EVALUATION OF THE IMPACT OF APP-BASED FEEDBACK AND MONETARY INCENTIVES ON TEEN DRIVER SAFETY

FINAL REPORT

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16. Abstract

Motor vehicle crashes remain the leading cause of fatalities among teens in the United States. These fatalities are often attributed to lack of experience or insufficient training. While these attributions are often accurate, there may be ways to improve teen driver safety by providing feedback and incentives to teen drivers. For this study, data were collected in four phases across six months of data collection. Twenty-five participants were recruited to participate; however, due to technical issues with data collection, data were only collected from 15 participants. The driving performance data that were collected (e.g., hard braking, speeding, and seat belt use) did not show improvement with feedback and incentives, but participants self-reported that they were more conscientious about following speed limits and monitoring their speeding behavior. While this study was unable to monitor speeding in reference to speed limit, these results suggest that teen drivers may slow down and be more mindful of speeding if it results in monetary incentives. Although the findings of this study are not generalizable due to the small sample size, monitoring and feedback for teen drivers continues to show promise as a useful and effective countermeasure to improve teen driving safety.

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EXECUTIVE SUMMARY

Motor vehicle crashes remain the leading cause of fatalities among teens in the United States (Insurance Institute for Highway Safety, 2022; National Center for Injury Prevention and Control, 2020). These fatalities are often attributed to lack of driving experience or insufficient training. While these attributions are often accurate, there may be ways to improve teen driver safety by providing feedback and incentives to teen drivers. The purpose of this study was to examine how providing a web-based feedback app and monetary incentives to reward teen drivers for safe driving can improve teen driver safety.

Data were collected in four phases across 6 months of data collection. Twenty-five participants were recruited to participate; however, due to issues with data collection, data were only collected from 15 participants. The first phase (one month) consisted of baseline driving, in which participants were not provided with access to any experimental intervention. For the second phase (two months), participants were provided with a feedback app accessible by any internet-capable device. For the third phase (two months), participants continued to have access to the feedback app and also received weekly monetary incentives for safe driving. These monetary incentives ranged from $15 to $50 depending on the teen driver's overall driving score. For the fourth phase (one month), participants no longer had access to the feedback app and no longer received monetary incentives. This last phase allowed the researchers to assess whether any changes in behavior that occurred due to the feedback would continue regardless of whether the feedback itself continued. Additionally, an optional check-in interview was conducted for nine teenage participants and 11 parents of teenage participants during the second half of Phase 2.

The collected data showed a slight increase of high-risk hard brake events per 100 miles and in late night trips after countermeasures were introduced, while moderate-risk braking events and speeding over 75 mph remained relatively flat. Mean seat belt violations per 100 trips dropped slightly for the sample.

Many participants in the study also indicated in the check-in interviews that they were already using monitoring and feedback software prior to the start of the study, which prevents a true baseline driving comparison, as some of the participants had access to many

of the features used for the experimental intervention. Responses on a subjective questionnaire during the check-ins suggested that teen drivers were more conscientious about their driving, especially speeding, during the monetary incentive phase. These results suggest that this type of monitoring and feedback system would be an appropriate model to use for future systems.

Although the findings of this study are not generalizable due to the small sample size, monitoring and feedback for teen drivers continues to show promise as a useful and effective countermeasure to improve teen driving safety.

DESCRIPTION OF PROBLEM

Motor vehicle crashes remain the leading cause of fatalities among teens in the United States (Insurance Institute for Highway Safety, 2022; National Center for Injury Prevention and Control, 2020). In 2020, drivers between the ages of 15 and 20 made up 5.1% of all licensed drivers yet made up 8.5% of drivers in all crashes (National Highway Traffic Safety Administration, 2022). Overall, the involvement of teens in fatal crashes is about four times that of adult drivers (Williams, 2003).

Naturalistic driving studies allow researchers to investigate teens' normal driving behavior in real-world settings and identify crash risks. Naturalistic driving studies measure crashes, near-crashes, and elevated g-force events as indicators of unsafe driving behavior. Crashes and near-crashes are defined by measurable physical contact or near contact. Changes in acceleration due to late braking, swerving, fast starts, and sharp turns comprise elevated g-force events (Simons-Morton et al., 2015). Although crashes and near-crashes are clearly dangerous, it is also important to recognize the dangers associated with elevated g-force events, which can reduce the time other drivers have to respond to these risky behaviors and increase the potential for loss of vehicle control (Simons-Morton et al., 2011, 2012).

Measuring g-forces and other naturalistic driving metrics is accomplished largely with the use of in-vehicle technology. Recent technological developments have allowed more complex and innovative ways to collect data on driver behavior and driving environments and potentially improve our knowledge about how teens learn to drive. In-vehicle data recorders (IVDRs) and/or data acquisition systems can come equipped with a variety of sensors and monitors. Common sensors include accelerometers, Global Positioning Systems (GPSs), and vehicle sensors that capture speed, activation of throttle/brake, and turn signals (Lerner et al., 2010). More complex and costly systems also incorporate multi-channel video, audio recordings, and real-time mapping for speed limit information, all of which can provide very precise monitoring of driver behavior (Simons-Morton et al., 2015).

When feedback on the driver's performance is incorporated into an in-vehicle monitoring technology, the opportunity arises to potentially alter risky driver behavior (Lerner et al., 2010). Feedback can be administered as real-time, in-vehicle visual or auditory alerts or as

delayed (or post hoc) feedback on past driving performance. Real-time feedback technologies use in-vehicle display screens, audio or voice alerts, or haptic feedback, such as vibrations, to signal the driver (IMS, 2020). Delayed feedback can include reports on driving behavior (e.g., report cards) and video clips, which can be made available on the vehicle display, a website, or a smartphone app. Finally, incentives may be provided as an additional form of delayed feedback and may be contingent upon specific driving events.

In-vehicle monitoring systems with feedback that are not video-based have shown mixed results for improving teen driver safety. For example, Toledo and Lotan (2006) investigated the effects of an IVDR that utilized two-dimensional acceleration, speed, and GPS. These variables were used to identify and classify 20 risky driving maneuvers, including hard braking, high accelerations, and excessive speed. The driver received real-time alerts when the monitoring system recognized one of these maneuvers. A risk index for each trip classified it as cautious, moderate, or aggressive. Delayed feedback was also presented in a monthly report that showed the risk index for every trip that month. While initial use of the system had a significant positive impact on the participant's driving safety, the effect disappeared by the fifth month.

Another non-video-based IVDR also detected seat belt use and could determine if the driver was going over the posted speed limit (Farmer et al., 2010). In-vehicle feedback consisted of an audible buzz immediately following an elevated g-force event, a continuous buzz when seat belts were not used, and sequential beeps when speeding. Results indicated that elevated g-force events did not decrease significantly for the treatment groups. Additionally, speeding behavior was either not affected at all or the effect diminished over time. Seat belt use increased significantly for all treatment groups. Although parents were provided driving performance information, they either did not find the information useful or chose not to use it. Results from these studies appear to show that IVDRs without video recording do not have a lasting positive effect on safety-related driving behaviors.

One study used a smartphone app to provide three levels of real-time feedback to teen drivers: no feedback, real-time feedback only, and real-time feedback plus parent notifications (Creaser et al., 2015). Drivers received feedback on cell phone use while driving

as well as speeding behaviors. Results showed that teens in the group that received feedback on speeding with parent notification spent a significantly smaller percentage of time traveling 7 mph above the speed limit compared to the other groups. Additionally, the real-time feedback only group was also speeding significantly less than the no feedback group, indicating that some levels of feedback can make a difference in teen behavior. This study demonstrates that providing pertinent speeding behavior information to either teens or both parents and teens can reduce speeding behavior in teen drivers.

IVDRs with event-triggered video have been assessed in several studies and offer even more promise in terms of driver feedback. Systems with real-time driver feedback paired with delayed event feedback provided to parents have been shown to reduce high g-force events such as sudden acceleration, hard braking, and hard cornering (Carney et al., 2010; McGehee et al., 2007). Additionally, supporting evidence shows that driving report cards, real-time feedback, and parental access to event-triggered videos may reduce the frequency of g-force events for teen drivers, while immediate feedback without reports may not (Simons-Morton et al., 2013).

Klauer et al. (2017) conducted a monitoring and feedback study where teen drivers received real-time alerts for hard braking, cornering, fast starts, swerves, crossing a lane line without a turn signal, and speeding above 75 mph. If a teen received one of these real-time auditory alerts while driving, they and their parents would also receive an email with a link to a website where they could see an electronic report card of the teen's driving performance as well as a video clip of the triggered event. The results for this study were mixed. If parents did not review the website, crash and near-crash rates were similar to the control group of teen drivers who did not receive any feedback. On the other hand, the teens whose parents did review the website had significantly lower crash and near-crash rates than both the teens whose parents did not log into the website and the control group. Therefore, parental involvement appears to be an important component in improving teen driving performance. Additionally, the results in Klauer et al. indicate that once the feedback was removed, crash and near-crash rates increased immediately. Thus, to improve safety for all teen drivers, monitoring and feedback need to engage the teen driver without requiring parental

supervision. One possible method for engaging the teen is to use an incentive-based intervention.

The following literature review begins by outlining research on incentive-based interventions across many domains. The review also examines incentive-based technologies, such as apps for drivers, that have been studied less scientifically but nonetheless show promise for increasing traffic safety. The review focuses on teen drivers but also presents interventions and technologies that have been used with other populations that could feasibly be applied to teen drivers as well. The goal of this review is to provide the background necessary for creating an incentive-based intervention for risky driving in teens.

The Science of Incentive-Based Behavioral Interventions

An incentive is a reinforcer, which is any stimulus that strengthens the behavior that precedes it. Later in this review, the term "reward" is used synonymously with "reinforcer" for ease of comprehension, but it should be noted that this synonymous meaning is not considered precise in the larger scientific literature. A classic example of reinforcement is when a child sees candy on the shelf at the grocery store and subsequently throws a tantrum. When the parent provides the candy to the child following the tantrum, the candy reinforces the tantrum behavior. The tantrum behavior thus becomes stronger in the sense that it is more likely to occur in future visits to the grocery store.

Reinforcers have been studied extensively since B.F. Skinner began experimenting with them in the 1930s (Ferster & Skinner, 1957; Skinner, 1938). Even before Skinner began systematically manipulating reinforcer arrangements, many scientists like Thorndike (1911) and Watson (1903) experimented with them (Pierce & Cheney, 2004). Subsequently, the reliable effects of reinforcement demonstrated by Skinner and other early behavioral psychologists have been harnessed to address both individual and societal behaviors. Given that risky driving by teens greatly contributes to injuries and fatalities on U.S. roadways, applying reinforcers to teens who drive *safely* may be one method to improve teen crash rates.

Incentives for Driving Behavior

Some incentives provide direct compensation to reward a behavior, while other incentives provide a more indirect reward, such as a feeling of accomplishment from competition with peers or completing challenges. Although indirect, these rewards still may serve to increase the desired behavior, but their strength, acceptability (how enjoyable they are), and feasibility of implementation may differ.

A pilot study conducted by the Texas Transportation Institute in 2017 looked at monetary compensation as well as a point system, where users accumulate either money or points for not using their phone while driving (Munira et al., 2018). Either the monetary compensation or number of points can be used to increase competition among users or for "leveling up" in the game as incentives. This study examined the period prior to implementation of incentives, the incentive period, and two post-incentive periods. The study found that the frequency of distracted trips (trips during which the cell phone was used) declined once incentives were implemented (Munira et al., 2018).

A five-month, 60-driver study in Israel examined the effect of monetary incentives on driver performance for public transportation providers (Cohen & Shmueli, 2018). This study compared monetary incentives based on individual performance with monetary incentives based on peer performance. The results showed a 15% improvement in driving performance (e.g., hard braking, hard cornering) for peer-relative incentives, and a 31% improvement for individual incentives (Cohen & Shmueli, 2018).

An online survey conducted by the Perelman School of Medicine at the University of Pennsylvania and Children's Hospital of Philadelphia enrolled 153 teens who admitted to texting while driving (Delgado et al., 2018). The survey found that 90% of respondents would be willing or somewhat willing to give up texting, social media, and email use while driving. Respondents were also presented with a list of potential methods to reduce distraction among teens and asked to rate their perceived effectiveness. As shown in Figure 1, the method with the highest perceived effectiveness was individual monetary rewards (Delgado et al., 2018).

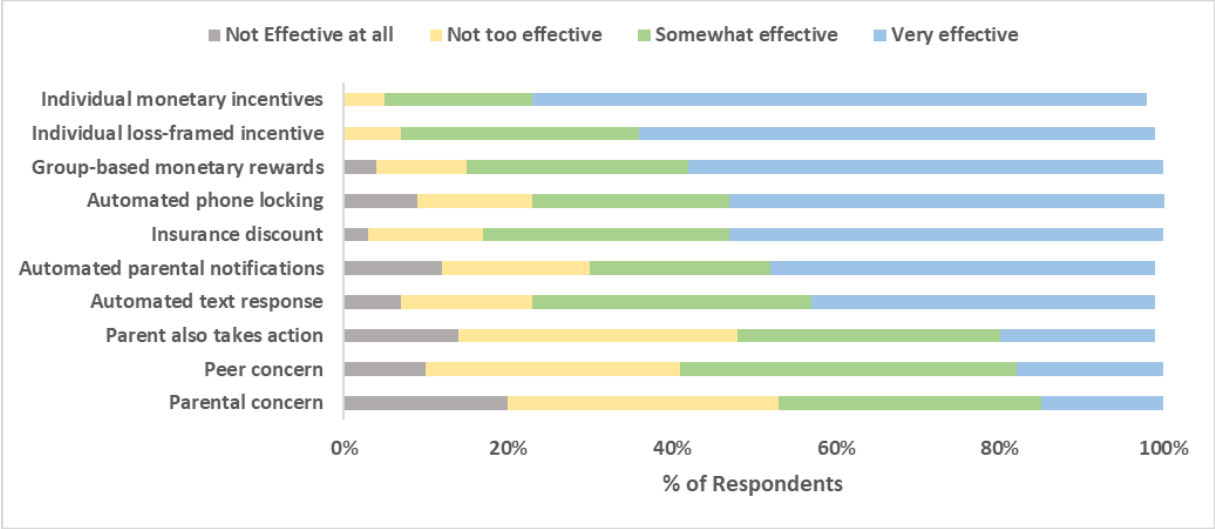

Figure 1. Perceived effectiveness of proposed strategies to reduce cell phone use while driving over the course of 1 year (recreated based on Delgado et al., 2018).

As shown in Figure 1, group-based rewards rank third in perceived effectiveness. A study by Musicant and Lotan (2016) examined the impact of group rewards on willingness to use a smartphone app that monitors safety behavior. Participants were provided group rewards and were encouraged to recruit additional participants to help the group win rewards. The study found that during the period of group incentives, participants were very willing to use the app; however, once the prespecified rewards were achieved, participants stopped using the app (Musicant & Lotan, 2016). This may indicate that the rewards were too high in value to maintain behavior (i.e., participants were satiated). It is possible that lower-value rewards earned over a longer duration of time would maintain use of the app and safe driving behavior.

In addition to monetary compensation, younger drivers may also be motivated by accomplishing predetermined objectives. One way to administer these objectives is to "gamify" the driving experience through a smartphone app. The idea of gamifying the driving experience is to use design elements found in video games to motivate good driving behavior. Sailer et al. (2017) looked at seven different game design elements to examine their motivational potential by relating them to self-determination theory, which states that the three main psychological needs are autonomy, competency, and social relatedness. The seven

design elements examined were points, badges, leaderboards, performance graphs, meaningful stories, avatars, and teammates.

Points can be used to numerically represent a user's progress. One of the main purposes of using points is to provide immediate feedback to the user. Badges and achievements are earned by accomplishing goals and are visual representations of the user's accomplishments. These incentives may provide a sense of belonging by being part of a group that has met the requirements to unlock a specific badge or achievement. If the method for unlocking these achievements is made known to the user, they could also be used as goals for the user to work toward. Leaderboards, a tool that ranks users against each other, can be an effective motivational tool, but Sailer et al. (2017) found that they are often only effective when there is close competition; they can actually be demotivators when the user is at or near the bottom. Performance graphs track the user's behavior over time, allowing the user to look back and evaluate how well they have done and how their performance has improved (or worsened).

Other researchers have specifically examined leaderboards and found that they can improve cognitive engagement in learning tasks, but some individuals seem to benefit more from leaderboards than others (Huang & Hew, 2015; Landers & Landers, 2014). Landers et al. (2017) further demonstrated the effectiveness of leaderboards and explained this by noting that participants set goals to reach the "top" of the board. A recent literature review on gamification also showed some positive effects on psychological (e.g., motivation, attitude, enjoyment) and behavioral outcomes, but the studies reviewed were very heterogeneous, some with methodological limitations, which prevents drawing clear conclusions. Personality traits, particularly extroversion (Jia et al., 2017) and emotional stability (Buckley & Doyle, 2017), have also been shown to increase the effectiveness of gamification and leaderboards in particular (Jia et al., 2017).

One example of a study that used gamification to motivate drivers is a simulator study conducted by the Queensland University of Technology (Steinberger et al., 2017). The study created and examined a smartphone app that provided objectives to participants to encourage safer driving. Each of the 24 participants experienced both a control period in which they

were not using the app and a treatment period in which they used the app. During both periods, the participants passed 13 speed limit signs that resulted in eight speed transitions. The results showed that mean speed was lower in the treatment group, which was attributed to earlier and smoother speed transitions. However, the study also found that long eye glances (>2 seconds) away from the road occurred more frequently in the treatment group than in the control group (Steinberger et al., 2017).

While there appear to be multiple options for providing incentives to teen drivers, teens seem to prefer monetary incentives. Several recent studies have evaluated the impact of monetary incentives for safe driving practices by teen drivers and found that the incentives enhance the improvement compared to feedback alone (Peer et al., 2020). Additionally, some gamification appears to be engaging, such as streaks (i.e., a continuous series of successes or wins), whereas leaderboards have mixed results and may be demotivating to those who are near the bottom of the group. Given these results, the current project provided feedback on driving performance via a mobile app to teens and their parents. Additionally, there was an incentive period when teens received both feedback and monetary incentives for safe driving. These two experimental periods (feedback, feedback + monetary incentives) were preceded by a control period with no feedback or incentives and followed by a control period for the last two weeks of the study to determine if poor driving performance returned.

Research Questions

This report will discuss the research methods used and statistical analyses performed to better understand the following research questions:

RQ 1: Does providing post hoc feedback to teens reduce the rate of unsafe driving behaviors?

RQ 2: Does providing performance-based monetary incentives reduce the rate of unsafe driving behaviors?

RQ 3: If performance-based monetary incentives do result in a reduction of unsafe driving behaviors, is that reduction sustained after the teen stops receiving incentives?

APPROACH AND METHODOLOGY

There were two primary data collection efforts for this project. The first, called the Task 1 Teen Feedback App Study, refers to the overall study with driving performance data collection and exit surveys. Task 2 Check-In Interviews refers to in-depth interviews that were conducted during the third phase (feedback app + incentive phase) of data collection with both teen and parent participants of the Task 1 study. This was a fairly extensive qualitative analysis and thus is reported separately in both the Approach and Methodology and Findings, Conclusions, Recommendations sections to highlight the importance of this effort. Final conclusions and recommendations, which encompass both data collection efforts, are provided at the end of the document.

Overview of Task 1: Teen Feedback Study

Data were collected from 15 teen drivers who participated in a six-month driving study. Participants received post hoc feedback that was uploaded to a web-based application (i.e., feedback app) after each trip. This web-based application was accessible via mobile device and any internet-capable device. Both the participant and their parent or guardian received access to the feedback app, which provided summary information for the teen's driving performance. There were four phases of data collection that spanned the six-month study period: Pre-Treatment Baseline (Month 1), Access to Driving Feedback App (Months 2 and 3), Access to Both Driving Feedback App + Monetary Incentives (Months 4 and 5), and Post-Treatment Baseline (Month 6).

General Motors (GM) was directly involved in the planning and development of the study design through weekly meetings, and GM contributed significantly to recruitment efforts. Participants were recruited by sending 500,000 letters to GM vehicle owners over seven days. These letters provided a brief description of the study and participant requirements, inviting interested individuals to contact the Virginia Tech Transportation Institute (VTTI) participant recruitment group by phone or email. The VTTI participant recruitment group fielded several hundred calls over the course of two weeks and identified and consented 25 participants within that two-week period. These 25 teen participants, 13 male and 12 female, were ages 16 to 18 with at least three months of licensed driving experience. However, due to

technical issues with data collection, only 15 participants were able to complete the study, 8 male and 7 female, as shown in Table 1.

Table 1. Teen participant breakdown by age at the start of data collection and gender.

Gender	Age	Count
Female	16	4
Female	17	2
Female	18	1
Male	16	6
Male	17	2

Participants were recruited from various regions across the United States. Figure 2 shows a map of the distribution of participant locations.

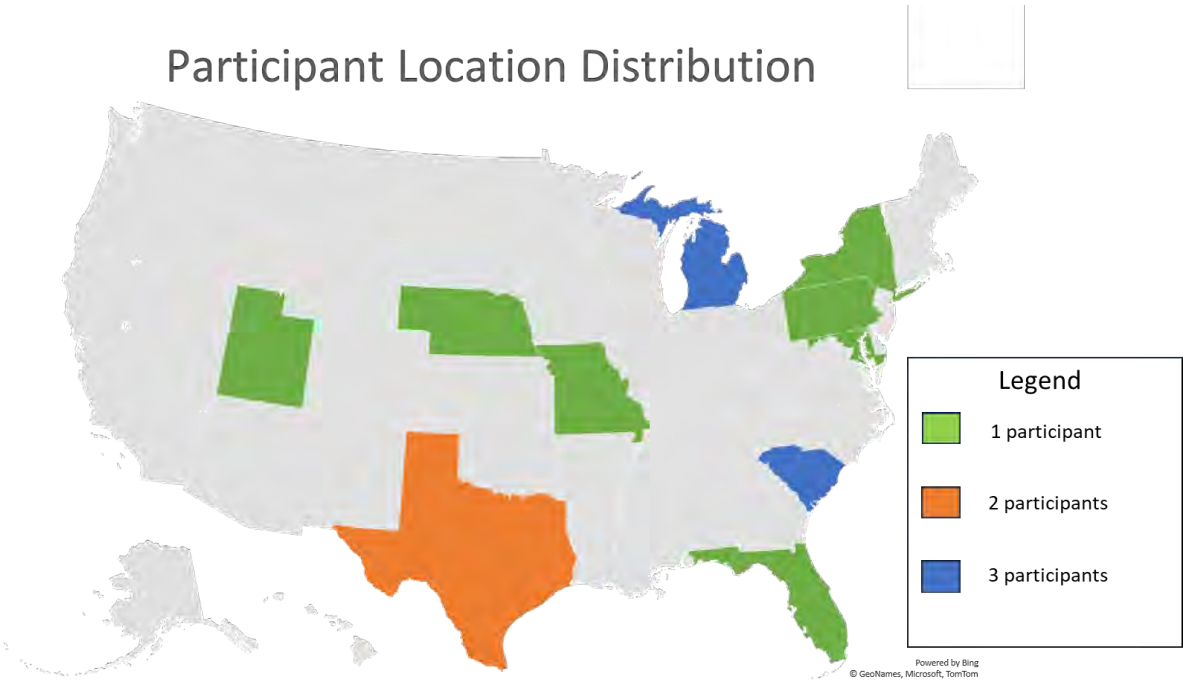

Figure 2. Map of participant location distribution.

Participants were required to be the primary driver of a vehicle that was OnStar capable and able to activate GM's Teen Driver Settings (i.e. most Buick, GMC, Cadillac, and Chevrolet vehicles model year 2015 or newer); participants also had to be willing to activate those features, and a one-year subscription to the OnStar Safety and Security package was provided

at the onset of the study at no cost to the participant. Participants were required to live at home with their parent or guardian and be the primary driver of the vehicle being used for the study. The teen was also required to have their own key fob for the vehicle and to pair their key fob with the vehicle to activate Teen Driver Settings whenever they drove the vehicle.

Experimental Design

The study design consisted of four phases, as shown in Figure 3. The first phase (Month 1) was a pre-treatment baseline driving phase during which participants did not have access to the feedback app, and they did not receive incentive payments. During the second phase (Months 2 and 3), participants only had access to the feedback app but did not receive any performance-based incentives. During the third phase (Months 4 and 5), participants had access to the feedback app and also received weekly performance-based monetary incentives that varied in amount based on their driving performance. The fourth phase (Month 6) was a second post-treatment baseline during which participants no longer had access to the feedback app and no longer received monetary incentives. The fourth phase allowed the research team to examine whether there was any sustained behavior change resulting from the experimental intervention after the intervention was removed.

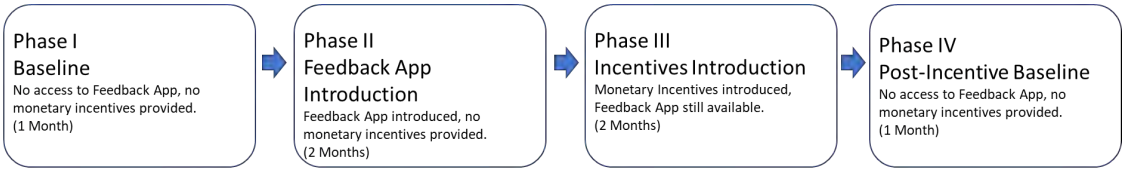

Figure 3. Data collection phase progression.

Dependent Variables

Primary dependent variables were collected using driving performance data provided by OnStar after each ignition cycle. These driving performance-based variables are defined in Table 2. Additionally, the feedback app provided a basic safety message for each of the dependent variables when clicked within the app. Participants were also asked to complete an intake questionnaire upon enrollment in the study and an exit questionnaire at the end of the data collection period. Finally, feedback app usage was tracked to determine frequency and date of both teen and parent logins.

Table 2. List of dependent variables.

Dependent Variable	Definition	Message in Feedback App	Metric
Overspeed events	Number of events in which the maximum speed threshold is exceeded for at least 30 seconds.	You should minimize your excessive speeding events.	The rate of exceedance of 75 mph (for over 30 seconds) relative to the number of total miles driven.
Hard braking events	Number of events in which the hard braking threshold is exceeded.	High Risk: Be sure to pay attention so you don't need to slam on your brakes to avoid a crash. Moderate Risk: Don't be a "late breaker!" Try to slow down more gradually instead.	The rate of braking maneuvers over -0.373 g-force was used as the threshold for high-risk braking, and -0.34 g-force was used as the threshold for moderate risk braking.
Seat belt usage	Number of trips in which the participant and front seat passenger use their seat belt.	You should always have your seat belt on, even if you think you're only going a short distance.	Proportion of trips in which the driver (and front seat passenger if applicable) use their seat belt.
Late night driving	Number of trips driven between 11 p.m. and 4 a.m.	You should limit your late night trips.	Proportion of trips in which the participant is driving between 11 p.m. and 4 a.m.

Independent Variables

The independent variables are listed in Table 3. The variables of primary interest in this study are experimental phase and time in study.

Table 3. List and levels of independent variables.

Independent Variable	Levels of Independent Variable
Experimental Phase (Within-Subject)	Phase 1 (Pre-Incentive Baseline), Phase 2 (Feedback App), Phase 3 (Feedback App Plus Incentive), Phase 4 (Post-Incentive Baseline)
Gender (Between Subject)	Female/Male

Feedback App (Phases 2 and 3)

Starting in the second month of data collection, participants and their parent or guardian were provided with secured credentials to access a web-based driving feedback app. At the conclusion of each trip, data were transferred from the vehicle network to a secure server at VTTI. These data were post-processed and were used to update the driving feedback app. The driving feedback app provided participants and their parent or guardian with summary information about the teen participant's driving behavior. An example screenshot of the driving feedback app is shown in Figure 4. Definitions of each of the driving behavior features were available to the user by hovering their cursor over the text for each, and a window would pop up to further explain the behavior. For example, if a user hovered their cursor over "Late Night Driving," a text box would appear indicating that Late Night Driving was any trip that started after 11 p.m. or before 4 a.m. All summary data reset on a weekly basis, other than scores calculated during the pre-treatment baseline period. A description of each of the features presented in the feedback app is shown in Table 4.

Figure 4. Example screen capture of feedback app.

Table 4. Details for each of the features used in the feedback app.

App Feature	Description	Variables Included
This week's score and driving	An overall driving score for the current week as well as summary drive information for the week	Overall driving score for the week, total number of trips, miles driven, total driving time
Driving behavior	The total number of violations for each of the variables used in driving score calculations	Late night driving, overspeed events, high risk hard brake events, moderate risk high brake events, driver seat belt violations
Additional safety systems	The total number of active safety system activations (not used in calculation of driving score)	Forward collision warnings, automatic emergency brake activations
Last week's score	The calculated driving score for the previous week	Last week's driving score
Baseline score	The driving score calculated based on the first month of baseline driving	Baseline score

Procedure

Prior to the start of data collection, participants completed a virtual intake interview over Zoom. This intake interview included review and signature of the informed consent/assent, completion of a W-9 tax form for payment purposes, completion of an intake questionnaire, and review of procedures required for them to begin data collection.

Procedures that participants had to complete before data could be collected included:

- Ensuring that OnStar was active in their vehicle.
- Ensuring that Teen Driver Settings was active in their vehicle and that the key fob that the participant would be using was paired to the vehicle to confirm that data were only collected when the participant was driving the vehicle.
- Setting the overspeed alert threshold to 75 mph in Teen Driver Settings (the highest allowable threshold).

After these procedures were complete, OnStar was able to collect data and transfer the data to VTTI after each trip. Unfortunately, upon beginning data collection, the data transfers for 10 participants could not be completed. VTTI attempted to troubleshoot this data transfer issue with assistance from GM and OnStar, but it could not be resolved, resulting in the removal of those 10 participants from the study.

Activating Teen Driver Settings also enabled real-time feedback for overspeed events. When the teen driver exceeded 75 mph, an auditory alert and a visual alert on their dashboard indicated that they were exceeding the set threshold. This overspeed alert was the only real-time audio alert participants received as a result of this study, though they may have received alerts from active safety systems already present in their vehicle. Additionally, if the teen driver did not use a seat belt, the vehicle's speakers did not transmit the radio signal, preventing the teen from listening to the radio without their seat belt buckled.

Driving Score Calculations

Participant driving score was calculated weekly and was based on four collected variables: rate of overspeed alerts (speed over 75 mph), rate of hard brake events, proportion of trips with seat belt violations, and proportion of trips with late night driving. Active safety alerts (e.g., forward collision warning) were provided in the "Additional Safety Systems" section on the feedback app but were not used in score calculations, as the active safety features varied across participant vehicles. Each of the four variables used for score calculation had thresholds for different risk levels based on participant behavior, as shown in Table 5. These risk thresholds were based on previous proprietary research and were used, with permission, to establish participant risk level for each of the event categories.

Table 5. Risk level criteria for each variable used in driving score calculation.

		Risk Thresholds				
	Event Definition	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Overspeed events	Vehicle speed exceeds 75 mph	0 events	1 or 2 events per 100 miles	3 or 4 events per 100 miles	5 or 6 events per 100 miles	Greater than 6 events per 100 miles
Hard braking	Moderate risk brake event ≥ -0.34 g, high risk brake event ≥ -0.373 g	Less than 2.515 moderate risk braking events	n/a	Greater than 2.515 moderate risk braking events per 100 miles and less than 4.48 high risk braking events per 100 miles	n/a	Greater than 4.48 high risk braking events per 100 miles
Seat belt violations	Unbuckled driver at any point while the vehicle is in motion	0 trips with an unbuckled driver	n/a	0% to 5% of trips with unbuckled driver	n/a	Greater than 5% of trips with unbuckled driver
Late night driving	Trip initiated between 11 p.m. and 4 a.m.	<1% of trips	1% to 3% of trips are late night	4% to 6% of trips are late night	7% to 10% of trips are late night	Greater than 10% of trips are late night

Based on the risk thresholds in Table 5, each of the event types was provided a coefficient to be used in the driving score calculation, as shown in Table 6.

Table 6. Risk coefficients used in calculating weekly driving scores.

	Risk Coefficient				
Variable	Very Low	Low	Moderate	High	Very High
Overspeed alerts (a)	1	0.8	0.6	0.4	0.2
Hard braking events (b)	1	n/a	0.6	n/a	0.2
Seat belt violations (c)	1	n/a	0.6	n/a	0.2
Late night trips (d)	1	0.8	0.6	0.4	0.2

Using the risk coefficients in Table 6, the overall driving score was calculated as:

Driving Score = a(25) + b(40) + c(20) + d(15)

Where:

- a = risk coefficient for overspeed alerts
- b = risk coefficient for hard braking events
- c = risk coefficient for seat belt violations
- d = risk coefficient for late night trips

This formula was designed to assign different weights to each driving score criterion, reflecting their relative importance. Specifically, overspeed alerts constitute 25% of the driving score, hard brake events account for 40%, seat belt violations represent 20%, and late night trips comprise 15%.

Monetary Incentives (Phase 3)

During the incentives phase of the study, participants received between $15 and $50 per week, depending on driving performance. Determination of participant incentive compensation was based on the weekly driving score at the end of each week during the monetary incentives phase using Table 7. The compensation rate that was used was uniform across participants whose socioeconomic status may have varied significantly. As a result, the level of motivation influenced by the compensation among participants is unknown.

Table 7. Weekly incentive payment calculations.

Weekly Driving Score	Payment
90-100	$50
80-89	$45
70-79	$40
60-69	$35
50-59	$30
40-49	$25
30-39	$20
<30	$15

Note that teens were not informed of exactly how the calculations were made and were not aware of the exact amount tied to different safe driving behaviors. During intake and on the assent/consent form, teen participants were only told that "safe driving behavior like following the speed limit and wearing your seat belt will result in higher weekly compensation."

Overview of Task 2: Check-In Interviews with Parents and Teens

For Task 2 of this study, teens and parents were invited to take part in a check-in interview to discuss what they thought about the study while the teens were still in the incentives phase. During the incentives phase, the teens and parents had access to the feedback app and the teens were receiving payments based on their driving scores. Teen participants received the incentive payments via a ClinCard (a Mastercard that the research team loaded payments to). For more information on the check-in interview recruitment/screening, scheduling, and consent process, see Findings for Task 2: Check-In Interview Results.

Both parents and teens were invited to take part in separate check-in interviews. Those who agreed to take part in a check-in interview were asked a series of questions. The questions varied slightly depending on if the participant had logged into the app prior to the check-in interview. Content of the teen and parent scripts can be found in Appendix A.

Participants

Task 1 of this study included 15 teen/parent dyads. As shown in Table 8, nine teens participated in a check-in interview. Of those nine, two teens had at least one recorded login to the feedback app prior to their check-in. In addition to the two teens who had recorded logins, there was one teen who looked at the app with a parent and another teen who said they had logged in, but there was no recorded login. Based on how much the teen knew about the app during the check-in, the research team believes this teen possibly used the parent's login instead of their own.

Of the 11 parents who participated in the check-in, three had at least one recorded login to the app prior to check-in. Two parents who did not log in but had teens who logged in said they had looked at and/or discussed the app with their teen.

Table 8. Check-in interview participants.

Participant Type	Task 1 Participants	Completed Check-In	Logged into the App	Looked/Discussed with Parent/Teen
Teen	15	9	2*	1
Parent	15	11	3	2

*One additional teen said they had logged in; they may have used a parent login.

FINDINGS, CONCLUSIONS, RECOMMENDATIONS

Findings for Task 1: Teen Feedback App Study

Due to issues with data collection/transfer and participant personal vacation/travel schedules, there was significant loss/missing data observed in the study. The team minimized this data loss by imputing weekly scores based on the mean for the weeks with available values within each corresponding phase. Thus, these calculated means were used to replace missing data. A summary of these missing data is shown in Table 9. It should be noted that the weeks with missing data shown in Table 9 include data missing due to technical issues and weeks in which the participant simply did not drive (e.g., during vacation travel).

Table 9. Missing weeks of data for each phase of data collection by participant.

		% of Participant Data Weeks Collected			
Participant ID	**Total (% of 26 weeks)**	**Pre-Treatment Baseline (% of 5 weeks)**	**App no incentives (% of 8 weeks)**	**App + Incentives (% of 8 weeks)**	**Post-Treatment Baseline (% of 5 weeks)**
1	77%	40%	63%	100%	100%
2	100%	100%	100%	100%	100%
3	100%	100%	100%	100%	100%
4	100%	100%	100%	100%	100%
5	69%	80%	75%	75%	40%
6	88%	60%	88%	100%	100%
7	85%	100%	88%	100%	40%
8	100%	100%	100%	100%	100%
9	100%	100%	100%	100%	100%
10	92%	80%	100%	88%	100%
11	96%	80%	100%	100%	100%
12	96%	100%	88%	100%	100%
13	100%	100%	100%	100%	100%
14	65%	80%	75%	63%	40%
15	58%	100%	88%	38%	0%

** All cells in which participants are missing weeks of data for the corresponding phase of data collection are **highlighted red**.

Data Summary

Overall, 52,861 miles of continuous driving data were collected across 6,021 trips over the course of data collection. Figure 5 and Figure 6 show the distribution of miles driven and trips completed per experimental phase, and Figure 7 and Figure 8 show the distribution of miles driven and trips completed per participant. These figures do not include any data that was not able to be collected due to technical issues, as discussed previously. The average mileage per participant was 3,576 (SD 2,340), and the average number of miles per trip was 8.76 (SD 11.33).

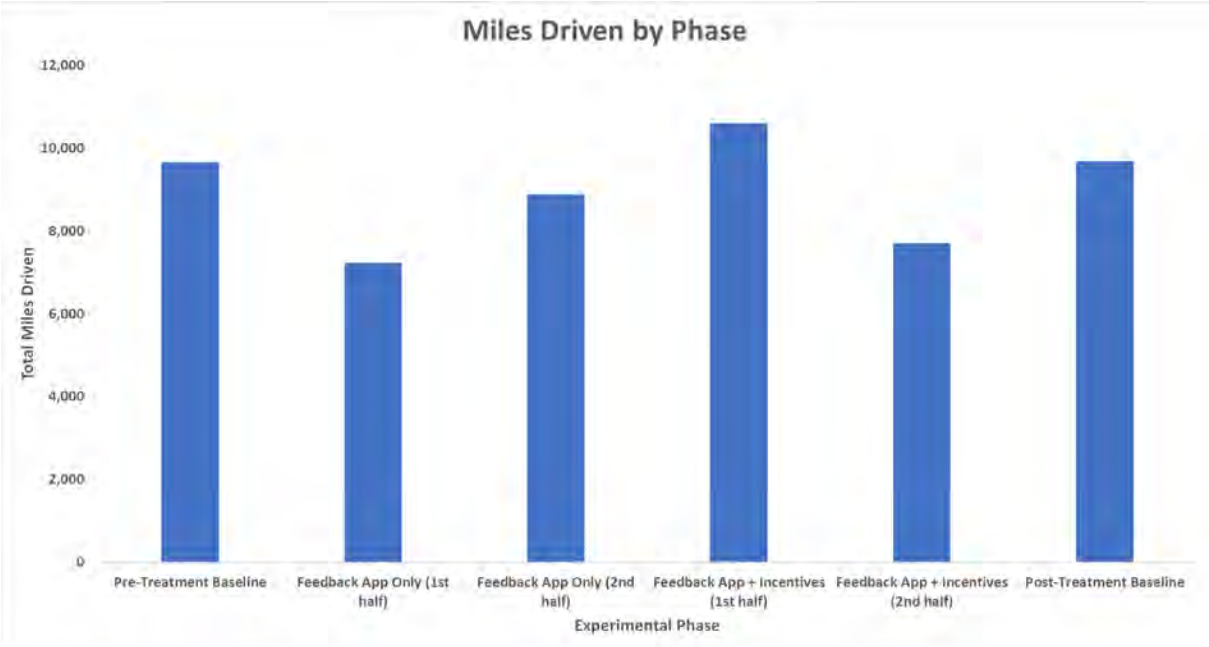

Figure 5. Total miles driven per phase.

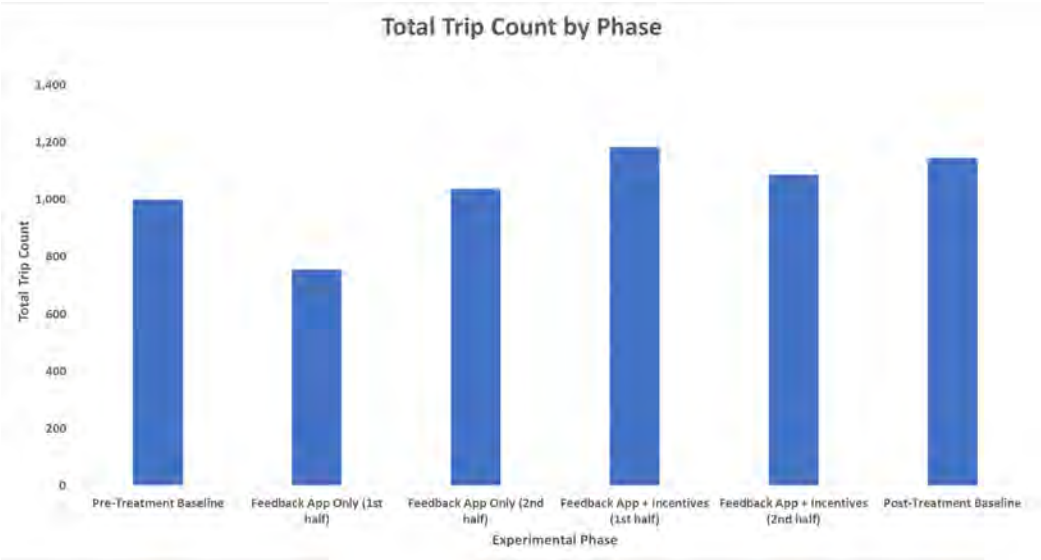

Figure 6. Total trip count per phase.

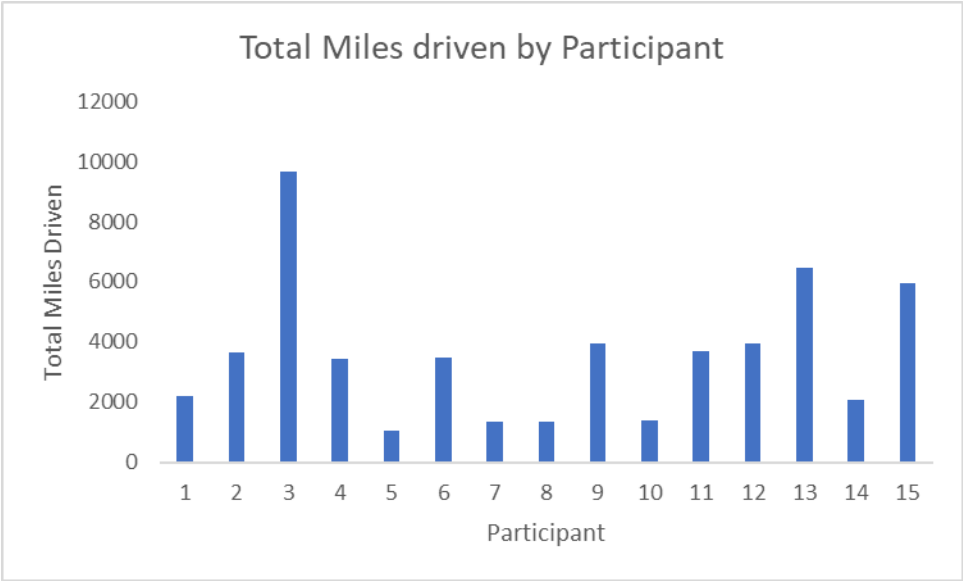

Figure 7. Total miles driven per participant.

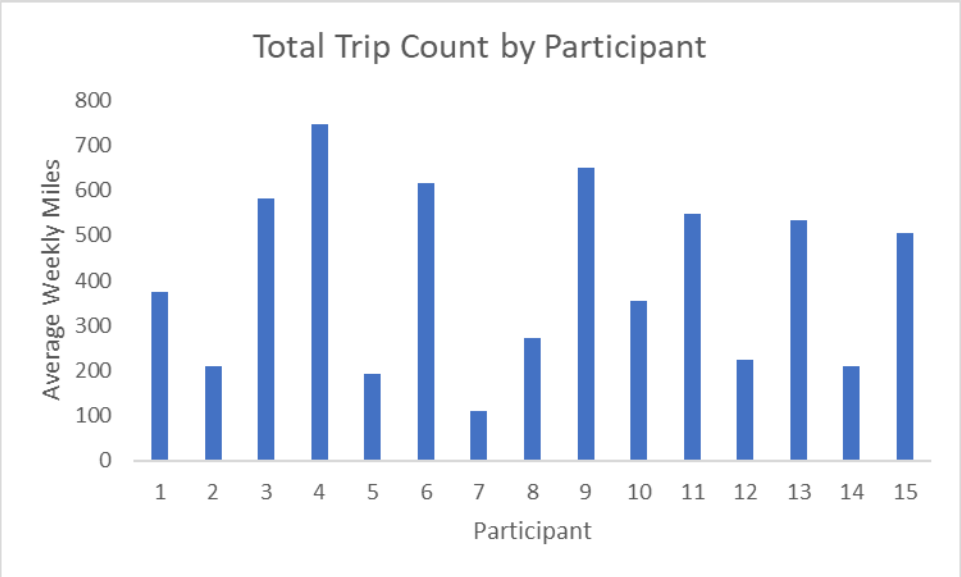

Figure 8. Total trip count per participant.

Feedback App Login Data

Participants along with their parent were provided access to the feedback app starting in the second month of their participation. Overall, only six of 15 teens and five of 15 parents logged into the feedback app during the study. The total numbers of page views per participant were recorded and are shown in Table 10. The research team did learn that some teen participants may have been using their parent's login credentials (e.g., P13). Note that parents may also have used the teen login credentials, or parents and teens may have viewed the feedback app simultaneously; however, the extent to which this may have happened is unknown.

Table 10. Total number of page views on the feedback app for participants and parents.

Participant ID	Teen Login	Parent Login	Total # of Teen Page Views	Total Number of Parent Page Views
1	No	No	0	0
2	No	Yes	0	75
3	Yes	No	27	0
4	Yes	Yes	2	6
6	Yes	Yes	10	54

Participant ID	Teen Login	Parent Login	Total # of Teen Page Views	Total Number of Parent Page Views
9	Yes	No	6	0
10	Yes	No	6	0
11	No	Yes	0	3
12	Yes	No	2	0
13	No	Yes	156	0
14	No	No	0	0
15	No	No	0	0

Driving Performance Measures

Overall driving scores were calculated on a weekly basis as described in the Feedback App (Phases 2 and 3) methods section. Mean driving scores by experimental phase are shown in Figure 9. The mean figures in this section are derived from normalized data, using the pre-intervention baseline as the reference value. They represent the average difference in participant performance across each phase compared to this reference value. Additional figures showing the overall means can be found in Appendix B. Because the intervention phases (feedback app only and feedback app + incentives) were longer than the baseline driving phases, they were split into two separate values on the *y*-axis to show the trend over time. In addition, Figure 10 shows the distribution of normalized weekly driving scores by participant.

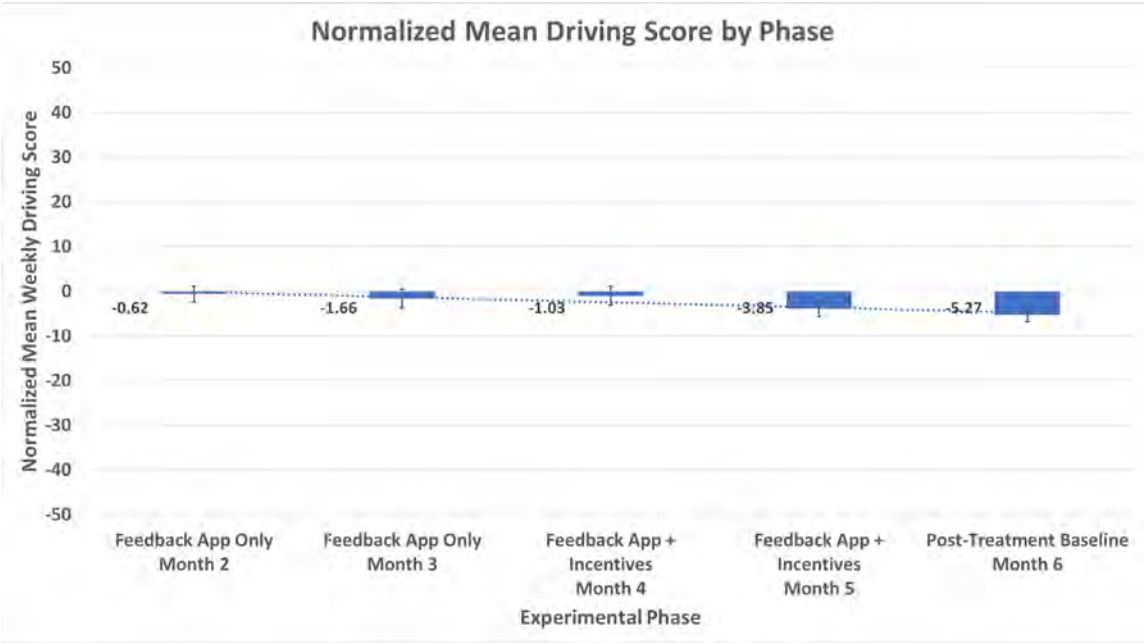

Figure 9. Mean driving score by data collection phase.

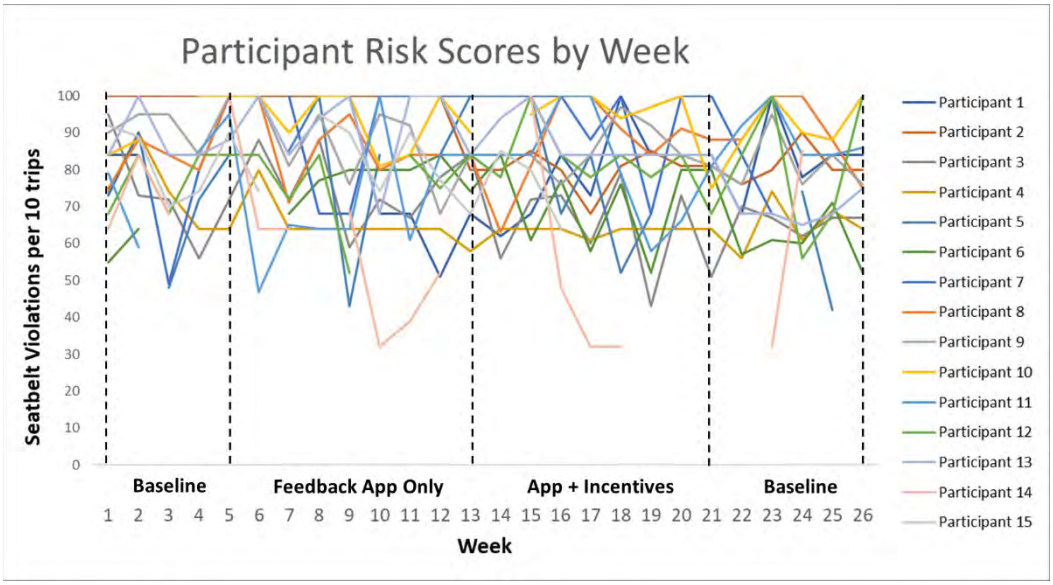

Figure 10. Distribution of participant driving scores by week.

Figure 11 shows the normalized average driving score for participants who logged into the feedback app at least once compared to participants who did not log into the feedback app at all.

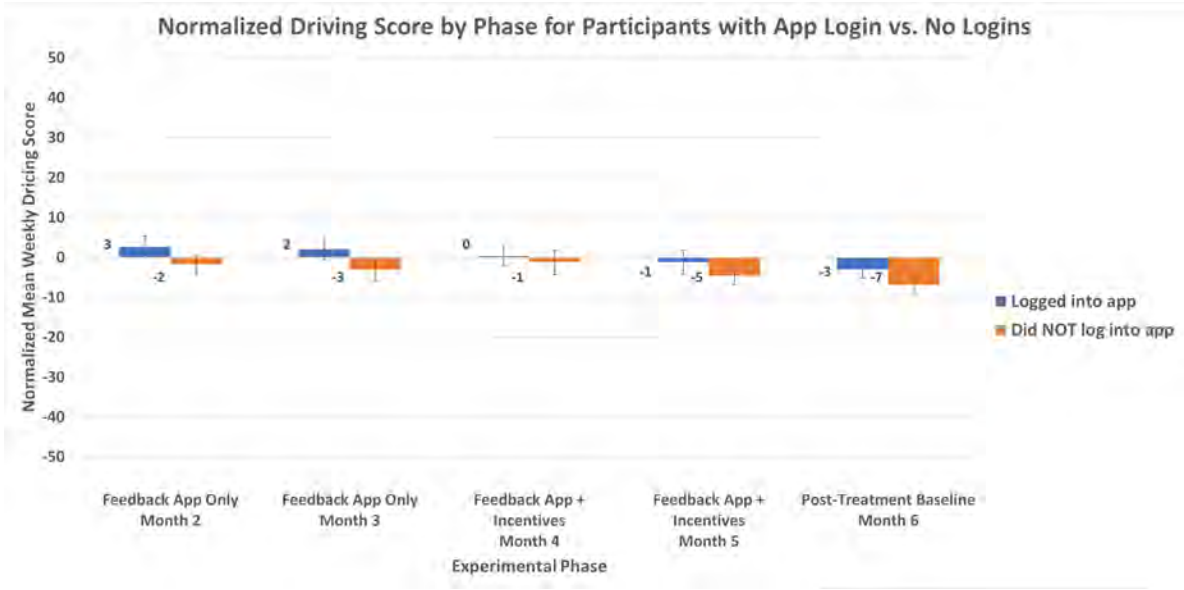

Figure 11. Mean normalized driving score for participants who logged into the feedback app versus participants who did not.

Seat belt violations were recorded throughout data collection, and the normalized average number of trips with seat belt violations per 100 recorded trips for each phase are shown in Figure 12. The dashed blue line cutting through the chart is the trendline for the change in seat belt violations over each of the phases. The distribution of seat belt violations by participant per week is shown in Figure 13.

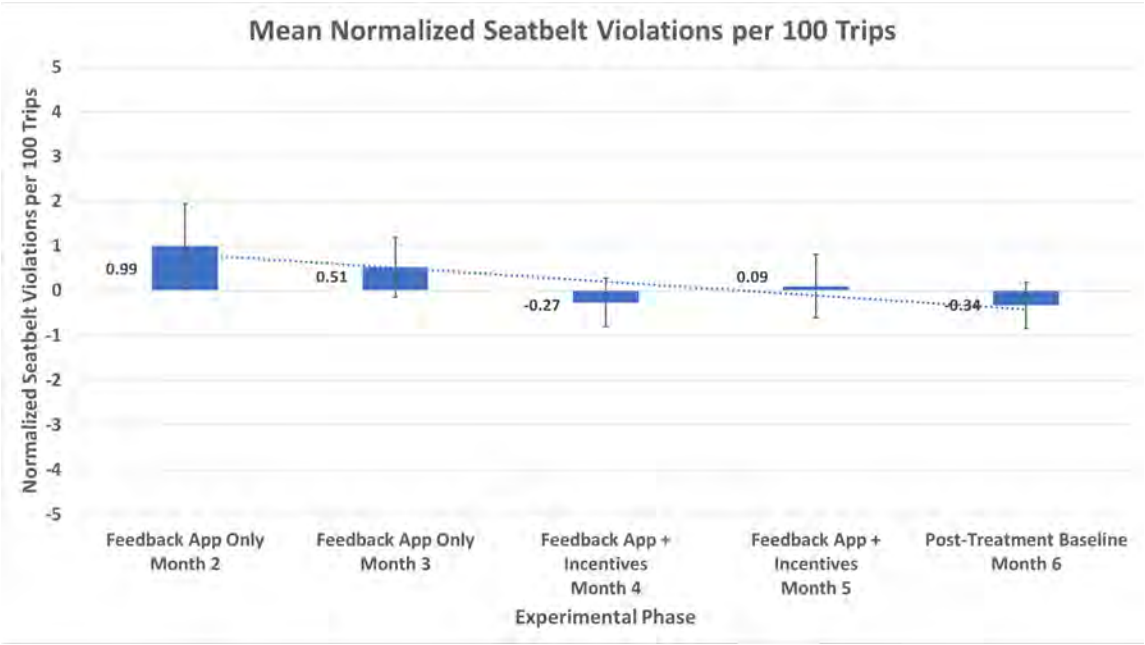

Figure 12. Mean normalized seat belt violations per trip by phase

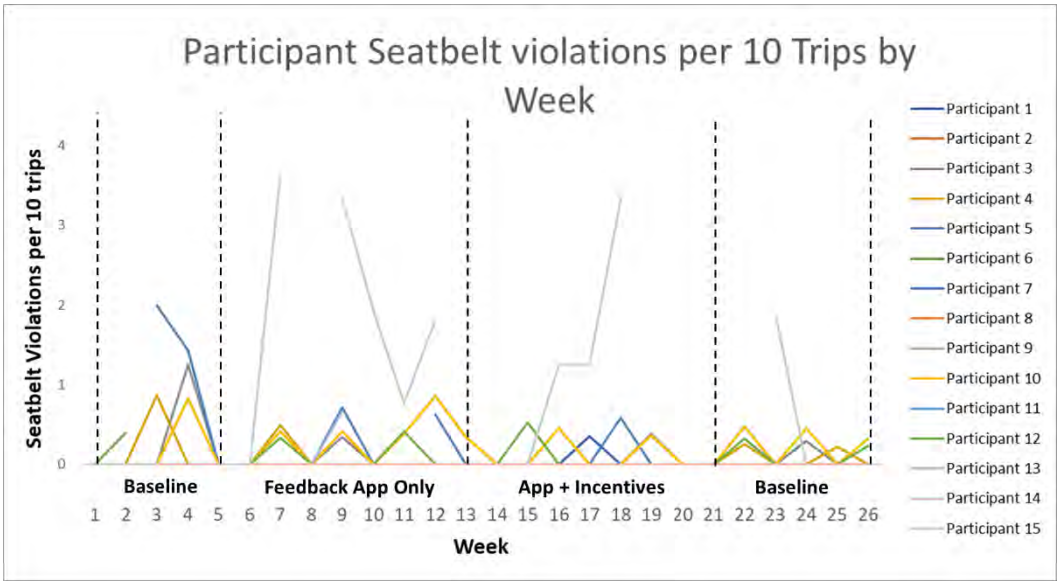

Figure 13. Distribution of participant seat belt violations per ten trips by week.

Hard braking events were classified into two categories: high-risk brake events (brake events greater than -0.373 g), and moderate risk braking events (brake events greater than -0.34 g, but less than -0.373 g). Figure 14 shows the normalized mean number of high-risk brake

events per 100 miles driven for each experimental phase, and Figure 15 shows the distribution of high-risk brake events per 100 miles by participant per week.

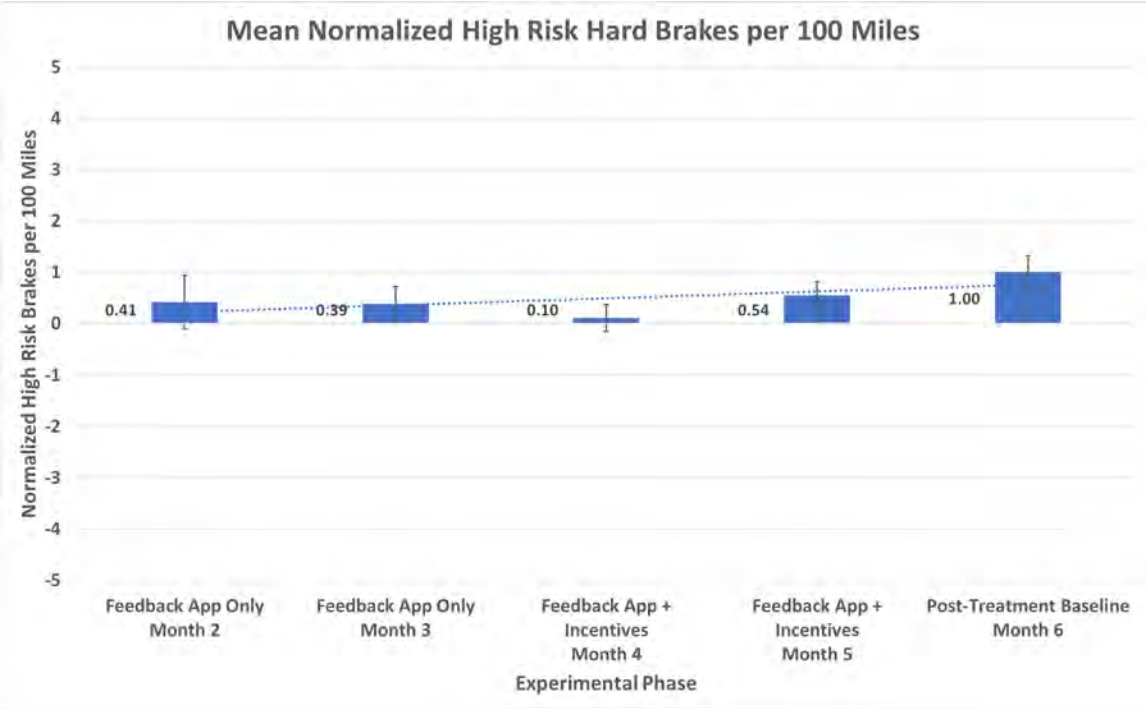

Figure 14. Mean normalized high-risk hard brake events per 100 miles.

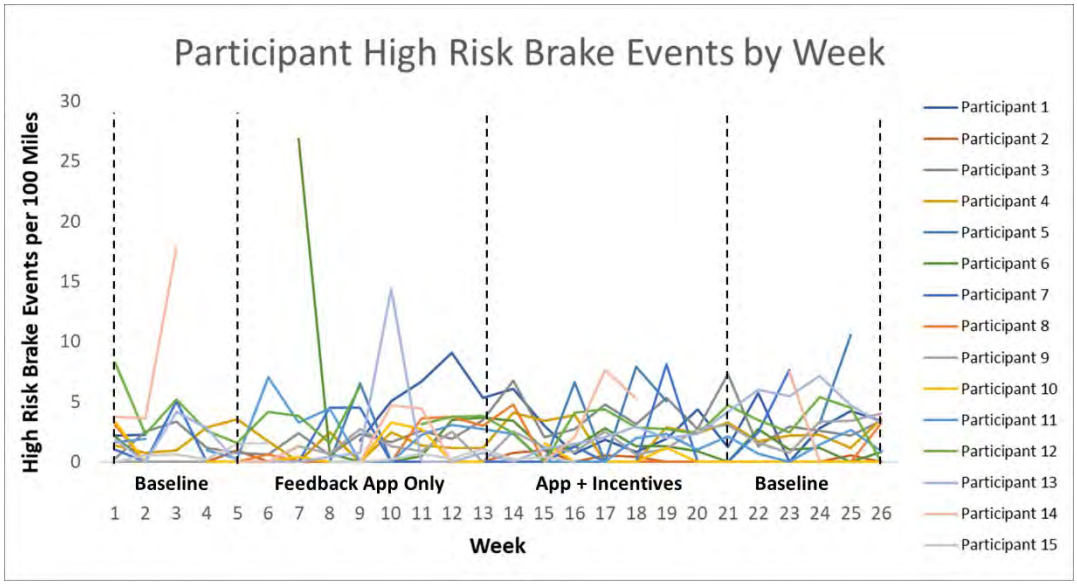

Figure 15. Distribution of participant high-risk brake events per 100 miles .

Figure 16 shows the normalized mean number of moderate risk brake events per 100 miles for each of the experimental phases, and Figure 17 shows the distribution of moderate risk brake events per 100 miles by participant per week.

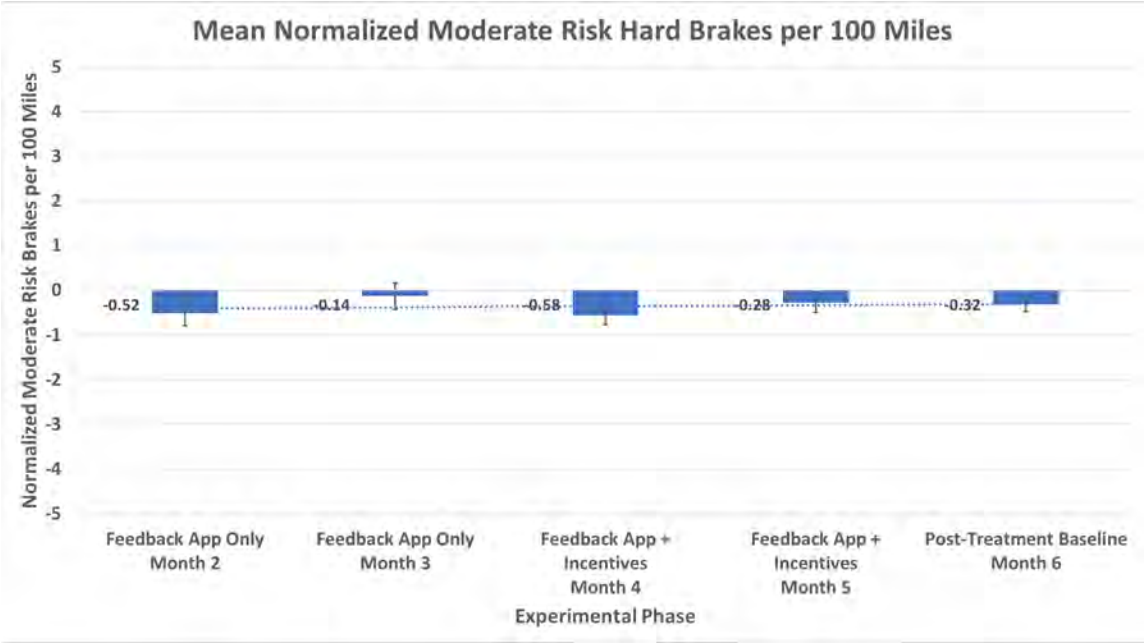

Figure 16. Mean normalized moderate risk brake events per 100 miles.

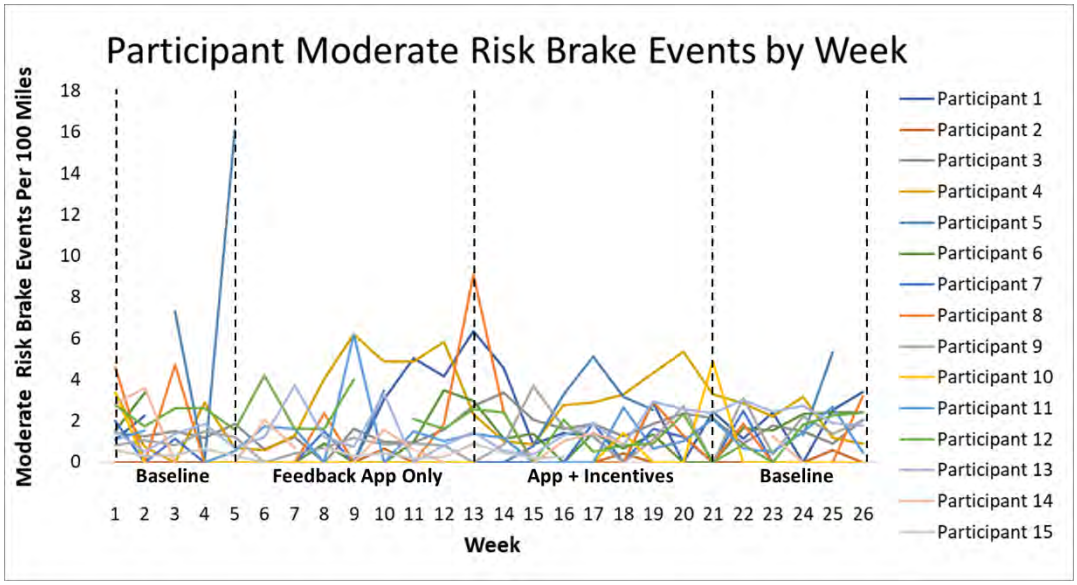

Figure 17. Distribution of participant moderate risk brake events by week.

Figure 18 shows the normalized mean number of speeding events per 100 miles (instances of participant speed exceeding 75 mph) for each of the experimental phases, and Figure 19 shows the distribution of speeding events per 100 miles by participant per week.

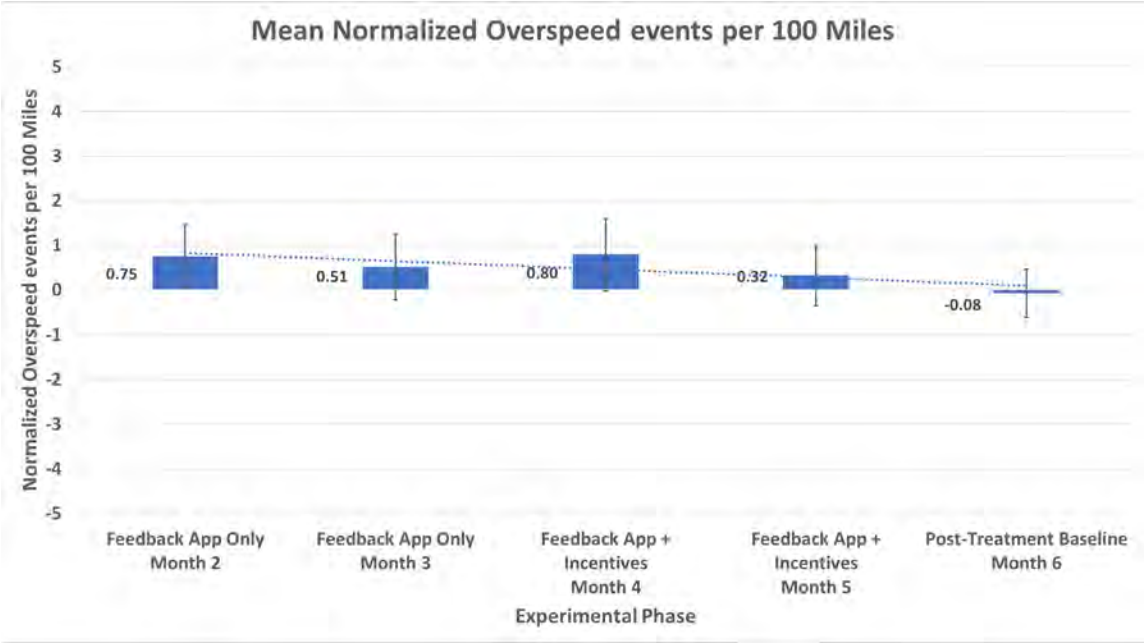

Figure 18. Mean normalized overspeed events per 100 miles.

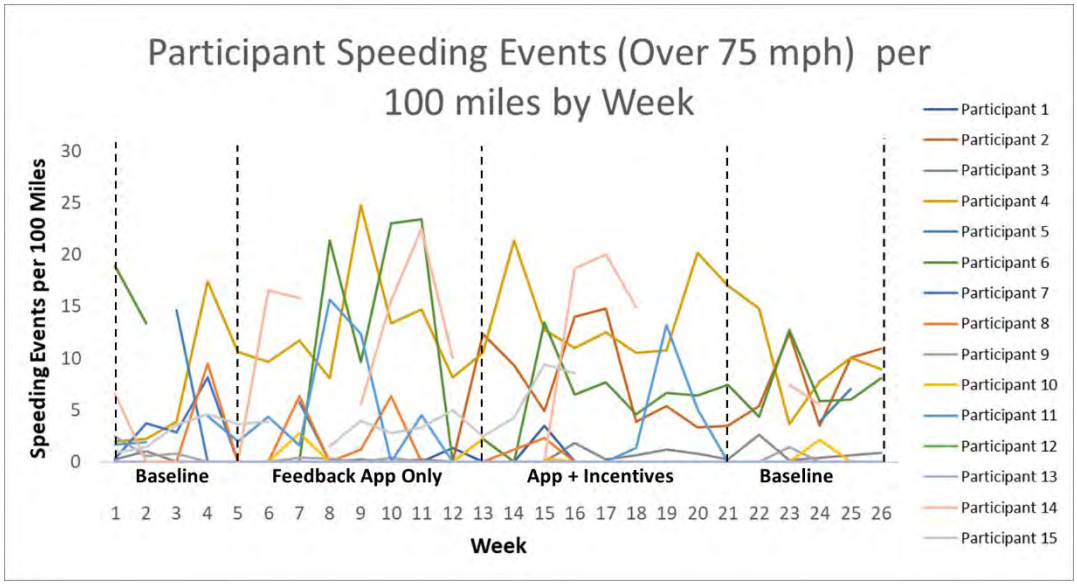

Figure 19. Distribution of participant speeding events by week.

Figure 20 shows the normalized mean number of late night trips (trips taken by participants between 11 p.m. and 4 a.m.) per recorded trip for each experimental phase, and Figure 21 shows the distribution of late night trips per recorded trip by participant per week.

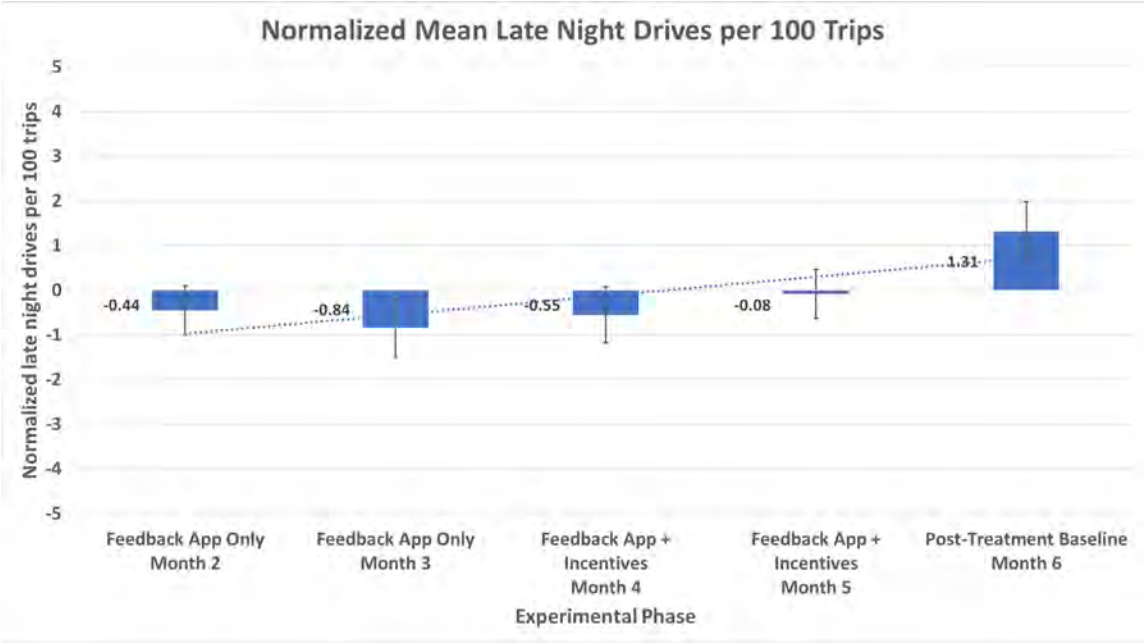

Figure 20. Normalized mean late night trips per 100 trips.

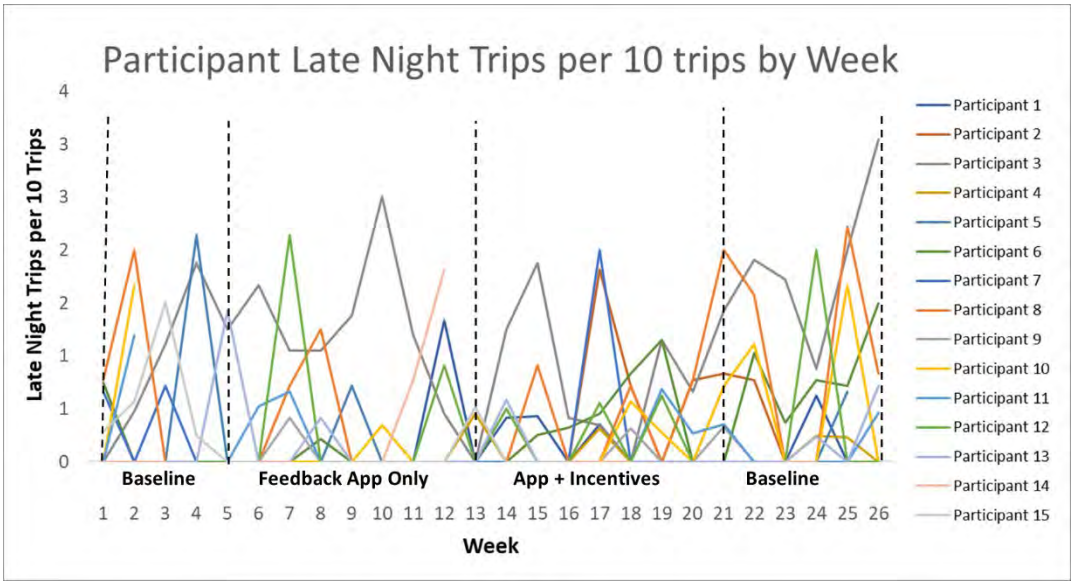

Figure 21. Distribution of participant late night trips per 10 trips by week.

Teen Feedback Study Questionnaire Data

Nine participants responded to exit questionnaires following the completion of data collection, and of those nine participants, five had logged into the app at least once prior to completing the questionnaire. Participants who had not logged in were asked to skip questions related to the feedback app, thus questions related to the feedback app had only five participant responses for each question. Participants were asked to rate their agreement with a series of statements regarding their experience with the feedback app using a Likert-scale response from 1 (strongly disagree) to 5 (strongly agree).

Figure 22 shows the mean participant responses for each of these ratings. The results suggest that participants found the feedback app easy to understand and useful for improving safety.

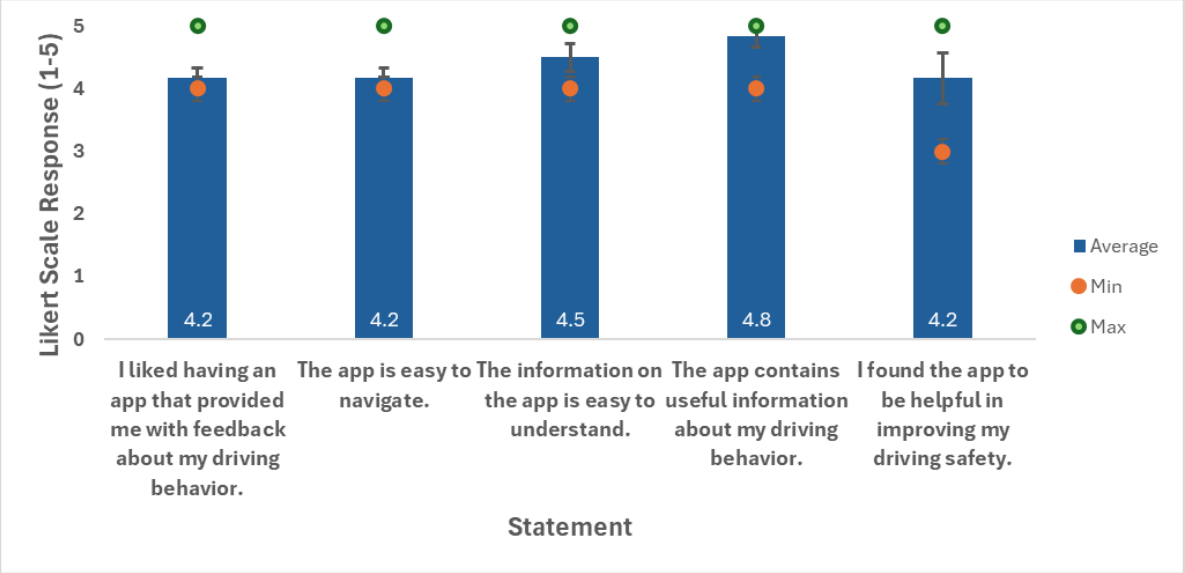

Figure 22. Participant agreement with statements regarding their experience with the feedback app.

Figure 23 shows the results when participants were asked “How effective were each of the following features [in the feedback app] at improving your driving safety” on a scale of 1 (not effective at all) to 5 (very effective). The results suggest that participants found the features on the app to be effective at improving driving safety.

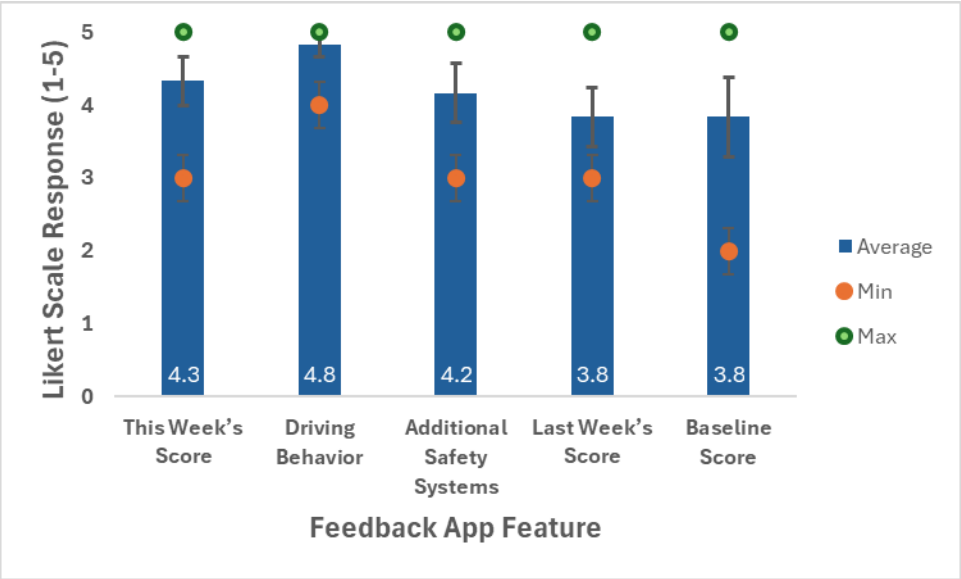

Figure 23. Participant response to effectiveness for feedback app features (N = 6).

All questionnaire respondents were asked to complete questions regarding the monetary incentives phase of the study. Eight of nine respondents answered all six questions, and one participant answered only the final question. These results are shown in Figure 24. Again, the results suggested that the participants liked the monetary incentives and thought they were effective at improving driving safety.

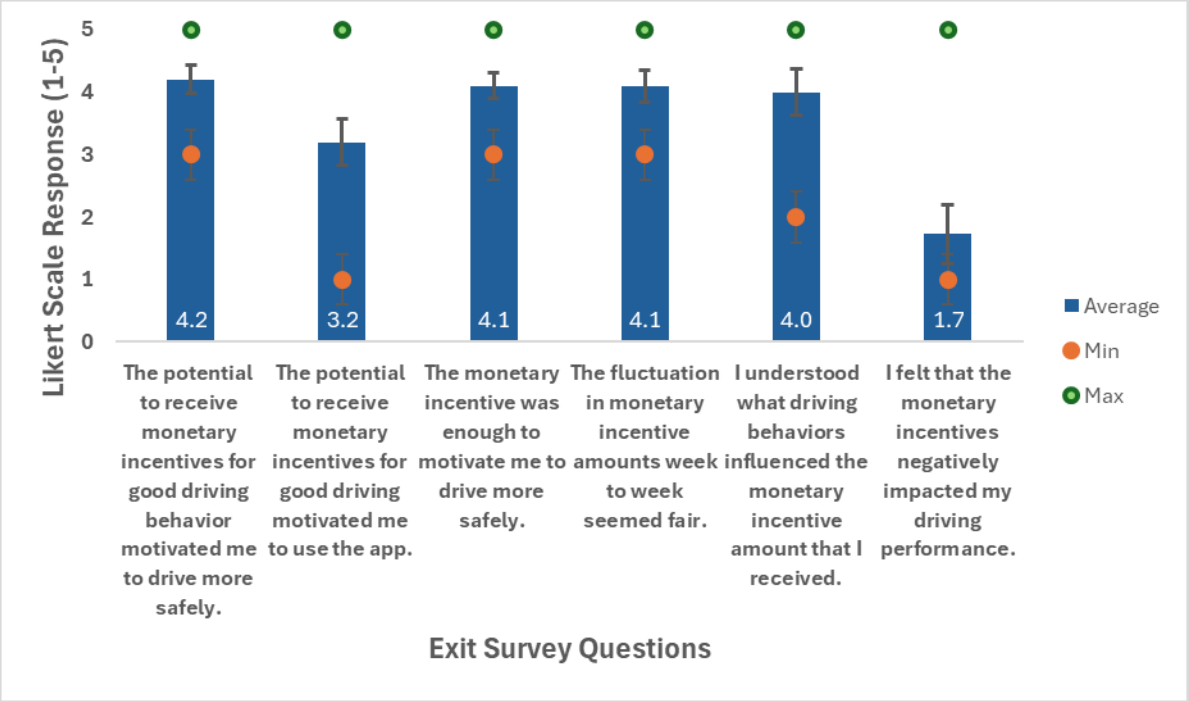

Figure 24. Participant responses to monetary incentives questions in exit questionnaire.

Findings for Task 2: Check-In Interview Results

The analysis centered around how participants answered the questions posed to them during the check-in interviews. These questions were designed to determine what the parents and teens thought about the email notifications, the feedback app, and incentives. Parents were not asked about the notifications, as they did not receive them. To analyze how participants answered questions, a qualitative analysis was conducted. The approach used was a modified version of framework methodology (Ritchie & Spencer, 1994). Using this iterative approach, an analyst reduced the data through summarization and synthesis while maintaining links to the original data, thus allowing a comprehensive and transparent analysis. The five steps of the analysis process are as follows:

- **Determine Focus**: The research team determined that the focus of the qualitative analysis would be on participant responses to the questions posed during the check-in interviews. Separate analyses were conducted for teens and parents.

- **Familiarization**: Transcripts were created for the check-in interviews, and an analyst reviewed each transcript to become familiar with the data set (i.e., nine teens, 11 parents). Participant names were replaced with codes during the reduction process.
- **Identify Thematic Framework**: Based on the sections of the check-in script (see Appendix A), the analyst identified themes that applied to the research focus. The themes were notifications, feedback app, incentives, and recommendations.
- **Data Coding and Charting**: Under each thematic area, participant responses to each question were pulled into Microsoft Excel spreadsheets (or thematic charts). Based on a review of the data set for each question, the analyst identified subthemes. For example, in the analysis of the question posed to the teens "Why did you like receiving notifications," three subthemes emerged (payment confirmation, tracking payment amount, and indication of good driving). While the analysis was carried out by one primary analyst, the outcomes were reviewed by the research team.
- **Interpretation**: The analyst applied the themes and subthemes detailed in the charts to better understand the information provided by participants. In general, when reporting out the data, the analyst only used subthemes that were mentioned by at least two unique participants. In a few cases, if something that was mentioned by only one participant appeared highly relevant to the study, it was included as well. These individual cases are noted in the results. Representative de-identified quotes were added under each thematic discussion.

There were a few limitations to this check-in process. Because data collection for Task 1 was delayed, the timeframe for the completion of Task 2 was limited. Due to the limited timeframe, the parent check-ins were conducted by multiple researchers, whose approaches varied in some instances (e.g., questions were asked slightly differently, some prompts were unintentionally skipped).

Another limitation was the small number of participants for both the teen and parent check-ins. Due to the small size of this data set in particular, the results of this analysis should be viewed as input into the development of future teen driver monitoring systems, not as definitive directives of what should be included in such systems.

The results of the data interpretation are organized by thematic area. De-identified quotes are included to exemplify the subthemes. The major themes covered in this section include notifications (teens only), feedback app, incentives, and recommendations. A final theme (crosscutting) was added after the initial analysis to capture some of the noteworthy comments participants made that crosscut the thematic areas. The teen and parent analyses are presented separately along with key takeaways at the end that cover both teens and parents. As stated, the parent results do not include notifications, as the parents did not receive email notifications related to incentive payments.

Throughout the presentation of results for the open-ended questions, there are references to "a couple," "a few," or "several" participants commenting on a particular subtheme. Generally, "a couple" refers to two participant comments, "a few" refers to three or four participant comments, and "several" is greater than four. Closed-ended responses are reported as counts.

Teen Results

The teen results section provides summary results for the check-in questions posed to the teens (see Appendix A for check-in script). Out of the 15 participants in Task 1, nine teens took part in a check-in interview. Of those nine, two teens had at least one recorded login to the app prior to their check-in. There was one teen who looked at the app with a parent. Another teen said they had logged in; however, there was no recorded login. The research team believes this teen possibly used the parent's login.

Notifications

Notifications were sent to teens to alert them that a payment had been applied to their account (money had been loaded onto their ClinCard). For more on the notifications that teens received, see Approach and Methodology. An analysis was conducted on the teens' opinions regarding the notifications and if they had any suggestions for improving them.

During the check-in, all the teens reported receiving an email that let them know that a payment related to the study that had been loaded onto their ClinCard and was available, and all reported that they liked receiving the notifications. The teens were then asked why they

liked receiving the notifications; several subthemes emerged related to this question (Table 11).

Table 11. Why teen participants liked notifications.

Theme	Subtheme
Notifications	Payment Confirmation
	Tracking Payment Amount
	Indication of Good Driving

The comment mentioned most often in relation to why teens liked receiving a payment notification was that the notification was helpful to confirm that their payment had been loaded onto the ClinCard. Similarly, a few participants commented that it helped them keep track of how much compensation had been loaded onto the card. A couple of participants commented that the payment indicated that their driving was good. It should be noted that one of these participants was not sure if the notification was indicative of good driving.

- *Payment Confirmation*: “I'm just glad that they sent it to me so I can confirm that I actually have stuff loaded onto my card.”
- *Tracking Payment Amount*: “It allowed me to kind of keep track of how much compensation I had throughout it.”
- *Indication of Good Driving*: “I mean, because for one, it makes me know my driving is going good and that I’m doing pretty good.”

When asked for suggestions for improving the notifications, only a few teens had a recommendation (Table 12). A couple of teens said they would have preferred to receive a text message instead of an email. One teen had a suggestion that the payment notification should include details about what the payment was for in relation to their specific driving behavior (e.g., amount of driving, speeding, hard braking, etc.).

Table 12. Teen suggestions for notifications.

Theme	Subtheme
Notifications	Text message instead of email.

- *Text*: "… some people don't check their emails. So, do text."

Feedback App

Login: Only two teens had confirmed logins prior to their check-in interviews, and both verbally confirmed during their check-in interviews that they had logged in. These teens had a slightly different set of questions than the teens who did not have recorded logins (see Appendix A). With only two participants with recorded logins, it was challenging to identify subthemes because subthemes required at least two unique participants. However, because these teens did log into the feedback app, the research team believed it was worthwhile to capture detail about their thoughts and experiences with the app. Both teens logged in using their phones, said they did not experience any problems accessing the feedback app, and thought that the information on the feedback app was accurate.

In terms of what they looked at most on the app, one teen reported looking at the score, and the other at the hard braking. The teen who looked at the hard braking commented that they were unsure if hard braking indicated safe or unsafe driving behavior. The teen who looked at hard braking the most said that, despite not being sure what it indicated, they used the information when stopping by "trying to be prepared extra ahead of time and slow down more ahead of time" so an action would not be logged as a hard brake.

Both teens reported in general looking at the score but had different thoughts when asked how they used the information. One teen said the score was helpful in comparing weeks and reported that the score was very useful, while the other teen said they did not really use the score because it was hard to remember from week to week why the score had changed, so they just tried to practice safe driving behaviors (not speeding or hard braking). It should be noted that the teen who said they did not use the score only logged into the app before the incentive period began, while the teen who used the score logged in periodically over the app and incentive period.

On a few of the questions posed to the teens who had recorded logins, only one teen provided responses. The teen had comments about what was unclear, what was missing, and what was not useful on the app. The teen commented that they were unclear if overspeed was for each speed zone or only for speed over a certain threshold (e.g., teen noted 80 or 85 mph). It

should be noted that the overspeed warning was set to 75 mph, so it appears this teen was unclear on that threshold and may have been referring to the speed limiting feature, which has a threshold of 85 mph. They went on to say that what was missing from the app were definitions for each of the items being marked or scored (e.g., overspeed, hard brakes, late night driving, etc.) so that they could be aware and cautious of those behaviors. This teen also commented that the trip information (number of trips, miles driven, hours driven) was not helpful or needed. In terms of suggestions for improving the app, they said that the app should include definitions of what everything means and how the score is calculated. As discussed in the Feedback App (Phases 2 and 3) section, these definitions were available, but the teen seemed unaware of how to access them. Information on how the score was calculated was not provided.

No Login: Seven of the teens had no recorded login, though one teen claimed to have logged in, likely using the parent's login information, and another reported looking at the app with their parent. The other five acknowledged that they had not logged in or looked at the app with a parent. Due to no recorded login prior to check-in, the seven teens were not asked questions about the features on the app. When asked for a reason why they did not log in, the most reported answer was that they forgot. A couple of participants said they were unaware there was an app.

- *Forgot*: "I think I just forgot about it, that it was available to me."
- *Unaware*: "So, I'm not going to lie. I did not know there was an app."
- *Viewed with Parent*: "Yeah, I didn't log in, but my mom did. So, she would keep me updated."

When those who forgot were asked what would have motivated them to log in, a couple of participants said being notified or reminded about the app would have helped. One participant said they would have logged in if it had been required.

- *Notification*: "Maybe, if you reminded me at some point in the middle of the study that the feedback app was there, and for me to log on, maybe that would have helped.'

Combined Responses (Login and No Login): A few of the app-related questions cut across teens who had documented logins and those who did not. Table 13 details the results of closed-ended questions related to the app that were asked across all the teen participants.

Table 13. Combined questions (teens).

Question	Did you ever discuss the feedback app with your parent?	Did your parent use the information on the feedback app to monitor your driving?	Are there other ways your parent monitors your driving?
Teens Responding 'Yes'	5	2	6

When asked how they felt about their parents having access to the information about their driving on the feedback app, all but one teen said it was fine ("good," "okay," "don't mind," etc.) that their parent had access to the information. The teens reported some of the following reasons that it was fine: their parent taught them how to drive, their parent often rides with them, their parent already uses a different monitoring app, they characterize themself as a good driver, and they like that their parent can use the information to help them improve their driving. One teen said it was fine, but the parent's access did make them a bit nervous because their parent checks the app and then asks the teen about their hard braking events (this issue is discussed further in the Crosscutting section).

Five teens reported discussing the app with their parents. When teens were asked what they discussed with their parent, the two most common responses were the score and the braking.

- *Score and Hard Brake*: "Yeah, we discussed it a little bit. Like occasionally my mom would show me, 'hey, like this is what your score was, make sure you're, I don't know, braking sooner, or make sure you're trying not to go over 75.'"

While only two teens reported that a parent used the information on the app to monitor their driving, six of the nine teens reported that a parent uses other ways to monitor their driving. The top two apps mentioned were the Guardian App (OnStar) and Life360. When asked how parents were monitoring them, several teens said that parents were monitoring their location, and a few said that their parents were monitoring their speed (Table 14).

Table 14. What parents are monitoring, according to teens.

Theme	Subtheme
App	Monitoring Location
	Monitoring Speed

- *Location*: "Yeah, [my parent monitors] through that Guardian app ... It shows them my location, and if I need to call in for, if I'm in a crash, or in an accident, resources for that. It's not as much like speed or danger of driving. More so just like, where I am."
- *Speed*: "We have the Life360 app … So, it's like a location tracker. But instead, when I get in the car, it tells you how fast I'm going, if there were any phone usage or it shows where the car went."

Incentives

All nine teens were asked about the monetary incentives, and eight of the nine said it was motivating them to drive more safely. When asked why the incentives were motivating, most of the teens said that it was due to the ability to get more money if they drove safely (Table 15). One teen said they were not motivated by the incentives, as they already drove safely.

Table 15. Why teens think incentives are motivating.

Theme	Subtheme
Incentives	More Money for Driving Safely

- *More Money for Driving Safely*: "It helps to make me want to drive safer knowing that I'm getting a payment, especially now that I'm not in a job, with school."

A few teens had suggestions for improving the incentives; all the suggestions were unique, so no subthemes emerged. The individual suggestions included: an in-vehicle end-of-trip notification of how they drove, a weekly email about how they drove that week, and specific information attached to each payment about how behavior correlated to that payment.

A couple of teens said there was something other than money that would motivate them to drive more safely. Both teens indicated that being observed is motivating. One teen said they

did not want to stand out as driving badly, and the other said they felt that they drove more safely when being watched.

Recommendations

All the teens said that they would recommend this app with incentives to their friends. The top two reasons mentioned by a few of the teens were that the incentives helped to keep teen drivers safe and that their friends could make money for safer driving (Table 16).

Table 16. Why teens would recommend the app with incentives.

Theme	Subtheme
Recommendation	Helps keep teen drivers safe
	Make money for safer driving

- *Helps Keep Teen Drivers Safe*: "I actually think it's a good thing for people to do. Especially if you have those kind of friends that are kind of off the charts who gets in the car and doesn't put on the seat belt, and they do speed, and they do drive at like two, three in the morning. Maybe it could help [them] see a different point of view."
- *Make Money for Safer Driving*: "… if they don't have time to work, this is a good way for them to practice safe driving and get paid for it while going places that they're already going anyway. So, they might as well get paid for it and be safe."

When asked if they would still recommend the app if there were no monetary incentives, all but one teen said they would still recommend it (Table 17). A few teens said a reason for recommending it without incentives is because it is a way to check how they are doing and/or the progression of driving improvement. Relatedly, a couple of teens said more generically that they would recommend the app for safety reasons. A few participants also commented on how the app might be better suited to parents as a tool for monitoring and/or discussion with their teens. One of the two teens with a recorded login had some hesitation about the recommendation, saying they were not sure they would have used it without the incentive payment.

Table 17. Why teens would recommend the app without incentives.

Theme	Subtheme
Recommendation	Check how they are doing
	Safety
	For Parents

- *Check How They Are Doing*: "I think I would, because it allows you to see how well you're driving, and then, if you need to stop speeding as much, then it would allow you to see it."
- *Safety*: 'There are a lot of apps that obviously help with driving and keeping you safe like turning off your notifications and other things, but I think it's pretty helpful to just have that to kinda help keep you safe."
- *For Parents*: "I think for parents it's a good thing, because then they can talk to their kids. And it's still a good thing for teens. But I don't know if people would really want it, or like care enough to use it without the incentive."

Crosscutting

Throughout the analysis of teen participant responses, the analyst identified a few subthemes that cut across more than one theme and were not tied to any specific question. It should be noted that an analysis was not specifically conducted to identify crosscutting subthemes, so there are likely others in the data set. Table 18 presents three noteworthy subthemes that stood out to the analyst. The crosscutting subthemes included: being a more conscious driver, in-vehicle alerts/notifications, and hard-braking.

Table 18. Crosscutting subthemes.

Theme	Subtheme
Crosscutting	More Conscious Driver
	In-Vehicle Alerts/Notifications
	Hard-Braking

More Conscious Driver: A few teens across different points in the check-in discussions (incentives, recommendations) discussed how they were more conscious of their driving due to being in the study, access to the app, and/or because of the incentive payments. One teen noted a realization after the fact that something (hard brake) might show up on the app and served as a reminder to try to avoid that behavior in the future.

- "I'm a lot more conscious of how I drive because of the incentives. And I think it has changed the way I think about being on the road more … Maybe as I'm driving, if I'm going above the speed limit a bit, I'm more inclined to put the speed down than I would be otherwise…Since I'm not looking at the app, I really just focus on every day. I think my overall average speed has gone down when I'm just going to school or going to my friend's houses. I press on the brakes a bit more, I turn a little slower just because it's in the back of my head, it's always there that the study is happening."

In-Vehicle Alerts/Notifications: A couple of the teens mentioned their experience with the in-vehicle notifications/alerts during the study related to the overspeed warning. One teen noted that the alerts would activate when they were driving on a road with a posted speed limit of 75 mph (the overspeed warning was set at 75 mph). The other teen said they liked how the in-vehicle overspeed warning helped them keep track of their driving.

- "The little beeping noise that I get … it tells you when you're driving too fast. I think that's nice to have. And then, of course, you get money when you drive more safe, so I was like, 'Okay, that's nice'. So, it (in-vehicle overspeed warning) kinda helps me keep up and keep track of how I'm driving."

One teen mentioned sometimes receiving alerts (red light that flashes on windshield) when passing parked cars along the side of the road. This was likely related to the active safety features on their vehicle. As noted in the Approach and Methodology section, the active safety features were not part of the scoring, as not all the vehicles in the study had the same features. One teen mentioned wanting in-vehicle notifications that provided details on their driving behavior (e.g., list of good or bad things) for each trip.

Discussions of the in-vehicle alerts/notifications crosscut the feedback app, incentives, and recommendations themes. Since only about half of the teens experienced the app (two logged

in, one used the parent's login, and one viewed with parent), the in-vehicle alerts may have served as an indicator to the teens of how their payment may be affected by their driving behavior.

Hard Braking: A couple of the teens brought up hard braking and how it was reported on the app. One of these teens had recorded logins, and the other likely used their parent's login. These teens compared their experience braking in the vehicle with what they saw on the app. One of the teens said they did not know if a hard brake indicated good or bad driving behavior but that they were trying to adjust braking behavior to avoid logging hard braking events. The other teen admitted that they brake hard, especially when they are tired, and that they get nervous when their parent checks the app because of the braking events. These discussions of braking crosscut the app and recommendations themes.

- "I know that I'm a very hard braker. I've tried to work on that, so I like to see how many times that I brake really hard, and I didn't even notice it maybe."

Parent Check-In Qualitative Analysis

Out of the 15 parents participating in the study, 11 took part in a check-in interview. Of those 11, three parents had at least one recorded login to the app prior to check-in. This section provides summary results for the check-in questions posed to the parents (see Appendix A for script). The results are presented by theme (feedback app, incentives, recommendations, and crosscutting). Within each thematic area are the subthemes that emerged under the questions posed to parents; these were ideas that were mentioned by at least two parents. Sometimes an idea is included that was mentioned by only one parent. In these cases, a note is provided to indicate it is a unique comment. As mentioned earlier, most of these subthemes are quite small (two parents) due to the limited number of participants who took part in a check-in interview.

Feedback App

Login: Three parents had confirmed logins prior to their check-in interviews. Like the teen check-ins, these parents had a slightly different set of questions than the parents who did not have recorded logins (see Appendix A). The parents used different types of devices to log into the feedback app (smartphone, iPad, computer), and only one parent experienced issues

with accessing the app and reported that it did not work once or twice. All the parents indicated that they used the information on the feedback app to monitor their teen's driving. The most common response (mentioned by a couple of parents) was using the information as a point of discussion with their teen about driving habits or behaviors.

No parents reported anything on the app being unclear, although one parent reported accuracy issues related to the trip and score information. This parent said they used the Chevy Smart Driver app (actual title is *MyChevrolet Mobile App)* and compared the number of trips reported on each app (i.e., Chevy Smart Driver and Teen Feedback), and sometimes the number of trips and score did not match. This parent said the app could be improved if "there was a way to sync up the trips" between the two apps. Another parent who said they used the GMC Smart Driver App did not report any accuracy issues with the Teen Feedback App. It should be noted that Chevy and GMC are both GM brands (https://www.gm.com/gm-brands). The first parent's experience may have been due to issues the research team had with receiving data for some of the teen drivers.

In terms of what parents looked at the most on the feedback site, features that were mentioned by at least two parents included the score, speed, and hard braking. A couple of parents commented on how they had looked at all the features on the app screen or dashboard, while another said they looked at the score (baseline and weekly). Various comments were made about how parents were using the features. One parent said that they used the features on the app as a point of discussion, while another said that they tried not to question their teen's driving too much because they think the teen is a good driver and they are more concerned about other issues, such as who is riding in the teen's car.

Only one parent provided information on what was very useful (weekly score) and what was not useful at all (trip information, as it was not accurate). In terms of what is missing from the feedback app that would have been helpful, only a couple of parents made suggestions. One parent said they wanted accurate and updated trip information. The other parent suggested adding a "reminder to go look at the app."

No Login: Eight of 11 parents had no recorded login; a few parents reported looking at the app with their teens, though in a couple of these cases the teens had not logged in. Due to no

recorded login prior to the check-in interview, these eight parents were not asked questions about the features on the app. When asked why they did not log in, the most reported answer was that they forgot. A couple of the parents who said they forgot also added that they were too busy. A couple of parents said they had other ways of monitoring their teen and so had not logged in. One of these parents cited using another app, and the other said they were logging into teen feedback in the vehicle (which the team assumed to mean Teen Driver Settings) to check on their teen's driving (e.g., speeding, hard braking).

- *Forgot*: "I just completely forgot about it."
- *Busy*: "Just too busy."
- *Other Ways of Monitoring*: "I logged into my car. I was able to look at some of the data from my car, under the teen feedback. Whether there was any excess of speeds or hard braking."

In general, subthemes are only reported for comments that arose from at least two unique parents. However, one comment made by only one parent is included here, as it seemed to be related to parent trust in the vehicle safety features. This parent said that one of several reasons they did not log in was because "the car has all those built-in safety features."

When asked what would have motivated them to log in, a few participants said being notified or reminded about the app would have helped. A couple of participants provided other input on what would have motivated them to log in. One participant said they would have logged in if it had been required, and another said they would have logged in if the teen had been in an accident.

- *Reminder*: "Probably just a reminder that it was available to me."

Combined Responses (Login and No Login): Some of the of the app-related questions cut across parents who had documented logins and those who did not. Table 19 details the results of the closed-ended questions related to the app that were asked across all parents. About half of the parents reported discussing the feedback app with their teens, and all the parents said they have other ways of monitoring their teen's driving.

Table 19. Combined app questions (parents).

Question	Did you ever discuss the feedback app with your teen?	Are there other ways you monitor your teen's driving?
Parents Responding 'Yes'	6	11

When asked how they felt about having access to the features on the feedback app about their teen's driving, all but two of the parents had a positive response (e.g., "good," "nice," "like"). A few of these parents said that it sparked conversation. It should be noted that some of these parents had not logged into the app, and one pointed out that they were looking at the information in the vehicle (assumed to be Teen Driver Settings), not the app. The other two parents did not answer the question, noting they had not looked at the app.

- *Positive*: "Really good. The process in itself was very reinforcing with my child. Like I said, kind of setting up those security things, having the conversations about what we're doing, how he was going to get feedback, and all of that was a very positive experience."
- *Sparked Conversation*: "I felt good about having it. It does help me to better understand that she is being safe on the road. And then sparking those conversations. If she is doing some hard braking or she is driving faster than she needs to be driving. It does help me to know what's going on and conversate with her about safety."

Several parents reported discussing the app or some aspect of the teen's driving related to the study (e.g., teen's use of the app, parent checking in-vehicle record). When the parents were asked what they discussed with their teens, the two most common responses were safe driving and speeding (see Table 20). A couple of parents also discussed hard braking.

Table 20. What parents are discussing.

Theme	Subtheme
App	Speed
	Safe Driving
	Hard Braking

All the parents reported other ways they are monitoring their teen's driving. The top two responses were using another app (Life360 being the most often mentioned) or riding along with their teen (Table 21). Parents did not consistently report what information they monitor, though location and speed were some of the types of information mentioned.

Table 21. Ways parents say they are monitoring their teen driver.

Theme	Subtheme
App	Other App
	Riding Along

- *Other App*: "I have an app on my phone, Life360. I use that quite a bit when I'm not around and he drives by himself. I check on that regularly just to see how fast he's going and how he's driving."
- *Riding Along*: "Well, the only other ways when I'm in the car with her, and she's driving me around. One thing I didn't realize was that how loudly she plays her music. So I think, having that volume control was actually a good thing to have as well."

When asked what, if any, additional tools parents would like to have to monitor their teen's driving, one small subtheme emerged. A couple of parents requested a summary of their teen's driving pushed to email or text.

- *Driving Summary*: "Yeah, I guess, since the car had the built-in features that we had activated, a summary of things after he was done driving that would be just pushed right to my email, would have been great."

Incentives

All the parents were asked about the monetary incentives; seven of the 11 said those incentives were motivating their teen to drive more safely, two said they were not, and two said they did not know or could not answer. When asked why the incentives were motivating, most of the parents said it was due to the ability for the teens to get more money if they drove safely (Table 22). One parent said their teen was motivated not only by the ability to get

more money for driving safely, but also because someone was watching. A couple of parents pointed out that their teens were already safe drivers.

Table 22. Why parents say incentives are motivating.

Theme	Subtheme
Incentives	More Money for Driving Safely

- *More Money for Driving Safely*: "Him being aware that the more closely he adheres to the rules of the road it affects the amount of money that he'd get. So, I think he pays a lot closer attention to the speed limit knowing that it can affect the amount of money that he raises."

Two parents said the incentives were not motivating because their teens did not remember that they were receiving incentives. One of these parents went on to say their teen was working multiple jobs and so was not motivated by the money and tended to forget about the incentive payments. Another parent said they did not know if the incentives were motivating but thought that the in-vehicle features were more impactful because the teen got notifications when they went over a certain speed or the radio would not turn on until their seat belt was buckled, and those things were more salient and raised awareness more than money.

When asked for suggestions on how the incentives can be improved so that they motivate their teen to drive more safely, several parents had recommendations. Each suggestion in Table 23 was only mentioned by a couple of parents, so these were small subthemes.

Table 23. Parent suggestions for improving incentives.

Theme	Subtheme
Incentives	Notifications
	Incentive Calculation
	Incentive Choice

A couple of parents suggested some form of notification, though the type of notification varied, as did the timeframe (post-trip text to teen, weekly email to parent). One parent

suggested a post-trip text to the teen on what they had scored and what they had earned. This parent discussed how they currently get post-trip information from the Life360 app, so if Life360 were used as part of the Teen Feedback App, it should be possible to provide that level of detail. The other parent suggested a weekly email about how the teen drove (hard braking, speeding, etc.) along with a comparison to the prior week (e.g., 20% improvement on braking or speeding).

- *Notifications*: "… going back to Life360, at the end of a drive I get an alert, 'this was your teen's driving'. If there was an instant 'Hey that drive was a score, you got this type of a score and you just earned ten bucks.' I don't know if OnStar can give you data that fast, but obviously it works for Life360, so if Life360 was incorporated into your program where you just join a circle and came on as a parent or something and you can say this data equals this little dollar amount, and then the teen just gets a text that says 'you just earned this much money because of that drive.'"

Another idea suggested by a couple of parents was providing the teens with information on how their driving behavior correlated to their payment or deduction of payment. One parent said they were unsure if this would be beneficial or not.

- *Incentive Calculation*: "I just wonder if they knew how the incentive was calculated based upon your driving. If there was a: 'Speeding by this much, you'll be deemed this much.' I don't know if that would be beneficial, or [if] it actually could have the opposite effect. So just a thought."

A couple of parents suggested that some choice be built into the type of incentive received (e.g., gift card of choice) to help motivate their teen. One parent thought that monetary payments should continue, but at the end a special "surprise" incentive (e.g., gift card of choice) could be rewarded based on how well the teen had driven over that period.

- *Incentive Choice*: "I would say tailor it more so to the teens want it to be. I feel like my daughter, she's into gaming so maybe [if] she would have got a $100 gaming card to, what she likes to do, it would have been more incentive for her."

One parent commented on how the incentives were a helpful way of teaching their teen to make the connection with how adults save money via good driving, not with monetary payments, but with reductions in insurance.

When asked about incentives other than money that would motivate their teens to drive more safely, the parents had more suggestions for incentives other than money (Table 24) than the teens did. Parents suggested that gift cards, insurance discounts, or negative consequences are all things that may motivate their teens to drive safely. Even though parents had these suggestions, some acknowledged that money is a good motivator. All these subthemes were small, only being mentioned by two or three parents.

Table 24. Parent suggestions for incentives other than money.

Theme	Subtheme
Incentives	Gift Card
	Insurance Discount
	Negative Consequence

A few parents suggested gift cards, though at least one parent pointed out that gift cards are still a monetary incentive. One parent suggested a point system where the teens could earn prizes towards a gift card. A couple of parents mentioned insurance discounts for good driving behavior, which is still a type of monetary incentive. The last small subtheme mentioned by a couple of parents was negative consequences as a motivator of safe driving, such as losing driving privileges. One parent suggested informational videos—not a speech or talk by parents or researchers, but a video that shows the consequences (e.g., crashes) of behaviors such as inattentive driving.

- *Gift Cards*: "… I guess it all comes out to getting something out of it, like a point system where you could trade those points to get a prize, or a gift card, or something to that effect."
- *Insurance Discount*: "Some type of positive reward for the insurance, because, as you all know, it's really expensive to add teens on to your car and auto insurance. So, if

they're doing what they're supposed to be doing instead of the monetary, I would suggest … maybe reduction on the insurance."

- *Negative Consequence*: "I mean the end all is if he has a problem driving, the car goes away…The lack of use of the car is probably the biggest de-incentive, right? It's a privilege to be able to drive the car to school and not take the bus."

When parents were asked if they had any further comments about the incentives, some comments came up from two individual parents that seemed noteworthy. The first is the idea that the teen speaking to someone other than the parent about their driving behavior was a powerful thing. This idea is similar to the earlier comment by one parent that an informational video, not a speech or talk with a parent, may be helpful for teen driving safety. These parents appeared to be suggesting that outside input, in the form of educational videos and/or talking with someone knowledgeable about driving safety, may be beneficial. The second comment was a suggestion that the app be available for parents to input money and use with their teens to incentivize good driving behavior.

Recommendations

All the parents said that they would recommend this app with incentives to their friends with teen drivers. Not all the parents provided a reason why they would recommend it, but of those who did, the most noted reason was that money motivates teens (Table 25). Another couple of parents said they would recommend the app with incentives, as they thought it encouraged their teen to be a more mindful or conscientious driver. A couple of parents said they would recommend it as a monitoring tool, though their comments varied. One parent said the app with incentives would be good for teens who start to drive early. The other parent said they liked the monitoring systems in the car.

Table 25. Why parents would recommend the app with incentives.

Theme	Subtheme
Recommendations	Money Motivates Teens
	Making Teens More Conscientious Drivers
	Monitoring Tool

- *Money Motivates Teens*: "Every teenager is looking for more money, so there you go."
- *Making Teens More Conscientious Drivers*: "I would recommend it just because I think it was a good tool for her to be mindful of the smaller things like the hard braking and things like that. And it's nice to have that app feedback of events to discuss about 'What were you doing?' and 'Why did you need to do that? What could you have done to prevent that?'"
- *Monitoring Tool*: "I think this is a great program because it monitors kids, especially younger kids who start driving early…I'm a little more comfortable with [my teen's] driving now, but in the beginning when she first started driving, I would've been on the app every day checking her driving."

Most of the parents who were asked said they would recommend the app to friends even if there were no incentives attached (note that this question was not asked to some parents). Of those who responded and provided a reason, two small subthemes emerged (Table 26). A couple of parents said that, even without the incentives, the app provided a good talking point with their teen about how they are driving. Another couple of parents said they would recommend it, but they discussed how they liked the in-vehicle information and/or safety features on the car. One of these parents highlighted that there are other good apps out there, like Life360, but that the program stood apart from other apps for its use of the vehicle safety features and incentives. It should be noted that active safety features were not part of the scoring for this study because not all the vehicles had the same features, though information was provided on the feedback app if it was available. The study did include aspects of the Teen Driver Report Card in the scoring (e.g., overspeed warning), as discussed in the Limitations section.

Table 26. Why parents would recommend the app without incentives.

Theme	Subtheme
Recommendations	Talking Point
	In-Vehicle Aspects

- *Talking Point*: “Absolutely [I’d recommend it] because it opens up that door to converse with how they're doing. I mean safety is the utmost importance. And I'm sure if the parents are like me, they will want their child being safe with or without monetary incentives, so to know what their child is doing is actually rewarding enough for the parent.”
- *In-Vehicle Aspects*: “But the cool part was how we were using it was because it was paired with the safety features in the car. I just feel like there's a lot of monitoring apps out there and everybody really likes the Life360 and the different features on there… I think the incentive side would be powerful, because that would be a big difference from any other app that's out there.”

When asked if there was anything else about the study they would like to share, a few parents provided comments, most of which varied. A couple of parents described how in-vehicle speed-related notifications and/or information impacted their teen drivers. One parent commented that their teen was driving on roads with 70- to 75-mph posted speed limits and that because the overspeed alert was set at 75 mph, notifications were popping up on the teen’s screen that were distracting. The other parent commented that the posted speed limit on certain roads was different than what the vehicle was displaying. The parent commented that, because the teen was being monitored, they avoided driving in areas where the posted speed varied from the in-vehicle speed. It should be noted that this inaccuracy was likely due to the vehicle’s built-in maps rather than anything related to the study.

There were a couple of noteworthy comments that were made by only one parent. The first was a parent who did not understand how their teen’s score impacted their incentive payments. The parent thought that their teen was supposed to earn a certain amount of money each month but shared that they thought the information related to seat belt usage was inaccurate.

Another parent commented that the study was a good experience because it taught them about the features that were already on their vehicle and how apps can help with safety. This parent commented that young drivers take the driver’s training course and then “off you go.”

The parent said this experience provided an approach of "trust and verify rather than just trusting."

Crosscutting

A few subthemes arose during the parent check-in interviews that crosscut themes including accuracy, drive summaries/notifications, and other monitoring approaches. As mentioned earlier under the teen analysis of crosscutting issues, there are likely other crosscutting subthemes in this data set, but the three listed in Table 27 seemed worthy of note. Many of the points discussed here are discussed in other sections of the parent results, thus relevant quotes are not reported again in this section.

Table 27. Crosscutting subthemes.

Theme	Subtheme
Crosscutting	Accuracy Issues
	Drive Summary/Notifications
	Other Monitoring Approaches

Accuracy Issues: A few parents raised issues related to the accuracy of the in-vehicle information or the information on the app. These issues were raised across the feedback app and recommendations discussions. Most parents who raised accuracy issues mentioned specific problems that they experienced. One parent mentioned that the trip information was inaccurate on the app, while another mentioned that the seat belt information was inaccurate in the vehicle (the radio would not turn on even if their teen had the seat belt buckled). A few parents noted that the speed information provided by the vehicle was different than posted speed limits. As mentioned earlier, this inaccuracy was likely due to the vehicle's built-in maps rather than related to the study.

Drive Summary/Notification: A few parents, across different points in the check-in discussions (feedback app, incentives, and recommendations), discussed wanting a notification with a drive summary. Parents mentioned wanting a drive summary at different points in time, including immediately after a trip, on a weekly basis, or periodically (e.g., mid and end point of the study). Most of these parents wanted the drive summary to come in an

email, though one parent mentioned text. One parent discussed having the drive summary include a comparison to earlier driving performance.

Other Monitoring Approaches: A subtheme that crosscut several themes was how some parents mentioned other monitoring approaches such as in-vehicle safety notifications, in-vehicle information, and/or other apps. These topics are discussed throughout the parent results, but the research team determined it was important to highlight these other monitoring approaches as a crosscutting subtheme. Several parents mentioned using other apps, including Life360, Geico, USAA Safe Pilot, and GMC or Chevy Smart Driver. At least one parent discussed logging directly into the vehicle for information on their teen's driving behavior. A few parents mentioned the in-vehicle safety features as a monitoring tool; some parents referenced these as helpful ways their teen was being monitored and alerted (speeding, not wearing seat belt), while others noted issues that they experienced with the in-vehicle alerts (e.g., overspeed alerts on roads with a 75-mph speed limit could be distracting).

Key Takeaways from Check-In Interviews

The research team developed a set of key takeaways based on the teen and parent results; these takeaways are presented by thematic area. As mentioned in the approach, due to study limitations, particularly the small data set, the results and key takeaways should be viewed as input into the development of future teen driver monitoring systems, not as definitive directives of what should be included in such systems. These findings also may serve as input to the development of future studies assessing teen driver monitoring systems. For instance, researchers may want to screen out teens who are already being monitored by parents or guardians via a driving app. Again, these suggestions were not made by all the parent or teen participants; rather, they are ideas that emerged from the analysis that may be beneficial to consider for future studies and/or teen driver monitoring systems.

Notifications

- Teens may prefer payment notifications via text, and some would like notifications to include details about what payments are for in relation to their specific driving behaviors (speeding, hard braking, etc.).

- Parents may benefit from a drive/trip summary pushed to them via email (with an option to choose how often they receive it) in addition to access to an app.
- Parents and teens may both benefit from reminders to check an app (with an option to choose how they receive it, via email or text).

Feedback App

- Several parents were already using monitoring tools (driving apps in particular), and that usage may have impacted their motivation to check the Teen Feedback App.
- Teens may benefit from a driving summary of what they are doing well and where they can improve their driving behaviors and thus receive a higher incentive payment.
- It may be beneficial to provide more information on what is being scored and why, along with informational descriptions and/or videos on how to drive more safely (e.g., hard braking is sometimes necessary to avoid a collision, but often hard braking is an indicator of unsafe driving behaviors such as following too closely or distraction).

Incentives

- Most teens want a monetary incentive and find that motivating (most parents agreed).
- Parents may appreciate safety information (e.g., an informational video on safe driving behaviors) be provided to their teen in addition to monetary incentives.

Study in General

- Some teens may have been more conscious/mindful of their driving behavior due to being in the study.
- Data accuracy is important. Parents had mixed feelings about in-vehicle safety alerts. They found them to be useful if they are accurate and appropriate (e.g., not recording activity as overspeed when the driver is driving speed limit).
- The combination of advanced safety features, in-vehicle notifications, and incentives may set programs like this apart from other apps.
- Even if parents and teens were not using the app, being in this study appeared to create a talking point or spark conversation about safe driving.

Overall Conclusions

RQ 1: Does providing post hoc feedback to teens reduce the rate of unsafe driving behaviors?

For this analysis, risky braking events, overspeed events, frequency of seat belt violations, and frequency of late night trips were compared for Phase 2 of the study (feedback provided, no incentives) and Phase 1 (pre-treatment baseline).

For the participants in the sample, the introduction of feedback did not appear to decrease risky braking behavior, late night driving, or speeding. Seat belt violations did appear to decrease slightly for most participants. These results were not conclusive, however, and additional research would need to be performed to confirm any safety benefit for the use of app-based feedback as it relates to seat belt usage rates.

One explanation for the lack of improvement for most of the safety measures used in this study is that more than half of the participants did not log into the feedback app. Additionally, according to results from the Task 2 check-in interviews, many of the participants were already using other feedback apps that provided more detail than the one used for this study, such as Life360 and GM's Smart Driver. This use of other apps may have deterred participants from using the app for this study. Furthermore, because these apps provide more detail than the app that was tested, teen driving performance may have already improved, and the Teen Feedback App used in this study was not able to produce additional improvement in driving performance. Future research should either provide additional ways for participants to engage beyond the capabilities of other applications (through further gamification, or other interactive features) or should screen out participants who are already using other driver monitoring software.

Although the lack of feedback app usage by a majority of participants does impact the ability to provide an accurate within-subjects analysis for all participants between the baseline and feedback phases, Figure 11 shows the difference in driving score over time between participants who logged into the app at least once and those who did not, and there does not appear to be much difference between these two groups. This result supports the previous hypothesis that any performance improvements that could be provided by teen driving

feedback apps have already occurred given that many of these parents were already using a monitoring app of some kind.

One of the crosscutting themes reported in the qualitative analysis of the Task 2 check-in interviews was that parents indicated that the feedback app "sparked conversation" about safe driving with their teen. Parental engagement in the learning-to-drive process is one of the key factors noted that improves overall safety outcomes for teen drivers (Simons-Morton, 2007). Thus, simply knowing that this app improved discussion about driving safety among parents and teens should be considered a "win" for overall improvement in driving safety among a high-risk driver population.

RQ 2: Does providing performance-based monetary incentives reduce the rate of unsafe driving behaviors?

Similar to Research Question 1, there does not appear to be improvement for risky braking, speeding, or late-night driving, but seat belt violations did continue to trend downward for the participant data that were collected. These results were not conclusive, and additional research would need to be performed to confirm any safety benefit for monetary incentives as it relates to seat belt usage rates.

The questionnaire data collected at the end of the study indicated that participants felt that the monetary incentives did help their driving safety. Additionally, results from the Task 2 check-in also indicated that the majority of teens and parents both felt that the feedback app improved driving safety. While we did not observe changes in their driving performance using overspeed, hard braking, and seat belt use, participants may have improved their performance in other ways that we were unable to observe, such as speeding by speed limit or attention to the forward roadway. It was also discovered during the Task 2 check-ins that the teen participants were unsure what types of behaviors we were monitoring, so it is possible that they changed some driving behaviors that were not measured by the OnStar system.

RQ 3: If performance-based monetary incentives do result in a reduction of unsafe driving behaviors, is that reduction sustained after the teen stops receiving incentives?

Due to the limited data set obtained for this study, there is no clear benefit of performance-based monetary incentives based on the data collected. A larger sample size may have provided a significant result, particularly if additional variables such as speed over speed limit were able to be obtained. Additionally, other measures of driving performance may also demonstrate changes in driving behaviors that may or may not continue after the incentives ceased.

Qualitative data collected from the Task 2 check-in indicated that teen drivers would still use the teen feedback app even if monetary incentives were not provided. Other options they reported as potentially effective included gamification (e.g., leaderboards, achievement medals) or competition with family and/or friends. Many parents in this sample were already using other monitoring devices without monetary incentives, so there is precedent here; however, to engage the teen with or without a parent, monetary incentives may still be an important component.

Limitations

The most impactful limitation for this study was data variable availability and data transfer reliability. Data collection was performed using the telematics service OnStar. Due to the novel nature of this research, there were more technical hurdles than expected by our research team or our collaborators at GM. First, we encountered several not fully resolved issues with some vehicles that prevented data transfer resulting in 10 of the initial 25 participants enrolled in the study to be removed either prior to starting data collection, or within the first few weeks. During data collection, several of the participant vehicles stopped transmitting for various periods of time (sometimes for multiple weeks). This was due both to families going on vacation and not driving and to connectivity issues. VTTI attempted to troubleshoot, with GM support, but this was an ongoing issue throughout data collection. There is no reason to believe that the data that were collected are inaccurate; however, there was a significant amount of data loss that reduced the overall size of our data set and resulted in only descriptive statistics being reported in this final report.

In addition to the data loss, there were variables that were not able to be collected at all or that could not be adjusted in a meaningful way that prevented a more significant analysis from being conducted. Speed over speed limit was unable to be collected for this study, which would have provided a more direct measure of risky speeding behavior than speed over a set threshold. Even the speed event data that were collected were less meaningful because the maximum speed that could be used for the overspeed alerts was only 75 mph. There were multiple participants who reported living near highways with either 70- or 75-mph speed limits, and although exceeding 75 mph in those cases is still considered speeding, the impact of such behavior on the measurement of risky driving is far less than if the threshold could have been adjusted to 80 mph.

Due to the small sample size, the experimental design kept the order of the treatment conditions the same for all participants. It would have been advantageous to alter the order of the treatment conditions for half of the participants, as some of the subthemes discussed in the Task 2 check-in interviews suggested that participants had forgotten about incentives and/or the feedback app by the fourth month, when incentives were first introduced. We may have found more interaction with both the app and incentives if half of the participants had experienced incentives + feedback app in Months 2 and 3 of data collection.

The data that were collected also lack any context to interpret the nuances of many of the events defined in this study as risky. Because there is no video, audio, or GPS data, any recorded braking or speeding events lack context to determine if the behavior was unsafe. For example, with the current data set, there is not enough detail to know if a hard brake performed by a participant was because they were distracted and slammed on their brakes to avoid rear-ending a stopped vehicle at a traffic signal, or if another vehicle pulled out in front of them, and the hard brake was indicative of a safe behavior. This nuance was also mentioned by participants during the Task 2 check-in interviews for the study.

Another limitation of this study is that although the study contained a within-subjects baseline condition at the start of data collection for all participants, many of the participants were already using feedback and monitoring applications prior to the start of this study. The result is that the baseline condition does not fully exclude the use of measures implemented

in subsequent phases of data collection. Additionally, the use of existing apps may have raised the expectations for the app in the study beyond its capabilities because the features provided were less detailed than many existing apps.

Another limitation of the data that were collected is the low engagement level of participants with the feedback app. Only six of 15 participants and five of 15 parents logged into the feedback app at least once. The low level of participation makes comparing the results between the first two phases difficult given that both phases are effectively identical for nine of 15 participants. The low level of participation also means that regardless of the capabilities of the app compared to existing apps, most participants would not have known if the app was useful.

Finally, in addition to the feedback app that participants had access to, they were also provided with additional feedback through Teen Driver Settings. Teen Driver Settings was active for all participants to allow collection of data, but in addition to passively collecting data, Teen Driver Settings provided participants with an audible chime and visual alert in the instrument cluster when an overspeed event occurred. Additionally, the radio was automatically muted when the driver's seat belt was not buckled. These features were not intended to be included in this study but could not be disabled. These features may have impacted participant behavior and may also have caused them to conflate the in-vehicle features for Teen Driver Settings with the feedback app that used Teen Driver Settings to collect data. Teen Driver Settings does provide information about seat belt usage, overspeed alerts, and active safety feature activations via the report card feature accessible in the vehicle. The output provided by the report card feature, however, does not include hard braking and driving score data. This confusion may have contributed to the low usage rate of the feedback app in this study.

Recommendations

Although the results of this study cannot be used for generalizations outside of this study, the qualitative results from the check-in interviews and questionnaires indicate that app-based feedback and monetary incentives could be beneficial to teen driver safety. This is true not only because teen drivers indicated that they were more conscientious about their driving, but

parents and teens also both indicated that they were more likely to discuss safe driving because of their involvement with the app. While we cannot conclusively report that monetary incentives could engage teen drivers to drive more safely, regardless of parental involvement, the qualitative results suggest that this remains an optimistic direction for future research. Additionally, more precise driving behavior monitoring (speeding over speed limit) as well as more consistent feedback with teen drivers (text messages with safe driving reports) would also greatly enhance the effectiveness of a teen driving app.

The research project reported in this document had multiple technical difficulties, and the proliferation and use of other teen monitoring and feedback apps was an issue that was not considered by the research team. Previous research in this space had not indicated that more parents were already using these types of monitoring apps; however, Life360 and others that inform parents of their teen's location have made strides in popularity. While primarily a location monitor, Life360 added key driving information that is quite useful to parents. Thus, the results of this study, while somewhat disappointing, may have been the direct result of improvements in driving safety already realized. While future research may need to identify parents who do not actively monitor, it is a testament to a change in parental involvement that may greatly benefit teen drivers in future years.

Effective monitoring and feedback for teen drivers, with or without parental involvement, remains an important priority, and this research adds to the literature indicating its potential for improving teen driving safety. Incorporating a safe systems approach will be important, as this project demonstrates that there are many key stakeholders, including car manufacturers, mobile app developers, parents, safety researchers, and public policy advocates, who all play critical roles in the reduction of teen driver fatalities and injuries. Coordination among these stakeholders could dramatically move the needle in producing a significant reduction in roadway fatalities and injuries within our teenage population.

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APPENDIX A. TEEN AND PARENT CHECK-IN SCRIPTS

Teen Check-In Script

Topic Area	Prompt
Email Notification	*Thank you for taking the time for this check-in. I'd like to start by discussing any emails you've received about incentive payments related to this study.* 1. During the past 7 to 10 days, did you receive an e-mail notifying you that you'd received an incentive payment related to this study? ☐ YES • Did you like receiving the notification? YES or NO 1. YES: Why did you LIKE receiving the notification? 2. NO: Why did you DISLIKE receiving the notification? • Do you have any suggestions for improving the notifications? ☐ NO/NOT SURE • Would you have liked to receive a notification? 1. YES: Why would you have LIKED receiving a notification? 2. NO: Why would you have DISLIKED receiving a notification?
DID LOGIN Usage and Driver Monitoring	*Next, I'd like to discuss the feedback app.* 2. Our records show that you **DID** login to the feedback app. Using the app was optional, so it's not a problem if you didn't. I just want to confirm that you DID login to the feedback app. ☐ DID ☐ DIDN'T: *If says didn't login, go to '**DIDN'T LOGIN**'* 3. How did you feel about your parent having access to the information on the feedback app about your driving? 4. Did you ever discuss the feedback app with your parent? ☐ NO ☐ YES: What did you discuss? 5. Did your parent use the information on the feedback app to monitor your driving? ☐ NO

	☐ YES: How did they use it to monitor your driving? 6. Are there other ways your parent monitors your driving (other than this feedback app)? ☐ NO ☐ YES: Please describe.
DID LOGIN Usability and Features	*Now I'd like to show you the feedback app and get your thoughts on it.* 7. What type of device did you use to login? 8. Did you experience any problems accessing the feedback app? ☐ NO ☐ YES: What problems did you experience? 9. Can you tell me what you looked at the most on the app? ☐ What did you think about _____? [*Ask them to elaborate as needed*] ☐ How, if at all, did you use the information? 10. Was there anything else you looked at? ***[Keep asking until they say "No"]*** ☐ What did you think about _____? [*Ask them to elaborate as needed*] ☐ How, if at all, did you use the information? 11. Was there anything on the feedback app that you thought was very useful? ☐ NO ☐ YES: What was very useful? _____ o What was useful about it? 12. Was there anything on the feedback app that you thought was not useful at all? ☐ NO ☐ YES: What was not useful? _____ o What was not useful about it? 13. Was there anything on the feedback app that was unclear? ☐ NO ☐ YES: What was unclear? _____

	○ What was unclear about it? 14. Was there anything missing on the feedback app that you would've found helpful? ☐ NO ☐ YES: What was missing? _____ ○ What about that would be helpful? 15. Did you think the information on the feedback app was accurate? ☐ NO: What information did you think was inaccurate? _____ ○ Can you provide any details as to why you think it wasn't accurate? ☐ YES 16. Any thoughts on how we can improve the feedback app? [*Skip to Incentives*]
DIDN'T LOGIN Usage and Driver Monitoring	*Next I'd like to discuss the feedback app.* 17. Our records show that you **DIDN'T** login to the feedback app. Using the feedback app was optional, so it's not a problem. I just want to confirm that you DIDN'T login to the feedback app? ☐ DIDN'T ○ Did you happen to look at the feedback app when your parent logged in? (Yes/No) ☐ **DID (or they say looked at it when parent logged in)**: Skip to question (**How did you feel** …) 18. Was there a reason you didn't login to the feedback app? 19. What would have motivated you to login to the feedback app? 20. **How did you feel** about your parent having access to the information on the feedback app about your driving? 21. Did you ever discuss the feedback app with your parent? ☐ NO ☐ YES: What did you discuss? 22. Did your parent use the information on the feedback app to monitor your driving?

	☐ NO ☐ YES: How did they use it to monitor your driving? 23. Are there other ways your parent monitors your driving? ☐ NO ☐ YES: Please describe.
Incentives	*Now I'd like to go over the monetary incentives.* 24. Are the monetary incentives motivating you to drive more safely? ☐ YES: what about the incentives is motivating you to drive more safely? ☐ NO: what about the incentives is not motivating you to drive more safely? 25. Any suggestions for how we can improve the incentives so that they motivate you to drive more safely? 26. Are there incentives, other than money, that would motivate you to drive more safely? ☐ NO ☐ YES: Please describe 27. Any other thoughts about the incentives you'd like to discuss?
Closing	*I have just a few more questions for you.* 28. Would you recommend this app with incentives to your friends? ☐ NO: What about this app with incentives makes it something you'd not recommend. ☐ YES: What about this app with incentives makes it something you'd recommend.

	• Would you still recommend the app if there were no incentives? Please explain. 29. Is there anything else about the study you'd like to share that I neglected to cover?

Parent Check-In Script

Topic	Prompt
DID LOGIN Usage and Driver Monitoring	*Thank you for taking the time for this check-in. I'd like to start by discussing the feedback app.* 1. Our records show that you **DID** login to the feedback app. Using the app was optional, so it's not a problem if you didn't. I just want to confirm that you DID login to the feedback app. ☐ DID ☐ DIDN'T: *If says didn't login, go to '**DIDN'T LOGIN**'* 2. How did you feel about having access to the information on the feedback app about your teen's driving? 3. Did you ever discuss the feedback app with your teen? ☐ NO ☐ YES: What did you discuss? 4. Did you use the information on the feedback app to monitor your teen's driving? ☐ NO: Was there a reason you didn't use it? ☐ YES: How did you use it to monitor their driving? 5. Are there other ways you monitor your teen's driving (other than this feedback app)? ☐ NO ☐ YES: Please describe. 6. What, if any, tools would you like to have to monitor your teen's driving?
DID LOGIN Usability and Features	*Now I'd like to show you the feedback app and get your thoughts on it.* 7. What type of device did you use to login? 8. Did you experience any problems accessing the feedback app? ☐ NO ☐ YES: What problems did you experience?

	9. Can you tell me what you looked at the most on the app? ☐ What did you think about _____? [*Ask them to elaborate as needed*] ☐ How, if at all, did you use the information? 10. Was there anything else you looked at? [***Keep asking this until they say "No"***] ☐ What did you think about _____? [*Ask them to elaborate as needed*] ☐ How, if at all, did you use the information? 11. Was there anything on the feedback app that you thought was very useful? ☐ NO ☐ YES: What was very useful? _____ o What was useful about it? 12. Was there anything on the feedback app that you thought was not useful at all? ☐ NO ☐ YES: What was not useful? _____ ☐ What was not useful about it? 13. Was there anything on the feedback app that was unclear? ☐ NO ☐ YES: What was unclear? _____ o What was unclear about it? 14. Was there anything missing on the feedback app that you would've found helpful? ☐ NO ☐ YES: What was missing? _____ o What about that would be helpful? 15. Did you think the information on the feedback app was accurate? ☐ NO: What information did you think was inaccurate? o Can you provide any details as to why you think it wasn't accurate? ☐ YES 16. Any thoughts on how we can improve the feedback app? [*Skip to 'Incentives'*]
DIDN'T LOGIN	*Thank you for taking the time to participate in this check-in. I'd like to start by discussing the feedback app*.

Usage and Driver Monitoring	17. Our records show that you **<u>DIDN'T</u>** login to the feedback app. Using the feedback app was optional, so it's not a problem. I just want to confirm that you DIDN'T login to the feedback app? ☐ DIDN'T o Did you happen to look at the feedback app when your teen logged in? (Yes/No) ☐ **DID (*or they say they looked it when teen logged in*):** Skip to question #20 (**How did you feel** ….) 18. Was there a reason you didn't login in the feedback app? 19. What would have motivated you to login to the feedback app? 20. **How did you feel** about having access to the information on the feedback app about your teen's driving? 21. Did you ever discuss the feedback app with your teen? ☐ NO ☐ YES: What did you discuss? 22. Are there other ways you monitor your teen's driving? ☐ NO ☐ YES: Please describe. 23. What, if any, tools would you like to have to monitor your teen's driving.
Incentives	*Now I'd like to go over the monetary incentives*. 24. Do you think the monetary incentives are motivating your teen to drive more safely? ☐ NO: from your perspective, what about the incentives is not motivating your teen to drive more safely? ☐ YES: from your perspective, what about the incentives is motivating your teen to drive more safely?

	25. Any suggestions for how we can improve the incentives so that they motivate your teen to drive more safely? 26. Are there incentives, other than money, that you think would motivate your teen to drive more safely? ☐ NO ☐ If Yes: Please describe 27. Any other thoughts about the incentives you'd like to discuss?
Closing	*In just have a few more questions for you.* 28. Would you recommend this app with incentives to your friends with teen drivers? ☐ NO: What about this app with incentives makes it something you'd not recommend. ☐ YES: What about this app with incentives makes it something you'd recommend. o Would you still recommend the app if there were no incentives? Please explain. 29. Is there anything else about the study you'd like to share that I neglected to cover?

APPENDIX B. OVERALL DRIVING PERFORMANCE RESULTS

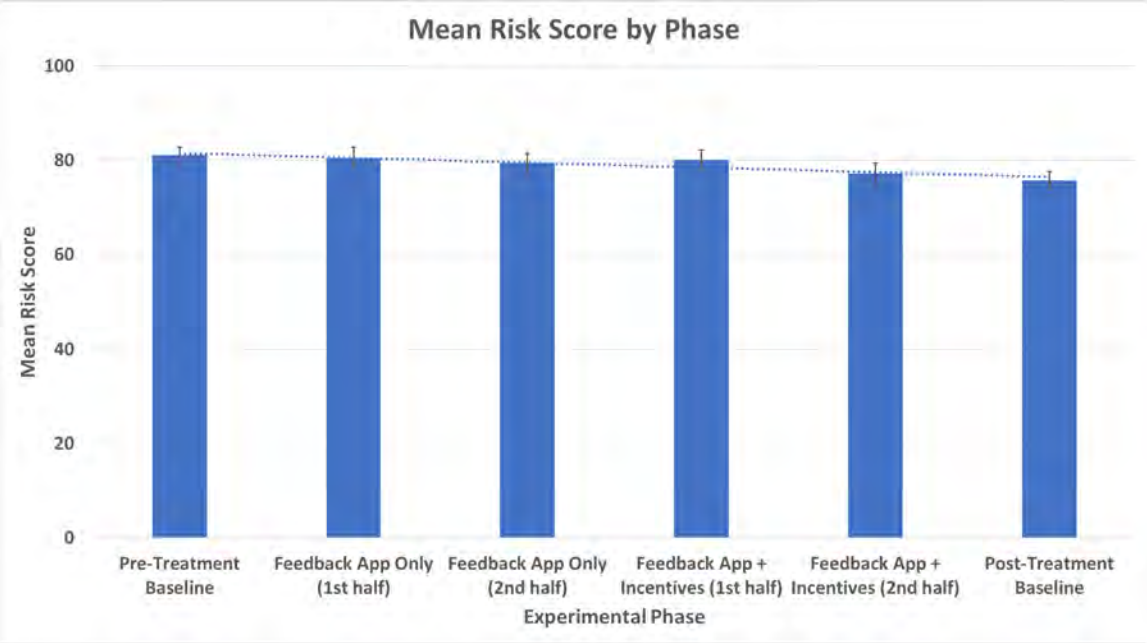

Figure 25. Average driving score by data collection phase.

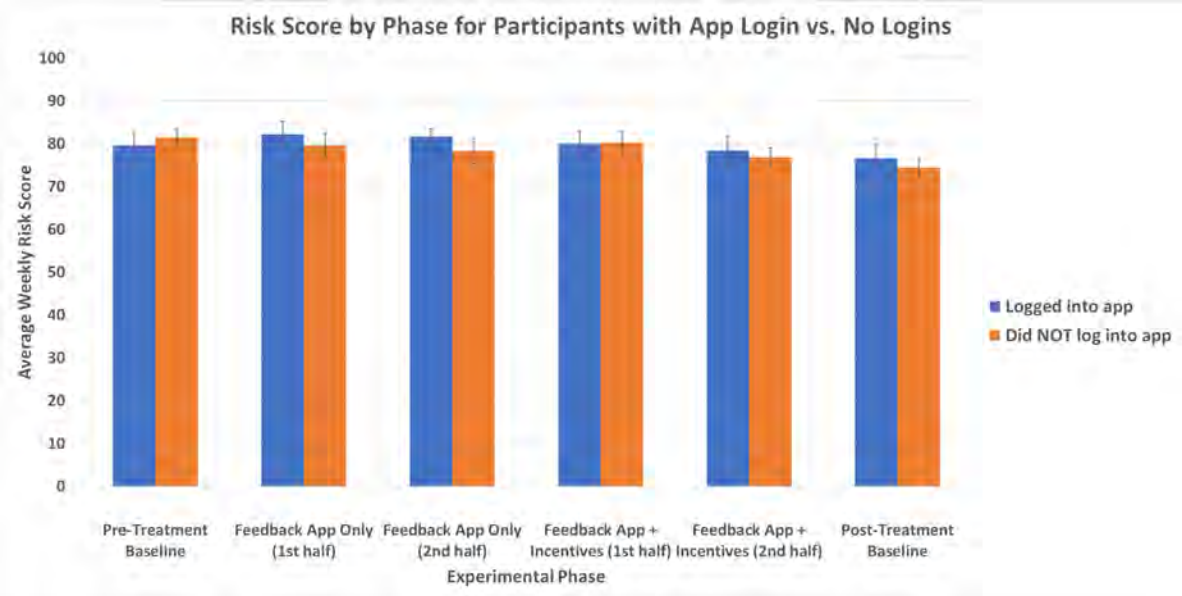

Figure 26. Average weekly driving score for participants who logged into the feedback app versus participants who did not.

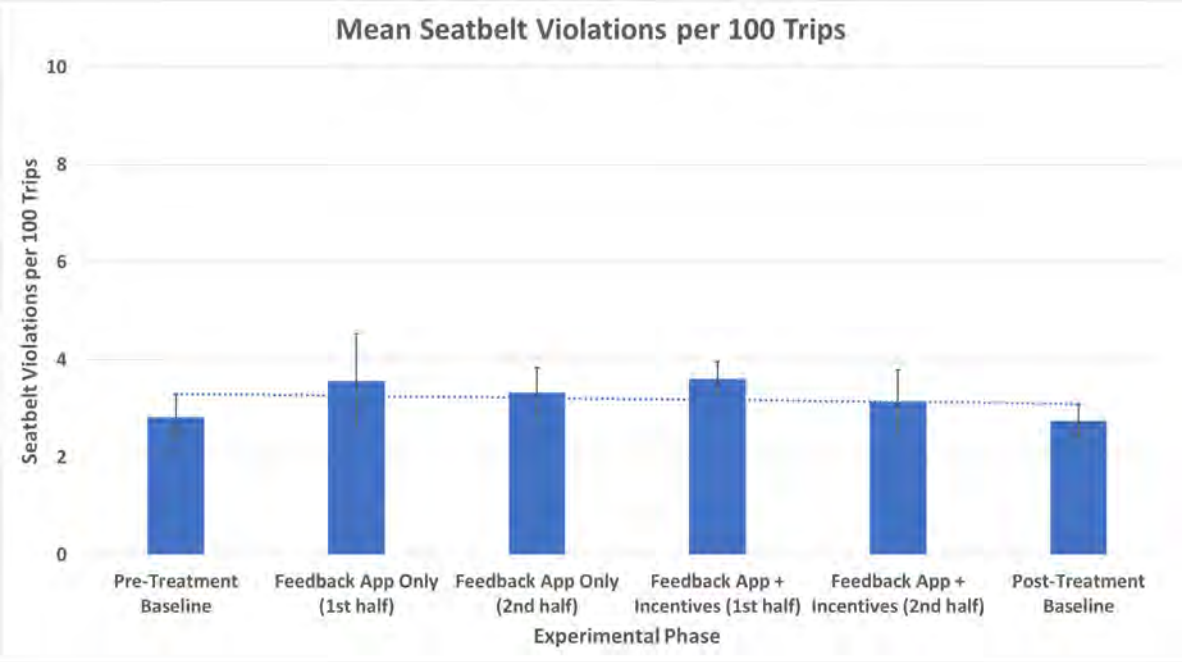

Figure 27. Mean seat belt violations per trip by phase.

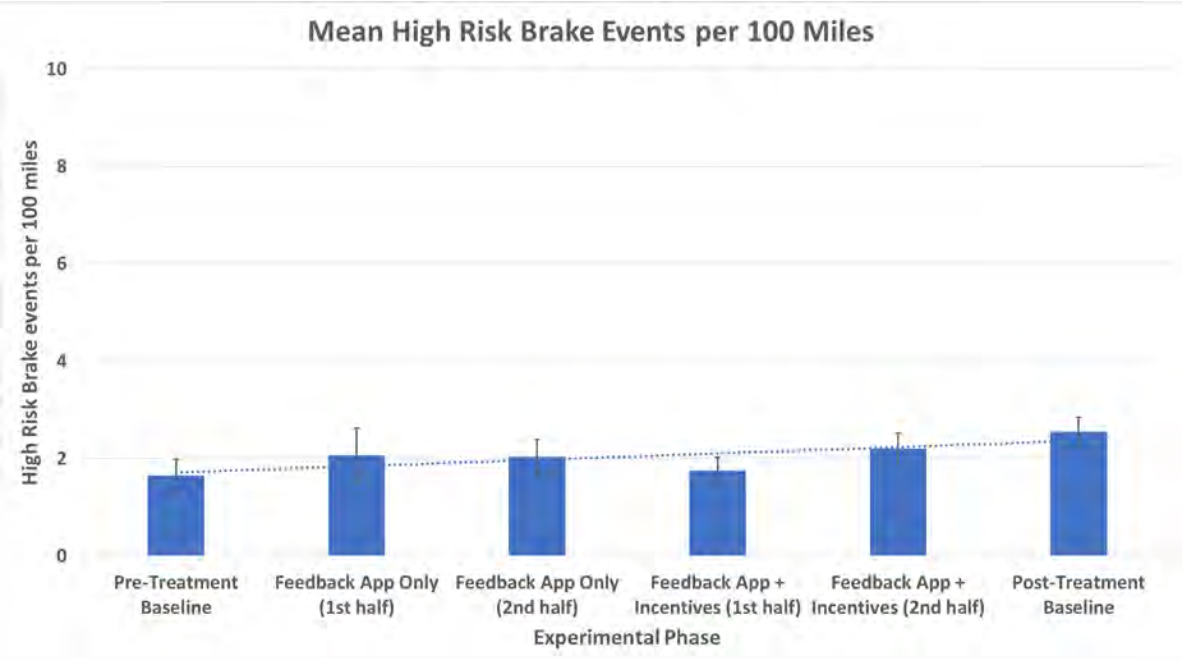

Figure 28. Mean high risk brake events per 100 miles by phase.

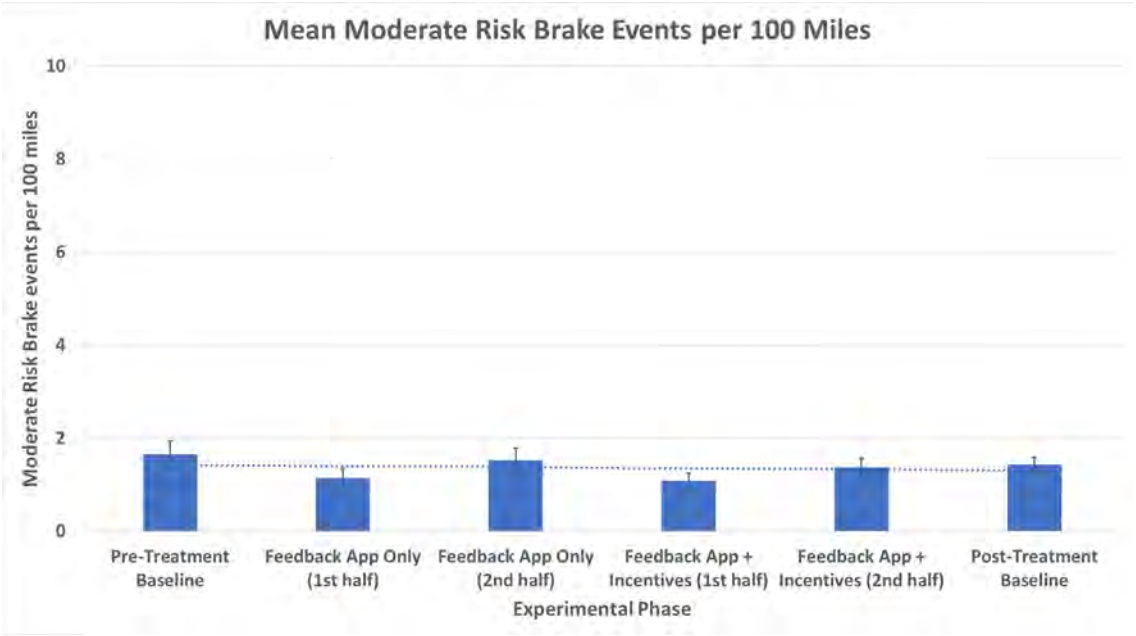

Figure 29. Mean moderate risk brake events per 100 miles by phase.

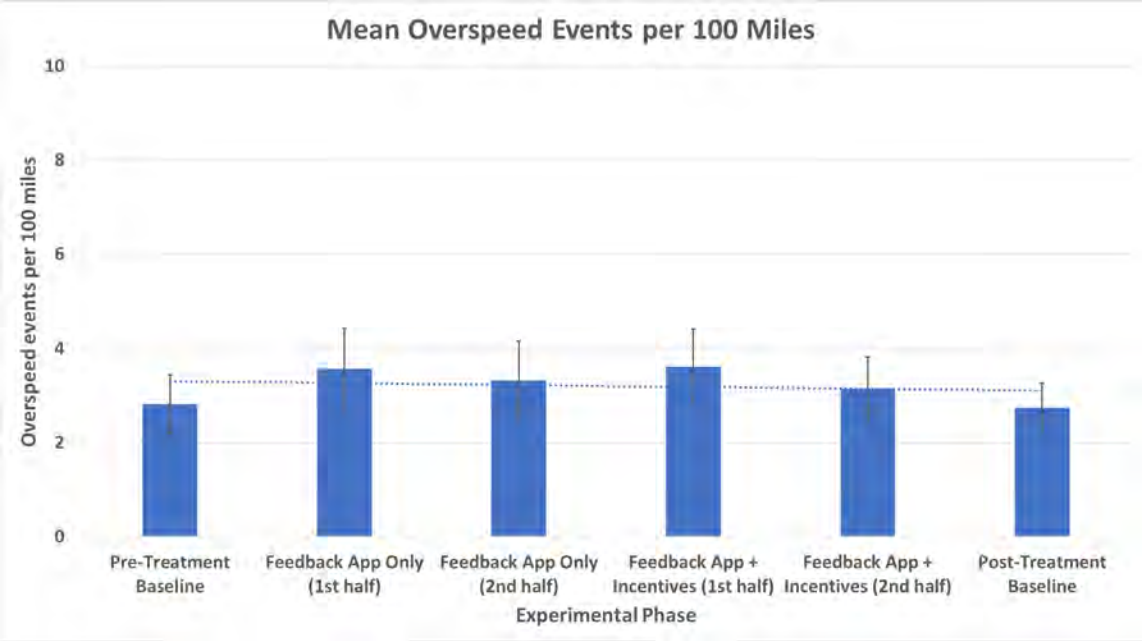

Figure 30. Mean speeding events per 100 miles by phase.

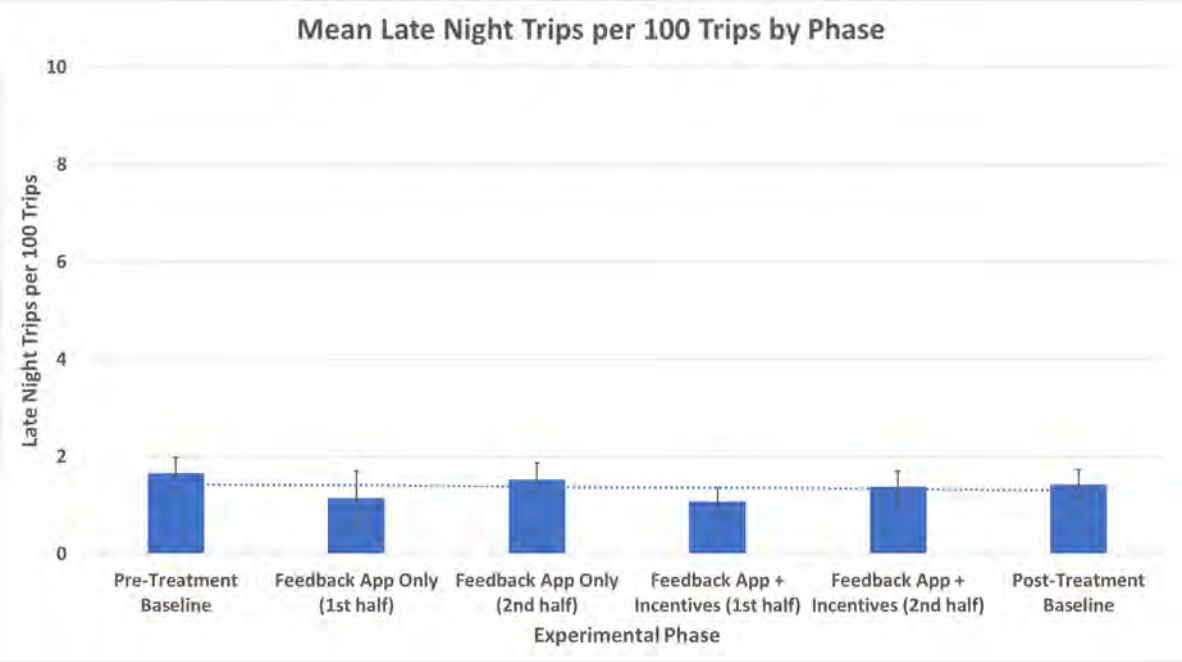

Figure 31. Mean late night drives per trip.