Categorizing Unintended Acceleration/Pedal Misapplication Collisions from Event Data Recorders

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Advantage Forensics

- Practice Areas
  - Collision Reconstruction
  - Road/Signage Assessment
  - Human Factors
  - Biomechanics
  - Slips, Trips & Falls
  - Product Failure
  - Material Failure
  - Safety Assessments
About the Author

- 17 years of forensic engineering investigations
- 1800+ cases
- 23 trials, including pedal misapplication collision
- Qualified by Superior Court as expert in:
  - Human Factors
  - Collision Reconstruction
  - Collision Avoidance
  - Road Design
  - Signage Assessment
- Human Factors Forensics Professional Program Co-chair
- TV featured expert on collision reconstruction
- Collision reconstruction instructor for Police courses
- Human factors instructor for municipal & university courses
Purpose of the Study

To demonstrate the unique aspects of EDR pre-crash data, particular to each category of unintended acceleration scenario.
Potential Benefits

- New tool for collision database analysis
- Categorization of unintended acceleration collisions to determine frequency of each category
- Improved vehicle safety systems, targeted to reduce most frequent categories of unintended acceleration
Definitions

Unintended Acceleration Collision
- Any instance of physical acceleration of the vehicle, for any reason whatsoever, without the driver’s intention

Includes:
- Mistaken/confused driver actions
- Secondary driver inputs occurring without knowledge of driver
- No driver inputs at all
- Forward or reverse acceleration
- All speeds and road types
Frequency of UAC’s

- Has been a chronic collision safety issue for decades in North America
- Over 16,000 reported unintended acceleration collisions per year in U.S.
- Historically difficult to categorize, since reports of UAC’s depend on driver statements
- Frequency and causes of UAC’s have been thoroughly studied by:
  - Transport Canada
  - NHTSA
  - NASA
Prevelance of UAC’s

- Has occurred at all speed ranges
- Has occurred on all road types
- Has occurred with all vehicle types, including:
  - Passenger vehicles
  - Commercial trucks
  - Municipal buses
  - Motorcycles
  - Boats
  - Golf carts
  - Power wheelchairs/scooters
  - Segways
- Many people in this room have likely been in UAC’s
Categories of UAC

- **Category 1: Pedal Misapplication**
  - Driver error
  - Mistaken application of gas pedal, or both pedals
  - Driver initially responds with increased pedal application
  - Panic response follows
  - Driver responds with full pedal application
  - Most common current category of UAC (90-99%??)
  - ~16,000 cases/year in U.S.
Categories of UAC

- Category 2: Gas Pedal Entrapment
  - Non-driver related error
  - Physical interference of floor mat or other floor object with gas pedal
  - Driver applies brake pedal only
  - Famous 2009 Toyota floor mat recall
  - 2nd most common current category of UAC (1-10%??)
Categories of UAC

- **Category 3: Cruise Control Driver Activation Error**
  - Driver error
  - Driver unknowingly activates ‘resume’ or ‘accelerate’ button with cruise control system active
  - Activation by hand, or theoretically by voice
  - Driver applies brake pedal only
  - Immediately deactivates ‘resume’ or ‘accelerate’ function
  - Collision can result if insufficient braking distance
  - Would likely be reported by driver as electronic failure
  - Very rare category of UAC (<1%)
Categories of UAC

- Category 4: Mechanical Failure
  - Non-driver related error
  - Mechanical failure of throttle cable (older vehicles only) or ‘stuck’ gas pedal without floor mat interference
  - Gas pedal locked in depressed position
  - Driver applies brake pedal only
  - Typically reported as an observed ‘stuck’ gas pedal
  - Rare category of UAC (<1%)
Categories of UAC

- **Category 5: Electronic Failure**
  - Non-driver related error
  - Electronic/computer malfunction of ETC or cruise control
  - Driver applies brake pedal only
  - Collision can result if insufficient braking distance
  - Most commonly claimed cause by drivers (Toyota cases, etc.)
  - NASA unable to create this failure (system redundancies)
  - Theoretical category with no documented cases, until:
    - May 2018 Fiat Chrysler recall
    - 4.8M vehicles: 2014-19 Chryslers, Dodges, Jeeps & Rams
    - Short circuit of cruise control redundancy: unable to deactivate
Event Data Recorders

- Integral part of the air bag control system since ‘90’s
- Record collision-related data in event of an airbag deployment, or near-deployment event
- 2012 US Regulation: EDRs in new passenger vehicles must be commercially downloadable
- EDRs are now present in over 99% of new passenger vehicles sold in Canada and US
Data Recorded by EDRs

- Varies in amount & format by make & model of EDR module
- Continually increasing amount of data stored
- Typical minimum data includes:
  - Frontal delta-v of collision
  - Driver seatbelt status
  - 2.5 to 5 s pre-impact data (speed, throttle, braking, RPM)
- Often, much more available (lateral delta-v, rollover g’s, cruise control status, secondary impacts, etc.)
Method

- Actual case studies used from databases of EDR downloads from unintended acceleration collisions:
  - NHTSA (58 UAC collisions from 2010)
  - Transport Canada (22 UAC collisions from 2010 to 2012)
  - Authors (investigation of 1400+ collisions from 1995 to 2017)

- Only EDR data verified as being from incident collisions were considered

- All EDR data copied into identical format for ease of visual comparison
Results

Pedal Misapplication Category - Gas pedal only:

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Speed (km/h)</th>
<th>Engine (RPM)</th>
<th>Throttle (%)</th>
<th>Brake (On/Off)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2.5</td>
<td>99.8</td>
<td>3840</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>-2</td>
<td>103.0</td>
<td>3968</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>-1.5</td>
<td>106.2</td>
<td>4032</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>-1</td>
<td>109.4</td>
<td>4160</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>-0.5</td>
<td>112.6</td>
<td>3968</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- Time (s): -2.5, -2, -1.5, -1, -0.5, 0
- Speed (km/h): 99.8, 103.0, 106.2, 109.4, 112.6
- Engine (RPM): 3840, 3968, 4032, 4160, 3968
- Throttle (%): 100, 100, 100, 100, 0
- Brake (On/Off): 0, 0, 0, 0, 0
Results

Pedal Misapplication Category - Both pedals:

1RTVV724XXX123456 Non-Deployment Pre-Crash Graph

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>-5</th>
<th>-4</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>-0.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>6.0</td>
<td>4.0</td>
<td>20.0</td>
<td>22.0</td>
<td>29.9</td>
<td>26.1</td>
</tr>
<tr>
<td>Engine (RPM)</td>
<td>400</td>
<td>1600</td>
<td>2000</td>
<td>2800</td>
<td>2800</td>
<td>3200</td>
</tr>
<tr>
<td>Throttle (%)</td>
<td>0</td>
<td>67</td>
<td>92</td>
<td>66</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>Brake (On/Off)</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Results

Gas Pedal Entrapment Category:

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Speed (km/h)</th>
<th>Engine (RPM)</th>
<th>Throttle (%)</th>
<th>Brake (On/Off)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>102.0</td>
<td>5200</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>-4</td>
<td>92.0</td>
<td>5200</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>-3</td>
<td>84.0</td>
<td>3200</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>-2</td>
<td>82.1</td>
<td>3600</td>
<td>74</td>
<td>100</td>
</tr>
<tr>
<td>-1</td>
<td>82.1</td>
<td>3600</td>
<td>74</td>
<td>100</td>
</tr>
<tr>
<td>-0.5</td>
<td>75.9</td>
<td>4400</td>
<td>74</td>
<td>100</td>
</tr>
</tbody>
</table>

1ZDEF712XXX123456 Non-Deployment Pre-Crash Graph
Results

Cruise Control Driver Activation Category:

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Speed (km/h)</th>
<th>Engine (RPM)</th>
<th>Throttle (%)</th>
<th>Brake (On/Off)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>80.5</td>
<td>4100</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>-4</td>
<td>88.5</td>
<td>4600</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-3</td>
<td>96.5</td>
<td>4700</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-2</td>
<td>98.1</td>
<td>3100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-1</td>
<td>80.5</td>
<td>2800</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>0</td>
<td>80.5</td>
<td></td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Vehicle Speed (km/h)

Engine RPM/100

Throttle (%)

Brake Status (100=ON;0=OFF)
Results

Mechanical Failure Category:

1QTRB707XXX123456 Deployment Pre-Crash Graph

- Vehicle Speed (km/h)
- Engine RPM/100
- Throttle (%)
- Brake Status (100=ON; 0=OFF)

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>-5</th>
<th>-4</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>77.1</td>
<td>86.7</td>
<td>91.9</td>
<td>89.3</td>
<td>84.8</td>
<td></td>
</tr>
<tr>
<td>Engine (RPM)</td>
<td>4200</td>
<td>4400</td>
<td>4520</td>
<td>4440</td>
<td>4300</td>
<td></td>
</tr>
<tr>
<td>Throttle (%)</td>
<td>68</td>
<td>68</td>
<td>68</td>
<td>68</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Brake (On/Off)</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Results

Electrical Failure Category:

1XBB411XXX123456 Deployment Pre-Crash Graph

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>-5</th>
<th>-4</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>56.3</td>
<td>66.0</td>
<td>72.4</td>
<td>78.8</td>
<td>53.1</td>
<td></td>
</tr>
<tr>
<td>Engine (RPM)</td>
<td>2950</td>
<td>3600</td>
<td>4550</td>
<td>3050</td>
<td>2150</td>
<td></td>
</tr>
<tr>
<td>Throttle (%)</td>
<td>21</td>
<td>21</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Brake (On/Off)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

Gas Pedal Entrapment vs. Mechanical Failure:

![Graph showing data]

- **Vehicle Speed** (km/h)
- **Engine RPM/100**
- **Throttle (%)**
- **Brake Status** (100=ON; 0=OFF)

*Time before Algorithm Enable (seconds)*
Cruise Control Driver Activation vs. Electrical Failure:

![Graphs showing vehicle speed, engine RPM, throttle, and brake status over time.]}
Conclusions

EDR data presented as 1 of 3 easily distinguishable UAC groups:

- Pedal Misapplication category
  - distinct from all other categories
  - can be identified quickly by visual examination

- Pedal Entrapment & Mechanical Failure categories
  - similar profiles to each other, but distinct from all other categories
  - mechanical inspection will confirm presence of mechanical failure, if any

- Cruise Control Driver Activation & Electrical Failure categories
  - similar profiles to each other, but distinct from all other categories
  - check initial gas pedal position or cruise control data to distinguish
Limitations of Study

- Case study date from documented mechanical failure category cases but no actual EDR data

- No documented cases of cruise control driver activation category to date

- No EDR data yet from recently documented electrical failure category recall
Areas for Future Work

- Inclusion of autonomous vehicle mode
- Recommend systematic collection of EDR data by Police from all reported UAC’s
- Recommend systematic categorization of all reported UAC’s using EDR data in collision databases
- Consider feasibility of customizable pedal positions
- Consider feasibility of UA ‘engine kill switch’
References

TOMERLIN et. al, Pedal Errors in Late-Model Automobiles, SAE #900142, 1990
SCHMIDT et. al, Pedal Misapplications: Their Frequency & Variety Revealed Through Police Accident Reports, HFES, 1997
TRACHTMAN et. al, The Role of Pedal Configuration in Unintended Acceleration & Pedal Error Accidents, HFES, 2005
MORTIMER et. al, Unintended Acceleration: Human Factors Engineering Issues & Solutions, HFES, 2011
Technical Assessment of Toyota Electronic Throttle Control Systems, NHTSA, 2011
LOCOCO et. al, Pedal Application Errors, NHTSA, 2012
YOUNG et. al, Human Factors in Sudden Acceleration Incidents, HFES, 2011
FMVSS No. 124, NHTSA-2012-0038, 2012
GERMAN et. al, The Use of Event Data Recorders in the Analysis of Real-World Crashes, CARSP, 2001
DALMOTAS et. al, Crash Pulse Analysis Using Event Data Recorders, CARSP, 2009
BORTLES et. al, A Compendium of Passenger Vehicle Event Data Recorder Literature & Analysis of Validation Studies, SAE #2016-01-1497, 2016
LEHOUILLIER et. al, The Use of Event Data Recorders in the Analysis of Unintended Acceleration Incidents, CARSP, 2013
Toyota EDR Data from NHTSA Pre-Crash Field Inspections, NHTSA, 2011
COLLINS et. al, Driver Brake & Accelerator Controls & Pedal Misapplication Rates in N.C., NHTSA, 2015
Questions