A COMBINED BRAKE-ACCELERATOR PEDAL AND ITS EVALUATION

Rickard Nilsson

Department of Psychology, Uppsala University  
Box 1225, S-751 42, UPPSALA, Sweden  
e-mail: Rickard.Nilsson@psyk.uu.se

ABSTRACT

Over the years designers have developed various combined brake-accelerator pedals in an effort to eliminate the operator’s risk of pressing the wrong pedal as well as to reduce his or her reaction time in braking. The goal of this study was to highlight problems that drivers may face when they switch between pedal systems. Eighteen male and female drivers varying in age participated in the study. The evaluation was carried out during special driving maneuvers and in normal traffic in which all drivers used the same test vehicle. The results indicate that drivers were able to learn the new combined pedal mechanism quickly and effortlessly and that the number of mistakes was extremely low during the acquisition phase in learning the new system. Difficulties in assessing risk with pedal systems are discussed and some ideas about future work are suggested.

INTRODUCTION

Background.

Since many years, all cars have had separate foot-pedals for accelerating and braking. This has become standard and there has been rather little dispute about this arrangement. However, some drawbacks are obvious:

First, the time it takes to move the foot from the accelerator to the brake adds to brake-reaction time. This movement time is about 0.2 seconds.

Second, there is risk for misapplications. That is, risk for bad hit of a pedal and, in the worst case, the driver may hit the accelerator instead of the brake. In cars with automatic transmission this may cause so-called “unintended acceleration” (Schmidt 1989) when the driver persists in pressing the accelerator instead of the brake without realising the mistake.

To eliminate these drawbacks several combined accelerator- brake pedals have been suggested over the years. A new Swedish solution invented by Mr Sven Gustafsson have such good features that it motivated a behavioural evaluation financed by the authorities in Sweden.

The Gustafsson`s combined accelerator- brake pedal.

An accelerator-plate is mounted to the end of a brake-pedal lever (see fig. 1). When operating the pedal-system the driver puts the foot, which should be kept there all the time when driving, on the accelerator-plate. When accelerating the driver pushes with the fore-foot and folds down the accelerator like in a conventional vehicle. But when braking the driver reaches out with the leg, still with the foot on the accelerator. The throttle is released as the
brake is affected so the driver does not have to release the throttle by lifting the fore-foot before braking.

An electromagnet supports the brake-lever to prevent accidental braking during acceleration.

For safety reasons an extra brake-pedal is mounted to the left side of the brake lever in case the driver moves the foot away from the pedal in, for example, emergency situations. This extra brake is not visible in the figure.

![Diagram of brake and accelerator functions of the combined pedal.](image)

**Figure 1.** Brake and accelerator functions of the combined pedal.

**Drawbacks?**

Could there be some problems with this combined pedal? Yes, there seems to be a risk for confusion when the driver changes between cars with different pedal systems. Maybe the driver who is used to conventional pedals will move the foot away from the combined pedal in demanding situations? A driver who is used to the combined pedal and drives a conventional car may affect the accelerator when braking instead of moving the foot to the separate brake-pedal.

There may be problems with ergonomy since the foot shall stay on the pedal all the time when driving.
If brake-reaction time becomes shorter there is a possibility that the driver compensates with smaller safety-margins. For example, drives faster or with shorter headway to leading cars.

In this study the aim was to evaluate the new combined pedal system with, in the first place, respect to problems that may or may not arise when changing between pedal systems.

**METHOD**

**Test-vehicle.**

A SAAB 9-5 with automatic transmission and a combined accelerator- brake pedal was used as test-vehicle. In manoeuvre tests the car was equipped with cameras for registration of pedal-handling and front and rear views.

**Test-drivers.**

The test-drivers were selected according to the scheme in Table 1. They were all ordinary drivers. In all there were 18 drivers, 9 of each gender. Six drivers were Young, Middle aged and Older, respectively.

**Table 1. Assignment of test-drivers according to gender and age.**

<table>
<thead>
<tr>
<th>GENDER</th>
<th>AGE (years)</th>
<th>Young (18-22)</th>
<th>Middle-aged (31-53)</th>
<th>Older (73-79)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

|        |             | 6             | 6                   | 6             | 18            |

**Procedure.**

Each driver went through the following procedure:

First, they were introduced to the function of the pedal and drove about 2 km.

Second, they were trained in a very demanding manoeuvre task. They were asked to drive, as fast as they could, back and through a course with plastic cones. Now and then a buzzer went on and they were to brake as fast as possible.

After that they went for a practice drive for about 30 minutes in city-traffic.

Now they could loan the test-vehicle for a period of about 1 - 2 weeks and they were asked to drive at least 500 km. During the loan-period they filled in a diary with questions about various mistakes and other phenomena concerning the handling of the combined pedal.

After the loan-period they got the manoeuvre test again and they were also observed when they, for the first time, changed back to conventional pedals.

They were interviewed about their experiences with the pedal.
At a later occasion prepared brake-reaction time was measured with the combined pedal and with conventional pedals.

**Observations.**

In the study the following phenomena were observed:

**Foot-lifting errors.** This means that the driver lifts or moves the foot from the combined pedal when braking. One can say that the driver exhibits two-pedal braking in a one-pedal car.

**Unintended acceleration.** This means that the driver reaches out with the leg when braking in a conventional car. Or, exhibits one-pedal braking in a two-pedal car.

Co-ordination errors are of two kinds, unintentional braking, that is, pressing the accelerator too hard and thereby depressing the brake. This releases the throttle. And forgetting to stop braking before accelerating. In this case the engine does not respond, the drivers pushes harder on the accelerator, still without effect on the engine, and, finally, when the brake is completely released and the accelerator takes effect, the car makes an unexpected jump.

Data on comfort and ergonomy and drivers acceptance were collected through the diary and the interview.

**RESULTS**

Results from the manoeuvre tasks.

In table 2 the frequency of foot-lifting errors in the manoeuvre tasks before and after the loan-period is shown. There were no errors in the young group, seven errors in the middle-aged group and 18 errors in the old group. After the loan period one middle-aged driver made one error. There was no significant effect of gender.

Table 2. Number of foot lifts during the maneuver tests before and after the vehicle loan period.

*Before the loan period*

<table>
<thead>
<tr>
<th>AGE</th>
<th>GENDER</th>
<th>Young</th>
<th>Middle-aged</th>
<th>Older</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td>0</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td>0</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>7</td>
<td>18</td>
</tr>
</tbody>
</table>
After the loan period

<table>
<thead>
<tr>
<th>AGE</th>
<th>GENDER</th>
<th>Young</th>
<th>Middle-aged</th>
<th>Older</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Women</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3 shows the frequency of unintended acceleration when reverting to standard pedals in the second manoeuvre test after the loan period. As you can see this phenomenon actually does occur, at least in a demanding situation. No relation to gender or age was found.

Table 3. Frequency of contacts with the accelerator during braking after reverting to the standard pedals on the second maneuver test.
Results from the loan period.

A total of 21304 km were driven and from that follows that each driver drove on the average 1180 km.

\[ \text{U n n e c e s s a r y f o o t l i f t s a n d m o v e m e n t s} \]

\[ \text{Table 4. Rate of occurrence of sudden braking for men and women.} \]

<table>
<thead>
<tr>
<th>OUTCOME</th>
<th>GENDER</th>
<th>Correct</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>29</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 2. Number of reported foot lifts and foot movement errors per 1000 km for driving stretches of 200 km.

Figure 2 shows the total number of reported foot-lifting errors per 1000 km for driving stretches of 200 km. After 600 km there were no reports of such errors. 10 drivers reported no errors at all.

The drivers were asked to give a detailed report on each instance of sudden braking. A sudden braking could be braking in an emergency situation but it could also be fast braking in any surprising situation as, for example, when the driver nearly missed a highway exit. 33 cases of sudden braking were reported. In four of these cases the driver made a foot-lifting error (see table 4). In two of those cases the foot was completely moved to the reserve pedal.
Figure 3 shows the total number of reported co-ordination errors per 1000 km for driving stretches of 200 km. The rate of errors decreased rapidly in the beginning but they did not disappear completely for a few of the drivers. Eight of the drivers reported no errors.

![Coordination errors](image)

**Figure 3.** Number of reported coordination errors per 1000 km for driving stretches of 200 km.

Table 5 shows that the co-ordination errors were reported mainly by the women. The effect of age was non-significant.

**Table 5.** Distribution of coordination errors as a function of age and gender of the driver.

<table>
<thead>
<tr>
<th>AGE</th>
<th>Young</th>
<th>Middle-aged</th>
<th>Older</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Women</td>
<td>9</td>
<td>14</td>
<td>21</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>14</td>
<td>21</td>
<td>48</td>
</tr>
</tbody>
</table>
Interview.

In the interview all driver gave about the same answers. They all thought it was easier than expected to handle the pedal. They preferred the combined pedal in comparison to conventional pedals. The most common word used when they were asked to describe the feel of the pedal was “natural”. They had a few suggestions on how to improve the pedal. Some complained about angle of the accelerator-plate and resistance of the return-spring in the brake.

Prepared brake-reaction time.

Mean brake-reaction time was 0.44 seconds with standard pedals and 0.24 seconds with the combined pedal.

CONCLUSIONS OF THE EVALUATION

The conclusions were rather positive. The over-all impression is that the combined pedal survived this evaluation and that it seems to be a promising solution this far. The risk for confusion when changing between pedal-systems seems low and the pedal works well for all drivers, even for older drivers. However, this study gave no answer on the question if there will appear a compensation phenomenon or not.

DISCUSSION

Comments on the method.

The design of the study did not include a control with standard pedals. This was, firstly, because there are no comparable error-types when operating standard pedals and when operating the combined pedal and, secondly, because it was the process of re-learning driving with new means for control that was in focus. A consequence of the lack of control is that the conclusions had to be based mainly on judgements from the results. As an exception, brake-reaction times were measured for both standard pedals and the combined pedal. For a design with control with standard pedals common parameters, like vehicle-dynamics, must be measured.

Further steps.

The next task in the evaluation process should be to demonstrate if there will appear a risk-compensation phenomenon or not. In a laboratory study we could investigate if drivers can learn to use the shorter brake-reaction time at all. If they can not in the laboratory compensation is unlikely to occur in real traffic as well. Another possibility is to make unobtrusive observations of, e. g., headway in traffic with standard pedals and the combined pedal.

Sooner or later long-term, large-scale studies must be done. In such studies it is likely that new negative, but perhaps rare, phenomena will be revealed.

Assessment of potential reduction of risk.

We do not know how much safety there is to gain with the combined pedal since we do not know the number of accidents "caused" by standard pedals. Perhaps data from accident-investigations can help.

How large will the effect of reduced reaction time be? Preliminary calculations can be made of the reduction of stopping-distance (e. g. 5 meters shorter when braking from 90 km /h),
The reduction of speed at some moment during the course of braking (e.g. 5 km/h lower when braking hard, – 0.7G) and the kinetic energy at some moment during the course of barking. If these preliminary calculations are combined with known relations between speed and risk in various situations the potential gain in road-safety would be estimated.

**Impact on behavioural theories.**

Some impact on behavioural theories could be expected from this evaluation. It is difficult to explain how the drivers can re-learn so very fast. Probably, we have to modify our thinking about the "automatic level of control". The automatic level is perhaps not so automatic after all?

**Responsibility for future work.**

The process of developing and evaluating a new invention is typically characterised by everyone waiting for some one else to take the initiative (and the risk to loose time and money). The inventor has certainly done his share in this case, the authorities and the scientists have done some work by doing this evaluation and the car-industry is informed. But if we agree on that this new pedal-system seems promising who is to take the next step?

*This study was supported by the Swedish National Road Administration.*

**REFERENCES**


