Recently, various automotive manufacturers have developed and installed adjustable pedal systems that allow the pedal package (accelerator, brake, and clutch) to be moved in unison toward or away from a driver’s standard (and historically fixed) position. To determine if there was a possible danger associated with adjusting or manipulating the pedals while operating the vehicle, we engaged in two separate investigations. First, we evaluated the potential risk associated with adjusting or manipulating in-vehicle controls, such as tuning the radio or moving the seat position, for an estimate of how the operation of similar devices influences vehicle safety. Our analysis of accident data from North Carolina shows that about 60 accidents per year occur while drivers are adjusting a radio, with only a few annual accidents tied to other in-vehicle controls such as wipers, mirrors, and heaters. Based on these findings, accidents associated with pedal location adjustment are likely to be extremely rare. Second, we completed a fixed-base simulator study to evaluate how the manipulation of the adjustable pedal system influenced driver behavior and vehicle control. Changes in pedal position had no detectable influence on brake reaction times. Adjusting pedal position (on demand from the experimenter) had only a very small effect on measures of speed, lane position, and brake reaction time, in all cases within the range of effects found with operation of radios, cell phones, and seat controls. Findings from this aspect of our work add further confidence to the prediction of low accident risk for pedal location adjustment. Implications for driver behavior and vehicle safety are discussed.

INTRODUCTION

The operation of a motor vehicle places various sensory, cognitive, and motor performance demands on drivers. Drivers must monitor information within and outside the vehicle adequately to control heading and speed, follow lanes, maintain sufficient headway from vehicles ahead, respond to events, and navigate towards their goal. Any additional activities have the potential for distracting a driver and leading to an accident, yet drivers routinely engage in a variety of secondary tasks that are generally regarded as reasonably (but not absolutely) safe, such as conversation with passengers, listening to radios, or drinking beverages.

The introduction of new task demands introduced for comfort and convenience during vehicle operation needs to be evaluated for likely net safety impact. Research on intelligent vehicle highway systems, for example, addresses the potential safety costs (along with the benefits) of devices that present new information to drivers (such as collision warnings or route guidance). The impact of cellular telephones on driver safety has been extensively investigated in recent years with a combination of laboratory, roadway, and epidemiological approaches (e.g., Goodman et al., 1998; Murray et al., 2001).

This paper describes research to evaluate the potential risk associated with adding an adjustable pedal system to a passenger car. This motorized system can move the “pedal-package”—brake and accelerator pedal together (and the clutch in a standard-shift car)—over a range of several inches from the normal or full-forward position (corresponding to typical placement in a car without this feature) to a full-rearward position, closer to the driver. The adjustment would be made using a two-direction momentary-contact switch, similar to the kind used for electric seat controls, with the switch location on the dash console or steering column. There is no need for drivers to adjust pedal position during normal driving. As with seat position and back-rest angle, it would be safest for pedal adjustment to be made while the vehicle is stopped. Nevertheless, it is possible that
some drivers would choose to adjust the pedals during driving (e.g., because they started driving without making the adjustment first, or because they want to change their posture). Therefore, it is appropriate to consider the potential risk of such an activity.

Two distinct research approaches were used to evaluate the risk of this and similar in-vehicle operations while driving. The first involved a review of accident data to assess the actual risks associated with various in-vehicle adjustments, to determine how often accidents are attributed to driver interaction with controls. The second involved a study of driver behavior and performance in a simulator, to evaluate effects of the actual movement of the pedals as well as of interaction with the control switch.

**ACCIDENT DATA REVIEW**

The interaction with the pedal control switch is reasonably similar to that of many other in-vehicle controls. In these instances, the driver might make an initial glance to guide hand contact, and then return to looking at the roadway while operating the control. Intermittent shifting of visual attention to the control and road might also take place to operate the control and the vehicle. To learn about how often such control operations are tied to accidents, an analysis was conducted of motor vehicle accident data from North Carolina. Unlike many other state accident databases, this database includes a verbatim written statement of the investigating officer for over 2 million accidents reported in 1979-96, in addition to the vehicle characteristics and driver information typically reported in police accident reports.

The analysis began with a sorting process that identified accidents involving in-vehicle devices commonly manipulated or adjusted by a driver of a motor vehicle. The terms or keywords selected for this project included “radio,” “heater,” “seat,” “wiper,” “cell phone,” “mirror,” “air conditioner,” and other word derivatives (e.g., “defrost”) in an attempt to find as many accidents as possible that involve an in-vehicle device. The culling process resulted in approximately 49,000 accidents. Next, each accident report was grouped into a category, based on a classification scheme that sorted the accidents by the type of in-vehicle device involved. The reports were read to determine if in fact an accident apparently occurred as a result of a driver diverting attention to the said in-vehicle device. Accidents that involved some other factor (e.g., failed to stop and hit head on rear-view mirror) that was not specific to the control, adjustment, or manipulation of an in-vehicle device were excluded. Similar procedures have been established previously (Wierwille & Tijerina, 1996; Schmidt, Young, Ayres, & Wong, 1997).

Over the 18-year period, we found only 1,853 reports of accidents in which the driver was adjusting something just prior to the accident; this represents about 103 accidents per year, or less than 0.1% of all the accidents in the database. The averaged annual number of accidents is sorted by device in Figure 1. Not surprisingly, the adjustment of the radio (i.e., turning on, adjusting the volume, selecting a channel, choosing a song on a CD, etc.) represented about 60% of the total. The remaining accidents involved the driver adjusting the HVAC (heater, vent, or air conditioning), cellular telephone, seat belt, wiper, mirror, sun visor, and seat. In addition, a small proportion of accidents involved the adjustment of some unspecified in-vehicle device.

**SIMULATOR STUDY**

In order to learn how drivers are likely to use a pedal adjustment system, as well as the effect this may have on safety, we studied driver performance during in-vehicle device operation in a fixed-base simulator environment. Fourteen adult subjects (6 female, 8 male; mean age 32 years and ranging from 23-49 years; mean height 5’8”, with a range of 5’1” to 6’2”) participated in an introductory session and three test sessions. McFadden et al. (2000) suggests that height and age are important determinants for distances from the steering wheel.

**Session I.** The goal of the first session was to determine the effect of various pedal positions on driver behavior. After participants became acquainted with the controls, they drove through a simulated course with the pedals in each of three separate conditions: (a) in a full-forward location, (b) in a full-rearward location, and (c) in a location set initially by the subject. In all conditions, the seat position could be moved at the discretion of the driver.

The simulated route driven was about 3 miles and took about 5-7 minutes of elapsed time maintaining a goal cruising speed of 35 mph. On 10 instances intermittently spaced within the route, an unannounced
Figure 1. Accidents per Year Involving the Adjustment of In-Vehicle Devices (North Carolina, 1979-1996).

“stop” sign was presented in the middle of the roadway as a stimulus to elicit a brake response from the driver. Participants were asked to fully depress the brake, release it, and return to a speed of 35 mph. All stops were presented on road sections that did not require braking to negotiate. Participants drove the route under each of the three conditions.

Two findings from this session provide insight about how drivers utilize and are affected by an adjustable-pedal package. First, the results indicate that most drivers did not prefer to move the pedals a large distance from the forward-most position. When given the chance to place the pedals in their preferred location, 7 drivers chose to keep the pedals full-forward, 5 drivers moved the pedals only 0.5” from the full-forward position, and 2 drivers moved the pedals 1.5” rearward. Furthermore, drivers generally moved the seat position along with a change in position of the pedals. Second, the reaction times for the stop signs were 0.78 s on average and not statistically different among the three pedal locations.

Session II. In the second session, participants were asked to manipulate the pedal switch, seat switch, radio controls, and a cellular phone while driving through the simulated route described in Session I. For each of these in-vehicle devices, a specific task was completed when drivers were instructed to operate the specific control. In an attempt to equate the tasks, subjects were asked to perform activities that were similar in either time or the number of actions necessary to complete the task: drivers were required to make adjustments or manipulations to each of the devices for about 6 s, and the number of actions needed was matched for the seat and pedal controls (3 adjustments) and for the radio and phone tasks (8 actions). Each participant executed these tasks on five separate instances while attempting to maintain the set speed and lane position. Our analysis of these data indicates that the manipulation of the pedal switch had a relatively small effect on driver performance, with less disruption than was caused by interaction with the cell phone or radio.

Session III. In the third test session, participants drove on a straightaway and attempted to maintain a speed of 60 mph. When drivers achieved the goal speed, a verbal cue was provided to engage the drivers in the adjustment or manipulation of one of the four in-vehicle devices (pedal, seat, radio, or cell phone) as described in Session II. During the time they were actually making the adjustment, a
“stop” sign was presented, and drivers were to fully depress the brake, release it, and return to goal speed. Reaction times (RTs) for a total of 10 trials were determined for each of the in-vehicle devices. The average brake RT values varied from 0.88 s for the seat adjustment to 0.84 s for the pedal adjustment and radio. The differences among RTs for the various devices were not statistically significant. All of these mean reaction times were slightly longer than the 0.78-s average obtained for braking in the first session (acting as a baseline in which no in-vehicle device manipulation was involved).

**DISCUSSION**

Any increased demand on driver attention or workload has the possibility of increasing accident risk. Drivers generally are aware that distraction, especially looking away from the road, is risky (Ayres et al., 1999); they tend to glance away only briefly, and to maintain more frequent sampling of the roadway ahead when traffic or environmental conditions are more demanding (Ayres et al., 1996; Wierwille et al., 1988). Based on this understanding, it is anticipated that most drivers would choose to avoid adjusting pedal-package location during driving if they found such adjustment distracting or otherwise problematic for driving safety. Furthermore, it is especially unlikely that drivers would choose to adjust pedal location in demanding situations such as merging with traffic.

Nevertheless, in-vehicle device operation is sometimes tied to accidents. Review of data from North Carolina showed that accidents occurred most frequently when drivers adjusted the radio, a task that is performed frequently and that could well involve more visual information (to check station frequencies), relative to various other in-vehicle adjustments. Overall, most tasks studied are tied to only a very small number of accidents per year. These findings are consistent with findings from earlier research (e.g., Goodman et al., 1998; Wierwille & Tijerina, 1996) as well as a recent analysis of national and North Carolina data for the American Automobile Association (Stutts et al., 2001), and indicate that the adjustment of in-vehicle devices has a low but measurable accident risk. If pedal location adjustment is performed only occasionally during driving (probably much less frequently that operating wipers, adjusting mirrors, or positioning sun visors), accidents associated with pedal location adjustment are likely to be extremely rare. Implications of our findings beyond the in-vehicle devices manipulated should be made with due caution. Limitations in the database, such as the sparse use of cell phones—which has certainly increased since 1996—and absence of data related to recent vehicle innovations (adaptive cruise control, enhanced night vision technology, etc.), prevent a full and complete understanding of how all in-vehicle devices influence driver behavior and safety. Clearly, there is a need for further study in this area.

The simulator study adds further confidence to the prediction of low accident risk for pedal location adjustment. Most drivers preferred a forward location, so it would be unusual to enter a vehicle and find the pedals are in a very unacceptable rearward position. Furthermore, pedal position did not have a detectable influence on brake RTs. Adjusting pedal position (on demand from the experimenter) had only a very small effect on measures of speed, lane position, and brake reaction time, and was within the range of effects found for the operation of radios, cell phones, and seat controls.

**REFERENCES**


distance from the steering wheel in motor vehicles. 
*Human Factors, 42*(4), 676-682.

Murray, J., Ayres, T., Wood, C., & Humphrey, D. 

Schmidt, R.A., Young, D.E., Ayres, T.J., & Wong, J.R. 

Stutts, J. C., Reinfurt, D. W., Staplin, L. & Rodgman, E. A. 

Wierwille, W. W., Hulse, M. C., Fischer, T. J., & Dingus, T. A. 

Wierwille, W.W., & Tijerina, L. 