Real-world effects of General Motors Rear Automatic Braking, Rear Vision Camera, and Rear Parking Assist systems

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Jessica B. Cicchino
Insurance Institute for Highway Safety
Abstract

Objective: To evaluate the effects of rearview cameras, rear parking sensors, and rear automatic braking systems from General Motors on backing crashes.

Method: Negative binomial regression was used to compare police-reported backing crash involvements per insured vehicle year in 23 U.S. states during 2012–2015 among General Motors vehicles with Rear Vision Camera alone; Rear Parking Assist alone (rear parking sensors); Rear Vision Camera and Rear Parking Assist; or the Rear Vision Camera, Rear Parking Assist, and Rear Automatic Braking to vehicles with none of these systems. Modeling controlled for other backing assistance systems on vehicles and factors that may affect crash risk.

Results: The combination of Rear Vision Camera and Rear Parking Assist reduced backing crash involvement rates by 42%, and adding Rear Automatic Braking to these two systems reduced rates by an additional 62%. Taken together, vehicles with all three systems had backing crash involvement rates that were 78% lower than vehicles with none of the systems. On vehicles with Rear Parking Assist alone or Rear Vision Camera alone, backing crash involvement rates were reduced 28% and 5%, respectively, but these reductions were not statistically significant.

Conclusions: Rearview cameras and rear parking sensors are preventing some backing crashes, but their effectiveness may be constrained in part by drivers not using or responding to the systems appropriately. Rear automatic braking adds to the effectiveness of these systems because it does not rely entirely on appropriate driver response.

Practical applications: Rear parking sensors and rearview cameras are available on most new vehicles, but availability of rear automatic braking is limited. If more vehicles were equipped with rear automatic braking that performed like the system from General Motors, many backing crashes that still occur among vehicles with rearview cameras and rear parking sensors could be prevented.

Keywords: Active safety system; Automatic braking; Backing technology; Backup camera; Crash avoidance technology; Park Assist; Rear autobrake
1. Introduction

Although backing crashes tend to occur at low speeds, they are a pervasive problem. According to the National Highway Traffic Safety Administration (NHTSA), approximately 188,000 passenger vehicles were backing in crashes reported to the police in the United States during 2015 (NHTSA, 2016). NHTSA’s police-reported crash data exclude crashes outside of public roadways, which is where many backing crashes occur, and thus backing crashes undoubtedly comprise a larger proportion of crashes than NHTSA’s data suggest. Among insurance claims filed for vehicles during 2016 under collision coverage, which covers damage to at-fault vehicles in crashes, 29% were initially impacted in the rear (Highway Loss Data Institute [HLDI], 2017d); because these vehicles were at fault, it is more likely that many of these vehicles were backing as opposed to being struck in the rear by other vehicles. Backover crashes in which a vehicle backs into and injures or kills a person are rarer than backing crashes that result in property damage, but tragic when they occur. Approximately 267 fatalities and 15,000 injuries occur annually in backover crashes (National Highway Traffic Safety Administration, [NHTSA] 2014).

Vehicle technologies hold promise for preventing backing crashes. Rearview cameras, which display an image to drivers of the area behind the vehicle, and rear parking sensors, which typically use ultrasonic sensors and provide an audible, haptic, and/or visual alert when an object is detected behind the vehicle, are prevalent in the new vehicle fleet. These technologies were offered on nearly all new passenger vehicles in model year 2018, with rear parking sensors standard on 33% of new series and optional on an additional 59%, and rearview cameras standard on 89% and optional on an additional 10% (HLDI, 2018). Rear visibility systems meeting specific rear field-of-view requirements will be required as standard equipment on new U.S. light passenger vehicles as of May 2018, and this requirement will be met on most vehicles with rearview cameras. HLDI (2017e) estimates that 24% of registered U.S. passenger vehicles in 2016 had a rearview camera and 17% had rear parking sensors.

A number of experimental studies have demonstrated that rearview cameras are more effective than alerts from rear parking sensors in reducing the likelihood that a driver will strike an object unexpectedly placed behind their vehicle while backing (Kidd, Hagoski, Tucker, & Chiang, 2015; Kim,
Rauschenberger, Heckman, Young, & Lange, 2012; Llaneras et al., 2005; Llaneras, Neurauter, & Green, 2011; Mazzae, 2010, 2013; Mazzae, Barickman, Baldwin, & Ranney, 2008; Perez et al., 2011). For example, Kidd et al. (2015) surreptitiously placed a child-sized stationary object 15 feet behind vehicles driven by volunteer drivers with parking sensors, a rearview camera, both systems, or neither system, and observed that every driver with no backing system struck the object, followed by drivers with sensors (94%), a rearview camera and sensors (75%), and a rearview camera alone (56%). It is worth noting that these experimentally-controlled studies do not address a typical backing situation where the driver is intentionally trying to back close to an object, which could also result in a backing crash.

More recently, studies on the real-world effects of rearview cameras and rear parking sensors have found that these systems are preventing some crashes reported to insurers and the police. HLDI has examined the effects of rearview camera and rear parking sensor systems from multiple manufacturers by comparing insurance claim rates for vehicles with and without these systems among vehicle models where the systems were optional, controlling for a number of other features that may affect crash risk. When averaged across manufacturers, rear parking sensors have reduced overall rates (since crash circumstance is unknown) of collision and property damage liability claims by 1% and 5%, respectively (HLDI, 2015, 2016a, 2016b; 2017a, 2017b, 2017c, 2017f); property damage liability claims cover damage caused by at-fault vehicles to other vehicles and property and collision claims cover damage to the at-fault vehicles. Vehicles with rearview cameras on average had property damage liability claim rates that were 4% lower than the same vehicle models without a backing assistance system, but collision claim rates were non-significantly higher among vehicles with the system than without.

HLDI could not identify backing crashes to isolate the effects of these systems on the target crash type, but backing crashes can be identified in data reported to the police. Flannagan, Kiefer, Bao, Leblanc, and Geisler (2014) used induced exposure with police-reported crash data to examine the effectiveness of rearview cameras and parking sensors among model year 2008–2010 General Motors vehicles. The ratio of involvement in backing crashes to being rear-struck was compared between vehicles with a rearview camera and rear parking sensors or rear parking sensors only and those with no backing system, among
General Motors models where not all vehicles were equipped with a system. The combination of a rearview camera and sensors reduced backing crashes by 52%. Rear parking sensors alone did not reduce backing crashes.

Cicchino (2017a) investigated the impact of rearview cameras, rear parking sensors, and both systems combined from a wider variety of manufacturers than Flannagan et al. (2014) on backing crashes reported to the police. Using similar methods to HLDI’s work, police-reported backing crash rates per insured vehicle year were compared between vehicles with backing systems and the same models where the optional systems were not purchased. On average across the four manufacturers included, rearview cameras reduced backing crash rates significantly by 17%. Rear parking sensors were examined from two manufacturers, with inconsistent results; the system significantly reduced backing crash rates by 34% among Buick Lucerne models, but reductions were small and non-significant among Mercedes-Benz vehicles. Backing crash rates were also 13% lower among Mercedes-Benz vehicles with both sensors and a rearview camera than among Mercedes-Benz vehicles without a backing system, but the reduction was not statistically significant.

A study using police-reported crash data on pedestrian injuries from Australia and New Zealand provided the first evidence of a benefit for rearview cameras and rear parking sensors on backover crashes. Keall, Fildes, and Newstead (2017) examined the odds that a pedestrian injury was caused by a backover crash for vehicles with a rearview camera, rear parking sensors, or both systems standard compared with vehicles where the technologies were optional or not available. The odds that a pedestrian crash was a backover was 31% lower for vehicles with rear parking sensors, 41% lower for vehicles with a rearview camera, and 30% lower for vehicles with both technologies compared to vehicles models without standard backing assistance systems.

Rear automatic braking is a newer type of backing assistance system that provides emergency braking when a backing crash with another vehicle or object is imminent. In model year 2018, the system was available as an optional feature on only 5% of new vehicle series and was standard on less than 1% (HLDI, 2018). Because automatic braking systems do not rely on an appropriate response from the driver
to successfully avoid a crash, they have the potential to be more effective than cameras and alerts from sensors for preventing backing crashes. HLDI (2017a, 2017f) performed the only existing research on the effectiveness of rear automatic braking. Systems from General Motors and Subaru were analyzed using identical methods to HLDI’s studies of other backing assistance systems. The rear automatic braking system from each of these automakers reduced collision claim rates by more than 10% and property damage liability claim rates in excess of 25%, far exceeding the benefits seen for rearview cameras and rear parking sensors on these insurance coverage types.

As with HLDI’s analyses of rearview cameras and rear parking sensors, their study of rear automatic braking could not investigate the effect of the systems on backing crashes because HLDI was not able to isolate crash types in their data set. The primary goal of the current study was to examine the effect of rear automatic braking on its target crash type, backing crashes, using police-reported data where crash types could be classified. Cicchino (2017a) and Flannagan et al. (2014) previously examined the effects of rearview cameras and rear parking sensors on police-reported backing crashes, and while both studies included some General Motors vehicles, neither included vehicles from this manufacturer newer than model year 2010. The secondary goal of this study was to examine the effects of rearview cameras, rear parking sensors, and their combination on newer model year General Motors vehicles.

2. Method

2.1 Vehicles

General Motors provided the vehicle identification numbers (VINs) of model year 2013–2015 Buick, Cadillac, and Chevrolet vehicles and the collision avoidance systems with which they were equipped. Backing assistance systems of interest were as follows:

- **Rear Parking Assist** uses ultrasonic sensors on the rear bumper that detect objects up to 8 feet behind the vehicle between bumper level and 10 inches off the ground when the vehicle is reversing at speeds of less than 5 mph. The instrument cluster may provide distance information to the detected object, and if the vehicle also has a rearview camera, a warning
triangle appears on the camera screen that changes from amber to red and increases in size in four stages as the vehicle moves closer to the object. In addition, these object detections trigger non-visual alerts. For most General Motors vehicles, beeps or, if equipped, Safety Alert Seat pulses (i.e., seat vibrations), occur when an object is first detected and if very close to an object.

- **The Rear Vision Camera** uses a rear-facing camera to show the area behind the vehicle on a center-stack or inside rear-view mirror display when the vehicle is in reverse. Some vehicles had a Surround Vision Camera, which in addition to the Rear Vision Camera display showed a “bird’s eye” view of the scene around the vehicle. The two camera systems are grouped together in this study and for simplicity are collectively referred to as the Rear Vision Camera.

- **Rear Automatic Braking** uses radar to detect objects behind the vehicle when reversing at speeds greater than 0.5 mph, alerts the driver, and applies emergency braking if necessary. When the system detects a potentially imminent crash, beeps will be heard from the rear, or five pulses will occur from both sides of the Safety Alert Seat. There may also be a brief, sharp application of the brakes. If the system detects the vehicle is backing too fast to avoid a crash with a detected object, it may automatically brake hard to a stop. The system is not designed to detect pedestrians. (In model year 2017, General Motors changed the feature name for “Rear Automatic Braking” to “Reverse Automatic Braking”.)

Vehicles may have been equipped with Rear Parking Assist alone; the Rear Vision Camera alone; both Rear Parking Assist and the Rear Vision Camera; Rear Parking Assist, the Rear Vision Camera, and Rear Automatic Braking; or none of these systems. Study vehicles are listed in Table 1 and included those where any of these backing systems or combination of systems was optional equipment; that is, drivers
<table>
<thead>
<tr>
<th>Make</th>
<th>Series</th>
<th>Model years</th>
<th>Vehicle type</th>
<th>Systems offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buick</td>
<td>LaCrosse 4D 2WD</td>
<td>2014</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Buick</td>
<td>LaCrosse 4D 2WD</td>
<td>2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Buick</td>
<td>Regal 4D 2WD</td>
<td>2014–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Buick</td>
<td>Regal 4D 4WD</td>
<td>2014–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>ATS 2D 2WD</td>
<td>2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>ATS 2D 4WD</td>
<td>2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>ATS 4D 2WD</td>
<td>2013–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>ATS 4D 4WD</td>
<td>2013–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>CTS 4D 2WD</td>
<td>2014–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>CTS 4D 4WD</td>
<td>2014–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>Escalade 4D 2WD</td>
<td>2015</td>
<td>SUV</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>Escalade 4D 4WD</td>
<td>2015</td>
<td>SUV</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>Escalade ESV 4D 2WD</td>
<td>2015</td>
<td>SUV</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>Escalade ESV 4D 4WD</td>
<td>2015</td>
<td>SUV</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>SRX 4D 2WD</td>
<td>2013–2015</td>
<td>SUV</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>SRX 4D 4WD</td>
<td>2013–2015</td>
<td>SUV</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>XTS 4D 2WD</td>
<td>2013–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Cadillac</td>
<td>XTS 4D 4WD</td>
<td>2013–2015</td>
<td>Car</td>
<td>x</td>
</tr>
<tr>
<td>Chevrolet</td>
<td>Impala 4D</td>
<td>2014–2015</td>
<td>Car</td>
<td>x</td>
</tr>
</tbody>
</table>

Series abbreviations: 2D=two-door, 4D=four-door, 5D=five-door, 2WD=two-wheel drive, 4WD=four-wheel drive
System abbreviations: RPA=Rear Parking Assist, RVC=Rear Vision Camera, RAB=Rear Automatic Braking
had the option of either not purchasing any of the three types of backing assistance systems, or had the option of purchasing at least two systems or two combinations of systems. Rear Automatic Braking was only available on Cadillacs.

Vehicles may have also been equipped with Rear Cross Traffic Alert, which warns drivers when they are backing and a vehicle is detected in their blind spot, or Automatic Parking Assist, which helps drivers find appropriately-sized parking spots and assumes steering control while parallel parking. The presence or absence of these systems were controlled for in the analyses.

2.2 Crash and exposure data

Police-reported crash data were obtained from 23 states that released the VINs of the vehicles involved in crashes with their data. Calendar year 2012–2015 data were obtained from Delaware, Florida, Georgia, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Washington, Wisconsin, and Wyoming. Additionally, 2012–2013 data were available from Indiana, 2014–2015 data from Maryland, and 2012–2014 data from New Mexico. Vehicle backing was determined from the vehicle’s action prior to the crash as coded by the police.

Data on vehicle exposure and characteristics of the vehicle’s garaging location (density of registered vehicles in the ZIP code where the vehicle is garaged) and rated driver on the vehicle’s insurance policy (age, gender, marital status, insurance risk level) were obtained from HLDI. HLDI’s database includes information on approximately 85% of insured U.S. passenger vehicles. Exposure was expressed as insured vehicle years. Crash and insurance exposure data were merged by matching VINs within states. Crashes that occurred in a different state than where a vehicle was insured were not included in analyses.

2.3 Regression model

Negative binomial regression was used to model backing crash involvement rates per insured vehicle year for vehicles with the backing assistance systems of interest, controlling for other factors that may affect backing crash risk. The model had four separate binary variables indicating the presence or
absence of: 1) Rear Parking Assist alone, 2) the Rear Vision Camera alone, 3) the combination of Rear Parking Assist and the Rear Vision Camera, and 4) Rear Automatic Braking. Vehicles without Rear Automatic Braking were coded as having a single system type (i.e., Rear Parking Assist alone; Rear Vision Camera alone; the combination of Rear Parking Assist and the Rear Vision Camera) or no system. All vehicles with Rear Automatic Braking also had Rear Parking Assist and the Rear Vision Camera, and these vehicles were coded in the model as having two types of systems (i.e., Rear Automatic Braking and the combination of Rear Parking Assist and the Rear Vision Camera). This allowed estimation of the added effect of Rear Automatic Braking beyond the effect of the sensor and camera systems.

Rear Parking Assist alone, the Rear Vision Camera alone, and the combination of these systems were treated as discrete systems because experimental data have shown that drivers may use the combination of these systems differently than either system alone (Hurwitz et al., 2010; Kidd et al., 2015; Mazzae et al., 2008), and thus the effect of having both systems may be different than the additive effect of each individual system. Because Rear Automatic Braking only responds to an object when a backing crash is imminent, it is expected to have an additive effect by preventing crashes that could not be avoided with use of the combination of the Rear Vision Camera and Rear Parking Assist alerts.

The analysis controlled for rated driver age (15–34, 35–54, 55–69, 70+, unknown), gender (male, female, unknown), marital status (married, single, unknown), insurance risk level (standard risk, nonstandard risk, unknown), state, calendar year, and registered vehicle density per square mile (0–499, 500+) in the ZIP code where the vehicle is garaged. These covariates were chosen for consistency with HLDI’s (2017a) previous study examining the effects of General Motors backing systems on insurance claim rates. A single variable capturing the vehicle series and model year was included to restrict estimates of effects within series and model year, preventing confounding of backing system effects with other vehicle design changes that may occur between model years. Binary variables indicating the presence or absence of Rear Cross Traffic Alert and Active Parking Assist were also included.

The model used a logarithmic link function. Suppose \( C_i \) represents the number of crash involvements, \( E_i \) represents exposure (i.e., insured vehicle days), \( V_i \) represents the presence or absence of
the Rear Vision Camera alone, $S_i$ represents the presence or absence of Rear Parking Assist alone, $B_i$ represents the presence or absence of the combination of the Rear Vision Camera and Rear Parking Assist, and $A_i$ represents the presence or absence of Rear Automatic Braking for vehicle $i$. Assuming $C_i$ is a negative binomial random variable with mean $E\lambda_i$, the statistical models were specified as $\log \lambda_i = \beta_0 + \beta_1(V_i) + \beta_2(S_i) + \beta_3(B_i) + \beta_4(A_i) + \beta_5(\text{covariates})$. Parameters $\beta_1$, $\beta_2$, and $\beta_3$ were exponentiated to represent rate ratios comparing crash involvement rates for vehicles with a particular backing assistance system to those without technologies of interest. The exponentiated parameter $\beta_4$ represented the incremental effect of Rear Automatic Braking above and beyond the effect for the Rear Vision Camera and Rear Parking Assist. The combined effect of Rear Automatic Braking, the Rear Vision Camera, and Rear Parking Assist was calculated by multiplying the exponentiated effects for Rear Automatic Braking for the combination of the Rear Vision Camera and Rear Parking Assist.

Percent change in backing crash rates associated with the technologies was computed by subtracting 1 from rate ratios. Vehicles with a backing assistance system were considered to have significantly lower backing crash rates than vehicles with none of the technologies of interest when estimates and their 95% confidence intervals were less than 1.

3. Results

Study vehicles were in 640 backing crashes, which made up 3% of all police-reported crashes in which they were involved. This is similar to the 2% each of national police-reported passenger vehicle crash involvements in 2015 where vehicles were backing (NHTSA, 2016) and of passenger vehicle crash involvements deemed relevant to backing assistance systems by Najm, Smith, and Yanagisawa (2007). Nearly two-thirds (62%) occurred off the roadway, in a parking lot, or on private property. Most backed into another vehicle that was not parked (71%) or a parked vehicle (21%). Few crash involvements involved non-motorists (2%) or only the backing vehicle (5%), and few involved injuries (5%). Backing crash involvement rates, without accounting for factors that can affect crash risk, were lowest among vehicles with all three features (Rear Automatic Braking, a Rear Vision Camera, and Rear Parking Assist), followed by those with combined Rear Vision Camera and Rear Parking Assist (Table 2).
Table 2. Police-reported backing crash involvement rates of study vehicles with Rear Parking Assist alone, the Rear Vision Camera alone, both systems, and both systems with Rear Automatic Braking

<table>
<thead>
<tr>
<th>System</th>
<th>Insured vehicle years</th>
<th>Crashes</th>
<th>Rate (x1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>39,803</td>
<td>109</td>
<td>2.74</td>
</tr>
<tr>
<td>Rear Parking Assist alone</td>
<td>14,719</td>
<td>36</td>
<td>2.45</td>
</tr>
<tr>
<td>Rear Vision Camera alone</td>
<td>26,076</td>
<td>55</td>
<td>2.11</td>
</tr>
<tr>
<td>Rear Parking Assist and Rear Vision Camera</td>
<td>303,666</td>
<td>426</td>
<td>1.40</td>
</tr>
<tr>
<td>(without Rear Automatic Braking)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rear Automatic Braking</td>
<td>21,202</td>
<td>14</td>
<td>0.66</td>
</tr>
<tr>
<td>(with Rear Parking Assist and Rear Vision Camera)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>405,465</td>
<td>640</td>
<td>1.58</td>
</tr>
</tbody>
</table>

Results of the negative binomial regression of the effects of the Rear Vision Camera alone, Rear Parking Assist alone, the combination of the Rear Vision Camera and Rear Parking Assist, and Rear Automatic Braking on police-reported backing crashes, controlling for characteristics of the rated driver, garage location of the vehicle, and the presence of other backing assistance systems on the vehicle, are summarized in Table 3. Rear Parking Assist alone and the Rear Vision Camera alone reduced police-reported backing crashes by 28% and 5%, respectively, but neither reduction was statistically significant.

The combination of the Rear Vision Camera and Rear Parking Assist reduced backing crash involvement rates significantly by 42%, and Rear Automatic Braking reduced backing crash rates significantly by 62% beyond the effect for cameras and sensors. Taken together, vehicles with the combination of all three systems had police-reported backing crash involvement rates that were 78% lower than vehicles with none of the systems.
### Table 3. Adjusted rate ratios from negative binomial regression model examining the effects of Rear Parking Assist, the Rear Vision Camera, Rear Parking Assist and the Rear Vision Camera combined, and Rear Automatic Braking on police-reported backing crash involvement rates.

<table>
<thead>
<tr>
<th>System</th>
<th>Rate ratio (95% confidence interval)</th>
<th>Percentage change</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear Parking Assist alone</td>
<td>0.72 (0.46, 1.13)</td>
<td>-28</td>
<td>0.15</td>
</tr>
<tr>
<td>Rear Vision Camera alone</td>
<td>0.95 (0.65, 1.39)</td>
<td>-5</td>
<td>0.78</td>
</tr>
<tr>
<td>Rear Parking Assist + Rear Vision Camera</td>
<td>0.58 (0.44, 0.77)</td>
<td>-42</td>
<td>0.0001</td>
</tr>
<tr>
<td>Rear Automatic Braking</td>
<td>0.38 (0.21, 0.69)</td>
<td>-62</td>
<td>0.0014</td>
</tr>
<tr>
<td>(added effect beyond Rear Parking Assist + Rear Vision Camera)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined effect for Rear Parking Assist, Rear Vision Camera, and Rear Automatic Braking</td>
<td>0.22 (0.11, 0.42)</td>
<td>-78</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

### 4. Discussion

As expected, the Rear Automatic Braking system from General Motors was highly effective in reducing backing crashes reported to the police. Rear Automatic Braking reduced the police-reported backing crash rate by 62% beyond the 42% reduction observed for the combination of the Rear Vision Camera and Rear Parking Assist. This resulted in a total reduction in police-reported backing crash rates of 78% for vehicles with all three systems.

Evidence from other collision avoidance systems suggest that technology is most effective when it does not rely entirely on an appropriate response from the driver to prevent a crash. For example, forward collision warning, which warns a driver when they are at risk of rear-ending the vehicle ahead, reduces rear-end striking crash rates by 27%, while forward collision warning combined with forward automatic emergency braking increases the effectiveness to 50% (Cicchino, 2017b). The current study demonstrates that this effect extends to backing assistance technologies.

It has been documented that drivers do not always react appropriately to alerts from rear parking sensors. Although it is unknown how drivers experienced with parking sensor systems respond to them in their own vehicles, in several experimentally-controlled studies, between one-third and three-quarter of drivers with rear parking sensors did not respond to warnings from the systems while backing in various scenarios where surprise objects were placed behind their vehicles (Kidd et al., 2015; Llaneras et al., 2005; Perez et al., 2011). Drivers who did brake in response to warnings did not appear to do so with
sufficient force to prevent a crash. Among drivers that braked in Llaneras et al.’s (2005) study, nearly 70% failed to reach a deceleration of 0.1g, and most still struck the object; most participants in Kidd et al. (2015) who braked in response to warnings from the parking sensors also struck the target.

Naturalistic and experimental studies of rearview camera use have found that drivers also do not always look at the rearview camera display while backing, both among drivers in their own vehicles and among drivers in test vehicles without prior experience with the technology (Hurwitz et al., 2010; Kidd et al., 2015; Kim et al., 2012; Llaneras et al., 2011; Mazzae, 2010; Mazzae et al., 2008; Mueller, Sangrar, & Vrkljan, in press; Perez et al., 2011). And when drivers do look at the rearview camera, obstacles are not always visible. For instance, Kidd et al. (2015) reported that drivers using a rearview camera were more likely to strike a surprise object behind their vehicle if the object was in the shade than when it was not.

Volunteer drivers in an experimental study backed towards unexpected obstacles in a variety of staged situations in vehicles with all three types of technologies evaluated in the current study – rear parking sensors, a rearview camera, and rear automatic braking – plus a backing warning that was active at higher speeds than the parking sensors (Perez et al., 2011). Rear automatic braking activated for 38–79% of participants, depending on the scenario, even though drivers had access to the rearview camera and often received a warning earlier in the trial. Taken together with the results of the current study, the findings from behavioral research suggest that rear automatic braking plays a similar function in the real world by activating when other backing assistance countermeasures are not sufficient to prevent a crash.

It is not immediately apparent why the combination of the Rear Vision Camera and Rear Parking Assist had a robust effect on backing crashes, while the Rear Vision Camera alone had a small effect that did not reach significance. It is possible that the Rear Vision Camera and Rear Parking Assist work synergistically, with sensors drawing the driver’s attention to obstacles visible on the rearview camera display. Rear Parking Assist overlays graphics onto the Rear Vision Camera to indicate object detection, which could provide an explanation for a synergistic effect; it should be noted that General Motors vehicles are unique relative to other manufacturers in doing this. However, experimental studies comparing the effects of rearview cameras alone to rearview cameras combined with rear parking sensors
on backing behavior have not reliably shown that both systems are more beneficial than just the rearview camera. Hurwitz et al. (2010) reported that among experimental drivers backing with a vehicle with both systems, 80% did not look at the camera before backing, but among those drivers about half looked at the system once they were warned by the sensor system; this is similar to trends reported by Perez et al. (2011). Yet, others have found that drivers with both systems back into objects surreptitiously placed in their path slightly more often than drivers with just a rearview camera, and are also less likely to look at the camera display during a backing event (Kidd et al., 2015; Mazzae et al., 2008).

The 42% reduction in backing crashes seen for the combination of the Rear Vision Camera and Rear Parking Assist in the current study is very similar to the 52% reduction in police-reported backing crashes reported by Flannagan et al. (2014) on earlier model year General Motors vehicles with the same systems, but is considerably higher than the 13% reduction for Mercedes-Benz vehicles with both a rearview camera and parking sensors in a prior study (Cicchino, 2017a). Differences in these effect sizes could be due to differences in the systems, the vehicles, the drivers of these vehicles, or a combination of these factors.

For example, the alerting methods used by Rear Parking Assist on most of the current GM study vehicles, in which visual information on how close the vehicle is to the detected object and non-visual auditory or seat vibration alerts are presented in discrete stages, differ from only using continuous beeping (without visual alerts) that increases with intensity as the vehicle approaches the detected object used by many rear parking sensor systems from other manufacturers. Differences in alerting methods can also potentially affect if drivers keep systems turned on. The size of the rear blind zone can vary considerably across vehicles (Kidd & Brethwaite, 2014; Mazzae & Barickman, 2009), which could relate to the efficacy of backing assistance systems, but it is not known how the rear blind zone of General Motors vehicles included in the study compare with vehicles from other manufacturers.

The lack of significant effect of Rear Parking Assist on backing crashes is consistent with the results of experimental studies with rear parking sensors, which have found that they are less effective than rearview cameras in reducing backing crashes with surprise objects (Kidd et al., 2015). Flannagan et
al. (2014) similarly found that this system on earlier-model General Motors vehicles did not reduce backing crashes reported to the police. In contrast, one previous study of Rear Parking Assist on the Buick Lucerne found a significant 34% reduction in police-reported backing crashes associated with the system, but the Lucerne was owned primarily by older drivers, which may have enhanced its effectiveness; older drivers typically have difficulty with backing, and both rearview cameras and sensors had higher effect estimates for drivers age 70 and older than for younger drivers (Cicchino, 2017a). Far fewer vehicles in the current study were equipped with Rear Parking Assist alone or the Rear View Camera alone than with both systems, and so it is possible that the effect of either system alone would reach significance in a larger sample of vehicles.

The police-reported crash data used in the current study have strengths and limitations. Using police-reported crash data allowed backing crashes to be isolated, which was not possible in prior studies of backing assistance systems using insurance data (e.g., HLDI, 2017a). However, not all backing crashes that occur are reported to police. It is especially likely that minor backing crashes involving a single vehicle or occurring off-road would go unreported, and so this study did not address the potential for the backing assistance systems examined to prevent a large number of unreported crashes. Because many states do not require crashes that occur outside of public roadways to be reported to the police, there may be bias in which off-road backing crashes were ultimately reported. And since Rear Automatic Braking is operational at higher speeds than Rear Parking Assist, it is possible that the benefit of Rear Automatic Braking over and above the benefits of Rear Parking Assist and the Rear Vision Camera is greater among backing crashes reported to the police than among backing crashes in general. This study does not address the effects of backing assistance systems on backover crashes with pedestrians, which Rear Parking Assist and Rear Automatic Braking are not designed to prevent.

Study vehicles were from a single manufacturer and results are not necessarily generalizable to systems from other manufacturers with similar functionality. Some of Rear Automatic Braking’s benefit may have come from the warning functionality and not the braking functionality, since the system also warned drivers in addition to providing automatic braking. Finally, the backing assistance systems in this
study were optional equipment. Although analyses controlled for some driver characteristics that may be related to crash risk, drivers who chose to purchase vehicles with different system combinations may differ in uncontrolled ways. The effect sizes reported here may be greater or less than the actual effects due to unknown differences between drivers.

While rearview cameras and rear parking sensors are preventing some backing crashes, their effectiveness hinges on drivers using and responding to them appropriately. Rear automatic braking overcomes this weakness by providing emergency braking to prevent backing crashes when the driver does not respond or responds too slowly. This study demonstrates that rear automatic braking systems have the potential to prevent a sizeable proportion of police-reported backing crashes that still occur among vehicles with a rearview camera and rear parking sensors. If all vehicles had a rearview camera, rear parking sensors, and rear automatic braking systems that performed like the systems from General Motors, three-quarters of backing crashes reported to the police could be eliminated.

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