Crash Trifecta: A Complex Driving Scenario for Describing Safety-Critical Event Causation

Naomi Dunn, Jeffrey Hickman, & Rich Hanowski

Center for Truck & Bus Safety
Virginia Tech Transportation Institute

Advancing Transportation Through Innovation
Overview

• Investigating crash causation:
  • Crash databases compiled from police accident reports and naturalistic driving (ND) studies
  • Emphasize the critical reason as primary proximal cause
  • Do not allow room for specification of any factor other than the critical reason

• In reality, there is often more than one factor that contributes to the formation of a safety-critical event (SCE)
  • Involves a convergence of several factors
  • E.g., distracted driving + sudden stop in traffic
Crash Trifecta Concept

• Defined as three separate, but converging, elements:
  1. Unsafe pre-incident behavior or maneuver
  2. Transient driver inattention
  3. An unexpected traffic event

• Each of these elements can (and does) occur individually and can result in an SCE
  • All 3 elements do not need to be present for a crash to occur
• The crash trifecta concept implies that the probability of a crash is greater if the three elements are present than if only one is present
  • i.e., higher severity SCEs are more likely to involve the convergence of multiple elements and lower-severity SCEs may be attributed to a unitary element
Example

Unsafe pre-incident behavior (e.g., tailgating)

Transient driver inattention (e.g., texting)

Unexpected traffic event (e.g., sudden braking due to animal on the road)

Outcome = CRASH
Objective

• Investigate the crash trifecta concept to determine if the convergence of multiple elements, rather than a single, unitary critical reason, has greater value in explaining the complexities of crash genesis
Methods

• Secondary analysis using seven existing naturalistic driving data sets
  • 4 truck-based ND studies
  • 3 light-vehicle ND studies
• Data were formatted and merged into one data set
• SCEs included:
  • Crash
  • Curb Strike
  • Near-Crash
  • Crash-Relevant Conflict
Methods – Data Reduction

• Previous data reduction provided driver behavior variable
  • Used to determine unsafe driver behavior
  • E.g., speeding; aggressive driving; improper turning; stop sign or signal violation; drowsy, inattentive, or distracted driving; excessive or sudden braking/stopping; following too close; illegal passing

• Eye-glance data had also been reduced and coded
  • Used to assess transient driver inattention
  • Threshold of > 1 sec
  • If a driver’s eyes were off the forward roadway for a total of more than 1 second prior to the triggering event, transient driver inattention was deemed to be present
Methods – Data Reduction

• New data reduction was needed to obtain the unexpected event variable

• Data analysts examined 10 seconds prior to SCE to determine if an unexpected event occurred
  • E.g., an animal, object, or debris on the road; another vehicle pulling out in front of the subject vehicle; lead vehicle braking suddenly; another vehicle cutting in front of subject vehicle; changes in traffic occurring while the subject was not paying attention

• Inter-rater reliability estimates verified that analysts followed data reduction protocols in the same way (~ 93% agreement)
## Results – Crash Trifecta Event Classification

<table>
<thead>
<tr>
<th>Severity Level</th>
<th>Number of Crash Trifecta Events ((n = 4,471))</th>
<th>Number of At-Fault Crash Trifecta Events ((n = 3,038))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash</td>
<td>138</td>
<td>94</td>
</tr>
<tr>
<td>Near-Crash</td>
<td>1,202</td>
<td>733</td>
</tr>
<tr>
<td>Crash-Relevant Conflict</td>
<td>3,060</td>
<td>2,150</td>
</tr>
<tr>
<td>Curb Strike</td>
<td>71</td>
<td>61</td>
</tr>
</tbody>
</table>
## Crash Trifecta Elements by SCE Severity

<table>
<thead>
<tr>
<th>Crash Trifecta Elements</th>
<th>Crash $(n = 138)$</th>
<th>Near-Crash $(n = 1,202)$</th>
<th>Crash-Relevant Conflicts $(n = 3,060)$</th>
<th>Curb Strikes $(n = 71)$</th>
<th>Total $(n = 4,471)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>4.35%</td>
<td>2.16%</td>
<td>3.27%</td>
<td>4.23%</td>
<td>3.02%</td>
</tr>
<tr>
<td>Unexpected Traffic Event</td>
<td>6.52%</td>
<td>9.07%</td>
<td>11.80%</td>
<td>0.00%</td>
<td>10.72%</td>
</tr>
<tr>
<td>Transient Inattention</td>
<td>9.42%</td>
<td>1.75%</td>
<td>2.19%</td>
<td>2.82%</td>
<td>2.30%</td>
</tr>
<tr>
<td>Unsafe Driving Behavior</td>
<td>9.42%</td>
<td>8.48%</td>
<td>19.97%</td>
<td>26.76%</td>
<td>16.66%</td>
</tr>
<tr>
<td>Unexpected Event + Transient Inattention</td>
<td>3.62%</td>
<td>3.08%</td>
<td>3.50%</td>
<td>0.00%</td>
<td>3.33%</td>
</tr>
<tr>
<td>Unexpected Event + Unsafe Behavior</td>
<td>18.12%</td>
<td>41.93%</td>
<td>15.19%</td>
<td>0.00%</td>
<td>22.23%</td>
</tr>
<tr>
<td>Unsafe Behavior + Transient Inattention</td>
<td>23.91%</td>
<td>9.40%</td>
<td>33.49%</td>
<td>61.96%</td>
<td>27.18%</td>
</tr>
<tr>
<td>Crash Trifecta</td>
<td>24.64%</td>
<td>24.13%</td>
<td>10.59%</td>
<td>4.23%</td>
<td>14.56%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
### Crash Trifecta Elements by At-Fault SCE Severity

<table>
<thead>
<tr>
<th>Crash Trifecta Elements</th>
<th>Crash ((n = 94))</th>
<th>Near-Crash ((n = 733))</th>
<th>Crash-Relevant Conflict ((n = 2,150))</th>
<th>Curb Strike ((n = 61))</th>
<th>Total ((n = 3,038))</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2.13%</td>
<td>2.32%</td>
<td>1.07%</td>
<td>4.92%</td>
<td>1.48%</td>
</tr>
<tr>
<td>Unexpected Traffic Event</td>
<td>3.19%</td>
<td>3.55%</td>
<td>1.26%</td>
<td>0.00%</td>
<td>1.84%</td>
</tr>
<tr>
<td>Transient Inattention</td>
<td>3.19%</td>
<td>1.91%</td>
<td>1.26%</td>
<td>3.28%</td>
<td>1.51%</td>
</tr>
<tr>
<td>Unsafe Driving Behavior</td>
<td>10.64%</td>
<td>11.59%</td>
<td>25.21%</td>
<td>29.51%</td>
<td>21.56%</td>
</tr>
<tr>
<td>Unexpected Event + Transient Inattention</td>
<td>1.06%</td>
<td>1.50%</td>
<td>0.70%</td>
<td>0.00%</td>
<td>0.89%</td>
</tr>
<tr>
<td>Unexpected Event + Unsafe Behavior</td>
<td>15.97%</td>
<td>37.24%</td>
<td>15.25%</td>
<td>0.00%</td>
<td>20.28%</td>
</tr>
<tr>
<td>Unsafe Behavior + Transient Inattention</td>
<td>31.91%</td>
<td>13.92%</td>
<td>44.46%</td>
<td>59.02%</td>
<td>37.00%</td>
</tr>
<tr>
<td>Crash Trifecta</td>
<td>31.91%</td>
<td>27.97%</td>
<td>10.79%</td>
<td>3.27%</td>
<td>15.44%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
Discussion

• Pattern of results seems to make intuitive sense
  • E.g., inattention present in ~70% of crashes but only 45% of near-crashes

• Approx. two-thirds of all SCEs and three-quarters of at-fault SCEs had at least two crash trifecta elements present
  • less than one-third of the total SCEs and one-quarter of at-fault SCEs had one crash trifecta element present
  • equivalent to a single critical reason

• Most notably, the presence of all three crash trifecta elements increased as the severity of the SCE increased
  • E.g., 32% of at-fault crashes vs. 11% of at-fault crash-relevant conflicts
Conclusions

• Assigning a critical reason may be suitable for lower-severity SCEs, but when investigating higher-severity SCEs, the convergence of multiple elements needs to be recognized.

• The crash trifecta concept may also assist researchers in determining why a crash occurred compared with a similar situation that resulted in a successful evasive maneuver.

• There were few crashes and curb strikes compared to near-crashes and crash-relevant conflicts.
  • More data is needed to confirm these results.
Thanks for listening!

Naomi Dunn, Ph.D.
ndunn@vtti.vt.edu

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