HHS Public Access
Author manuscript
J Safety Res. Author manuscript; available in PMC 2018 February 01.

Published in final edited form as:
J Safety Res. 2017 February ; 60: 125–136. doi:10.1016/j.jsr.2016.12.008.

Evaluation of an in-vehicle monitoring system (IVMS) to reduce risky driving behaviors in commercial drivers: Comparison of in-cab warning lights and supervisory coaching with videos of driving behavior

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Abstract

Problem—Roadway incidents are the leading cause of work-related death in the United States.

Methods—The objective of this research was to evaluate whether two types of feedback from a commercially available in-vehicle monitoring system (IVMS) would reduce the incidence of risky driving behaviors in drivers from two companies. IVMS were installed in 315 vehicles representing the industries of local truck transportation and oil and gas support operations, and data were collected over an approximate two-year period in intervention and control groups. In one period, intervention group drivers were given feedback from in-cab warning lights from an IVMS that indicated occurrence of harsh vehicle maneuvers. In another period, intervention group drivers viewed video recordings of their risky driving behaviors with supervisors, and were coached by supervisors on safe driving practices.

Results—Risky driving behaviors declined significantly more during the period with coaching plus instant feedback with lights in comparison to the period with lights-only feedback (ORadj = 0.61 95% CI 0.43–0.86; Holm-adjusted $p = 0.035$) and the control group (ORadj = 0.52 95% CI 0.33–0.82; Holm-adjusted $p = 0.032$). Lights-only feedback was not found to be significantly different than the control group's decline from baseline (ORadj = 0.86 95% CI 0.51–1.43; Holm-adjusted $p > 0.05$).

Conclusions—The largest decline in the rate of risky driving behaviors occurred when feedback included both supervisory coaching and lights.

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Practical applications—Supervisory coaching is an effective form of feedback to improve driving habits in the workplace. The potential advantages and limitations of this IVMS-based intervention program are discussed.

Keywords

In-vehicle monitoring system; Occupational safety; Driving; Motor vehicle; Injury

1. Introduction

Roadway incidents are the leading cause of workplace injury death in the United States across all industries (including the truck transportation and oil and gas operations industries), with 1157 (25% of the total workplace injury deaths) occurring in 2014, the most recent year for which data are available (Bureau of Labor Statistics, 2016; National Institute for Occupational Safety and Health, 2015; Retzer, Hill, & Pratt, 2013). Work-related roadway incidents cover events involving transportation vehicles under normal operation, on roadways, which includes the parts of the public highway, street, or road normally used for travel, as well as the shoulder or surrounding areas, telephone poles, bridge abutments, trees aligning roadway, etc. (Bureau of Labor Statistics, 2012).

Advancing technologies are making it possible to provide instant feedback to drivers about vehicle and driver performance in real-time, which could help address the large public health problem of work-related fatal roadway incidents. Technologies such as collision warning systems and lane departure systems have been found to reduce risky driving behaviors (following too closely, lane departures), and rates of crashes (Chen, Jenkins, & Husting, 2004; Lee, McGehee, Brown, & Reyes, 2002; Merrikhpour, Donmez, & Battista, 2014). In addition to technologies that use sensors to detect nearby vehicles, there has been increased use of "on-board" or "in-vehicle" monitoring of driving behaviors (Hickman & Hanowski, 2010; Hickman, Hanowski, & Bocanegra, 2010; Horrey, Lesch, Dainoff, Robertson, & Noy, 2012; International Association of Oil and Gas Producers, 2014; Jones, 2016; Miller, Saldhana, Hunt, & Mello, 2013). These in-vehicle monitoring systems (IVMS) record vehicle maneuvers through sensors and can interface with the vehicle's computer; they may also utilize cameras to record video footage of the driver actively engaged in driving. The information collected by IVMS technology can be fed back to the driver, either in real-time or retrospectively, through a variety of mechanisms, such as in-cab warning lights, sounds, reports, or by viewing video contents, all of which are intended to help drivers avoid or correct risky driving behaviors.

Most of the published safety-related research on IVMS has been conducted in non-occupational settings using volunteers (both teenage and adult) from the general population, both in real-world driving conditions and driving simulators (Carney, McGehee, Lee, Reyes, & Raby, 2010; Donmez, Boyle, & Lee, 2007, 2008; Farmer, Kirkey, & McCartt, 2010; McGehee, Raby, Carney, Lee, & Reyes, 2007; Merrikhpour et al., 2014; Roberts, Horrey, & Liang, 2016; Simons-Morton et al., 2013; Wu, Ageuro-Valverde, & Jovanis, 2014). Research on effectiveness of IVMS for improving driving behaviors of workers during work time is less extensive, and has focused on short-haul and long-haul truck drivers (Hickman &

Geller, 2003; Hickman & Hanowski, 2011; Lisk, Cruice, & Pollard, 2013), technicians (unspecified industry) driving to make service calls (Toledo, Musicant, & Lotan, 2008), and emergency medical services (EMS) drivers (Levick & Swanson, 2005). All of the aforementioned studies done in occupational settings reported at least some success during the feedback period in reducing undesirable driving behaviors.

A key component of IVMS technology is the way in which feedback on driving performance is delivered to the driver. In three of these studies (Hickman & Geller, 2003; Levick & Swanson, 2005; Toledo et al., 2008), feedback came in the form of in-cab sounds, lights and/or summary reports to the driver, was available on vehicle performance measures only as effected by the driver, such as speeding, hard braking, and excessive idling, and did not include supervisory monitoring and feedback on driving data. In the population of EMS drivers (Levick & Swanson, 2005) seatbelt use was monitored as an outcome through a seatbelt sensor, but the authors acknowledged that the drivers may have circumvented the sensor by fastening and placing the belt behind their backs; thus, the actual rate of seat belt use may have been much lower than reported.

Only two of the aforementioned studies (Hickman & Hanowski, 2011; Lisk et al., 2013) used an IVMS that had a driver-facing camera capable of audio and video event capture and employed supervisory coaching of the driver, using videos of the driver as a feedback mechanism. The Lisk et al. (2013) study was a pilot effort in 37 commercial vehicles doing short-haul operations. They found a beneficial effect through a 60% reduction in the number of incidents and an 86% reduction in the cost of vehicle crashes from the three years prior to three years post-implementation of IVMS and supervisory coaching of drivers. Limitations of this pilot study include not reporting information on potential variation in number of vehicles, miles, or time driven over the course of the study period, and the lack of a control group. Hickman and Hanowski (2011) found that supervisors' coaching of long-haul truck drivers resulted in a reduction in risky driving behaviors (examples include driving unbelted, following too closely, and improper lane change) by 37 and 52% in two carriers, respectively. Their study involved in-cab feedback with lights to the driver, as well as supervisory coaching using video events. Because the data collection involved video footage of active driving, the study was able target a much broader range of unsafe driving events than previous studies, including behaviors such as belt use, hand-held phone use and other distractions, driving too close to other vehicles, and unsafe lane changes. Limitations of this study were that no control group was included, and the study was completed in a relatively short time span (four months total to encompass both baseline and follow-up periods).

Although the Hickman and Hanowski (2011) study demonstrated the potential for IVMS feedback to reduce unsafe driving events in long-haul truck drivers, further research is needed to complement this work and validate these results, particularly in industry fleets with varying usage patterns. The objective of this research was to evaluate the effectiveness of two types of feedback from a commercially available IVMS in reducing two outcomes, overall risky driving behaviors, as well as driving unbelted, in drivers operating trucks for work in the truck transportation (box trucks) and oil and gas operations support (pickup trucks) industries. The first type of feedback consisted of warning lights from an in-cab device which notified drivers when they performed harsh driving maneuvers (i.e., hard braking, speeding, swerving that exceeds set accelerometer thresholds), and the second type of feedback was coaching by supervisors on safe driving practices that included viewing video recordings of drivers' own risky driving behaviors.

2. Methods

2.1. In-vehicle monitoring system technology

This study used a commercially available IVMS from one vendor, and this IVMS vendor supplied all equipment, coding of videos for observed driving behaviors (Table 1), and training on the use of the technology. For privacy purposes, NIOSH researchers did not code videos. However, the entire database of videos used in the study was accessible both to the industry partners and to the IVMS vendor. The IVMS vendor is not named here so as not to imply endorsement of any one IVMS vendor, as multiple commercial vendors exist to provide similar types of technology and services.

Each IVMS unit included two camera views: a forward-facing exterior camera view and driver-facing interior camera. The IVMS unit captured two types of video events: (a) regular-threshold triggered video events and (b) constant-threshold triggered video events, with the constant-threshold triggered video events being used for the analysis in this study. Regular-threshold triggered video events represent video events that are typically captured within the IVMS vendor's commercial services program, whereas constant-threshold triggered video events were captured for the specific purposes of this study as explained further below. For both types of events, the IVMS unit was configured to capture 30-s of video, audio and other event data (15 s before and 15 s after the trigger). The recorded video events were given a time and date stamp, and the unit of measurement was video events per vehicle per 24-h day.

Both regular-threshold and constant-threshold triggered video events relied on the same set of triggering algorithms that primarily use a three-axial accelerometer. These triggering algorithms detect vehicle maneuvers such as hard braking, acceleration, cornering, swerving, and sudden forces.

Different methods were used to manage the triggering sensitivity levels for the two sets of video events. Sensitivity levels for regular-threshold triggered events were set to initial levels based on the IVMS vendor's guidance and experience with driving events, as has been done in other published research (e.g., Hickman & Hanowski, 2011; McGehee et al., 2007), with the goal of maximizing the capture of safety-related events, and minimizing the capture of videos that were recorded but don't show any risky driving behaviors by the driver. Then, triggering sensitivity levels were periodically changed, if needed, to ensure consistent inflow of video events as drivers learned to “drive softer” and avoid triggering cameras. The changes were consistently applied to all vehicles of a given type to ensure that drivers were always evaluated based on a consistent set of criteria. From the vendor's perspective, this method ensures a consistent sampling rate for driver behaviors in order to avoid overstating the improvement of driver behaviors. For example, if one simply counts the number of video events that involve mobile phone use of a given driver but leaves the triggering sensitivity levels constant for the period of the study, any measured reduction in the number of video events with risky distracted behavior would have two components: (a) the actual reduction in risky behavior (mobile phone usage), and (b) the reduction in the number of triggered video events as the driver learned to “drive softer” (but may have continued the risky driving behavior such as use of the mobile phone). Regular-threshold triggered events were not used as an outcome measure in the current study, they were just used as a constant pool of videos for driver coaching.

In addition to the regular-threshold triggered video events, the IVMS vendor also captured constant-threshold triggered video events explicitly for the purposes of this study and based on a specific request from the study researchers. Triggering sensitivity levels for the constant-threshold triggered video events were set to values more sensitive (meaning it was easier to trigger and record videos) that what the IVMS vendor typically uses for commercial clients (regular-threshold), and were then left unchanged for the duration of the study (such as 0.236 g for hard braking for a medium duty truck). Unlike the regular-threshold triggered video events, the constant-threshold triggered video events were not immediately selected for offload (wirelessly transmitted from the IVMS unit to the central database). Rather, a process was put in place to randomly sample and select for offload one constant-threshold triggered video events per vehicle per day. If a regular-threshold triggered video was selected in the constant-threshold triggered sampling scheme (possible because the constant-threshold triggering sensitivity level was lower than the regular-threshold triggering sensitivity level), the vendor did not have to review the video again. The remainder of the constant-threshold triggered video events (after the one was sampled and downloaded) was not retained for use in the study. Constant-threshold triggered video events (the one randomly selected video event per vehicle per day) were the main unit of analysis used to evaluate the interventions. The constant-threshold triggered video events allowed researchers to evaluate the effectiveness of feedback from the technology and avoid any potential bias, if it existed, due to the method that IVMS vendor typically used to capture the regular-threshold triggered video events for commercial clients. Additionally, the procedure of havinga triggering threshold held constant for the entire duration of a study (as it was for the constant-threshold video events), as opposed to the slightly variable triggering threshold (as it was done for the capture of regular-threshold video events), is more comparable to methods of other previously published work evaluating IVMS technology (e.g., Hickman & Hanowski, 2011; Lisk et al., 2013; McGehee et al., 2007).

The IVMS unit included a small box-like device to provide immediate feedback to the driver with a series of lights that indicated when a risky driving maneuver had been executed; the device was located inside the vehicle cab near the windshield-mounted rearview mirror. The light remained green when ‘safe’ driving was occurring but flashed red or yellow to denote potentially risky driving maneuvers, with the red light indicating more severe risky driving behaviors. The thresholds between colors were determined by algorithms set by the IVMS vendor. Triggered video events (both regular-threshold and constant-threshold triggered videos) were reviewed by the vendor's trained observers for approximately 60 individual risky driving behaviors such as driving unbelted, smoking, hand-held device use while driving, unsafe stopping, and speeding (see Table 1 for a list of all possible coded risky driving behaviors used in the study). An overall severity category from 0 to 4 was then calculated for each video based on the sum of scores assigned to the individual risky driving behaviors. A severity score of 0 indicated the video was reviewed and no risky driving behaviors seen, with 1 through 4 denoting an increasing level of safety concern. The methods of coding individual behaviors seen within a video, and overall severity score assigned to the video, were held constant over the course of the study, such that a video showing a driver unbelted for example would be given the same severity score in all periods of the study. Collisions were not given a severity score by the vendor due to liability concerns, and are not included in this analysis.

2.2. Outcome measures

The main outcome measure determined a priori in the study protocol was any constant-threshold triggered video that was vendor-scored as a severity level of 3 or 4. These may be a single severe event seen by trained coders in the video, such as aggressive driving, texting on hand-held phone, hands off the wheel, or driving the wrong way, or multiple lesser risky behaviors (such as driving unbelted and moderate speeding) seen together such that the total score of the multiple lesser behaviors elevated it to severity 3 or 4 (hereafter "overall risky driving"). The scoring methods for the behaviors seen in each video were held constant over the course of the study. As learned from earlier published research using IVMS data, many individual risky driving behaviors may be too rare on their own to be used as an outcome measure, such as single instances of running a red light, running a stop sign, driving on wrong side of road, etc. as reported in the findings of McGehee et al. (2007). Therefore the total count of overall risky driving video events was the key outcome of interest in this study, as was similarly done for the earlier research of Hickman and Hanowski (2011). Driving unbelted as an individual behavior was not considered by the IVMS vendor to be a severity 3 or 4 event, but was included as an outcome of interest in this study due to its public health significance (e.g. Cameron, Crandall, Olson, & Sklar, 2001; Chen et al., 2015; Evans, 1986; Huang & Lai, 2011; National Highway Traffic Safety Administration, 1999), as well as its use as an outcome in earlier IVMS research (Levick & Swanson, 2005).

2.3. Feedback mechanisms

The IVMS vendor provided training to supervisors on all feedback mechanisms in a train-the-trainer format to industry partners prior to the installation of IVMS equipment. The goal of the training was to provide supervisors of drivers with a complete overview of the IVMS system and to equip supervisors with the necessary information to present and describe the IVMS program to their drivers, as well as to access and view videos, and coach their own drivers. The training also helped the supervisors address any drivers' questions and concerns in order to familiarize drivers with the program prior to implementation. The orientation also helped familiarize supervisors with IVMS equipment.

This study evaluated two types of feedback from the IVMS to the driver:

- Instant driver feedback (referred to as IDF-only) from the feedback light on the IVMS unit inside the vehicle cab. A green light indicated safe driving, and a flashing yellow or red light informed the driver about risky driving behaviors. There were no sounds associated with the lights. Drivers were trained by supervisors on how to interpret the IDF feedback. Supervisors did not receive any summary information about the IDF feedback that went to the drivers.

- IDF feedback to the driver coupled with one-on-one coaching between supervisor and driver (referred to as Coaching + IDF). Although the IVMS vendor provided training to supervisors on how to perform the coaching process, the supervisors were the entities that reviewed videos with drivers and performed coaching sessions privately with drivers. The IVMS vendor's services include an online “video response center” where the supervisors could log in and view the individual videos, the listing of risky behaviors detected (if any) by the IVMS vendor in the videos, as well see the overall severity score assigned to each of the videos by the IVMS vendor. This was part of the pre-study training process for the industry partner. So as not to unintentionally bias the study results, once the study began, the supervisors agreed to not access the online video response center and view videos from the non-coaching periods. However the supervisors did have the ability to access videos from any time period on request from the IVMS vendor if they deemed it necessary to see an event. To follow the experimental guidelines of the study, during the coaching feedback period, the industry partner supervisors would log into the vendor's online video response center, view videos, and actively coach drivers. Due to the large number of videos recorded, the videos with a severity 3 or 4 were flagged in the online dashboard to make them easy to pick out for review, however all videos were present in the online dashboard available for viewing by the industry partner if desired. The supervisors were to select severity 3 and 4 video events to review with drivers, and were given the goal of conducting in-person coaching sessions with any drivers that had Severity 3 and 4 video events occurring that same week, for every week of the Coaching + IDF intervention period. Training was given on where and how to conduct coaching sessions, such as in a private setting where the conversation would not be overheard by co-workers. Goals of the sessions included clearly defining the high risk behaviors observed, reinforcing company policies and safe driving habits, rewarding safe driving behaviors, and the suggestion to present the information in a positive manner, akin to a coach “going over game films to improve performance” with an athlete. When supervisors completed a coaching session with a driver, they were to log a record of the coaching session in the online video response center, and had the option of writing a text narrative about what was covered in the coaching session. An additional feature of the Coaching + IDF period was bi-weekly conference calls held by the IVMS vendor where supervisors were invited to call in and discuss progress or concerns.

In addition to these two main types of feedback that went only to the intervention groups, graphic feedback was given to all sites participating in the study, both intervention and control. The graphic feedback was posted weekly at each site and showed aggregated data on safe driving for all drivers at each site (no individual drivers identified or specific behaviors mentioned). This third form of feedback was used so that all drivers would be receiving at least some meaningful information about their driving performance from the IVMS that were installed on the vehicles. The group feedback came in the form of a vendor-generated graph showing miles driven without a severity 3 or 4 event for all drivers at the site, and if drivers were improving as a whole, the trend line should go up as miles of safe driving increased. These weekly graphs were distributed to supervisors by the IVMS vendor, and were presented to drivers via display in common areas and at staff meetings to establish the general goal of improving driving behavior with positive supervisor support.

2.4. Study population

This research study protocol was reviewed and approved by the National Institute for Occupational Safety and Health (NIOSH)'s Institutional Review Board. NIOSH had no direct contact with drivers and did not obtain any personally identifying information for this analysis. The study population came from two companies from two industries, the “Support activities for oil and gas operations” and “General freight trucking, local” industrial classifications of the North American Industry Classification System (NAICS) codes (NAICS codes 213,112 and 48,411, respectively) (Office of Management and Budget, 2007). These two companies implemented IVMS technology in a subset of their fleets as a pilot effort. The employees were technicians driving pick-up trucks to oil and gas operations where they would perform maintenance and support activities, and drivers of refrigerated box trucks in the 26,000–33,000 lb range doing short-haul deliveries of goods to convenience stores. The industry partners selected a total of 20 sites (7 from truck transportation and 13 from oil and gas) located in 12 states (CA, CO, LA, MA, MD, NJ, OK, PA, TX, UT, VA, WA) within the United States. All vehicles at each of 20 sites had IVMS installed so that all drivers at each site would have the same equipment and working conditions. The 20 sites were apportioned into intervention and control groups (described in more detail in Section 2.5 Study Design). The study population was a dynamic cohort where the amount of person-time contributing to the study could vary for each individual depending on how long they were employed at the site. Data from any employee at the sites operating a vehicle equipped with IVMS during the course of the study were included (i.e., if an employee terminated employment during the course of the study, a newly hired employee could use the same vehicle equipped with IVMS). All participants in the study were anonymous, and any data analyzed at the driver level (i.e., coaching data) identified drivers by only a unique anonymous number created by the IVMS vendor. No demographic data (such as gender, age, or race) were available for the study population, however it is likely that most of the drivers in this study were male as gender distribution data from the truck transportation and oil and gas industries show that the majority of workers in these two industries are male (Bureau of Labor Statistics, 2015; Chen, Fang, Guo, & Hanowski, 2016; Sieber et al., 2014).

In the oil and gas industry partner, drivers could use the vehicles for both work and personal purposes, and it was not possible to differentiate between events logged during work or personal use time in this study because data were not available for workers' daily on and off work hours. Workers' family members were not permitted to drive the vehicles unless it was an emergency situation. Generally one driver was assigned to one vehicle during the course of the study. In the truck transportation industry partner, multiple drivers at the site could drive a vehicle within the same 24-h period, due to shift changes. For both industry partners, in general, both vehicles and drivers remained at the same site throughout the course of the study.

2.5. Study design

The study was conducted from April 2012 through July 2014 and entailed a 3-group, 4–period cross-over design for each company (Fig. 1). Groups 1 and 2 were intervention groups, and Group 3 was a control group. Video events were triggered and reviewed in all 3 groups during all 4 periods of the study. In period 1, no groups received any IDF-only or Coaching + IDF feedback, and period 1 was considered the baseline period. In period 2, Group 1 received IDF-only feedback, Group 2 received Coaching + IDF feedback, and Group 3 received no feedback. In period 3, Group 1 received Coaching + IDF feedback, Group 2 received IDF-only feedback, and Group 3, the control group, received no feedback. In period 4, all 3 groups entered an end-baseline period identical to the initial baseline period. The graphic feedback chart data was given to Groups 1, 2 and 3 during all 4 periods of the study, including the beginning and end baseline periods. Supervisors had online access to the triggered video events only for Group 1 and 2, and only during the Coaching + IDF intervention periods.

In the truck transportation company, non-random methods were used to assign the 7 sites to the 3 groups (3 sites in Group 1, 2 sites in Group 2, 2 sites in Group 3). In the oil and gas support operations company, the 13 sites were randomized to the 3 groups (5 sites to Group 1, 5 sites to Group 2, 3 sites to Group 3). Because of the mix of methods used to assign sites to groups in the two companies, the overall study design was considered to be quasi-experimental (Harris et al., 2004; Rothman & Greenland, 1998). All trucks at each of the 20 study sites were equipped with IVMS; a total of 315 IVMS were installed at the start of the study. There were a total of 163 IVMS-equipped trucks in the oil and gas operations company (64 in Group 1, 35 in Group 2, and 64 in Group 3) and 152 IVMS-equipped trucks in the truck transportation company (53 in Group 1, 50 in Group 2, and 49 in Group 3). Collection and review of regular-threshold video events began immediately after vehicles were equipped with IVMS, but drivers drove the vehicles performing regular work duties for at least 10 weeks before collection and review of constant video events began.

2.6. Statistical analysis

Logistic regression was the statistical method used in this study for analyzing dichotomous response data. Each individual constant-threshold video was a unit of analysis. A response of one indicated that the behavior of interest occurred within the constant-threshold video event, and a response of zero indicated that the behavior of interest did not occur within the constant-threshold video event, with factors suspected to affect the response incorporated into the model for analysis of relationships (Hosmer & Lemeshow, 2000; Walker, 1997). In this study, logistic regression was used to model the probability of risky driving behavior (a dichotomous outcome: risky driving behavior present, or risky driving behavior absent) in constant video events and to test for significant differences in the probability of risky driving behavior between all groups of interest; a generalized estimating equation (GEE) approach was used to account for repeated measurements on the same vehicles over time (Stokes, Davis, & Koch, 1995). The analysis was performed using the GENMOD procedure in SAS v. 9.3 (SAS Institute Inc., 2011). The prediction variables were group (3 levels), period (4 levels), and the interaction between group and period (12 levels), and contrasts were constructed using parameter estimates from the model to test specific hypotheses of interest.

Data from intervention Groups 1 and 2 were combined to test some of the hypotheses of interest, and are hereafter referred to as the “intervention” group, while Group 3 remains the “control” group. The following were the five questions of interest to be addressed (repeated for both outcome measures, overall risky driving behaviors, and driving unbelted, so 10 overall) in the contrast estimate analysis:

1. Was there a significant difference in the decline of the probability of risky driving behavior from baseline between the intervention group's (Group 1 and Group 2 combined) Coaching + IDF period and the control group (Group 3)?
2. Was there a significant difference in the decline of the probability of risky driving behavior from baseline between IDF-only in its “pure” form (from Group 1 where IDF-only feedback came first and as not influenced by preceding Coaching + IDF feedback) and the control group (Group 3)?
3. Was there a significant difference in the decline of the probability of risky driving behavior from baseline between intervention group's IDF-only feedback period (Group 1 only) and intervention group's (Group 1 and Group 2 combined) Coaching + IDF period? That is, do the two treatment IDF-only and Coaching + IDF give rise to the same decline in probability of risky driving behaviors?
4. Was there a significant difference in the decline of the probability of risky driving behavior from baseline between the intervention group (Group 1 and Group 2) during the treatment periods, where Group 1 had IDF-only followed by Coaching + IDF feedback, and Group 2 had Coaching + IDF followed by IDF-only feedback? That is, did the treatment order have a significant effect on the decline in probability of risky driving behavior?
5. Was there a significant difference in the decline of the probability of risky driving behavior from baseline to the end baseline period between the intervention group (Group 1 and Group 2 combined) and control group (Group 3)?

Data from both companies were used in aggregate in the analysis because comparing the companies to one another was not an objective of the study, and adding a company variable to the model resulted in only a small decrease in quasi-likelihood under the independence model criterion (Pan, 2001). Due to the multiple hypotheses to be tested ($n = 10$), contrasts were determined to be significant when $p < 0.05$, after performing Holm's Bonferroni correction (Aicken & Gensler, 1996).

3. Results

3.1. Constant-threshold triggered video events

During the study period, there were a total of 73,099 constant-threshold triggered video events randomly sampled and downloaded for review and inclusion in the study from all 625 drivers in the study (as identified by unique anonymous driver identification numbers). Of those constant-threshold triggered video events (hereafter just “video events”), 1670 (2% of the total) had missing values and could not be used, and an additional 11,711 video events

(16% of the total) had an obstructed camera view, either partially or fully obstructing the view of the driver and/or the external camera view. Because the obstructed-view video events could not be coded properly, they were omitted from the analysis, leaving 59,718 (82% of the total) fully visible video events which were used in this analysis. Of the fully visible video events, 55% did not show any risky driving behaviors and the remaining 45% showed some level of driving behavior of safety concern (anything with severity 1 and above).

3.2. Frequency of risky driving behaviors

For the entire study period, frequency counts were done for risky driving behaviors coded Severity 1–4 in triggered video events (Table 2). More than one driving behavior could be coded from each video event (e.g., a driver could be driving unbelted, and eating while driving). Of the 34,899 coded behaviors, driving unbelted was the most commonly seen risky driving behavior, coded 14,185 times, or 40.6% of total video events. This was followed by distractions at 31.9% of total video events, and then by unsafe stopping, speeding, and hand-held mobile device use. Within the subset of all triggered video events that were coded as more severe (severity 3 or 4) by the IVMS vendor (Table 3), the top five most common behaviors were the same as in the overall video events; however, the rank order differed within the top five.

3.3. Coaching

During the Coaching + IDF feedback period, supervisors had the goal of meeting with every driver that had severity 3 or 4 driving video events during that week for a coaching session. From these data, an ever-coached metric was calculated, meaning any driver that had at least one severity 3 or 4 regular-threshold video event at any time during the coaching intervention period was coached at least once during that period. Of the 324 drivers who drove during Coaching + IDF feedback period, 292 drivers triggered at least one severity 3 or 4 regular-threshold video event during that time. Of those, 258 (88%) had a coaching session logged by their supervisor in the vendor's online video response center. Of the 13 intervention sites that received Coaching + IDF intervention, 6 sites showed 100% of their drivers being coached during coaching sessions, 5 sites showed 90–99% of drivers coached, 3 sites showed 80–88% of drivers coached, and 1 site showed only 52% of drivers coached.

3.4. Overall risky driving behavior

The five questions of interest outlined in the statistical analysis section (Section 2.5) were examined using overall risky driving (severity 3 or 4 video events) as an outcome measure. Data were combined as shown in Table 4 and Fig. 2 to test these questions of interest.

The first question of interest was to determine if there was a significant difference in the decline of the probability of risky driving behavior from baseline between the intervention group's (Group 1 and Group 2 combined) Coaching + IDF period and the control group (Group 3). While the control group's odds of risky driving behaviors declined from baseline to the treatment periods, the intervention group had a significantly greater reduction in odds of risky driving behaviors during Coaching + IDF feedback periods in comparison to the control group (OR_{adj} = 0.52 95% CI 0.33–0.82; Holm-adjusted $p = 0.032$).

The second question of interest was whether there was a significant difference in the decline of the probability of risky driving behavior from baseline between IDF-only in its “pure” form (from Group 1 where IDF-only feedback came first and was not influenced by preceding Coaching + IDF feedback) and the control group (Group 3). The findings showed that IDF-only in its “pure” form did not show a significantly greater reduction in odds of risky driving from baseline than the control group (ORadj = 0.86, 95% CI 0.51–1.43; Holm-adjusted $p > 0.05$).

The third question was whether there a significant difference in the decline of the probability of risky driving behavior from baseline between intervention group's IDF-only feedback period (Group 1 only) and intervention group's (Group 1 and Group 2 combined) Coaching + IDF period. In comparison to IDF-only feedback, Coaching + IDF showed a significantly larger reduction in odds of risky driving from baseline (ORadj =0.61 95% CI 0.43–0.86; Holm-adjusted $p = 0.035$).

The fourth question was whether there was a significant difference in the decline of the probability of risky driving behavior from baseline between intervention Group 1 and Group 2 during the treatment periods, where Group 1 had IDF-only followed by Coaching + IDF feedback, and Group 2 had Coaching + IDF followed by IDF-only feedback. To examine the temporal effect of order of presentation of IDF-only feedback, Group 2's average (Coaching + IDF and IDF-only) departure from baseline for periods 2 and 3 was compared to Group 1's average (IDF-only and Coaching + IDF) departure from baseline for periods 2 and 3. It was found that the two were not significantly different from one another (ORadj =1.10, 95% CI 0.66–1.86; Holm-adjusted $p > 0.05$).

The fifth question was to see if there was a significant difference in the decline of the probability of risky driving behavior from baseline to the end baseline period between the intervention group (Group 1 and Group 2 combined) and control group (Group 3). To examine the sustained effect of prior exposure to Coaching + IDF feedback, the combined intervention group's end baseline decline compared to their beginning baseline was compared to the control group's end decline compared to its beginning baseline. A significant difference between the intervention and control groups was found (ORadj =0.27, 95% CI 0.12–0.60; Holm-adjusted $p = 0.012$).

3.5. Driving unbelted

The IVMS vendor did not consider driving unbelted to be a severity 3 or 4 event, so while driving unbelted was a component of approximately 20% of the severity 3 or 4 video events (Table 3), it was the most commonly seen risky driving behavior of any severity level at 41% (Table 2). The five questions of interest outlined in the statistical analysis section (Section 2.5) were also examined using driving unbelted as an outcome. Data were combined as shown in Table 4 and Fig. 3 to test specific questions of interest.

The first question of interest was to determine if there was a significant difference in the decline of the probability of risky driving behavior from baseline between the intervention group's (Group 1 and Group 2 combined) Coaching + IDF period and the control group (Group 3). The intervention group had a significant reduction in odds of driving unbelted during Coaching + IDF feedback periods in comparison to the control group, which showed an increase (ORadj = 0.18 95% CI 0.08–0.41; Holm-adjusted $p < 0.001$).

The second question of interest was whether there was a significant difference in the decline of the probability of driving unbelted from baseline between IDF-only in its “pure” form (from Group 1 where IDF-only feedback came first and was not influenced by preceding Coaching + IDF feedback) and the control group (Group 3). IDF-only in its “pure” form did not show a reduction in odds of driving unbelted from baseline in comparison to the control group (ORadj = 0.66 95% CI 0.30–1.45; Holm-adjusted $p > 0.05$).

The third question was whether there a significant difference in the decline of the probability of driving unbelted from baseline between intervention group's IDF-only feedback period (Group 1 only) and intervention group's (Group 1 and Group 2) Coaching + IDF period. In comparison to “pure” IDF-only feedback, Coaching + IDF showed a significantly larger reduction in odds of driving unbelted from baseline than the IDF-only group (ORadj = 0.27 95% CI 0.15–0.48; Holm-adjusted $p = 0.035$).

The fourth question was whether there was a significant difference in the decline of the probability of driving unbelted from baseline between intervention Group 1 and Group 2 during the treatment periods, where Group 1 had IDF-only followed by Coaching + IDF feedback, and Group 2 had Coaching + IDF followed by IDF-only feedback. To examine the temporal effect of order of presentation of IDF-only feedback, Group 2's average (Coaching + IDF and IDF-only) departure from baseline for periods 2 and 3 was compared to the Group 1's average departure from baseline for periods 2 and 3 (IDF-only and Coaching +IDF). It was found that the two were not significantly different from one another (ORadj = 1.24, 95% CI 0.53–2.89; Holm-adjusted p N 0.05).

The fifth question was to see if there was a significant difference in the decline of the probability of driving unbelted from baseline to the end baseline period between the intervention group and control group. To examine the sustained effect of prior exposure to Coaching + IDF feedback, the intervention group's end baseline decline compared to its beginning baseline was compared to the control group's end decline compared to its beginning baseline. No significant difference in the odds of driving unbelted was found between the intervention and control group in this comparison (ORadj = 0.57, 95% CI 0.16–2.00; Holm-adjusted $p > 0.05$).

4. Discussion

On-the-job feedback, reinforcement of new training, and knowledge of consequences for non-conformance are considered to be critical parts in the jump from knowledge to behavior change (Quintana, 1999). For workers who perform many of their tasks (including work-related driving) in isolation, on-the-job feedback may be particularly difficult for supervisors to provide (Hickman & Geller, 2003; Olson & Austin, 2001; Smith & Jones, 2016). Because of this, IVMS are increasingly being used by fleet owners to gather data on employees' driving patterns and behaviors. The main rationale for IVMS is to provide objective information that will allow supervisors to coach drivers to adopt safer driving practices. The results from this occupational driving study demonstrate evidence for the effectiveness of feedback (both IDF feedback and supervisory coaching) from IVMS to reduce risky driving behaviors in a population of truck drivers representing two industries. Despite the fact that the control group showed a decline in overall risky driving behaviors during the treatment periods of the study, the odds of risky driving behaviors declined to a significantly greater extent in the intervention group during the Coaching + IDF period. The odds of driving unbelted also declined to a significantly greater extent in the Coaching + IDF period in comparison to the control group. The IDF-only feedback period, representing IDF in its “pure” form where it was the first type of feedback given to drivers, did not show a significant reduction in odds from baseline in the intervention group as compared to the control group for overall risky driving or driving unbelted. It is possible that if only vehicle maneuver-related behaviors were examined as an outcome, IDF-only feedback may show more effectiveness, and this is a research question that could be examined in future research.

A secondary objective was to examine temporal effects of order of presentation of IDF-only feedback. It was hypothesized that IDF-only feedback may be more effective after drivers had already received one-on-one coaching with supervisors, during which they saw videos of themselves while driving, as opposed to when IDF-only feedback was presented first, before drivers had ever seen videos of their driving. Evidence for temporal effects was mixed. A visual inspection of the proportion of overall risky driving behaviors by group and period implied a greater decline in IDF-only rates when presented after coaching rather than before, however, there was no statistically significant difference in the magnitude of change between the two groups and their baseline.

Driving unbelted, distractions (such as smoking, eating, drinking a beverage, and handheld mobile device use), unsafe stopping, and speeding were the most common risky driving behaviors seen in this study. Two of these driving behaviors that are of particular interest in the published safety literature are driving without a seatbelt and hand-held device use while driving. The companies participating in the study had policies prohibiting both these behaviors at the start of the study. These policies are supported by the body of literature showing a link between hand-held device-use, decline in driving performance, and an increased risk of collisions (Fitch et al., 2013; Leung, Croft, Jackson, Howard, & Mckenzie, 2012; McKeever, Schultheis, Padmanaban, & Blasco, 2013; Wilson & Stimpson, 2010). In addition, the effectiveness of seat belts in increasing crash survivability and reducing injury severity is well-documented, as is the public health importance of seat belt use (e.g. Cameron et al., 2001; Chen et al., 2015; Evans, 1986; Huang & Lai, 2011; NHTSA, 1999). In the current study, hand-held device use was categorized in the severity 3 and 4 group by the vendor and included with the overall risky driving behavior measure. Because driving unbelted in the absence of other risky driving behaviors was not considered to be a severe driving behavior (less than severity 3), it was examined in this study as a separate outcome. Prior research has shown that primary seat belt laws (where violators can be stopped and cited independently of any other traffic behavior) can impact belt-wearing of drivers in both occupational and general driving in states that have such laws (Beck & West, 2010; Boal, Li, & Rodriguez-Acosta, 2016; Lee et al., 2015; Shults, Haegerich, Bhat, & Zhang, 2016). In this study, both the intervention group and the control group involved sites in states both with and without a primary belt law, as defined by CDC (2015). The intervention group comprised sites from 5 states with and 4 states without primary belt laws, and the control group comprised sites from 3 states with and 2 states without primary belt laws. None of the states in this study experienced a change in their primary belt law status during the course of this study (CDC, 2015), and each group (intervention and control) was compared to its own baseline in the analysis, so the primary belt law status of study sites' states should not impact the evaluation of the effectiveness of feedback. Furthermore, both industry partners had as part of their policies that belt use was required by drivers in their companies regardless of site location.

The Hickman and Hanowski (2011) study of truck drivers reported decreases in safety-critical events (using methods that collected all events over a set triggering threshold) during a 13-week feedback period but reported no information as to whether safety-critical events were maintained at rates comparable to those during the intervention period or if risky driving increased with the removal of the intervention (post 13 week period). In the current study, after feedback was withdrawn from the intervention group, the reduction in odds of overall risky driving was maintained, and remained significantly different from the control group. However, this greater decline in the intervention group compared to the control group was not maintained for driving unbelted. Because there was a reduction in risky driving after feedback was withdrawn, this prompts questions about the variables that influence the maintenance of safe driving behavior (i.e., how long can reductions in risky driving behaviors be sustained after feedback is reduced or withdrawn). Previous studies have found that feedback combined with rewards or incentives provide greater behavior change than feedback without rewards or incentives (Alvero, Bucklin, & Austin, 2001; Cooper, 2009; Kang, Oah, & Dickinson, 2003). However, it was not known to researchers what consequences (positive or negative) there may have been for safe or unsafe driving practices in this study. Because the greater decline in the intervention group compared to the control group was not maintained for the outcome of driving unbelted, further research into this facet is warranted.

Prior research has found that supervisors play an important role in providing performance feedback to drivers and improving safety outcomes in the work-related driving context (Newnam, Lewis, & Watson, 2012) and safety-oriented interactions between supervisors and employees to be associated with positive safety outcomes (Zohar, 2002). In the current study, supervisors' compliance with the coaching component varied among the sites in the study from 52% to 100% for those drivers who should have been coached at least once during the entire coaching period. Overall, 94% of sites in the intervention groups achieved 80% or better coaching of employees. Future research may want to explore interventions that could increase the reliability of supervisors' coaching of drivers. For example, by reducing the effort and time that is required to conduct a coaching session, supervisors may conduct coaching sessions at a higher rate and in a timelier manner (e.g., Sigurdsson, Taylor, & Wirth, 2013). Future research could also investigate the relationship between measures of risky driving behavior and higher or lower coaching rates.

In interpreting the findings of this research, there are four limitations that should be considered and will be discussed: misalignment of driver-facing and exterior-facing camera resulting in obstructed camera views, the collection of data at the vehicle unit as opposed to the driver unit, the limited information available on the content of the confidential supervisor-driver coaching sessions, and the lack of a true baseline data collection period unaffected by IVMS feedback. The first limitation, misalignment of the video camera, where either the external or driver-facing video camera was obstructed or misaligned, was a challenge, as it caused some video recordings to be unusable in the study. It was necessary for the video coders to evaluate variables from visual detection such as seatbelt use or handheld device use by the driver, or from the external cameras, roads signs, lights, and other vehicles. Of the total events, 16% had an obstructed camera view and were omitted from the analysis. It is possible that omission of these video events may have biased the findings to some degree, and this is an area that could be further investigated in future research.

A second limitation was that it was not always possible to reliably link individual drivers to vehicles within a site. Video event data were recorded on a per-vehicle per-day time unit, and some of the vehicles had multiple drivers for vehicle in a 24-h period due to shift changes. Additionally, driver schedules were not always uploaded from the industry partners to the IVMS vendor, so it was not always possible to tell within each site which drivers were driving which vehicles. Because the study involved a dynamic cohort, if a driver left the company during the course of the study, a newly hired driver could take the place of the old driver, using the vehicle equipped with IVMS. Due to these limitations, conclusions can be made about changes in risky driving behavior at the group level, but not at the individual driver level.

A third limitation was the lack of data on the quality, content, and tone of discussions during coaching sessions. Although supervisors were trained on how and on what to coach by the IVMS vendor, it is quite possible that discussions during the coaching session varied from supervisor to supervisor. Because the coaching sessions were private, there is no way to know for sure exact details of how coaching was performed or what topics were covered. Despite the fact that coaching levels did not consistently reach 100% of drivers who had logged severity 3 and 4 events, significant declines in risky driving behaviors were seen.

And finally, the baseline period in this study does not represent a true state of “no feedback.” At the outset of the study it was determined that all drivers in the study should be given some feedback from the IVMS installed in their vehicle, even if it was not driver-specific. Group feedback was given to both intervention and control groups during all periods in the study, including beginning and end baseline periods. In theory this should bias the findings of the study toward the null of no treatment effect. Despite the group feedback given, there were significant differences detected. Without the group feedback provided in the beginning baseline period, it is possible that greater effect sizes may have been observed with the intervention group between baseline and intervention periods.

5. Practical applications

Future research should address the impact of IVMS feedback on outcomes such as crash-related auto liability and workers' compensation injury claims over longer periods of time. Additionally, return on investment analyses should be done as there has been only limited research published in this area (Boodlad & Chiang, 2014; Pitera, Boyle, & Goodchild, 2013), and IVMS is considered to be a fairly low-cost intervention in comparison to other safety technologies (Hickman & Hanowski, 2010). Given that motor vehicle crashes are consistently the leading cause of work-related death, in addition to affecting the general population, this research has addressed a significant public health problem. Despite limitations, results from this current research provide evidence that the intervention of supervisor coaching of drivers combined with feedback from warning lights feedback successfully reduced risky driving behaviors that are policy priorities for employers.

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Acknowledgments

The authors would like to acknowledge Dr. Harlan Amandus, Dr. Elyce Biddle, and Dr. Oliver Wirth for their work on the project, including the development of the original study protocol and design, and Mr. Dave Hilling for early programming support. The authors would also like to thank Dr. Stephanie Pratt, Dr. James Collins, Dr. Tomer Toledo, Dr. Robin Gillespie, and Dr. Christine Schuler for their critical review of earlier drafts of this paper. The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health. In addition, citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date. This project was made possible through a partnership with the CDC Foundation.

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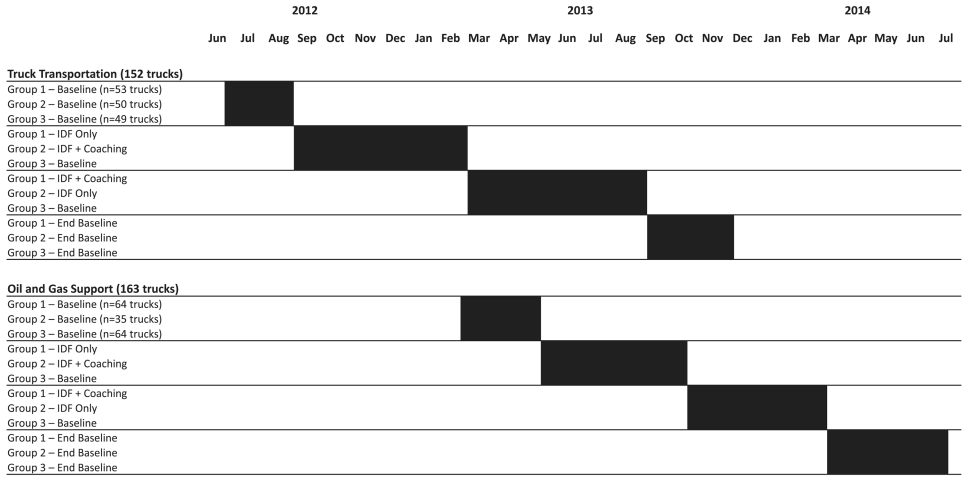

Fig. 1.

Timeline and study design, showing three groups (Intervention Group 1, Intervention Group 2, Control Group 3) and 4 study periods replicated in 2 industries.

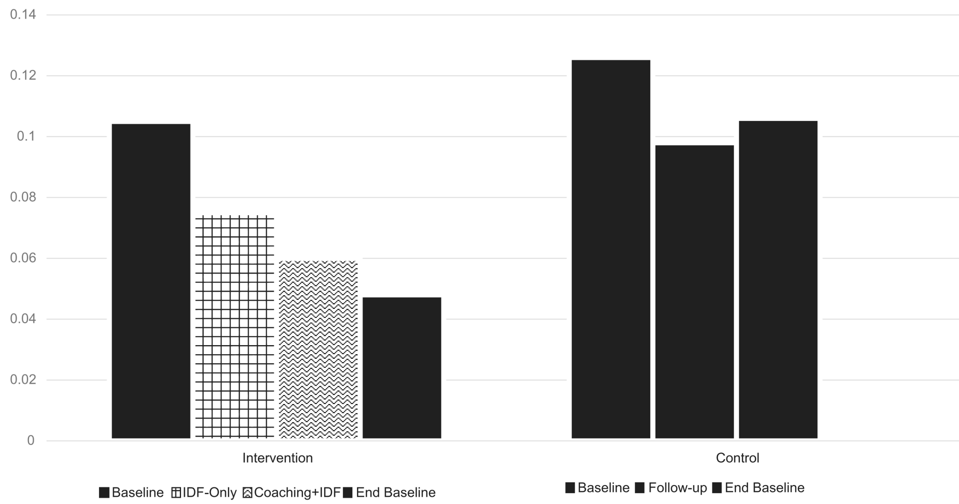

Fig. 2.

Proportion of constant-threshold triggered video events showing risky driving behaviors (severity 3 or 4) for the Intervention Group (Intervention Group 1 and Intervention Group 2, combined) and Control Group 3, and period, groupings for statistical contrast estimates. The IDF-only period includes data from Intervention Group 1 only, where IDF-only feedback

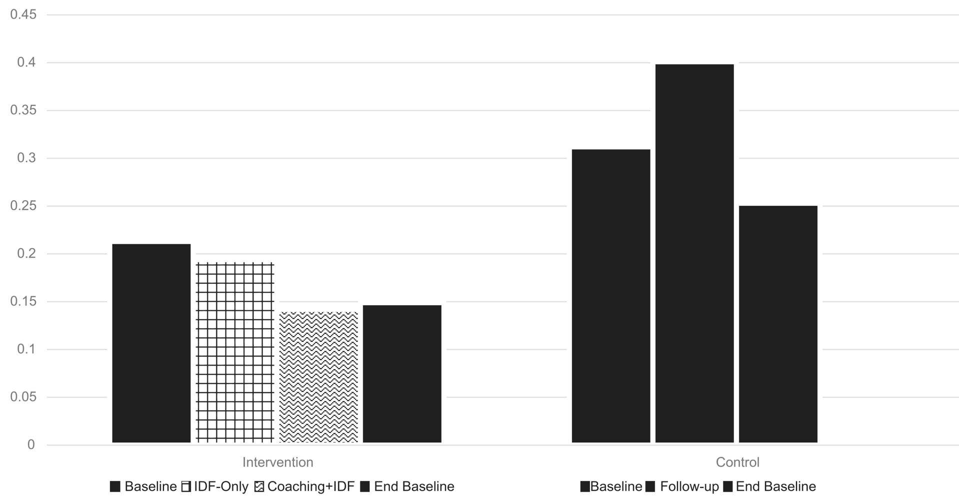

Fig. 3.
Proportion of constant-threshold triggered video events showing driving unbelted for the Intervention Group (Intervention Group 1 and Intervention Group 2, combined) and Control Group 3, and period, groupings for statistical contrast estimates. The IDF-only period includes data from Intervention Group 1 only, where IDF-only feedback was presented as the first type of feedback.

Table 1

List of risky driving behaviors coded from triggered video events.

Fundamental Driving Errors

Unprofessional Driving

- Unsafe backing
- Unsafe braking
- Unsafe lane change/merging/passing
- Unsafe railroad crossing
- Unsafe turning
- Lane departure/straddling lanes
- Competitive/aggressive driving
- Driving the wrong way – on roadway
- Driving the wrong way – off roadway
- Curb check/jumped curb

Vehicle control

- Driving with two hands off wheel
- Unattended moving vehicles

Stopping

- Incomplete stop at light
- Incomplete stop at stop sign
- Failure to attempt to stop at light
- Failure to attempt to stop at stop sign
- False start
- Failure to yield to pedestrian(s)
- Failure to yield to vehicle(s)

Speeding

- Moderate speeding (<10 mph over limit)
- Excessive speeding (>10 mph over limit)
- Exceeded maximum fleet speed

Situational awareness

- Unsafe following (<1 s)
- Unsafe following (1.25–2 s)
- Unsafe following (2.25–3 s)
- Unsafe following (3.25–4 s)
- Not checking mirrors
- Not scanning road ahead
- Not scanning intersection

Distracted & inattentive driving

Distraction

- Mobile Phone – texting/dialing

- Mobile phone – talking (handheld)
- Mobile phone – talking (hands free)
- Operating other mobile device
- Reading paperwork
- Grooming/personal hygiene
- Food
- Beverage
- Smoking
- Passenger(s)
- Other task

Fatigue

- Drowsy/falling asleep
- Yawning

Other unsafe Driving

Seatbelts

- Driver seatbelt unfastened (<20 mph)
- Driver seatbelt unfastened (>20 mph)
- Passenger seatbelt unfastened

Non-driving observations

Unprofessional conduct

- Rude gesture
- Raised voice

Event of interest

- Captured passenger incident
- Captured roadway incident

Equipment

Obstructed view

- Obstructed view of driver
- Obstructed exterior view

Tampering

- Tampering/abusing equipment

Recorder issues

- Suboptimal camera position
- Non-performing camera

Table 2

Frequency count of risky driving behaviors coded from constant-threshold triggered video events for Intervention Groups 1 and 2 and Control Group 3 combined for the entire study period (multiple behaviors could be coded from a single video event).

Category	Total event count	Percent
Driving unbelted	14,185	40.6
Driver seatbelt unfastened (≤20 mph), driver seatbelt unfastened (>20 mph), passenger seatbelt unfastened		
Distractions (smoking, eating, etc.)	11,116	31.9
Smoking, beverage, food, reading paperwork, other task, passenger(s), grooming/personal hygiene, mobile phone – talking (hands free)		
Unsafe stopping	2814	8.1
Failure to attempt to stop at stop sign, incomplete stop at stop sign, failure to attempt to stop at light, incomplete stop at light, false start		
Speeding	2494	7.1
Exceeding maximum fleet speed, moderate speeding (≤10 mph over limit), excessive speeding (>10 mph over limit)		
Mobile use handheld	2136	6.1
Mobile phone – talking (handheld), operating other mobile device, mobile phone – texting/dialing		
Fatigue	1625	4.7
Yawning, drowsy/falling asleep		
Unprofessional driving	226	0.6
Rude gesture, unsafe backing, unsafe turning, unsafe braking, driving the wrong way – off roadway, unsafe lane change/merging/passing, curb check/jumped curb, raised voice, unsafe railroad crossing, lane departure/straddling lanes, competitive/aggressive driving		
Situational awareness	53	0.2
Not scanning road ahead, not checking mirrors, unsafe following (≤1 s), unsafe following (1.25–2 s), unsafe following (2.25–3 s)		
Other events	250	0.7
Driving with two hands off wheel, captured roadway incident		
Total	34,899	100

Table 3

Frequency count of risky driving behaviors coded from constant-threshold triggered video events for Intervention Groups 1 and 2 and Control Group 3 combined for the entire study period, where severity score was 3 or 4 only (multiple behaviors could be coded from a single video event).

Category	Total event count	Percent
Unsafe stopping	2814	36.0
Failure to attempt to stop at stop sign, incomplete stop at stop sign, failure to attempt to stop at light, incomplete stop at light, false start		
Driving unbelted	1542	19.7
Driver seatbelt unfastened (≤20 mph), driver seatbelt unfastened (>20 mph), passenger seatbelt unfastened		
Distractions (smoking, eating, etc.)	1093	14.0
Smoking, beverage, food, reading paperwork, other task, passenger(s), grooming/personal hygiene, mobile phone – talking (hands free)		
Mobile use handheld	1053	13.5
Mobile phone – talking (handheld), operating other mobile device, mobile phone - texting/dialing		
Speeding	681	8.7
Exceeding maximum fleet speed, moderate speeding (≤10 mph over limit), excessive speeding (>10 mph over limit)		
Unprofessional driving	177	2.3
Rude gesture, unsafe backing, unsafe turning, unsafe braking, driving the wrong way - off roadway, unsafe lane change/merging/passing, curb check/jumped curb, raised voice, unsafe railroad crossing, lane departure/straddling lanes, competitive/aggressive driving		
Fatigue	164	2.1
Yawning, drowsy/falling asleep		
Situational awareness	47	0.6
Not scanning road ahead, not checking mirrors, unsafe following (≤1 s), unsafe following (1.25–2 s), unsafe following (2.25–3 s)		
Other events	249	3.2
Driving with two hands off wheel, captured roadway incident		
Total	7820	100

Table 4

Count and proportion of constant-threshold triggered video events showing risky driving behavior (severity 3 or 4 score), and driving unbelted, by combined Intervention group (Intervention Groups 1 and 2 combined by intervention period) and period, groupings for statistical contrast estimates.

Treatment Group	Count of video events with risky driving behaviors (severity 3 or 4) present / absent	Count of video events with driving unbelted[a] present / absent	Total count of video events[b]	Proportion of video events with risky driving behaviors (severity 3 or 4)[c]	Proportion of video events with driving unbelted[c]
Intervention Groups 1 & 2	*Present/Absent*	*Present/Absent*			
1 Baseline (Groups 1 & 2)	628 / 5353	1276 / 4705	5981	0.105	0.213
2 IDF-Only before coaching (Group 1)	677 / 8301	1744 / 7234	8978	0.075	0.194
3 IDF-only after coaching (Group 2)	501 / 6938	1858 / 5581	7439	0.067	0.250
4 Coaching + IDF (Group 1&2)	1024 / 16,035	2420 / 14,639	17,059	0.060	0.142
5 End Base (Group 1&2)	305 / 6111	957 / 5459	6416	0.048	0.149
Control Group 3					
1 Baseline	292 / 2029	725 / 1596	2321	0.126	0.312
2 Period 2&3	1006 / 9231	4106 / 6131	10,237	0.098	0.401
3 End Base	137 / 1150	326 / 961	1287	0.106	0.253

[a]Driving unbelted was not considered by the vendor to be a severity 3 or 4 event.

[b]This column represents the total count of constant-threshold triggered video events triggered and reviewed for the study (one per vehicle per day). Some video events show risky driving behaviors while other video events show no risky behaviors. Regardless of content all videos are counted in this total.

[c]Proportion of events is calculated by dividing count of video events with risky driving behavior present by total count of video events.