David vs Goliath: The effect of vehicle incompatibility on motor vehicle fatalities

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The problem

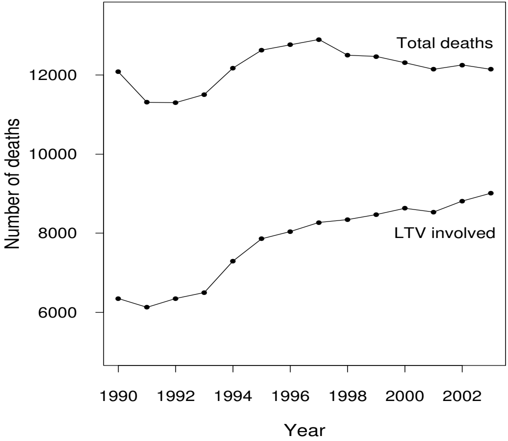
In a crash between a passenger car and a light truck the occupants of the car are more likely to be killed than the occupants of the light truck.

But we don't know

- How much the car occupant risk is raised,
- Whether the LTV occupant risk is lowered,
- What the net effect is.

The problem

Deaths in multi-vehicle passenger vehicle crashes, 1990–2003.



Aggressivity index

NHTSA's aggressivity index is the ratio of deaths in cars to deaths in the LTV in car versus LTV crashes.

Hummer	5.2
Ford Explorer	4.2
Ford fullsize pickup	7.6
Chevrolet Suburban	6.2
Honda Odyssey	5.7

This measure has obvious flaws.

Contributors to incompatibility

- Weight
- Height
- Frame type (unibody versus truck frame)
- Stiffness

Study goals

1. Estimate the risk that car occupants face in a car versus light truck crash, compared to a car versus car crash.
2. Estimate the risk that light truck occupants face, compared to the risk they would face if they were in a car.
3. Estimate the net effect of car versus LTV crashes compared to car versus car crashes.

Study design

The study is a case-control study.

Data was collected by NHTSA:

- cases from Fatality Analysis Reporting System (FARS)
- controls from General Estimates System (GES)

Study design

I included crashes meeting these conditions:

- The crash occurred between 1990 and 2006,
- Two-vehicle crash between 2 passenger vehicles,
- No pedestrians are involved,
- Both vehicles are model year 1980 or newer.

Number of case crashes: 119,573
Number of control crashes: 333,041

Study design

case vs control crashes; index vs opposing vehicles

In the *case* crashes, a decedent is selected as the *index* person. If there was more than one fatality in the crash, one is selected randomly to be the index person. The vehicle the index person was in is the *index* vehicle. The other vehicle in the crash is the *opposing* vehicle.

In the *control* crashes, one vehicle is selected randomly to be the index vehicle, and one person in that vehicle is selected randomly to be the index person. The other vehicle in the crash is the opposing vehicle.

Study design

Index and opposing vehicles were categorized as:

- car
- compact SUV (Explorer, 4Runner)
- full-size SUV (Suburban, Hummer)
- minivan
- full-size van
- compact pickup (Ranger, S-10)
- full-size pickup (Ford F150, F250)

Study design - challenges

Missing data on potential confounders:

- Vehicle speed at the time of the crash is missing for about 60% of vehicles. Speed is more likely to be missing in cases than controls, and more likely to be missing for cars than for LTVs.
- Seatbelt use is missing for about 10% of vehicle occupants.

Multiple imputation

I used multiple imputation to fill in missing values:

1. Form a prediction model for the missing values, using all the information that will be used in the analysis,
2. For each missing value, draw a simulated value from the distribution described by the prediction model,
3. Repeat several times (maybe 5–10 times) to form several complete datasets,
4. Analyse each dataset with standard methods,
5. Combine the point estimates and variance estimates.

Multiple imputation does not add information to the data — it is a method to produce valid estimates in the presence of missing data.

Analysis method

I used logistic regression, using methods that account for the stratification, clustering, and weighting of the GES sample.

I tested whether these factors modified the effect of index or opposing vehicle type:

- the type of the other vehicle in the crash,
- the vehicle model year,
- the year of the crash

None of these effect modifications were statistically significant.

Results

Potential confounders I controlled for:

- the speed and squared speed of index and opposing vehicles
- speed limit and squared speed limit
- seatbelt use
- age and squared age of the index person
- sex
- year of crash
- number of occupants in the index vehicle
- seating position of the index person
- crash type (head-on, angle, etc)
- road type (interstate, other divided, other)

Results

Vehicle type	Effect of opposing vehicle	Effect of index vehicle	Net effect
Car	—	—	—
compact SUV	2.6 (2.3, 3.0)	0.71 (0.6, 0.8)	1.7 (1.5, 1.8)
full-size SUV	3.1 (2.6, 3.7)	0.36 (0.3, 0.4)	1.7 (1.5, 2.0)
minivan	1.8 (1.6, 2.1)	0.54 (0.5, 0.6)	1.2 (1.0, 1.3)
full-size van	4.6 (3.8, 5.5)	0.33 (0.3, 0.4)	2.5 (2.1, 2.9)
compact PU	1.7 (1.5, 2.0)	0.59 (0.5, 0.7)	1.2 (1.0, 1.3)
full-size PU	3.4 (2.8, 4.0)	0.31 (0.3, 0.4)	1.8 (1.6, 2.2)

odds ratios and 95% CIs

The “net effect” compares the risk of death in both vehicles in a car versus LTV crash to the risk of death in both vehicles in a car versus car crash.

Results

The net effect of LTVs on the number of deaths during 1990–2006:

- There were a total of 33,579 deaths in LTVs. If all the people in LTVs were in cars, there would have been 68,915 deaths among them. So 35,336 lives were saved by LTVs. The 95% CI is (28,738, 42,633).
- There were a total of 78,455 deaths in vehicles that crashed with an LTV. If all the other vehicles had been cars, there would have been 30,348 deaths. So LTVs cost the lives of 48,107 people. The 95% CI is (45,251, 50,718).
- The net effect is 12,771 more deaths because of LTVs. The 95% CI is (5,150, 20,392).

Caution!

These results are for two-vehicle crashes only. Vehicle effects may be different in single vehicle crashes.

I assessed only *crashworthiness*, not *crash avoidance*.

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