

The Wagging Foot of Uncertainty: Data Collection and Reduction Methods for Examining Foot Pedal Behavior in Naturalistic Driving

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ABSTRACT

Pedal misapplications may be rare, but the outcomes can be tragic. A naturalistic driving study with 30 drivers was conducted to gain a better understanding of foot pedal behaviors. Foot movements were observed from the moment subjects entered and positioned themselves in their vehicle, and continued through starting the ignition, shifting into gear, accelerating to driving speed, and finally, resting their foot after parking the vehicle. A coding methodology was developed to categorize the various foot movements and behaviors. Over 3,300 startup and parking sequences were coded. This paper describes the unique challenges involved in classifying foot movements and behaviors when drivers' intentions are not known. For example, hesitant or interrupted foot movements often occurred when a driver was transitioning from a gas pedal press to a brake pedal press. Such behaviors required definitions beyond what might be typically considered a "pedal error" (e.g., pressing the wrong pedal, or pressing both pedals simultaneously). Over 650 back-pedal hooks (foot catching the underside or side of the brake pedal when transitioning from accelerator), incorrect trajectories, uncertain foot wags, misses, slips, and other behaviors were observed. Understanding such foot movements and behaviors provides insight into how pedal misapplications can occur-and how they might be mitigated in the future.

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INTRODUCTION

In recent years, a number of high-profile crashes have involved a sudden unintended acceleration (SUA). SUA is the "occurrence of any degree of acceleration that a vehicle driver did not purposely cause to occur" [1]. The majority of these crashes have been linked to pedal misapplications, with some associated with floor mats or sticky accelerator pedals [1]. While pedal misapplication is most frequently cited as the cause of such crashes, not much is known about how and why they occur. Information regarding the context of these crashes could provide insights on the various types of pedal application errors and how best to prevent them.

Each year, many preventable crashes occur due to the US Department of Transportation, National Highway Traffic Safety Administration (NHTSA) definition of "pedal errors," in which drivers mistake the accelerator for the brake. The majority of reported pedal

misapplication crashes occur during the day, in clear weather, with good road conditions [2] and in commercial parking lots [3]. Other common situations include when a driver is parking or backing [4, 5].

The most obvious vehicle factors associated with pedal errors were identified and largely corrected in 1990 when brake-to-shift interlocks (BTSI) became mandatory (Federal Motor Vehicle Safety Standard (FMVSS) 114). With these mechanisms require that the driver apply the brake pedal in order to shift from Park to Drive or Reverse.

The remaining SUA errors arise from the complex interaction of the driver, vehicle, and environment. Few studies have systematically explored how these factors interact within the driver-vehicle system during acceleration/braking scenarios to give rise to incidents that appear to surface for certain vehicle/customer combinations. Studies have shown that many driver-related factors contribute to pedal errors including age and gender [2, 4]. More specifically, older drivers demonstrated more variability in foot movements compared to young

adults [6] and females were over-represented in reported crashes associated with pedal errors [2]. Cognitive deficits may also lead to pedal crashes [7].

There have been many different classifications of pedal errors (Table 1). While previous studies have provided a variety of definitions of pedal errors, none have examined drivers as they pressed the pedals in their own vehicles.

Table 1. Summary of pedal response classifications in previous studies

Authors	Classification	Type of Data
Tran et al. [8]	Misses or misapplications	Vehicle experiment
Schmidt and Young [5]	Slips and wrong pedal	Crash data
Young et al. [4]	Slip and miss errors	Crash data
Rogers and Wierwille [9]	Serious, catch and scuff errors	Simulator study

Naturalistic observations can provide insights into the different foot movements as drivers proceed to stop or accelerate. The goal of this paper is to present an approach to examine and categorize foot pedal movement and behaviors. The naturalistic approach to data collection also provides an opportunity to observe and classify a wide range of pedal behaviors that, while not strictly “errors,” add to our understanding of the context within which rare “pedal errors” occur.

METHOD

Participants

A total of 30 participants were drawn from two age groups: drivers 25-35 years ($n=10$); and drivers over 65 years ($n=20$). An attempt was made to balance by gender; however, some subjects had to be eliminated due to left-foot braking (for the purpose of experimental control), and the final sample included two more females than males. Study participation requires a vehicle of model year 1996 or newer with an automatic transmission. Vehicles also had to be free of knee air bags, and certain electronic configurations that limited footwell space for our cameras. Subjects were required to have normal color vision and a visual acuity of at least 20/40.

Procedure

All participants signed an informed consent and completed a short demographic and driving-history questionnaire. They underwent a visual acuity and color blindness exam, two neuropsychological tests, and anthropometric measurement.

Height, weight, foot length and foot width were recorded. The right foot was traced onto a sheet of paper and was measured horizontally at the widest point to determine width. Length was determined by measuring from the heel to the tip of the toe.

Neuropsychological function tests included the Trails Test (A and B Versions). These tests were administered using an application called the “Brain Baseline” on an iPad. During the Trails Tests, subjects performed a kind of “connect-the dots” task. In the version called Trails A, they were asked to draw a continuous line between numbered circles in order (1 - 2 - 3, etc.). In Trails B, they traced a line that alternately connected numbered and lettered circles in order (1 - A - 2 - B - 3 - C, etc.). Participants were asked to draw the lines without lifting their finger or stylus until the task was complete; otherwise, they had to start over.

Subjects received compensation of \$160 for completing the four-week period of the study.

Naturalistic Driving Equipment

Participants’ vehicles were equipped with a naturalistic driving instrumentation suite, called the Digital Artefacts Video Event Recorder (DAVER), for about 4 weeks (see figure 1). The system included: two footwell cameras, a palm-sized device that integrated two video cameras (forward and interior view with audio), a three-axis accelerometer, GPS, a cellular modem and LG sim card, a variable pre-set data buffer, two infrared illuminators (to light the vehicle’s interior and footwell at night) and a wireless transmitter. The main recording device, which captured views of the inside and the outside of the vehicle, was mounted on the windshield behind the rearview mirror. Each vehicle had a different footwell configuration, making it difficult to have identical placement for the foot cameras. However, the location of the instrumentation suite in each vehicle was similar in that they did not interfere with driving while capturing nearly identical views of the accelerator and brake pedals, and the heel of the driver. Video data was captured at the start and end of each drive, during safety critical events, and at accelerometer threshold settings of 0.5 g or more. GPS, accelerometer and OBD data were collected continuously. All data were encrypted and automatically uploaded on a daily basis to a secure server through a cellular connection.

The DAVER’s were programmed to record the following during the naturalistic driving period:

Startup

The data recorder initialized within 3-6 seconds after the driver’s side door was opened and recorded for one minute or until the vehicle’s speed reached 20 mph.

Parking

The system recorded the last one minute of the drive going back from vehicle ignition being turned to off.

Exceeding Lateral and Longitudinal Trigger Thresholds

The force level required to trigger the system with a positive or negative acceleration was $\pm 0.5g$. Longitudinal triggers are most often caused by hard braking, while lateral triggers are most often caused by hard cornering or swerving. The system began recording 20 seconds prior to the trigger and continued for 30 seconds after the trigger.