Reduce Distracted Driving with Real-Time In-Vehicle AI

A Nauto study on the impact of In-Vehicle Alerts on distracted driving behavior
Introduction

At Nauto, we’re committed to applying artificial intelligence (AI) in the vehicle to help commercial fleets impact driver behavior and prevent collisions before they occur.

One of the leading causes of collisions in the United States is distracted driving. In fact, 9% of all fatal collisions in 2017 involved distraction of one or both drivers, resulting in 3,166 deaths.¹

In April 2017, Nauto took the first step towards addressing distracted driving by equipping safety and fleet management leaders with insights and video evidence of the highest-risk events in their fleets. This included hard acceleration, harsh braking, and sharp cornering events, but more importantly: distracted driving.

This was made possible by detecting the high-risk behavior in real-time with artificial intelligence (AI) deployed on Nauto Devices. The insights and video evidence enabled fleet managers to coach their drivers with full context and reduce high-risk behaviors in their fleets.

In June 2018, we introduced a new capability to automate coaching in real-time to further improve safety results: In-Vehicle Alerts. With In-Vehicle Alerts, fleets can automatically notify drivers as soon as distracted driving behaviors are detected by the AI-powered Nauto Device. Built with driver privacy in mind, the automated alerts help stop distracted driving in real-time without the intervention from a manager.

In this study, we analyze the impact of In-Vehicle Alerts on the distracted driving behavior of commercial drivers. Our study observes distracted driving events before and after the introduction of In-Vehicle Alerts across a range of different fleet industries.

Defining Distracted Driving

In general, a distraction is anything that inhibits a person from paying full attention to the primary task at hand. In the case of distracted driving, this means a person is not fully engaged in the driving task and is unable to adequately respond to changes in the driving environment, which can lead to catastrophic consequences.

According to the National Highway Traffic Safety Administration, distractions typically fall into three categories:

- **Visual**: Driver’s eyes are off the road
- **Manual**: Driver’s hands are off the wheel
- **Cognitive**: Driver’s mind is off the driving tasks

Nauto’s goal is to address all forms of distraction. Currently, In-Vehicle Alerts for distracted driving addresses visual distraction, including instances when a driver is looking down for a period of time long enough to lose situational awareness of the forward driving scene.

With a continuously growing database of real-world driving scenarios, Nauto has additional forms of distraction detection in production and R&D. This study assesses distracted driving events in which drivers were primarily looking down, given this detection model has been deployed commercially since the launch of In-Vehicle Alerts.
Nauto’s Driver Behavior Learning Platform is the only solution that deploys AI in the vehicle to continuously capture and analyze sensor data from driver behaviors, exterior hazards, and vehicle movement in real-time. By fusing data from an array of sensors in real-time and comparing against insights derived from over 400 million AI-analyzed video miles and billions of telemetry data points, Nauto can instantly advise drivers to take action and prevent collisions before they happen.

Embedded with AI and equipped with GPS, inertial measurement unit (IMU), and interior and exterior image sensors, Nauto’s device is designed to mount on the upper center portion of the windshield and can be installed in passenger vehicles, and light, medium and heavy duty trucks.
In a 2016 naturalistic driving study by Proceedings of the National Academy of Sciences (PNAS) using the SHRP 2 NDS dataset, researchers reviewed six seconds of video preceding collisions compared to non-collision baseline video segments to identify 17 distinct observable distraction categories. Of these observable distraction categories, Nauto's assessment concluded that 11 involved the action of a driver “looking down.”

To detect distracted driving behavior, Nauto continuously processes images from the interior image sensor to analyze facial movements and identify unsafe driver behavior in real-time. The primary component of the Nauto distraction detection system is a convolutional neural network (CNN) trained on a large, diverse dataset of drivers and driving scenarios. This allows the model to achieve a high level of precision and generalize even in difficult situations, when the driver may be wearing headwear or eyewear, or the driver's face is partially obscured by a visor or other object.

In this study, a “distraction event” is considered to be any period of time in which the driver is looking down for longer than two seconds while the vehicle is moving at greater than a minimum speed.

- Activities detected by Nauto as “looking down” distractions

<table>
<thead>
<tr>
<th>In-vehicle radio</th>
<th>Climate control</th>
<th>Radio (other)</th>
<th>Cell browse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell text</td>
<td>Reading/writing</td>
<td>Cell dial</td>
<td>Cell reach</td>
</tr>
<tr>
<td>Eating</td>
<td>Drinking</td>
<td>Reaching for object</td>
<td>Cell talk</td>
</tr>
<tr>
<td>Dancing in seat</td>
<td>Interaction with passenger</td>
<td>Personal hygiene</td>
<td>Child rear seat</td>
</tr>
<tr>
<td>Extended glance</td>
<td></td>
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</tr>
</tbody>
</table>
In-Vehicle Alerts for Distracted Driving

Leveraging an in-vehicle distraction detection AI model, the device delivers three progressive levels of audible alerts based on the duration of the distraction event:

- **Behavior nudge**
  The first alert is issued 2.5 seconds after a distraction event is detected.

- **Voice coaching**
  The second alert is activated if the driver continues to be distracted for more than 4 seconds, and includes a verbal cue, “distracted!”

- **Urgent warning**
  The third alert is triggered if the driver continues to be distracted for more than 5 seconds.
Study Period

This study is focused on comparing detected distraction data between two steady-state observation periods outside of two adaptation periods. We define these periods using the following assumptions:

**Initial adaptation period**
When first installed, drivers are initially aware they are being observed and may immediately modify their driving behavior; however, they eventually adapt to the presence of Nauto’s safety solution and return to their normal habits. The study assumes a period of two weeks after installation.

**“Pre-Alert” observation period**
The “Pre-Alert” observation period refers to the time span after the initial adaptation period to the day that In-Vehicle Alerts for distracted driving are enabled. This period provides a baseline measurement of the drivers’ distracted driving behavior.

**In-Vehicle Alerts adaptation period**
When In-Vehicle Alerts are activated, we assume drivers undergo another adaptation period before converging to a new driving behavior. The study assumes a period of two weeks after activation of In-Vehicle Alerts.

**“Post-Alert” observation period**
The ”Post-Alert” observation period refers to the time span starting after the In-Vehicle Alerts adaptation period to the end of the study period. This period helps provide a measurement of the drivers’ modified behavior with the effect of In-Vehicle Alerts.
The overall dataset considered for this study covers an eight-month period between September 2018 and April 2019. A total of 30 Nauto customer fleets were included in the dataset from the following industries: Passenger, Services, Distribution, Logistics & Transportation, and Oil & Gas. Fleets were selected based on the total number of devices installed and sufficient observation periods both before and after the activation of In-Vehicle Alerts. The dataset includes the largest fleets possible from each industry based on the assumption that they include a more diverse set of driver behaviors and a higher volume of drivers with a sufficient measurement period. The study also applied the following exclusion criteria:

- Distractions: Events must last between 2 and 20 seconds.
- Trips: Must last longer than 5 minutes.
- Driving Hours: At least 5 driving hours in each observation period.

Based on the distraction detection and Nauto In-Vehicle Alert specifications, the study only considered detected “looking-down” distraction events between two to 20 seconds. The study filtered events with durations longer than 20 seconds based on the assumption that these events are more likely to be false positives caused by abnormal conditions in the vehicle. These long events constituted less than 0.04% of detected events.

In addition, only trips with moving durations longer than five minutes were considered, which constituted 83.7% of all observed trips.

To achieve the main objective of examining the shift in distracted driving behavior, the study only considered distraction events from identified drivers who had driven consistently for more than five hours each in both the Pre-Alert and Post-Alert observation periods.
With the inclusion and exclusion criteria applied, the final data volume considered for this analysis included 2.1 million distraction events from 1,376 drivers across 696,441 trips, with a total of 13.5 million driving miles. 1,371 of the total 1,376 drivers triggered at least one “looking-down” distraction event during the study period (99.6%). On average, each driver was observed for 82 days in the Pre-Alert period and 95 days in the Post-Alert period. A breakdown of the drivers by industries and their corresponding lengths of observation periods are shown in Table 1.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Drivers (#)</th>
<th>Average Length in Observation (days)</th>
<th>Median Length in Observation (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-Alert</td>
<td>Post-Alert</td>
</tr>
<tr>
<td>All drivers</td>
<td>1376</td>
<td>82</td>
<td>95</td>
</tr>
<tr>
<td>Industry: Passenger</td>
<td>862</td>
<td>89</td>
<td>91</td>
</tr>
<tr>
<td>Industry: Services</td>
<td>432</td>
<td>78</td>
<td>95</td>
</tr>
<tr>
<td>Industry: Other</td>
<td>82</td>
<td>35</td>
<td>135</td>
</tr>
<tr>
<td>Most Distracted</td>
<td>137</td>
<td>30</td>
<td>141</td>
</tr>
</tbody>
</table>

Table 1. Studied drivers by aggregate level and number of observation days
STUDY METHODOLOGY

Study Metrics

The study assessed three metrics for measuring the severity of distracted driving behavior:

1. Event frequency per driving hour
   \[
   \text{Total distraction events detected (\#)} \div \text{Total driving time (hours)}
   \]

2. Distracted duration per driving hour
   \[
   \text{Total duration of distraction events detected (seconds)} \div \text{Total driving time (hours)}
   \]

3. Distance travelled while distracted per driving hour
   \[
   \text{Total distance travelled during distraction events detected (feet)} \div \text{Total driving time (hours)}
   \]

All three metrics were normalized for a driver’s total driving time, defined as the total duration of when the vehicle was moving (measured as non-zero speed). The study uses this metric of driving time instead of overall trip duration, which includes both moving and stopped time, for the following reasons:

1. Distracted driving is detected at non-zero speeds
2. If vehicles have to make frequent or prolonged stops, such as when waiting for traffic lights or passenger pick-up/drop-off, normalizing distraction measures by overall trip duration would substantially underestimate the severity of drivers’ distracted driving behavior.

The study analyzed these distraction metrics for each driver by the Pre-Alert and Post-Alert observation periods, and subtracted the Post-Alert values from the Pre-Alert values to identify the change per driver in each metric.
Study Reporting

This study reports on the impact of In-Vehicle Alerts at several levels:

- **By individual driver**
  The study examines the impact of In-Vehicle Alerts at the individual driver level to understand how each driver’s distraction behavior was affected.

- **By entire driver population**
  The study reports the distraction metrics from all studied drivers to assess the general impact of In-Vehicle Alerts on the entire population.

- **By industry**
  The study reports the distraction metrics at the industry level to compare driver behavior between industries.
  Three industry categories are reported: Passenger, Services, and Other. The “Other” category includes fleets from Distribution, Logistics & Transportation, and Oil & Gas industries, combined due to relatively limited availability of drivers meeting the selection criteria from each individual industry.

- **By most distracted drivers**
  The study examines the impact on the bottom 10% of drivers, as ranked by their total distracted durations per driving hour in the Pre-Alert observation period. These drivers are deemed to be most likely at risk of a distracted driving-related collision.

For the test of statistical significance, both two-sample t-tests and paired t-tests were applied. The two-sample t-test assesses the differences between populations (pre-Alert and post-Alert); the paired t-test focuses on the shift in metrics at the driver-level for drivers in the group. For all statistical analyses, p-values less than 0.05 are considered significant.
Behavior Change by Driver

The study analyzed the proportion of the driver population that actually witnessed improvements in their distracted driving behavior. These results are shown in Figure 1, highlighting a significant reduction in distraction metrics:

- **76% of drivers reduced their event frequency**
- **77% reduced their distracted duration**
- **77% reduced their distance travelled while distracted**

*Figure 1. Cumulative distributions of the behavioral changes of individual drivers.*

Results from the paired t-tests indicate the changes in each distraction metric are statistically significant (event frequency p < 0.001; distracted duration p < 0.001; distracted distance p < 0.001).
RESULTS

Behavior Change Across Entire Driver Population

This study found a reduction in the three distracted driving behavior metrics after the activation of In-Vehicle Alerts. Observed distraction event frequency per driver decreased on average by 39.61%, from 4.83 to 2.92 distraction events per driving hour. Similar improvements were observed in the distraction duration and distance travelled while distracted metrics as well: observed distracted duration reduced on average by 42.94%, and observed distance travelled while distracted reduced on average by 46.61%.

\[\downarrow 39.61\%\]
\[\text{Distraction events per driving hour}\]

\[\downarrow 42.94\%\]
\[\text{Distracted duration per driving hour}\]

\[\downarrow 46.61\%\]
\[\text{Distance travelled while distracted per driving hour}\]

The results of this analysis are summarized in Table 2. We include average and median driver metrics because the distributions of each of the distraction metrics were not normally distributed.

<table>
<thead>
<tr>
<th></th>
<th>Event Frequency Per Driving Hour</th>
<th>Distracted Duration (Seconds)</th>
<th>Distance Travelled while Distracted Per Driving Hour (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Alert</td>
<td>Post-Alert</td>
<td>Difference</td>
</tr>
<tr>
<td>All Drivers</td>
<td>4.83</td>
<td>2.92</td>
<td>-39.54%*</td>
</tr>
<tr>
<td>Driver Average</td>
<td>1.83</td>
<td>0.81</td>
<td>-55.73%</td>
</tr>
<tr>
<td>Driver Median</td>
<td>1.83</td>
<td>0.81</td>
<td>-55.73%</td>
</tr>
</tbody>
</table>

* Indicating that result from two-sample t-test is statistically significant with p-value < 0.001

Table 2. Aggregated summary results by metric

Before activating In-Vehicle Alerts, 50% of the drivers triggered 1.83 distraction events per driving hour. After enabling In-Vehicle Alerts, only about 30% of the drivers triggered distraction events at the same frequency (see Appendix, Figure A1. Reversed cumulative distributions of driver distraction metrics). Also, after activating In-Vehicle Alerts, 50% of the drivers triggered only 0.81 distractions per driving hour (55.73% reduction; Figure A1).
Behavior Change by Industry

Across Nauto’s Passenger, Services, and Other fleets, the study observed substantial improvements in all three distraction metrics, as shown in Table 3. Prior to the activation of In-Vehicle Alerts, drivers in the Passenger industry triggered distraction events most frequently (on average 5.20 events per driving hour) and for the longest duration (on average 16.63 seconds per driving hour), followed by drivers in the Services industry (4.44 times and 13.97 seconds per driving hour), then drivers in all Other industries (3.06 events and 9.39 seconds per driving hour).

Among the three industry groups, drivers in the Services industry appeared to improve the most after receiving In-Vehicle Alerts: an average reduction of 67.98% in distraction event frequency, 71.76% in distracted duration per driving hour, and 72.16% in distance travelled while distracted per driving hour. In comparison, drivers in the Passenger industry reduced distraction event frequency per driving hour on average by 27.49%, distracted duration per driving hour by 30.87%, and distance travelled while distracted per driving hour by 32.43%.

Table 3. Industry-level summary results by metric

Refer to Figures A2 and A3 in the appendix for additional information on driver behavior change at the industry level.
**RESULTS**

**Behavior Change Among Most Distracted Drivers**

Similar to the overall population, the study found a significant reduction in distracted driving behavior metrics after activation of In-Vehicle Alerts for drivers who exhibited the most distracted driving behavior prior to activation of the alerts. The summary results for these drivers are shown in Table 4.

- **39.80%** \(\text{Distraction events per driving hour}\)
- **43.46%** \(\text{Distracted duration per driving hour}\)
- **46.80%** \(\text{Distance travelled while distracted per driving hour}\)

All 137 most distracted drivers were distracted for at least 10.72 events (frequency), 39.87 seconds (distracted duration), and 1,325.03 feet (distance travelled while distracted) per driving hour before receiving In-Vehicle Alerts. More substantially, 30% of the most distracted drivers were distracted for more than 100 seconds per driving hour, and more than 60% of them were distracted for more than 3,280 feet per driving hour before the activation of In-Vehicle Alerts (see Appendix, Figure A4. Reversed cumulative distributions of driver distraction metrics of the 10% most distracted drivers).

At the individual driver level, 84% of these most distracted drivers reduced their distraction event frequency, 85% reduced their distracted duration, and 85% reduced their distance travelled while distracted after the activation of In-Vehicle Alerts (see Appendix, Figure A5. Cumulative distributions of the behavioral change of the 10% most distracted drivers). While it should be noted that the absolute improvement of the most distracted drivers was greater than the overall studied drivers, the improvements across both groups were generally consistent.

<table>
<thead>
<tr>
<th>Most Distracted</th>
<th>Event Frequency Per Driving Hour</th>
<th>Distracted Duration Per Driving Hour (Seconds)</th>
<th>Distance Travelled while Distracted Per Driving Hour (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Alert Post-Alert Difference</td>
<td>Pre-Alert Post-Alert Difference</td>
<td>Pre-Alert Post-Alert Difference</td>
</tr>
<tr>
<td>Driver Average</td>
<td>25.33 15.25 -39.79%*</td>
<td>85.60 48.40 -43.46%*</td>
<td>4,556.99 2,424.28 -46.80%*</td>
</tr>
<tr>
<td>Driver Median</td>
<td>21.57 11.94 -44.65%</td>
<td>71.33 34.23 -52.01%</td>
<td>3,824.08 1,718.73 -55.05%</td>
</tr>
</tbody>
</table>

*Table 4. Summary results by metric of the 10% most distracted drivers.*
RESULTS

Behavioral Changes in Observed Distraction Events

The study also included an evaluation of behavior impact at the event level; for instance, if In-Vehicle Alerts reduced the average duration of each distraction event.

Figure 2 shows the distributions of the duration (left) and vehicle speeds (right) of detected distraction events for both the Pre-Alert and Post-Alert observation periods. The distributions were similar between the two periods for both distributions, suggesting there was minimal impact of In-Vehicle Alerts on the duration of individual events and the speed at which the events occur. This suggests that the primary effect of In-Vehicle Alerts is a reduction in distraction event frequency.

That being said, there was an observed reduction in the duration of distracted driving events at higher speeds. For distraction events at higher speeds, the study found that the event duration reduced substantially after In-Vehicle Alerts were enabled (see Figure 3). For example, at vehicle speeds in the 75 - 80 miles per hour range, the 95th-percentile event duration dropped from 5.9 to 4.6 seconds.

Figure 3. The median, 90th-, and 95th-percentile of distraction event durations at different vehicle speeds
Conclusion

In this analysis from nearly 1,400 drivers across 30 fleets in multiple industries, drivers with In-Vehicle Alerts demonstrated a significantly improved distraction rate: an average decrease of 39.54% in distraction event frequency, 42.90% in distracted duration, and 46.61% in distance travelled while distracted. This study observed a reduction across all three distraction metrics in 4 out of 5 drivers evaluated.

The study observed customers across multiple industries: Passenger, Services, Logistics & Transportation, Distribution, and Oil & Gas and found Passenger fleets were the most distracted with over five distractions per hour before In-Vehicle Alerts were enabled, followed by Services (4.44), and Other industries studied (3.06). While Service fleets were the second most distracted to start, they witnessed the greatest overall improvement in distraction frequency after the activation of In-Vehicle Alerts, reducing distraction frequency by over 65%, followed by Other industries studied (39.22%), and Passenger (27.50%).

On average, the 10% most distracted drivers triggered an average of 25.33 distraction events per hour, drove distracted for 85.60 seconds per hour and for nearly one mile every hour. After enabling In-Vehicle Alerts, close to 85 percent of these drivers improved their distracted driving behaviors.

Overall, these results indicate that In-Vehicle Alerts are an effective tool to reduce distracted driving behavior across a range of industries.

What to reduce distracted driving in your fleet?
Start your trip with Nauto today and learn more about In-Vehicle Alerts.

nauto.com/product | info@nauto.com

Nauto® is the only real-time AI-powered Driver Behavior Learning Platform able to predict, actively prevent, and reduce high-risk events in the mobility ecosystem. By analyzing billions of data points from over 400 million AI-analyzed video miles, Nauto’s machine learning algorithms continuously improve and help to impact driver behavior before events happen, not after. Nauto has enabled the largest commercial fleets in the world to avoid more than 25,000 collisions, resulting in nearly $100 million in savings.

Nauto is located in North America, Japan, and Europe. Learn more at nauto.com or on LinkedIn, Facebook and Twitter.
Appendix

Figure A1. Reversed cumulative distributions in driver distraction metrics

- Event frequency per driving hour
- Distracted duration per driving hour (seconds)
- Distance travelled while distracted per driving hour (feet)

Figure A2. Reversed cumulative distributions in driver distraction metrics, by industry

- Passenger
- Services
- Other
Appendix

Figure A3. Cumulative distributions of the behavioral changes of individual drivers, by industry

- **Passenger**
  - Change in distraction event frequency per driving hour (after - before): 75.17%
  - Change in distracted duration per driving hour (after - before): 76.80%
  - Change in distance travelled while distracted per driving hour (after - before): 76.57%

- **Services**
  - Change in distraction event frequency per driving hour (after - before): 82.87%
  - Change in distracted duration per driving hour (after - before): 83.10%
  - Change in distance travelled while distracted per driving hour (after - before): 82.41%

- **Other**
  - Change in distraction event frequency per driving hour (after - before): 51.22%
  - Change in distracted duration per driving hour (after - before): 54.88%
  - Change in distance travelled while distracted per driving hour (after - before): 58.54%
Appendix

Figure A4. Reversed cumulative distributions of driver distraction metrics of the 10% most distracted drivers

Figure A5. Cumulative distributions of the behavioral change of the 10% most distracted drivers