In-Vehicle Monitoring and the Driving Behavior of Teenagers

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ABSTRACT

Objectives: The primary objective of the current study was to determine if teenage driving behavior improves when a monitoring and feedback device is installed in the teen's vehicle.

Methods: Vehicles of 85 recently licensed teenage drivers were fit with a monitoring device that detected all instances of sudden braking, sudden acceleration, speeding, and nonuse of seat belts. For each detected event, a detailed notification was transmitted via satellite to a central computer. Drivers were assigned randomly to one of four research groups, differing in whether or not an alert sounded in the vehicle and whether or not parents were given access to websites containing notification records. Event rates per mile traveled for the four groups were compared using Poisson regression.

Results: Although seat belt use rates already were high, they improved significantly when violations were reported to the parent websites, and improved even more when in-vehicle alerts were activated. In-vehicle alerts and website notifications also were associated with reductions in instances of sudden braking/acceleration, but most reductions were not statistically significant. Report cards emailed to parents were more effective than giving parents access to a website detailing the teenager's driving. Instances of speeding by more than 10 mph above the posted limit were reduced significantly only when each of three conditions was satisfied: (1) alerts sounded in the vehicle, (2) speed-related report cards were emailed to parents, and (3) teenage drivers were given the chance to cancel report card notifications by slowing down.

Conclusions: Electronic monitoring of teenage drivers can reduce the incidence of risky behavior, especially seat belt nonuse, which declined in all treatment conditions. More complicated behavior was more difficult to change, however. No consistent effects were achieved for sudden braking/acceleration for any treatment group. Consistent reductions in speeding were achieved only when teenagers received alerts about their speeding behavior, believed their speeding behavior would not be reported to parents if corrected, and when parents were being notified of such behavior by report cards. Parent participation in the monitoring process is key to successful behavioral modification, but it is yet to be determined how best to encourage such participation.

Keywords: Novice drivers; Feedback; Aggressive driving

INTRODUCTION

The elevated crash risk of teenage drivers is well documented in the literature. Teenage drivers have consistently higher crash rates than any other age group (National Highway Traffic Safety Administration (NHTSA), 2008). Studies have demonstrated an even greater risk among 16-year-old drivers compared with older teenage drivers, especially during the first few months of driving (Mayhew et al., 2003; McCartt et al., 2003; Williams et al., 2005). During 2001-02, 16-year-old drivers were involved in approximately 26 crashes per million miles traveled compared with a rate of 14 per million miles for drivers ages 18 and 19 (Ferguson et al., 2007).

Parents have a significant influence on the behavior of their teenagers. Teens whose parents are more involved in their lives are less likely to engage in all types of risky behavior including smoking, alcohol/drug abuse, and crime (Beck et al., 2003; Simons-Morton, 2004; Wells and Rankin, 1988). Parents influence the driving behavior of their children through either setting an example, training, or supervision (Ferguson et al., 2001; Simons-Morton and Ouimet, 2006; Williams et al., 2006). Parents also make the final decisions on when their teenagers become licensed and what vehicles they are allowed to drive.

One possibility for reducing teenage driver crash risk is the use of technologies that can monitor and potentially reduce risky behavior such as speeding, aggressive driving (i.e., sudden maneuvers), and driving without using seat belts. These technologies are being used increasingly in commercial fleets to reduce driver crash and injury risk. Some companies report large reductions in speeding, increases in belt use, and reductions in crashes among fleet drivers (Levick and Swanson, 2005; Olson and Austin, 2001; Toledo and Lotan, 2006; Wouters and Bos, 2000).

Similar devices have been marketed to parents to monitor where their teenagers are driving, as well as their driving speeds and how aggressively they are driving (Lerner et al., 2008; NHTSA, 2006). However, there have been few published studies of their effectiveness. McGehee et al. (2007) reported on 25 teenage drivers who had video-based monitoring devices installed in their vehicles. Accelerometers in the vehicles triggered both forward and interior-facing video cameras whenever readings exceeded a given threshold. Researchers reviewed the captured videos each week and mailed personalized reports to each family. Overall, the weekly reports were associated with a 58 percent reduction in safety-related events and a 15 percent increase in seat belt use.

A recent survey conducted in three states suggests a desire by parents of newly licensed teenagers to know how and where their teens are driving (McCartt et al., 2007). In each state, more than half of the parents surveyed wanted to know whether their teens were speeding and at least a third wanted to know if they were inattentive, using cell phones, or had too many passengers while driving. Between 40 and 60 percent of parents surveyed said they would consider installing a computer chip that continuously monitored mileage, speed, sudden braking, and sudden acceleration. However, only 26-39 percent said they would consider using a video camera.

The primary objective of the current study was to determine if teenage driving behavior improves when a monitoring and feedback device is installed in a teen's vehicle. Recently licensed teenage drivers were assigned randomly to various research groups, and their vehicles were monitored continuously for 24 weeks. Secondary objectives included determining parent and teen acceptability, use, and perceived effectiveness of the device.

METHOD

Between May 2007 and March 2008, parents of 85 recently licensed 16- and 17-year-old drivers were recruited in the suburban Washington, DC area. Recruitment was through contacts with Parent Teacher Associations at local high schools, advertisements in local community newspapers, and information distributed at offices of the Maryland Motor Vehicle Administration. In addition, a list of new teenage drivers was obtained from the Virginia Department of Motor Vehicles, and recruitment letters were sent to the parents of these drivers. It was required that the teens be the primary drivers of vehicles to be monitored and that their parents have access to the internet. Families were offered $500 compensation for their participation. Informed consent was obtained from both the parents and the participating teens. In addition, a certificate of confidentiality was obtained from the National Institutes of Health to protect participants' privacy.

Each teenager's vehicle was fit with a monitoring device consisting of a shoebox-size *black box* installed in the vehicle's cargo area, global positioning system (GPS), satellite modem, and small speaker box installed beneath the front dashboard. The device detected all instances of sudden braking/acceleration (longitudinal deceleration/acceleration of more than 0.5 g) and nonuse of seat belts, transmitting a record of these events via satellite to a central computer. In addition, the GPS was used to continuously monitor vehicle speed and compare it with a database of posted speed limits. All instances of exceeding a posted speed limit also were reported to the central computer. The monitoring of vehicle events did not include any video or audio recordings.

Descriptions of all sudden braking, sudden acceleration, and seat belt nonuse notifications were posted on password-protected internet websites specific to each teenager's parents. Speeding notifications were posted on the parent website only when the vehicle exceeded a posted speed by more than 10 mph. Participants were assigned randomly to one of four research groups:

Group 1: Vehicle monitoring with in-vehicle alert and immediate website notification (alert and web),

Group 2: Vehicle monitoring with in-vehicle alert and conditional website notification (alert then web),

Group 3: Vehicle monitoring with website notification but no in-vehicle alert (web only),

Group 4: Vehicle monitoring with no in-vehicle alert and no website access (control group).

In-vehicle feedback consisted of audible alerts immediately following each event. Sudden braking/acceleration events were followed by a single short, low-pitched buzz. Seat belt nonuse was accompanied by a continuous low-pitched buzz, terminating only when the belt was fastened. Speeding led to a single short beep at 2.5 mph above the posted limit, then a continuous string of beeps (with increasing pitch and frequency) when exceeding the posted limit by more than 10 mph. Speaker volume was set high enough so that alerts could be heard above both traffic noise and the vehicle radio. Location and current time information were transmitted to the central computer immediately following each detected event. Parents with website access (i.e., groups 1-3) could review the teenager's events using a map showing the location and nature of each event.

In the case of a speeding or seat belt violation, the study design called for two possible scenarios of parent notification. In the immediate notification mode, an audible alert was to be sounded in the vehicle and, concurrently, notification was to be posted on the parent website. In the conditional notification mode, an audible alert was to be sounded in the vehicle but, instead of an immediate message sent to the parent website, the teenager was to be given 20 seconds to correct the behavior. Parent websites were to be notified only if the teen did not correct the offending behavior within the allotted time. Unfortunately, it was discovered late in the study that the conditional notification mode had never been initiated. So, although groups 1 and 2 were meant to receive different treatments, in reality their devices were the same. Data for these two groups were analyzed separately because teenagers (and parents) in group 2 still believed the teen could correct the behavior without consequence.

For all four research groups, the first 2 weeks with the device included no in-vehicle alerts and no data on the parent websites. This served to establish a baseline measure of teenagers' driving behavior. Following the baseline period, the alerts and website notifications were initialized for the treatment groups. Upon completion of the 20-week treatment phase, in-vehicle alerts and parent website access were disabled. However, monitoring data continued to be transmitted to the central computer during a 2-week post-treatment phase. After the post-treatment phase, devices were removed from the vehicles.

Following the study period, teenagers and parents were interviewed separately (either by telephone or in-person during device removal) in regard to perceived effectiveness of the device, parents' use of the monitoring features, and overall satisfaction. Families in the control group were given the option to use the monitoring device (with in-vehicle alerts and website notification) for a 6-month period after their participation in the data collection concluded.

Analyses began with simple comparisons of event rates per mile traveled by time period and treatment group. Poisson regression then was used on vehicle-specific event rates to estimate the effects of the treatments after adjusting for characteristics of the vehicles and drivers. Effects were adjusted for differences in vehicle type (pickup and SUV vs. car), driver age (17 vs. 16), driver experience (at least 4 months vs. less), and driver gender. Data points were event rates per mile traveled for each vehicle during each 2-week period (i.e., 12 data points per vehicle).

RESULTS

Eighty-five participants began the study, but one subject in group 2 was involved in a collision just 1 week after having the monitoring device installed. In-vehicle alerts and website notifications had not yet been initiated. Although there were no injuries, the vehicle was scrapped and the family chose to leave the study. All other subjects remained in the study for at least 8 weeks. Table 1 classifies the 84 teenage drivers according to research group. The randomized assignment was planned so that the number of drivers in each research group would be approximately equal. However, driver gender was not restricted, so there were more female than male participants — 38 male and 46 female drivers. At the time of device installation, drivers ranged in age from 16 years, 3 months to 17 years, 10 months, with a median age of 16 years, 11 months (Table 2). Driving experience at the time of device installation ranged from 0 to 15 months licensed, with a median of 3 months. Twenty-one of the teenagers drove light trucks (i.e., pickups and SUVs) rather than cars.

(Tables 1 and 2 inserted here)

The total number of miles driven during the study varied widely by participant, from a low of 338 to a high of 10,345. The baseline period was especially variable, ranging from 8 to 1,031 miles driven during the initial 2 weeks. Six participants did not register any miles during the post-treatment phase; four of these either sold or scrapped their vehicles before the post-treatment phase began. Counts of sudden braking/acceleration, seat belt nonuse, and speeding violations also varied among participants. For example, seven participants had no sudden braking/acceleration notifications during the 24 weeks of study, whereas one participant had 145.

Table 3 lists miles driven and sudden braking/acceleration events summed by research group, gender, and time period. For male drivers in group 1 (alert and web), the rate for sudden braking/acceleration fell from 0.66 events per 100 miles during the baseline period to 0.45 during the treatment phase, and then rose to 0.77 during the post-treatment phase. Female drivers in group 1 exhibited a similar decline between the baseline period and treatment phase, but this decline continued into the post-treatment phase. Trends for group 2 (alert then web) were similar, except that males continually improved their behavior over time, whereas females reverted somewhat during the post-treatment phase. For group 3 (web only) and group 4 (control), changes in sudden braking/acceleration behavior were less pronounced.

(Table 3 inserted here)

Unlike sudden braking/acceleration, seat belt nonuse and speeding events varied in their durations. A seat belt alert that continues for 20 miles is more serious than one that ends after 1 mile. Thus seat belt and speeding events were analyzed as total miles of alerts rather than as counts. For example, subjects in group 1 drove unbelted for 3.69 percent of their miles during the baseline period, 0.09 percent during the treatment phase, and 3.03 percent during the post-treatment phase (Table 4). The trend was similar for subjects in groups 2 and 3, although the baseline rates varied greatly for group 3. However, subjects in group 4 were less likely to use seat belts during the treatment phase than during the baseline period. Percentages in Table 4 are based on the behavior of only 71 subjects; seat belt sensors in the other 13 vehicles became inoperative or unreliable during the course of the study. Seat belt use ranged from 25 to 100 percent of miles driven, but it was high for most subjects. Thirteen of the 71 subjects with reliable seat belt sensors used belts all the time, and another 53 used belts at least 90 percent of the time.

(Table 4 inserted here)

Table 5 lists miles driven while above posted speed limits summed by research group, gender, and time period. Overall, 25 percent of miles driven by these teenagers were above posted limits. For most groups, the percentage of miles driven while speeding increased between the baseline period and treatment phase. The only exception was female drivers in group 2 (alert then web).

(Table 5 inserted here)

Many of the speeding miles in Table 5 were 1-10 mph above the limit, so the in-vehicle feedback consisted of a single beep and the event was not posted on the parent website. Consequently, such events may not have been much affected by the monitoring device. A more appropriate measure of the monitoring effect is the percentage of miles during which the vehicle was more than 10 mph above the speed limit (Table 6). These trends were similar to those for all speeding events. Except for female drivers in group 2, the percentage of miles driven while more than 10 mph above the limit increased between the baseline period and treatment phase.

(Table 6 inserted here)

Figure 1 shows the percentage of miles driven while more than 10 mph above posted speed limits by research group for each 2-week period. Subjects in groups with in-vehicle alerts (groups 1 and 2) exhibited sharp declines in speeding for the first few weeks of treatment, but then speeding rates began to rise. Subjects in groups without in-vehicle alerts (groups 3 and 4) began increasing their speeding behavior right from the start.

(Figure 1 inserted here)

Table 7 summarizes the Poisson regression of sudden braking/acceleration rates. Subjects driving pickups and SUVs had sudden braking/acceleration rates approximately 25 percent lower than subjects driving cars. Drivers age 17 had sudden braking/acceleration rates approximately 17 percent lower than drivers age 16, and female drivers had rates approximately 23 percent lower than male drivers. Participants who began the study with at least 4 months driving experience had sudden braking/acceleration rates approximately 16 percent higher than participants with less than 4 months experience. Compared with the baseline period and relative to the control group, sudden braking/acceleration rates during the treatment phase were approximately 43 percent lower for group 1 (alert and web), approximately 31 percent lower for group 2 (alert then web), and approximately 12 percent lower for group 3 (web only). However, only the result for group 1 (alert and web) was statistically significant. Relative rates increased for all three treatment groups during the post-treatment phase, but the increases were not statistically significant.

(Table 7 inserted here)

Similar Poisson regressions were conducted for the other measures of unsafe driving behavior (seat belt nonuse, speeding, speeding more than 10 mph). Vehicle and driver factors again were statistically significant, but the direction of the effect was different. For example, drivers age 17 had seat belt nonuse rates approximately 18 percent higher than drivers age 16. Compared with the baseline period and relative to the control group, seat belt nonuse rates during the treatment phase declined more than 90 percent for group 1 (alert and web) and group 2 (alert then web) and 61 percent for group 3 (web only) (Table 8). Nonuse rates increased significantly during the post-treatment phase for groups 1 and 2 while remaining constant for group 3. However, seat belt nonuse rates still were significantly lower during the post-treatment phase compared with the baseline period.

(Table 8 inserted here)

Rates of speeding by any amount during the treatment phase declined approximately 10 percent for group 2 but rose 12 percent for group 1, compared with the baseline period and relative to the control group. Web notifications alone (group 3) had essentially the same effect on speeding rates as no treatment (group 4). Speeding behavior during the post-treatment phase was unchanged for all three treatment groups.

Compared with the baseline period and relative to the control group, rates of speeding by more than 10 mph during the treatment phase declined 37 percent for group 2 (alert then web) but were unchanged for group 1 (alert and web) and group 3 (web only). Rates of speeding by more than 10 mph during the post-treatment phase increased slightly for group 2 but still were 30 percent lower than the baseline rate.

As noted previously in Figure 1, groups 1 and 2 exhibited sharp declines in rates of speeding by more than 10 mph during the first few weeks of treatment, but then rates began to rise. To account for this, the Poisson regression model was redefined to test for differences between the first 10 weeks of the treatment phase (early) and the last 10 weeks (late). Rates of speeding by more than 10 mph during the early treatment phase declined 15 percent for group 1 (alert and web) and 43 percent for group 2 (alert then web) (Table 9). Speeding rates during the late treatment phase then increased 31 percent for group 1 and 24 percent for group 2.

(Table 9 inserted here)

The initial 31 devices were installed in subjects' vehicles periodically during the first 6 months of the study. Preliminary analyses made it apparent that parents rarely were visiting the websites, so the study design was changed to encourage more parent participation. For all devices installed subsequent to the initial 31, a schedule of email notifications was implemented. Every 2-3 weeks, each family in research groups 1-3 received a brief email from the study coordinator. The email stated how many times during the previous week the teenager's vehicle had exceeded the speed limit by more than 10 mph and prompted each parent to visit their website for more information. These *report cards* were limited to a single statement to avoid being seen as a substitute for the website.

Parents' visits to the websites were tracked automatically by the central computer. The majority of the 24 families in the initial study design groups with website access made few visits to the websites. One family made no visits during the 20-week access period, 11 made 1-4 visits, four made 5-9 visits, and six made 10-30 visits. Of these website visits, 42 percent took place during the first 2 weeks of the treatment phase. The remaining two families accounted for 63 percent of all website visits, with 118 and 159 visits, respectively. In total there were 440 visits to the websites, thus averaging only 18 visits per family (Table 10).

(Table 10 inserted here)

Families in the revised study design groups made even fewer visits to the websites (Table 11). There were 420 visits to the websites by the 39 families with access. Seven families made no visits during the 20-week access period, 12 made 1-4 visits, six made 5-9 visits, and 11 made 10-30 visits. The remaining three families made 32, 38, and 47 visits, respectively.

(Table 11 inserted here)

The percentage of miles driven while more than 10 mph above posted speed limits was plotted for each 2-week period separately for the 31 subjects under the initial study design and the 53 subjects under the revised design (i.e., report cards). Rates of speeding by more than 10 mph generally increased for the three treatment groups under the initial design. However, the control group (group 4) exhibited a temporary drop in speeding rates approximately midway through the study (Figure 2). Under the revised design, group 1 (alert and web) exhibited a sharp decline in speeding by more than 10 mph for the first few weeks of treatment, but then speeding rates began to rise. Group 2 (alert then web) exhibited an immediate decline in speeding rates that was sustained through most of the study. Groups 3 and 4 (both without in-vehicle alerts) did not exhibit any consistent trends in speeding behavior (Figure 3).

(Figures 2 and 3 inserted here)

Poisson regressions were conducted for all measures of unsafe driving behavior separately for the 31 subjects under the initial study design and the 53 subjects under the revised design. Compared with the baseline period, seat belt nonuse rates essentially disappeared during the treatment phase under the initial design, but the other unsafe driving behaviors either worsened or remained the same. For example, compared with changes in the control group, rates of speeding by any amount increased approximately 35 percent for initial group 1 and 13 percent for initial group 2 (Table 12).

(Table 12 inserted here)

Under the revised study design, seat belt nonuse rates during the treatment phase declined more than 90 percent for groups 1 and 2 and 59 percent for group 3, compared with the baseline period (Table 13). Sudden braking/acceleration rates during the treatment phase also declined for all three treatment groups, but these declines were not statistically significant. Speeding by any amount declined approximately 23 percent for revised group 2, but was unchanged for revised group 1. Speeding by more than 10 mph declined 21 percent for revised group 1 during the early treatment phase but increased 32 percent during the late treatment phase. Speeding by more than 10 mph declined 57 percent for revised group 2 during the early treatment phase then leveled off during the late treatment phase. Again, web notifications alone (group 3) had essentially the same effect on speeding rates as no treatment (group 4).

(Table 13 inserted here)

Tables 14 and 15 summarize the trends in teenagers' risky driving behavior during the course of the study. For teens under the initial study design (i.e., no report cards), the only consistent effect was for seat belt use. Rates of nonuse decreased during the treatment phase for all three treatment groups, relative to the control group, and the reductions continued into the post-treatment phase, although the post-treatment reductions were statistically significant only for groups 1 and 3. For the other two risk behaviors, results were less clear. Rates of sudden braking/acceleration declined for group 1 and increased for groups 2 and 3, but none of the changes were statistically significant (Table 14). Exceeding the speed limit by any amount generally increased over time for all three treatment groups, but the incidence of speeding by more than 10 mph showed no clear pattern.

(Table 14 inserted here)

For teens under the revised study design (i.e., with report cards), seat belt use again improved significantly for all three treatment groups, relative to the control group, and the improvements continued into the post-treatment phase (Table 15). Effects on sudden braking/acceleration again were uncertain. Rates declined during the treatment phase for all three treatment groups, but none of the changes were statistically significant; during the post-treatment phase, rates were not significantly different than the baseline rates for the treatment groups relative to the control group. Effects on speeding also were inconsistent with the exception of group 2, for which exceeding the speed limit by any amount or speeding by more than 10 mph declined significantly. Although rates of speeding behavior for group 2 increased somewhat after the treatment was removed, it still was significantly lower than would have been expected if the treatment had not been applied.

(Table 15 inserted here)

During interviews conducted following the study, 86 percent of parents indicated a general concern for their teenagers' safety as a primary reason for installing the monitoring device. When asked what they most wanted to know about their teenagers' driving, parents most often indicated speeding (81 percent). Ninety-seven percent of parents with website access indicated visiting the website at least once, but 80 percent of them admitted their website visits declined as time went on. Most of these parents felt the monitoring system improved the teenager's driving (average rating of 7.6 out of a possible 10 points), and 98 percent would recommend the device to parents of another teenage driver.

The majority of teenagers reported they typically drove several times per day, with school, a friend's house, and sports/extracurricular activities as the most common destinations. When asked how they felt about having the device in their vehicle, teenagers with in-vehicle alerts (groups 1 and 2) indicated they were not very happy (average rating of 5.3 out of a possible 10 points). More than half of the teenagers in each group described the in-vehicle alerts as "annoying." Teens with website notification only (group 3) were only slightly happier (average rating of 5.8). However, teens in all three treatment groups said they thought the device had improved their driving skills. Eighty-three percent of teenagers with in-vehicle alerts (groups 1 and 2) and 81 percent of teens with website notification only (group 3) thought the device was effective at improving their driving skills.

DISCUSSION

Rates of sudden braking/acceleration declined for the treatment groups relative to the control group, especially for the groups with in-vehicle alerts, but the differences were statistically significant only for the group with immediate website notification. Alerts sounded only briefly after each sudden braking/acceleration event and were not particularly annoying, so alerts by themselves probably had little effect on driving behavior. Effects were somewhat greater for teenagers whose parents received periodic report cards.

Nonuse of seat belts was a rare event for most teenagers in the study. During the baseline period, teenagers were belted 94 percent of the time, a rate much higher than in the general population. However, the few teenagers that failed to use belts changed their habits when a continuous seat belt alert was present. Seat belt use improved even for teenagers with website notification only. Parents may be more critical of seat belt nonuse than they are of other risky driving behavior. Use rates remained high even when in-vehicle alerts and website notifications were discontinued.

The most prevalent risky driving behavior was speeding (i.e., exceeding the speed limit), which occurred during about 25 percent of miles driven. Most of the teenagers increased their speeding behavior over time regardless of how the alerts and website access were set. This may have been due to teenagers' increasing familiarity with the driving task and the roads on which they traveled. Drivers tend to be less cautious when dealing with familiar situations (Martens, 2007). It also could have been that, during the study, many teenagers completed the probationary period for graduated licensing. New drivers ages 16-17 were restricted from carrying young passengers for the first 5 months in Maryland and restricted to one young passenger for the first year in Virginia. Teenage passengers have been associated with risky behavior among teen drivers, so lifting the passenger restriction could account for some of the trend in speeding (Williams et al., 2007).

There was some evidence that emailing speed-related report cards to parents had a beneficial effect, but this was inconclusive. Teenagers with in-vehicle alerts and conditional website (parent) notification suppressed their speeding behavior, but teens with immediate notification did not. Exceeding the speed limit by 1-10 mph is a common practice in the Washington, DC area, even when police presence is heavy (Retting et al., 2008). Also, these relatively minor events were not posted on the parent websites. It is possible that some teenagers used the short in-vehicle alert at 2.5 mph above the limit as a speed indicator, thus saving them the trouble of watching the speedometer. If so, then the distance traveled at or around this target speed would increase over time.

Instances of speeding by more than 10 mph above the limit were posted on the parent websites, but these also increased over time for 2 of the 3 treatment groups. The largest increase was for teenagers with website notification only, even when parents were periodically emailed reports of the behavior. Notifying parents without first alerting the teenagers seemed to have had no effect. In-vehicle speeding alerts may have diminished the trend toward excessive speeding, as rates for teens in both alert groups declined during the first several weeks of treatment. Teenagers interviewed stated they were both annoyed and influenced by the alerts.

However, after the initial reduction in speeding, teenagers with in-vehicle alerts and immediate website notification began to narrow the gap between themselves and the control group. By the end of the study, their rate of speeding by more than 10 mph was approaching what would have been expected if the treatment had never been applied. Teenagers with in-vehicle alerts and conditional website notification whose parents received report cards suppressed their speeding behavior much longer, up until the last few weeks of the treatment phase. Even so, the trend toward increased speeding at the end of the treatment phase and during the post-treatment phase diminishes hope for a long-term effect from these treatments. A proper evaluation of long-term effects will require more than the 2 weeks of post-treatment observation obtained for this study.

The parent websites were used very little, as most parents admitted when interviewed. Parents tended to check their website a few times early on, but then lost interest. Emailing report cards to parents did not increase website visits. The report cards may have been too brief to engage parents' interests, or they may have provided enough information so that parents felt they did not need the websites.

The lack of parent involvement may have been due to other common tasks having a higher priority. Parents did not pay for the monitoring device, so they may not have felt compelled to get their money's worth. They also knew that the researchers were monitoring driver behavior and perhaps trusted that they would be informed of any serious problems.

In a sense, teenagers in groups 1 and 2 of the initial study design were subject to feedback only from in-vehicle alerts. Their parents typically were unaware of the website notifications, so they could not provide any feedback. In-vehicle alerts alone were insufficient to change teenage driver behavior. If teen drivers were initially wary of the monitoring device, many soon realized their actions did not entail any serious consequences. This is another possible explanation for the increase in risky behavior.

Teenagers in group 1 of the revised study design were subject to feedback from both in-vehicle alerts and their parents, but again their behavior did not improve significantly. After an initial decline in speeding, teens reverted to levels even higher than before the alerts were turned on. This may be because they knew that, by the time they heard an alert, it was too late to prevent the notification and improve their report card. Thus there was no incentive to stop speeding once they had begun.

Teenagers in group 2 of the revised study design had an incentive to stop speeding once the alert sounded. They believed that a quick correction would prevent any parent notification and, more important, would improve the report card. This is the one group with consistent and significant behavioral improvement.

The effect of the monitoring system in the current study is less than those reported in studies of other monitoring systems. It should be expected that the monitoring device would affect teen drivers less than commercial and fleet drivers. Teenage drivers are monitored by parents rather than employers, so they are not likely to suffer economic consequences from too many alerts. However, McGehee et al. (2007) reported large positive effects for teen drivers. Effects may have been overstated due to the lack of a control group, but the authors measured general improvements in driving behavior over time. Some trends in the current study are towards worsening behavior over time.

The monitoring device and parent websites in this study were adapted from a system designed for commercial trucking fleets. Although considerable time was spent prior to the study testing and adjusting the system for the different suspension and handling characteristics of passenger vehicles, there still was a potential for false alarms. In particular, notifications of extreme lateral and vertical movement (hard turns and hill cresting) were excluded from analysis because of the high rate of false alarms. Also, consideration for subjects' vehicles necessitated devising an unobtrusive, temporary mount for the monitoring equipment (as opposed to the permanent mount for heavy trucks). As a result, some vehicles had to be called in for equipment repairs when sensors or wiring became loose. The websites were less user-friendly than they could have been, possibly discouraging use by some parents.

In conclusion, in-vehicle alerts are somewhat effective in reducing the risk-taking behavior of recently licensed 16- and 17-year-old drivers. Teenage drivers find the alerts to be annoying but feel the device helps them become better drivers. Loud music and traffic noise can mask the in-vehicle alerts but not completely. However, teenagers may learn to tune out the alerts over time, so reinforcement from parents appears necessary to sustain good behavior. Surprisingly, access to a website detailing their child's behavior is not enough motivation for parents to actually visit the website. Teenagers seem to realize this and may ignore the communication aspects of the monitoring device. Emailing report cards to parents is more effective than giving them website access. It could be that the website offers more information than most parents want. Personalized report cards are very convenient for parents, but it is not clear how much information they should contain or how often they should be produced.

This study has shown that it is possible to monitor teenagers' driving electronically, but in-vehicle alerts are insufficient to change behavior. Close and continuous monitoring by their parents is the other key factor in improving teen driver behavior. It is yet to be determined how best to encourage such parent participation in the monitoring process.

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Table 1. Assignment of teenage drivers to research groups

Research group	Male	Female	All
Group 1: In-vehicle alert with immediate website notification (alert and web)	10	12	22
Group 2: In-vehicle alert with conditional website notification (alert then web)	9	11	20
Group 3: Immediate website notification only (web only)	10	11	21
Group 4: Control group (control)	9	12	21
Total	38	46	84

Table 2. Age and experience of subject drivers at time of device installation

	Age (years, months)			Experience (months licensed)		
Research group	Minimum	Maximum	Median	Minimum	Maximum	Median
Group 1 (alert and web)	16, 3	17, 10	17, 0	0	13	3.5
Group 2 (alert then web)	16, 4	17, 5	16, 10	0	13	3.0
Group 3 (web only)	16, 4	17, 6	16, 10	0	13	2.0
Group 4 (control)	16, 4	17, 6	16, 11	0	15	4.0
Total			16, 11			3.0

Table 3. Sudden braking/acceleration events per 100 miles driven

	Baseline			Treatment			Post-treatment		
Research group	Miles	Events	Rate	Miles	Events	Rate	Miles	Events	Rate
Group 1 (alert and web)									
Male	1,982	13	0.66	30,370	138	0.45	2,870	22	0.77
Female	3,001	19	0.63	34,759	125	0.36	3,912	5	0.13
Total	4,983	32	0.64	65,129	263	0.40	6,782	27	0.40
Group 2 (alert then web)									
Male	1,638	19	1.16	19,686	217	1.10	2,088	12	0.57
Female	4,123	49	1.19	38,076	306	0.80	4,070	39	0.96
Total	5,761	68	1.18	57,762	523	0.91	6,158	51	0.83
Group 3 (web only)									
Male	3,319	16	0.48	29,986	108	0.36	1,756	16	0.91
Female	4,349	26	0.60	39,367	255	0.65	3,940	19	0.48
Total	7,668	42	0.55	69,353	363	0.52	5,696	35	0.61
Group 4 (control)									
Male	2,845	17	0.60	33,808	290	0.86	2,747	22	0.80
Female	2,396	12	0.50	31,248	114	0.36	2,597	6	0.23
Total	5,241	29	0.55	65,056	404	0.62	5,344	28	0.52

Table 4. Miles not using seat belts per 100 miles driven (based on 71 subject vehicles)

	Baseline			Treatment			Post-treatment		
Research group	Miles driven	Miles nonuse	Rate	Miles driven	Miles nonuse	Rate	Miles driven	Miles nonuse	Rate
Group 1 (alert and web)									
Male	1,792	82.7	4.61	27,984	30.1	0.11	2,498	167.8	6.72
Female	2,657	81.4	3.06	31,048	22.7	0.07	3,290	7.7	0.23
Total	4,449	164.1	3.69	59,032	52.8	0.09	5,788	175.5	3.03
Group 2 (alert then web)									
Male	1,349	1.1	0.08	15,248	1.2	0.01	1,592	2.3	0.14
Female	3,184	9.9	0.31	29,287	9.2	0.03	2,672	2.0	0.07
Total	4,533	11.0	0.24	44,535	10.4	0.02	4,264	4.3	0.10
Group 3 (web only)									
Male	2,522	480.4	19.05	23,211	2,450.6	10.56	1,756	205.8	11.72
Female	3,225	60.4	1.87	30,276	182.4	0.60	2,914	20.2	0.69
Total	5,747	540.8	9.41	53,487	2,633.0	4.92	4,670	226.0	4.84
Group 4 (control)									
Male	2,681	377.3	14.07	29,418	4,910.6	16.69	2,171	490.8	22.61
Female	2,051	4.8	0.23	27,137	829.9	3.06	2,455	18.8	0.77
Total	4,732	382.1	8.07	56,555	5,740.5	10.15	4,626	509.6	11.02

Table 5. Miles speeding per 100 miles driven

	Baseline			Treatment			Post-treatment		
Research group	Miles driven	Miles speeding	Rate	Miles driven	Miles speeding	Rate	Miles driven	Miles speeding	Rate
Group 1 (alert and web)									
Male	1,982	345.6	17	30,370	6,366.7	21	2,870	644.5	22
Female	3,001	596.2	20	34,759	8,858.5	25	3,912	924.8	24
Total	4,983	941.8	19	65,129	15,225.2	23	6,782	1,569.3	23
Group 2 (alert then web)									
Male	1,982	376.8	19	21,966	4,818.9	22	2,296	411.6	18
Female	4,123	1,139.2	28	38,076	9,823.2	26	4,070	1,087.4	27
Total	6,105	1,516.0	25	60,042	14,642.1	24	6,366	1,499.0	24
Group 3 (web only)									
Male	3,319	806.0	24	29,986	8,339.8	28	1,756	436.4	25
Female	4,349	1,042.0	24	39,367	10,386.6	26	3,940	1,054.6	27
Total	7,668	1,848.0	24	69,353	18,726.4	27	5,696	1,491.0	26
Group 4 (control)									
Male	2,845	699.8	25	33,808	9,121.1	27	2,747	727.3	26
Female	2,396	614.1	26	31,248	8,771.5	28	2,597	711.6	27
Total	5,241	1,313.9	25	65,056	17,892.6	28	5,344	1,438.9	27

Table 6. Miles speeding by more than 10 mph per 100 miles driven

	Baseline			Treatment			Post-treatment		
Research group	Miles driven	Miles speeding	Rate	Miles driven	Miles speeding	Rate	Miles driven	Miles speeding	Rate
Group 1 (alert and web)									
Male	1,982	144.5	7	30,370	2,550.9	8	2,870	294.4	10
Female	3,001	232.0	8	34,759	3,156.8	9	3,912	328.1	8
Total	4,983	376.5	8	65,129	5,707.7	9	6,782	622.5	9
Group 2 (alert then web)									
Male	1,982	167.5	8	21,966	1,935.3	9	2,296	160.7	7
Female	4,123	678.4	16	38,076	4,147.5	11	4,070	620.4	15
Total	6,105	845.9	14	60,042	6,082.8	10	6,366	781.1	12
Group 3 (web only)									
Male	3,319	327.0	10	29,986	3,767.3	13	1,756	180.2	10
Female	4,349	433.0	10	39,367	4,696.5	12	3,940	535.3	14
Total	7,668	760.0	10	69,353	8,463.8	12	5,696	715.5	13
Group 4 (control)									
Male	2,845	345.0	12	33,808	4,406.8	13	2,747	403.1	15
Female	2,396	263.1	11	31,248	4,377.8	14	2,597	388.9	15
Total	5,241	608.1	12	65,056	8,784.6	14	5,344	792.0	15

Table 7. Relative risk of sudden braking/acceleration

Comparison	Risk ratio	95% confidence interval	
		Lower limit	Upper limit
Light truck vs. car	0.75	0.67	0.83
17- vs. 16-year-old driver	0.83	0.75	0.91
4+ months driving experience vs. less	1.16	1.05	1.28
Female vs. male driver	0.77	0.70	0.85
Group 1 (alert and web): Treatment vs. baseline	0.57	0.34	0.97
Group 2 (alert then web): Treatment vs. baseline	0.69	0.44	1.09
Group 3 (web only): Treatment vs. baseline	0.88	0.54	1.44
Group 1 (alert and web): Post-treatment vs. baseline	0.70	0.34	1.45
Group 2 (alert then web): Post-treatment vs. baseline	0.76	0.40	1.43
Group 3 (web only): Post-treatment vs. baseline	1.21	0.61	2.40

Table 8. Relative risk of unsafe driving behavior (adjusted for vehicle and driver characteristics)

Behavior	Comparison	Risk ratio	95% confidence interval	
			Lower limit	Upper limit
Seat belt nonuse	Group 1 (alert and web): Treatment vs. baseline	0.02	0.01	0.02
	Group 2 (alert then web): Treatment vs. baseline	0.07	0.03	0.17
	Group 3 (web only): Treatment vs. baseline	0.39	0.34	0.45
	Group 1 (alert and web): Post-treatment vs. baseline	0.51	0.40	0.66
	Group 2 (alert then web): Post-treatment vs. baseline	0.25	0.08	0.77
	Group 3 (web only): Post-treatment vs. baseline	0.37	0.30	0.46
Speeding	Group 1 (alert and web): Treatment vs. baseline	1.12	1.03	1.22
	Group 2 (alert then web): Treatment vs. baseline	0.90	0.83	0.97
	Group 3 (web only): Treatment vs. baseline	1.02	0.94	1.09
	Group 1 (alert and web): Post-treatment vs. baseline	1.12	1.00	1.25
	Group 2 (alert then web): Post-treatment vs. baseline	0.88	0.80	0.98
	Group 3 (web only): Post-treatment vs. baseline	1.01	0.91	1.12
Speeding >10 mph	Group 1 (alert and web): Treatment vs. baseline	0.98	0.86	1.12
	Group 2 (alert then web): Treatment vs. baseline	0.63	0.57	0.70
	Group 3 (web only): Treatment vs. baseline	1.05	0.94	1.17
	Group 1 (alert and web): Post-treatment vs. baseline	0.92	0.78	1.09
	Group 2 (alert then web): Post-treatment vs. baseline	0.70	0.60	0.80
	Group 3 (web only): Post-treatment vs. baseline	1.00	0.86	1.16

Table 9. Relative risk of speeding by more than 10 mph

Comparison	Risk ratio	95% confidence interval	
		Lower limit	Upper limit
Light truck vs. car	1.06	1.03	1.08
17- vs. 16-year-old driver	1.16	1.13	1.19
4+ months driving experience vs. less	0.86	0.84	0.88
Female vs. male driver	1.11	1.09	1.14
Group 1 (alert and web): Early treatment vs. baseline	0.85	0.74	0.98
Group 2 (alert then web): Early treatment vs. baseline	0.57	0.51	0.64
Group 3 (web only): Early treatment vs. baseline	1.02	0.91	1.14
Group 1 (alert and web): Late vs. early treatment	1.31	1.23	1.40
Group 2 (alert then web): Late vs. early treatment	1.24	1.16	1.32
Group 3 (web only): Late vs. early treatment	1.07	1.01	1.14

Table 10. Average website visits by parents per subject – 24 subjects with initial study design

Research group	Male	Female	All
Group 1: In-vehicle alert with immediate website notification (alert and web)	14	2	7
Group 2: In-vehicle alert with conditional website notification (alert then web)	8	35	23
Group 3: Immediate website notification only (web only)	16	23	20
Total	12	23	18

Table 11. Average website visits by parents per subject – 39 subjects with revised study design

Research group	Male	Female	All
Group 1: In-vehicle alert with immediate website notification (alert and web)	14	5	9
Group 2: In-vehicle alert with conditional website notification (alert then web)	14	9	11
Group 3: Immediate website notification only (web only)	13	13	13
Total	14	8	11

Table 12. Relative risk of unsafe behavior – 31 subjects with initial study design

Behavior	Comparison	Risk ratio	95% confidence interval Lower limit	95% confidence interval Upper limit
Sudden brake/ acceleration	Group 1 (alert and web): Treatment vs. baseline	0.76	0.27	2.16
	Group 2 (alert then web): Treatment vs. baseline	1.31	0.51	3.32
	Group 3 (web only): Treatment vs. baseline	1.49	0.55	4.00
	Group 1 (alert and web): Post-treatment vs. baseline	0.41	0.10	1.74
	Group 2 (alert then web): Post-treatment vs. baseline	1.40	0.44	4.47
	Group 3 (web only): Post-treatment vs. baseline	1.40	0.39	5.06
Seat belt nonuse	Group 1 (alert and web): Treatment vs. baseline	0.00	0.00	0.10
	Group 2 (alert then web): Treatment vs. baseline	0.00	0.00	0.11
	Group 3 (web only): Treatment vs. baseline	0.00	0.00	0.04
	Group 1 (alert and web): Post-treatment vs. baseline	0.00	0.00	0.23
	Group 2 (alert then web): Post-treatment vs. baseline	0.08	0.00	3.57
	Group 3 (web only): Post-treatment vs. baseline	0.01	0.00	0.12
Speeding	Group 1 (alert and web): Treatment vs. baseline	1.35	1.15	1.59
	Group 2 (alert then web): Treatment vs. baseline	1.13	1.00	1.28
	Group 3 (web only): Treatment vs. baseline	1.17	1.04	1.31
	Group 1 (alert and web): Post-treatment vs. baseline	1.39	1.14	1.70
	Group 2 (alert then web): Post-treatment vs. baseline	1.07	0.90	1.26
	Group 3 (web only): Post-treatment vs. baseline	1.30	1.11	1.52
Speeding >10 mph	Group 1 (alert and web): Treatment vs. baseline	1.18	0.92	1.53
	Group 2 (alert then web): Treatment vs. baseline	0.96	0.79	1.15
	Group 3 (web only): Treatment vs. baseline	1.12	0.94	1.33
	Group 1 (alert and web): Post-treatment vs. baseline	0.97	0.71	1.32
	Group 2 (alert then web): Post-treatment vs. baseline	0.92	0.72	1.16
	Group 3 (web only): Post-treatment vs. baseline	1.23	0.97	1.56
	Group 1 (alert and web): Early treatment vs. baseline	1.17	0.90	1.52
	Group 2 (alert then web): Early treatment vs. baseline	0.93	0.77	1.13
	Group 3 (web only): Early treatment vs. baseline	1.10	0.92	1.33
	Group 1 (alert and web): Late vs. early treatment	0.95	0.84	1.08
	Group 2 (alert then web): Late vs. early treatment	0.98	0.88	1.09
	Group 3 (web only): Late vs. early treatment	0.98	0.88	1.09

Table 13. Relative risk of unsafe behavior – 53 subjects with revised study design

Behavior	Comparison	Risk ratio	95% confidence interval	
			Lower limit	Upper limit
Sudden brake/ acceleration	Group 1 (alert and web): Treatment vs. baseline	0.62	0.34	1.14
	Group 2 (alert then web): Treatment vs. baseline	0.61	0.36	1.02
	Group 3 (web only): Treatment vs. baseline	0.81	0.46	1.43
	Group 1 (alert and web): Post-treatment vs. baseline	1.00	0.43	2.36
	Group 2 (alert then web): Post-treatment vs. baseline	0.52	0.23	1.21
	Group 3 (web only): Post-treatment vs. baseline	1.19	0.52	2.69
Seat belt nonuse	Group 1 (alert and web): Treatment vs. baseline	0.01	0.01	0.02
	Group 2 (alert then web): Treatment vs. baseline	0.05	0.02	0.15
	Group 3 (web only): Treatment vs. baseline	0.41	0.36	0.48
	Group 1 (alert and web): Post-treatment vs. baseline	0.54	0.42	0.70
	Group 2 (alert then web): Post-treatment vs. baseline	0.05	0.00	0.78
	Group 3 (web only): Post-treatment vs. baseline	0.41	0.33	0.50
Speeding	Group 1 (alert and web): Treatment vs. baseline	1.01	0.91	1.12
	Group 2 (alert then web): Treatment vs. baseline	0.77	0.69	0.85
	Group 3 (web only): Treatment vs. baseline	0.95	0.86	1.05
	Group 1 (alert and web): Post-treatment vs. baseline	0.95	0.83	1.09
	Group 2 (alert then web): Post-treatment vs. baseline	0.78	0.68	0.90
	Group 3 (web only): Post-treatment vs. baseline	0.86	0.75	0.98
Speeding >10 mph	Group 1 (alert and web): Treatment vs. baseline	0.90	0.77	1.06
	Group 2 (alert then web): Treatment vs. baseline	0.42	0.37	0.48
	Group 3 (web only): Treatment vs. baseline	1.07	0.92	1.23
	Group 1 (alert and web): Post-treatment vs. baseline	0.86	0.71	1.06
	Group 2 (alert then web): Post-treatment vs. baseline	0.57	0.47	0.69
	Group 3 (web only): Post-treatment vs. baseline	0.89	0.74	1.09
	Group 1 (alert and web): Early treatment vs. baseline	0.79	0.67	0.93
	Group 2 (alert then web): Early treatment vs. baseline	0.43	0.37	0.50
	Group 3 (web only): Early treatment vs. baseline	1.08	0.93	1.26
	Group 1 (alert and web): Late vs. early treatment	1.32	1.22	1.44
	Group 2 (alert then web): Late vs. early treatment	0.92	0.83	1.02
	Group 3 (web only): Late vs. early treatment	0.95	0.87	1.02

Table 14. Percent change in risky behavior relative to control group (from Poisson regression) – 31 subjects with initial study design

Research group	Risky behavior	Treatment vs. baseline	Post-treatment vs. baseline
Group 1 (alert and web)	Sudden brake/acceleration	-24	-59
	Seat belt nonuse	-100*	-100*
	Speeding	+35*	+39*
	Speeding >10 mph	+18	-3
Group 2 (alert then web)	Sudden brake/acceleration	+31	+40
	Seat belt nonuse	-100*	-92
	Speeding	+13*	+7
	Speeding >10 mph	-4	-8
Group 3 (web only)	Sudden brake/acceleration	+49	+40
	Seat belt nonuse	-100*	-99*
	Speeding	+17*	+30*
	Speeding >10 mph	+12	+23

*Statistically significant at the 0.05 level

Table 15. Percent change in risky behavior relative to control group (from Poisson regression) – 53 subjects with revised study design

Research group	Risky behavior	Treatment vs. baseline	Post-treatment vs. baseline
Group 1 (alert and web)	Sudden brake/acceleration	-38	0
	Seat belt nonuse	-99*	-46*
	Speeding	+1	-5
	Speeding >10 mph	-10	-14
Group 2 (alert then web)	Sudden brake/acceleration	-39	-48
	Seat belt nonuse	-95*	-95*
	Speeding	-23*	-22*
	Speeding >10 mph	-58*	-43*
Group 3 (web only)	Sudden brake/acceleration	-19	+19
	Seat belt nonuse	-59*	-59*
	Speeding	-5	-14*
	Speeding >10 mph	+7	-11

*Statistically significant at the 0.05 level

Figure 1
Percent of miles driven while more than 10 mph above posted speed limits

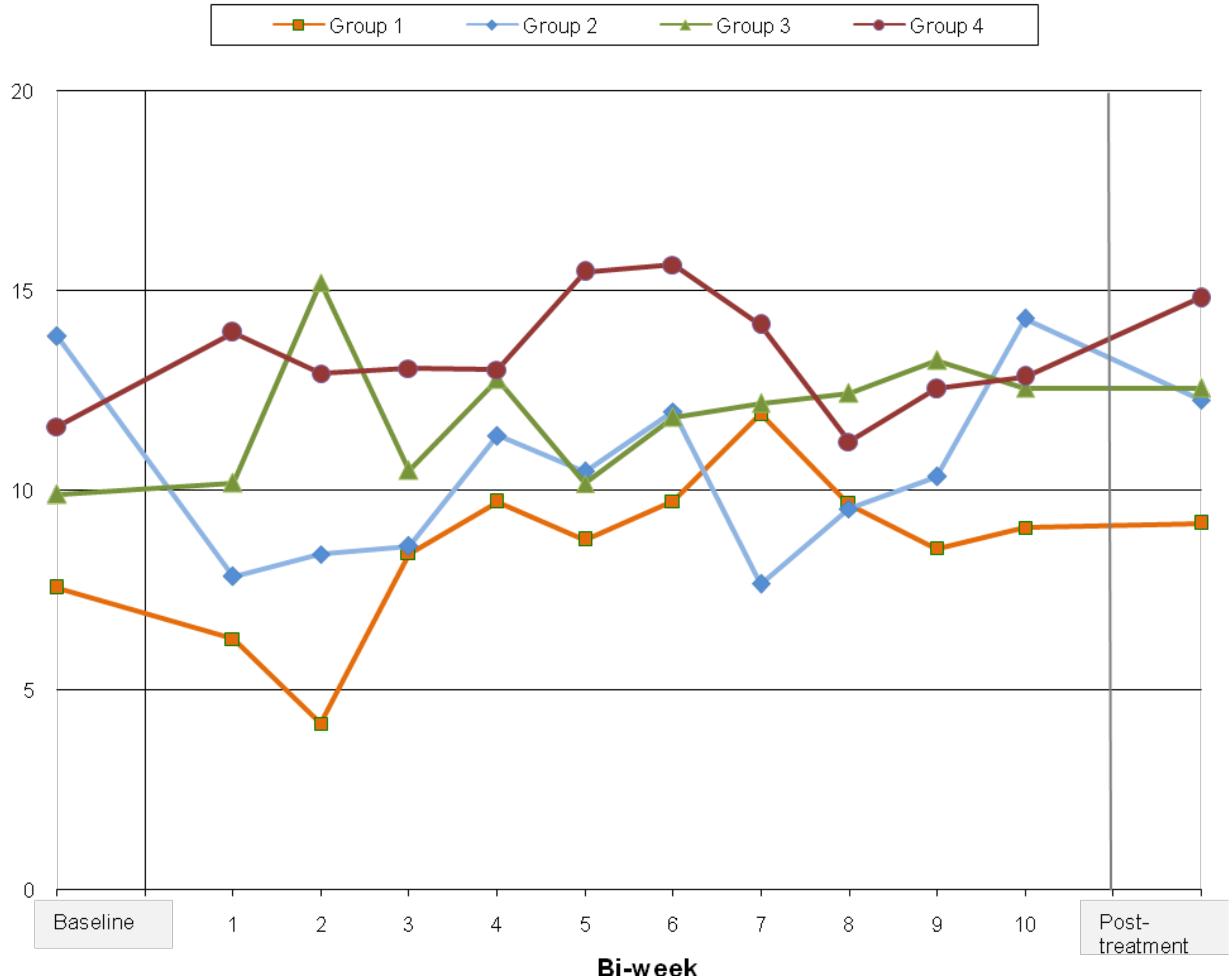

Figure 2
Percent of miles driven while more than 10 mph above posted speed limits – 31 subjects with initial study design

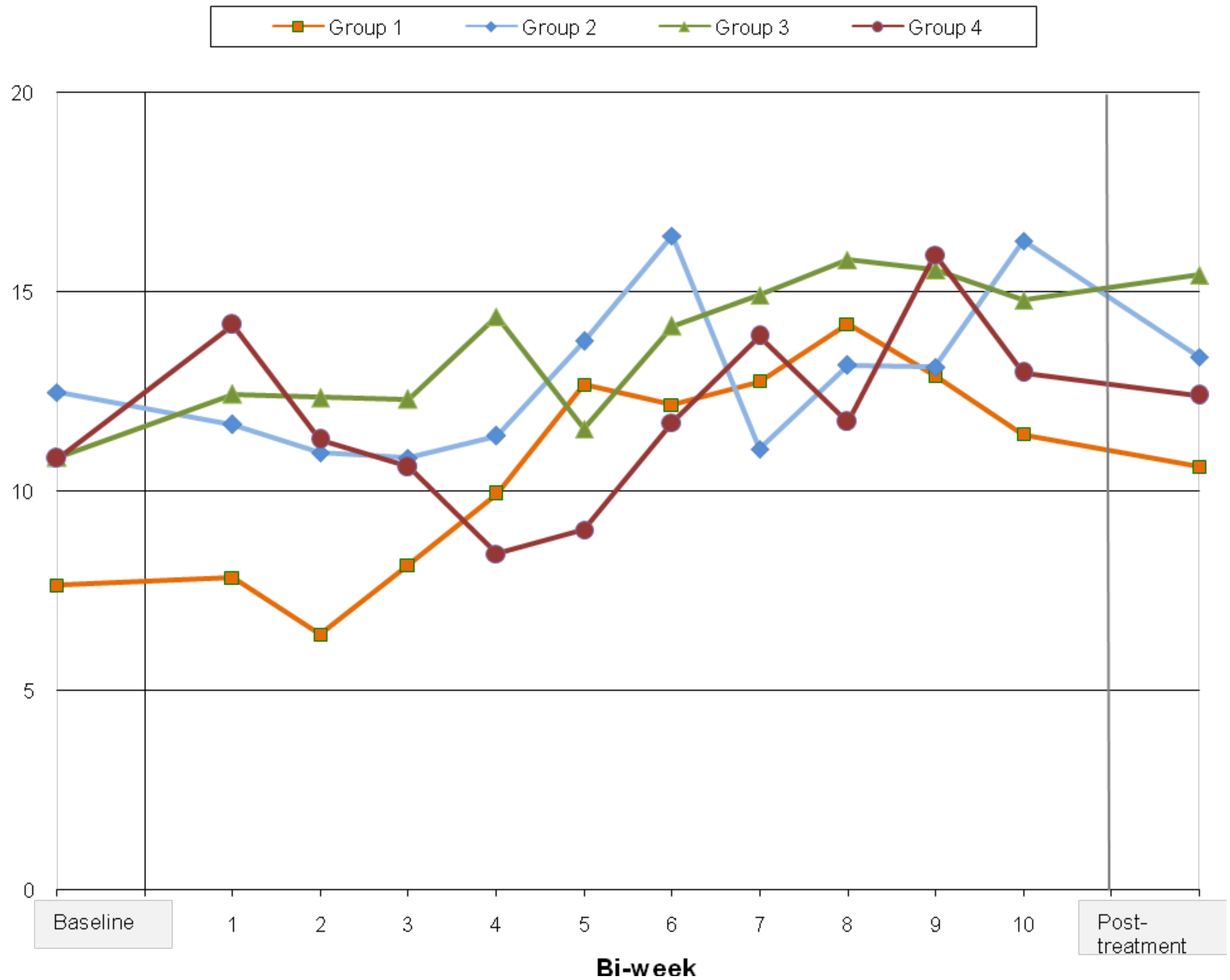

Figure 3
Percent of miles driven while more than 10 mph above posted speed limits – 53 subjects with revised study design