill gradient, the vehicle picked up speed. The piston then gently moved upwards, along with the accelerator pedal and driver's foot, to exactly the position required to bring speed back to the preset speed. If the driver encountered an uphill gradient and speed began to fall below the preset speed, the piston slowly and smoothly retracted to allow the driver's natural foot weight to depress the pedal to the exact position required to bring the vehicle back to the preset speed. To enforce pedal position, the system used a constant 18-pound back force. This force provided no punishment or aversive stimulation unless the driver attempted to override it. In summary, the device's position control system was designed to control vehicle speed and operated across a 2-mph speed range regarding the maintenance of the preset speed. The position control system was active unless an unbuckled driver exceeded 40 kph (25 mph). That is, the driver could remain unbuckled and drive quite comfortably in this mode.

Force control mode. As already noted, the system's pedal position control made use of 18 pounds to enforce the position of the pedal. This particular pedal position back force was chosen so that even the heaviest foot would not unintentionally override the system during travel at the preset speed. However, this 18-pound position control back force was easy to override given the strength of most drivers. Once the 18-pound position control system was overridden, the vehicle increased in speed. At this juncture, pedal resistance increased up to 38 pounds if the driver was unbuckled. To escape the system, the driver had to buckle the

seat belt. Once the driver buckled, accelerator pedal resistance dissipated gradually over a 4-s interval. It is important to note that this high resistance value was present regardless of pedal position. In other words, throughout the full travel of the accelerator pedal, a higher force than the force used to control pedal position was imposed. Once speed began to drop 1 mph above the preset speed, the pedal position system was once again activated. The 40-kph speed criterion was selected for two reasons. First, many drivers buckle their seat belts after placing the vehicle in drive and while moving at slow speeds right after starting the trip (Malenfant & Van Houten, 2008). It is important not to inconvenience these drivers if the system is to be widely accepted. Second, drivers in previous studies with the seat belt shift interlock (Van Houten *et al.*, 2005, 2010) found it aversive to buckle their seat belts when moving a vehicle a short distance or backing up to a loading dock. Fleet drivers often move vehicles around at speeds in excess of 24 kph (15 mph), and fleet drivers in previous studies had suggested we use 40 kph. If drivers exceeded this speed, it was assumed they would be traveling on an actual trip.

To prevent drivers from bypassing the device by buckling the seat belt behind them, the system was designed to apply force when the system detected the seat belt was fastened before the participant sat in the driver's seat. The microprocessor detected zero attempts by drivers to fasten the seat belt behind them.

Safety features. With respect to the higher resistance encountered when the system was in the force mode, it is important to note that 38 pounds of accelerator pedal resistance can be easily overridden by a normal driver. In fact, it is probably the case that in a life-threatening passing situation, almost all drivers press on the accelerator pedal with considerably more force than that imposed by the force mode system. If the driver reduced the degree of pedal depression or stopped depressing the accelerator pedal

altogether during any part of the system's operation, the pedal acted in a normal manner. It popped upwards and the vehicle slowed in the typical manner. When the force mode was activated, the force gradually increased to 38 pounds over a 3-s interval to ensure the driver had time to respond to the increased force to maintain or increase speed. As already noted, the force gradually decreased over a 4-s interval if the driver buckled the seat belt. This measure was taken so that the driver had time to adjust to the change in the force required to operate the pedal. Without such a measure, a driver might overdepress the pedal due to a sudden decrement in the force required for its operation. This could lead to a sudden and unintended increase in the rate of acceleration. If the force was activated and the driver did not buckle his seat belt, the force was removed as he decelerated below 40 kph for any reason (e.g., approaching a red light, a stop sign, or a slower vehicle that pulled in front of him). Hence, the force was never in place when drivers drove below 40 kph. All of these features were demonstrated to drivers prior to the treatment phase.

Measures

The microprocessor sampled the following events at a rate of 1 Hz: vehicle ignition, vehicle speed, person seated in driver's seat, seat belt closure, brake use, vehicle motion, start and end of trip, and implementation of increased accelerator pedal force. The data-logging component of the microprocessor recorded each of these events with a date and time stamp (year, month, day, hour, minute, and second), with events recorded every 6 s or when a variable changed status. The program also calculated the percentage of trips the seat belt was fastened and the times when the seat belt was unbuckled while the vehicle was moving. If the driver was unbuckled during vehicle motion for more than 30 s while traveling over 40 kph, the trip was scored as unbuckled. The microprocessor also recorded the number of trips per day and

average trip duration. The dependent variables were the percentage of trips the seat belt was fastened, the percentage of trips the driver's seat belt was removed, and the percentage of trips that the driver buckled in response to increased pedal resistance. Seat belt use was measured only for trips that attained a speed of 40 kph or more. Drivers were scored as wearing the seat belt on a trip during baseline and treatment if they buckled it within 30 s of attaining a speed of 40 kph (drivers that buckled in response to increased pedal resistance). The 30-s grace period was added to allow the drivers time to buckle their seat belts to escape the force. It was judged that 30 s would afford the driver adequate time to buckle in response to the increased pedal force at a time when the driving workload was not too high. This criterion was also employed during baseline for comparability. On only one occasion during baseline did a driver buckle his seat belt within 30 s of attaining a speed of 40 kph.

System Reliability

Because the study involved automated recording and treatment implementation, we tested the microprocessor and the device extensively after installation during weekends when the devices were not in use. The system was also tested several times during the study in the evenings after the drivers went home, as well as at the end of the study. During these tests one person drove the vehicle while the other monitored data collection on a laptop connected to the microprocessor. The system worked flawlessly during all tests.

Design

A multiple baseline design across two groups of participants was employed in this study. Each of the participants drove one of the two vehicles that were equipped with the apparatus. Two participants drove one vehicle and the remaining five participants drove the other vehicle. The treatment was first introduced to the first group of two drivers and later introduced to the

second group of five drivers. Baseline lengths were staggered based on the number of days that the car was driven by any of the participants in the group. One driver in Group 1 drove the vehicle 3 days during baseline and 7 days during the treatment condition, whereas the other driver drove the vehicle 2 days during baseline and 6 days during the treatment condition. In Group 2, four drivers drove the vehicle 2 days during baseline and 2 days during the treatment condition. The remaining driver drove the vehicle 1 day during baseline and 1 day during treatment. Dispatchers determined the order in which participants drove the vehicles. Multiple drivers were employed for two reasons. First, we did not have data on belt use before the study, and it would be more likely that a group of drivers would include drivers who did not consistently wear seat belts. Second, we needed to collect data from seven drivers and we did not have sufficient resources to install the device in a larger number of vehicles. Only one driver drove the vehicle on any given day.

Procedure

Baseline. Prior to installing and recording data, meetings were held with the drivers to explain the baseline data-collection phase of the study. Drivers were informed that a data logger had been placed in their vehicles as part of a study for NHTSA, but drivers were not told that the target behavior was seat belt use. After the microprocessors were installed and baseline began, the data loggers recorded the dependent measures but drivers did not experience the increased accelerator force contingency until the intervention phase.

Intervention. After obtaining baseline data, the force contingency was activated for the first group of drivers and later introduced for the second group of drivers. Drivers in the first group were instructed not to talk to other drivers about the research device. At the start of this condition, each of the drivers for a particular vehicle received an explanation of

the pedal force contingency. Because this device affected the accelerator pedal in a novel manner, each driver test drove the vehicle with a researcher to experience the system's operation. All of the drivers indicated to the research assistant that they were impressed with the device and that they would not want to drive any distance with the force in place.

Focus Group

The study ended with a focus group discussion with drivers to obtain feedback about the contingent pedal resistance system. Topics of interest included perceived effectiveness on seat belt use, ability to bypass the system, usefulness for teenage drivers, annoyance, acceptance, any rules formed as a result of the demonstration, their reaction if the device was placed in all of their fleet vehicles, their reaction if it were placed in all vehicles sold provided it was paired with reduced insurance rates, and aspects of the device they liked best.

RESULTS

Figure 1 shows the percentage of trips each day that drivers buckled their seat belts and the percentage of trips that pedal force was applied. During baseline, the first group of two drivers buckled the seat belt on an average of 69% of the trips and the second group of drivers buckled the seat belt on 61% of the trips. During baseline, one driver in Group 2 removed his belt during motion for less than 1 min and then rebuckled it. There were two instances of buckling the seat belt after motion during baseline in the first group of drivers, with the drivers buckling 2 s and 17 s after motion. There were three instances of buckling the seat belt after motion during baseline in the second group of drivers, with the drivers buckling 3 s, 7 s, and 29 s after motion. These all occurred at speeds below 40 kph and were all scored as buckled trips.

Activating the pedal force contingency increased seat belt use to 100% for both groups of

drivers. Drivers in Group 1 encountered increased pedal resistance during 7% of their trips and drivers in Group 2 encountered increased pedal resistance during 13% of their trips. In every case in which increased pedal resistance was applied, the driver buckled the seat belt within 25 s of the force being applied, with an average latency of 12 s.

Drivers in Group 1 average 8.6 trips per day during baseline and 8.5 trips per day during the intervention. Drivers in Group 2 averaged 8.9 trips per day during baseline and 9.7 trips per day during the intervention. The number of trips per day was scheduled by dispatchers who were not aware of the purpose of the study.

DISCUSSION

Results of this study support the effectiveness of the accelerator pedal force contingency in producing 100% compliance regarding seat belt use. It is interesting to note that all drivers indicated during the initial demonstration that they would always wear the seat belt to avoid the force. However, drivers occasionally failed to wear their seat belt until the force was applied during the treatment condition. It was necessary to both explain and demonstrate the system at the start of the treatment because of its obvious novelty regarding the behavior of the accelerator pedal. Participants indicated that the demonstration of the accelerator pedal device was an important factor in its acceptance. In particular, the drivers appreciated knowing how the pedal force could be overcome in an emergency by exerting greater down pressure on the accelerator pedal, how it felt when the force initiated, and how the force gradually decreased when the buckle was fastened. Given the suddenness of the change in seat belt use, it is apparent that the demonstration of the contingency had an immediate effect on seat belt use. It is likely that this effect was mediated by the formation of rule-governed behavior of the general form, "If I don't buckle, the accelerator pedal will be harder to press when I go over 40 kph."

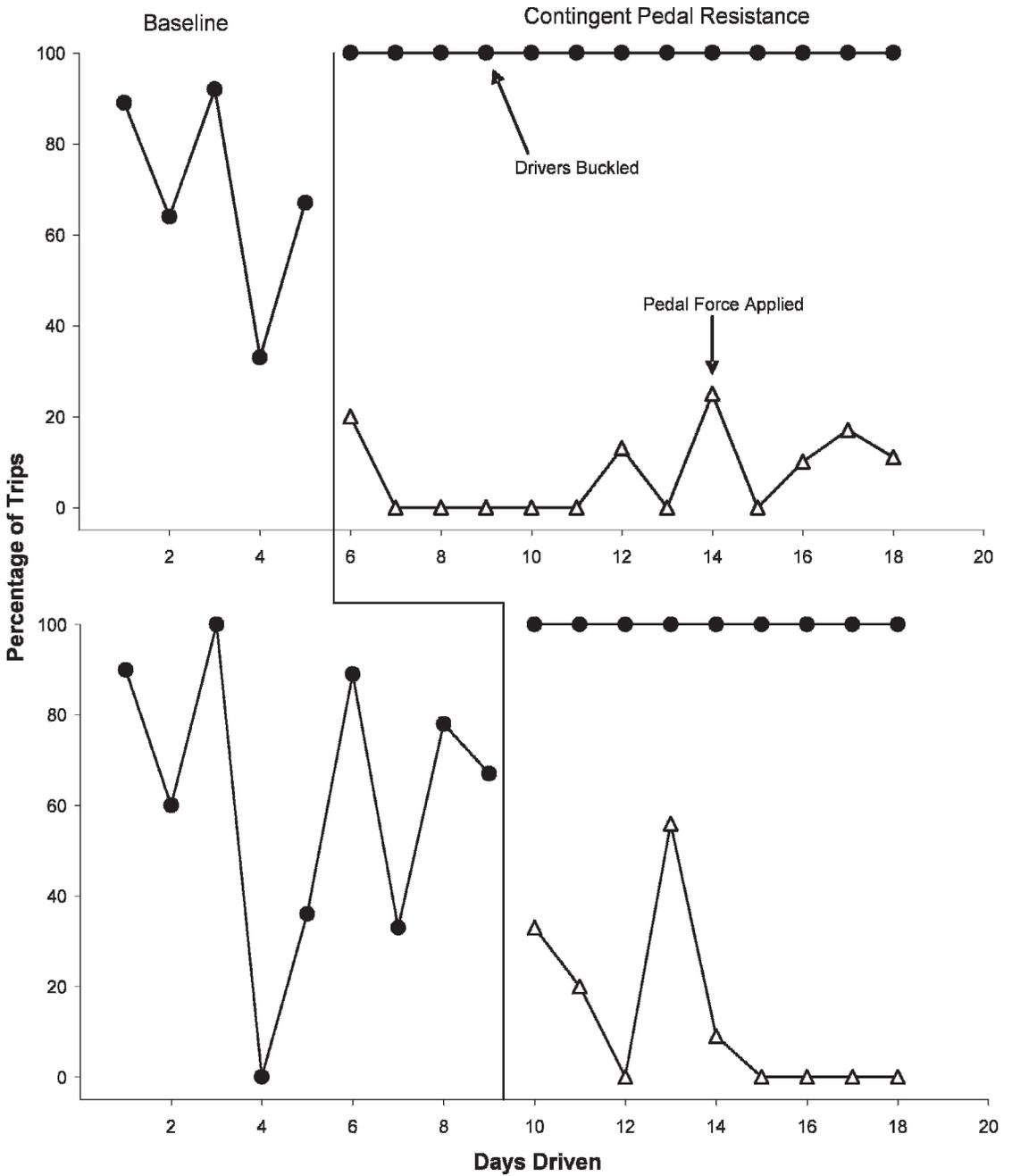


Figure 1. The percentage of trips each day with the driver buckled and the percentage of trips each day that the pedal force was applied for the two groups of drivers.

This system has several advantages over interlock systems that require drivers to wear their seat belts to start the vehicle or to take the vehicle out of park. First, there are many reasons why a driver would want to start a vehicle without putting on a seat belt. For example, the driver might wish to scrape the windshield while running the defroster or to preheat the vehicle in winter or cool it in summer. Second, it does not require the driver

to fasten the seat belt to move the vehicle (operators of vehicle fleets often need to move their vehicles short distances at speeds well under 40 kph). Instead this system requires the operators to fasten the seat belt only when they exceed a predetermined speed criterion that defines an actual trip. Third, this system can be installed in vehicles with either a standard or an automatic transmission, which is a clear advantage compared to other seat belt shift interlock systems.

The 40-kph speed criterion was selected in this experiment because many drivers in previous studies on the shift delay strongly opposed being required to wear seat belts when moving vehicles within the company parking lot or at other locations (Van Houten *et al.*, 2005, 2010). Driving in excess of 40 kph ensured that the driver was actually making a trip. The use of a slower criterion would likely also be effective but could result in more opposition to the device and attempts to tamper with it, as was found by Van Houten *et al.* (2005). It is also interesting that some drivers in previous studies said they wore seat belts when driving private vehicles but not work vehicles. This could represent contextual control of seat belt use that emerges from not wearing the seat belt on all trips. The use of pedal force overcomes this problem by introducing the force at a criterion speed.

Because the use of accelerator pedal force has also been demonstrated to be effective in reducing speeding behavior, it offers the advantage of being used to control multiple driving behaviors. Unlike speed or tachometer governors, this system can be overridden in an emergency if a driver needs to increase speed to avoid a crash. (The inability of drivers of governed vehicles to increase speed beyond the artificially imposed preset speed under any conditions has been the bane of these systems.) Besides being incapable of emergency-related increases in the preset speed, governed vehicles, such as semitrailers, cause bottlenecks on

highways as they attempt to pass one another at marginally different maximum speeds.

After completing the intervention, drivers provided feedback about the perceived effectiveness, reliability, usefulness, acceptance, and annoyance of the system. The comments were overwhelmingly positive. Table 1 shows sample responses to the focus group questions. In general, the drivers indicated that the system was very reliable, stating that it activated when they went over 40 kph and were unbuckled. This feedback also supported the seat belt use data, with drivers stating that the imposed pedal force generated buckling behavior. All participants felt that novice drivers would benefit from the system, and many drivers said they would accept it being available for all vehicles, particularly if having it provided an insurance break. Negative comments about the device were limited. Two drivers commented that the device was somewhat noisy. (This research prototype was not soundproofed as one would find in a production unit.) No driver could think of a way to bypass the system other than by intentionally breaking it (the research unit was not tamper resistant). It is likely that the high level of driver acceptance of the device was in part a function of it requiring them to wear seat belts only when they initiated an actual trip rather than when they were moving a vehicle. The device was also never encountered by drivers who buckled after motion, provided they buckled before attaining a speed of 40 kph.

In summary, this field study showed that an accelerator force contingency could increase seat belt compliance to 100% among a small group of adult drivers. The upcoming phase of the study will test the system using a larger sample of drivers and will track seat belt use over a longer period of time to evaluate further the generality of this finding. Subsequent research should examine whether changes in behavior produced by the device are maintained after the device is turned off. If the effects are not maintained, further studies could determine

Table 1
Sample Responses from Focus Group Testing

Question	Responses
How effective was the system?	"Every time I didn't wear my seat belt it let me know." "Pretty well effective." "I started wearing my seat belt more." "Very effective." "I would wear my seat belt every time."
How could you or would you beat the system?	"Not without breaking it." "Cut wires."
How would teen drivers react to the system?	"They would get tired very fast of pushing a rock hard pedal and would put their seat belt on." "Lights and tones can be ignored but not the pedal." "Great thing to have because many teens don't think of buckling, they just forget." "Excellent for teen drivers." "Not cool for teens to wear their seat belt." "Would benefit teen drivers, they would avoid tickets."
Did you form any rules about belt use?	"No seat belt and it is a pain to drive." "If you don't wear your seat belt it is hard to press."
How would you react if it were in all vehicles?	"Would be great." "It's a cool feature." "Great if it lowered insurance." "Anything to save money." "It would not bother me."
What aspect did you like best?	"It made me put my seat belt on for every trip. Never saw a feature like that." "(The force) eases out when you buckle your seat belt so that pedal does not go to the floor." "Seems safe, does not affect the way the vehicle drives." "Felt safer because something was there to remind me to buckle." "Did not take long to remind you that you were not wearing your seat belt." "It worked." "Good idea." "Don't know it's there unless you are on a trip."

whether the intermittent application of the device would lead to sustained seat belt use. One strategy for introducing the treatment to a large number of participants would be to equip several vehicles and give each vehicle to a driver for a 4-week to 6-week period. This strategy would allow more data to be collected on each participant while using a small number of equipped vehicles.

REFERENCES

- Cox, M. G., & Geller, E. S. (2010). Prompting safety belt use: Comparative impact on the target behavior and relevant body language. *Journal of Applied Behavior Analysis, 43*, 321–325.
- Malenfant, J. E. L., & Van Houten, R. (2008). Observations of how drivers fasten their seat belts in relation to various startup tasks. *Accident Analysis and Prevention, 40*, 309–314.
- National Highway Traffic Safety Administration. (2009). *Traffic safety facts research note seat belt use in 2008—Demographic results* (DOT Publication No. 811 183). Washington, DC: Author.
- Schulman, R. (2005). The Deaccelerator: A behavioral solution to highway speeding. *Behavioral Technology Today: Cambridge Center for Behavioral Studies, 4*, 2–24. Retrieved from http://www.behavior.org/journals_Btt
- Tison, J., Solomon, M. G., Nichols, J., Gilbert, S. H., Siegler, J. N., & Cosgrove, L. A. (2008). *May 2006 Click It or Ticket seat belt mobilization evaluation: Final report* (DOT Publication No. HS 810 979). Washington, DC: U.S. Department of Transportation.
- Van Houten, R., Malenfant, J. E. L., Austin, J., & Lebbon, A. (2005). The effects of a seat belt-gearshift delay prompt on the seat belt use of motorists who do not regularly wear their seat belt. *Journal of Applied Behavior Analysis, 38*, 195–203.
- Van Houten, R., Malenfant, J. E. L., Reagan, I., Sifrit, K., & Compton, R. (2010). Increasing seat belt use in service vehicle drivers with a gearshift delay. *Journal of Applied Behavior Analysis, 43*, 369–380.

Received October 9, 2009
Final acceptance May 26, 2010
Action Editor, Joel Ringdahl