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

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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

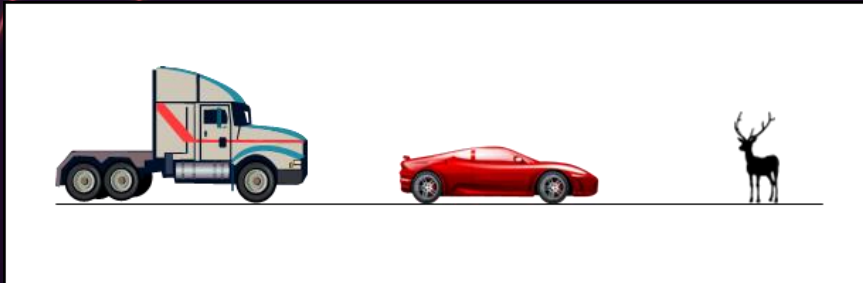Virginia Tech®
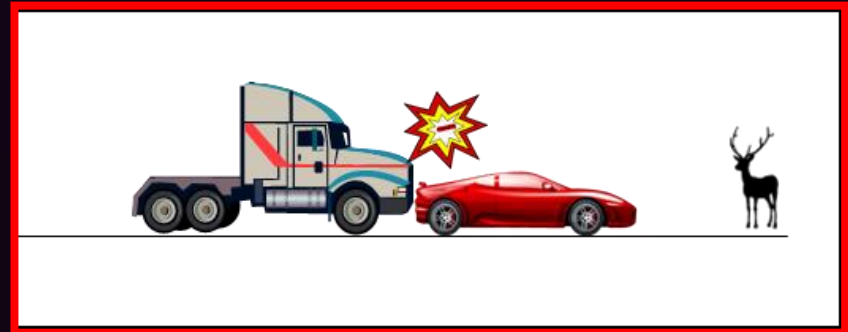Transportation Institute

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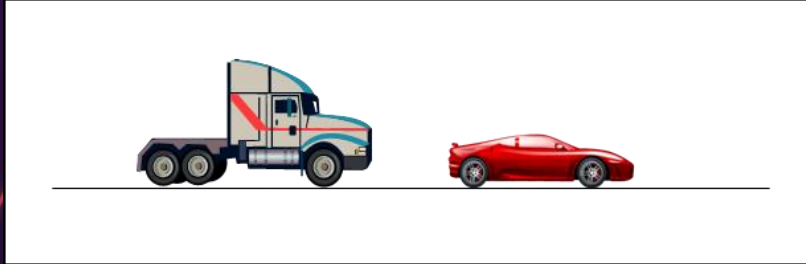
Unsafe pre-incident behavior (e.g., tailgating)

Transient driver inattention (e.g., texting)

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

Outcome = CRASH

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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

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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

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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

Severity Level	Number of Crash Trifecta Events ($n = 4,471$)	Number of At-Fault Crash Trifecta Events ($n = 3,038$)
Crash	138	94
Near-Crash	1,202	733
Crash-Relevant Conflict	3,060	2,150
Curb Strike	71	61

Crash Trifecta Elements by SCE Severity

Crash Trifecta Elements	Crash (*n* = 138)	Near-Crash (*n* = 1,202)	Crash-Relevant Conflicts (*n* = 3,060)	Curb Strikes (*n* = 71)	Total (*n* = 4,471)
None	4.35%	2.16%	3.27%	4.23%	3.02%
Unexpected Traffic Event	6.52%	9.07%	11.80%	0.00%	10.72%
Transient Inattention	9.42%	1.75%	2.19%	2.82%	2.30%
Unsafe Driving Behavior	9.42%	8.48%	19.97%	26.76%	16.66%
Unexpected Event + Transient Inattention	3.62%	3.08%	3.50%	0.00%	3.33%
Unexpected Event + Unsafe Behavior	18.12%	41.93%	15.19%	0.00%	22.23%
Unsafe Behavior + Transient Inattention	23.91%	9.40%	33.49%	61.96%	27.18%
Crash Trifecta	24.64%	24.13%	10.59%	4.23%	14.56%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Crash Trifecta Elements by At-Fault SCE Severity

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

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

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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

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Thanks for listening!

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