Chapter 20: Feedback Technologies to Young Drivers

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Abstract

Newly-licensed drivers are over-represented in road crashes, and especially during their first months of solo driving. Changes in licensing and development of training programs have addressed this inflated risk with focus on gradual exposure of young drivers to the various risky driving conditions and circumstances, and training towards improvement of hazard anticipation, hazard mitigation and attention maintenance.

Recent advancements in ADAS (Advanced Driver Assistance Systems) to drivers can help young drivers reduce their risks. In this Chapter we focus on feedback technologies which monitor and provide feedback to young drivers and their parents. These systems have been in the market, mostly in research studies and insurance programs for over a decade. Most studies showed large reductions (over 50%) in safety related event rates when feedback was provided. However, only one study, yet, managed to show positive correlation with crash rates of teen drivers. Despite these positive indications regarding safety benefits – feedback systems to young drivers are still far from being widely acknowledged, accepted and used. Barriers to acceptance and usage from the young drivers' point of view include: invasion of privacy and restriction of independence, lack of trust and fear that the feedback will become an instrument for punishment and limitation of car use.

Similarly, parents express concerns related to privacy, parent-young driver relationship and erosion of trust.

This chapter suggests directions to overcome the barriers through improved operation, increased motivation and incentives. These directions include: improving ease of installment, Pay-How-You-Drive insurance model, increased parents' involvement, incentives, positive positioning of the feedback systems, privacy protection and legislation. The importance of positive Media discourse, as well as the recommendation to install the system prior to onset of the solo driving can also contribute to wide acceptance and effective usage.

Finally, it is important to note that effective operation of feedback systems requires a sustainable process which incorporates feedback indicating deviations from safe driving behavior of young drivers over time.

Keywords

Feedback, monitoring, in-vehicle technologies, parental involvement, safety-related events, young drivers

Key points

- Feedback technologies are mature and readily available.
- Feedback can help reduce risky behaviors being monitored
- Parental involvement is essential for feedback effectiveness.
- In most studies, event rates increase after the feedback is removed, but partial effects are sustained.
- Limited evidence exists to correlate event rates to crash risks.
- Teen and parents lack of acceptance are barriers to wide use
- Wide use may be promoted by systems of monetary and social incentives

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1. What are Feedback Technologies?

With current licensure practices, the formal training and monitoring of young drivers end immediately after passing the driving test, or at the end of a provisional licensing period within graduated driver licensing (GDL) programs. However, the empirical evidence shows that at this point young drivers still lack the skills, experience and understanding to perform well as drivers. They also often lack the maturity to drive responsibly, in particular in the presence of peer pressure. Furthermore, parents' presence, which played a significant role during the learners and provisional phases, disappears, leaving the young drivers on their own. Thus, continuous training, monitoring and feedback on driving to the young, already licensed, drivers could play a useful role in the intermediate period until they gain experience, skills and maturity.

Driving is a continuance of actions and interactions between the driver and the environment in which the driver operates. According to traditional classifications, feedback is defined by provision of information about a system or process that may affect a change in the process. In the context of driving, feedback generally pertains to information about the environment in which the driving occurs. This definition is clearly very broad as information is everywhere and pertains to numerous aspects that can have an effect on driving and is continuously generated and accumulated.

In the context of driving, feedback systems filter the huge amounts of data available into information that pertains to specific behaviors, conditions, predicted risks and interactions. Dynamic feedback systems are often user-specific, updated in real-time and can be continuously accumulated and provided. These can be further sub-divided into alerting and monitoring systems. Alerting systems focus on specific behaviors (e.g., distance keeping, speed management, distraction, and fatigue) and provide real-time alerts to drivers for the purpose of avoiding specific actual risks, mitigating undesired behavior or preventing dangerous behaviors while driving. Their focus is on preventing various situations before they occur or before they escalate. Monitoring systems document and accumulate actual (driving) behaviors, analyze them according to specific measures, determine their potential safety implications and provide feedback to either the driver or other parties (e.g. parents, insurers).

In this Chapter we address monitoring systems. In particular, the focus is on systems that are tailored for young drivers. The feedback can be provided in near real time about an event that has already occurred (as opposed to an alerting system which provides information in real time about an event that is about to occur) or off-line. The feedback is user-specific meaning that it pertains to actual behavior of a specific driver. In some cases it may also be situation specific, meaning that it pertains to specific behavior occurring in specific circumstances. We will not address alerting systems which do not store data on behavior.

The reason for this focus on monitoring systems is three fold. First, there are (yet) hardly any studies on young drivers' reaction and interactions with alerting systems (such as forward collision or lane departure warning systems), the circumstances that triggered the provision of alert, the actual response (if any) to alerts and their impact on crash risks. Second, alerting technologies can be (wrongly) interpreted as taking away the responsibility from the driver. For example, a forward collision warning systems that alerts the driver about the high probability of a rear-end crash into the lead vehicle might cause the driver to (over) trust its reliability and be less attentive to distance keeping or attention maintenance. Hence, drivers can be tempted to shift responsibility from themselves to the alerting technology and therefore increase their risk. Monitoring systems, on the other hand, do not take responsibility away from the driver, but rather collect and provide information that can eventually (if handled correctly) help drivers modify their behavior to be safer. Third, a major key success factor for the effectiveness of monitoring feedback systems is the presence and involvement of a relevant entity that cares about the safety of the specific driver. For young drivers this entity is often the parents. Indeed, monitoring feedback systems provide parents with actual tools to be actively involved in the driving behavior of their children. Hence the relevance of such systems to young drivers and their parents is direct, measurable and has already proven to be effective.

2. How does it work?

Various feedback applications have been developed and tested. Some examples include those reported by McGehee et al. (2007), Toledo et al. (2008) and Lerner et al. (2010). While they vary in specific features and capabilities, they commonly incorporate several generic tasks as described in Figure 1.

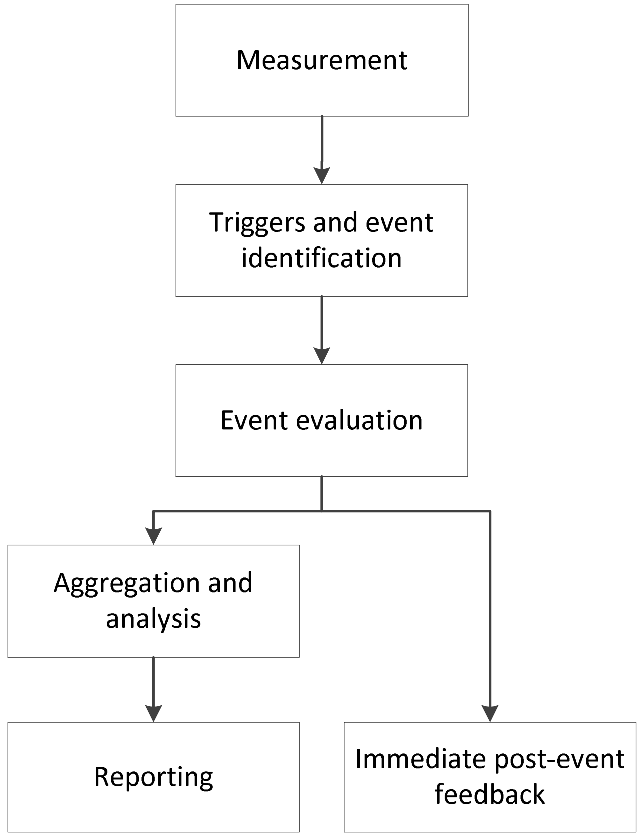

Figure 1 Generic framework of a feedback system

Measurement. The core technology may include one or several types of sensors that provide the raw information about the state of the vehicle and its surroundings. The technology may use sensors that already exist in the vehicle or in another device that the technology is attached to (e.g. a smartphone or navigation device). It may also incorporate its own integral sensors that make the technology stand-alone. Typically several information items are collected, with the corresponding types of sensors, for example:

1. G-forces that operate on the vehicle. These are typically measured by accelerometers in two or three dimensions.
2. The speed of the vehicle measured by a vehicle speed sensor or derived from a global positioning system (GPS).

3. Position of the vehicle, typically measured using a GPS receiver.
4. Use of seat belts. This and the state of various other systems in the vehicle may be obtained from the on-board diagnostics (OBD) or using a camera inside the vehicle.
5. Identification of the driver and presence of passengers may be detected by a camera or by the use of magnetic keys, Bluetooth readers or similar devices.
6. Distance and headway from the vehicle in front (and potentially other vehicles and obstacles). This is measured by range sensors or cameras.
7. Lane keeping and lane departure measured by range sensors or cameras according to lane markings.
8. Time stamp on measurements.

Triggers and event identification. The collected measurements are processed to detect various types of events. This step is necessary in order to reduce the large amount of raw data to meaningful information. In some cases, event identification may be straightforward and performed within the sensor system. For example, braking or speeding events may be defined when deceleration rates or speed values, respectively, exceed certain thresholds. Identification of other events, such as cornering or lane departures, typically involves complex image processing or pattern recognition algorithms.

Event evaluation. The identified events are evaluated in terms of their severity and predicted associated risk. The evaluation takes into account parameters of the events, such as the values of the variables of interest that were measured (e.g., maximum deceleration value in a braking event), other relevant variables (e.g., the speed at which the event took place) and the event duration.

Some applications use different types of information to trigger events and subsequently to identify and evaluate them. This is relevant in particular applications that use video cameras in order to avoid recording information continuously. They define specific conditions on other types of data that when satisfied, events are identified. For example, when acceleration values measured by accelerometers exceed a certain threshold, a video camera is triggered and a potential event is generated. The video data itself is used to determine whether or not a relevant event has actually occurred, and if so what its severity is.

Feedback from the applications may be provided in two ways:

1. Off-line, aggregated feedback on the overall driving
2. Immediate feedback related to a specific event that has just occurred.

Immediate post-event feedback. Feedback is provided shortly after the event has ended. It is typically delivered to the driver in the vehicle and involves an auditory and/or minimal visual signal. A distinction is made here between alerts that are aimed to warn the driver of a potential risk and feedback on a past event. The latter aims to help the driver identify and avoid risky situation in the future through increased awareness and sense of monitoring. It should be noted, that some current applications provide both warning and feedback capabilities. For the purpose of monitoring, immediate post-event feedback may also be provided outside the vehicle. For example, an automated text message detailing the event that has occurred may be delivered to the parents of a novice driver. This can serve two purposes: First, it allows providing immediate post-event feedback to another person that can act, in real-time, to prevent the driver from continuing to undertake undesired driving behaviors. Simply knowing that this threat exists might have a moderating effect on driving behavior (Ernest-Jones et al. 2011, van-Bommel et al. 2014). Second, provision of immediate feedback in the vehicle may be distracting to the driver. We are not aware of any studies evaluating this effect. But, it is clear that the risk of distraction has led to implementation of very limited and minimal forms of immediate feedback in current feedback systems.

Aggregation and analysis. Summary statistics on events are accumulated and analyzed for the purpose of providing feedback on the driving performance. These typically involve calculation of the rates of events (normalized by driving time or mileage) or other similar measures. These statistics are supposed to indicate on the risk of crash involvement. However, only few studies have evaluated the association between these statistics and crash risk. Wahlberg (2006, 2007), Bagdadi and Varhelyi (2011) found significant correlations between g-force measures and self-reported crash rates. The former used celerations (changes in speed), while the latter used jerk (changes in acceleration) as the predicting variables. Klauer et al. (2008) showed significant association between the classifications of drivers based on their crash records and the rates of each of lateral and longitudinal acceleration events and yaw rates. Toledo et al. (2008) found a positive connection between the overall rates of events defined by complex g-force patterns and recorded crash rates. Simons-Morton et al. (2012) developed a composite measure that takes into account the rates of several types of events. The composite measure was positively associated with crash rates. This study is the only one that addressed teen drivers.

In order to simplify the presentation of the results to drivers, some applications classify the event rates into categories based on pre-defined ranges of values.

Reporting. Periodic reports are presented to the driver, and in the context of novice drivers, often to their parents. These reports summarize the exposure and aggregate event statistics (or classifications) for the driver over the reporting period (e.g., week or month). In order to make the presented data more meaningful it is presented sometimes in comparison to the mean of a reference group of drivers. Trends in the events statistics over time are also shown. Reports are provided through dedicated webpages or emails. Figure 2 shows an example of a web-based monthly driver report that was used in Toledo et al. (2008). The chart at the top of the figure shows the various trips the driver made in the month. Each square represents a trip. The X axis indicates the day of the month and the Y axis indicates the accumulation of trips within each day. The color-coding of trips expresses classification in terms of event rates. Detailed information on each trip is presented as shown at the bottom of the figure.

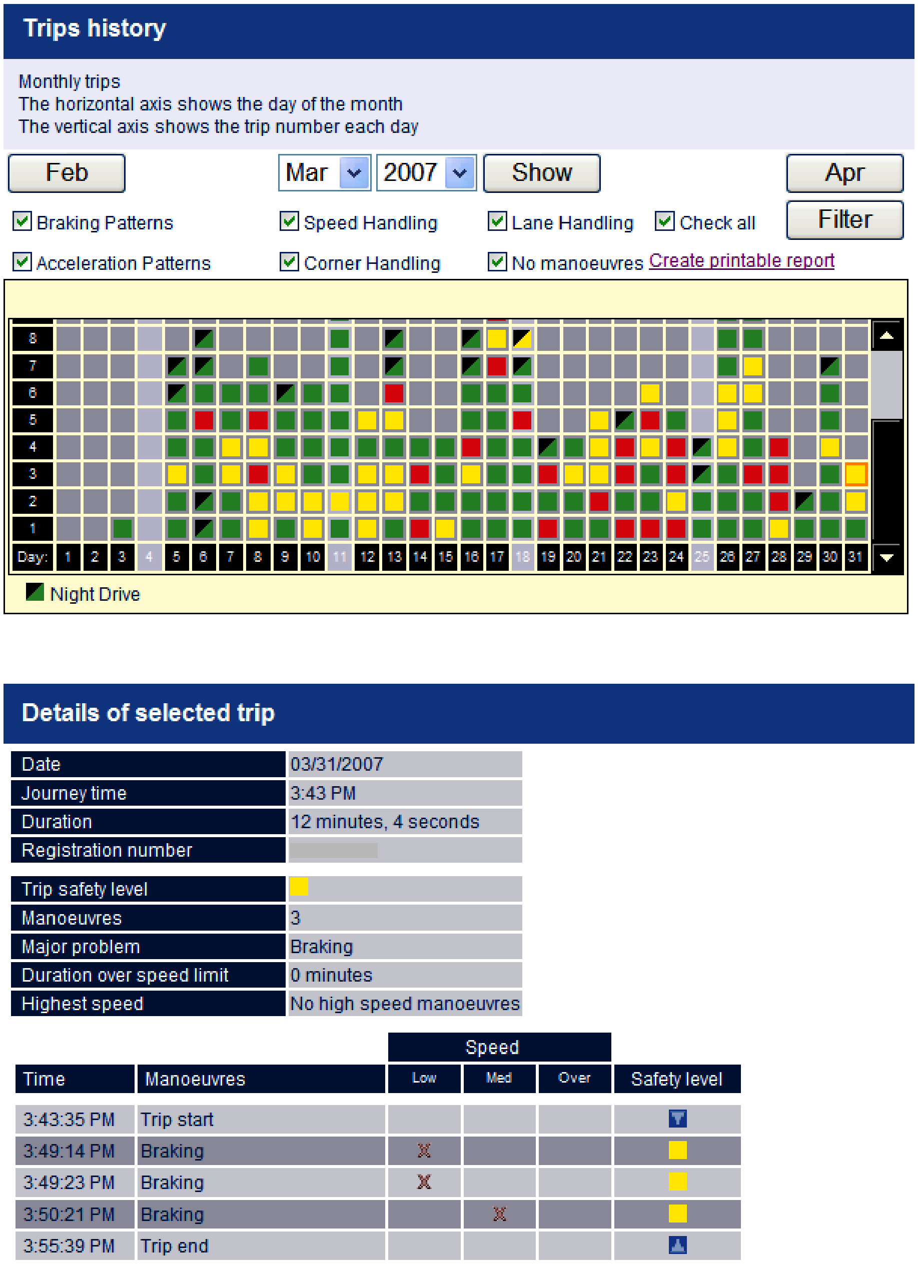

Figure 2 An example of a web-based driver report. The selected trip is the third trip taken on March 31, a yellow square outlined in red.

3. How effective are they?

Relatively few studies evaluated the effect of feedback technologies on driving behavior and risk, and in particular in the context of novice drivers.

Table 1 summarizes the setup and results of these studies.

Table 1 Studies that evaluated the effect of driving technologies

Reference	Description
McGehee et al., 2007	**Sample size and composition**: N=25, 16-17 years old drivers in Iowa with up to 1 year driving experience. **Measurement system**: Video-based recording of events that are triggered by g-force conditions, seat belt use. **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – weekly mail summaries of events and video clips to both parents and teens. **Experiment phases and duration**: Baseline – 9 weeks, no feedback. Intervention – 40 weeks with feedback. **Study groups**: Treatment only (no control). **Results**: *Impact* – Reduction of 58% and 76% in event rates in first and second 8-week feedback periods. 15% decrease in seat belt non-use. *Group effects* – Large reductions up to 89% in event rates within intervention for drivers with high event rates in baseline. No significant effect on drivers with low event rates in the baseline.
Carney et al., 2010	**Sample size and composition**: N=18, 16-17 years old drivers in Minnesota with up to 5 months of unsupervised driving experience. **Measurement system**: Video-based recording of events that are triggered by g-force conditions. **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – weekly mail summaries of events and video clips to parents who were asked to discuss them with the teens. **Experiment phases and duration**: Baseline – 6 weeks, no feedback. Intervention – 40 weeks with feedback. Second baseline – 6 weeks immediately after intervention, no feedback.

	Study groups: Treatment only (no control). **Results**: *Impact* – Reduction of 61% in event rates during intervention. Almost no effect on drivers with low event rates in the baseline. 64% reduction for drivers with high event rates. *After intervention* – No significant change from intervention to second baseline. *Feedback access* – 67% of novice drivers talked with parents about feedback at least once per month.
Farmer et al., 2010	**Sample size and composition**: N=84, 16-18 years old drivers in Washington DC with 0-15 (median: 3) months of unsupervised driving experience **Measurement system**: G-force events, seat belt use, speeding **Feedback**: *Real-time* – in-vehicle sounds. *Off-line* – web-based reports to parents only. **Experiment phases and duration**: Baseline – 2 weeks, no feedback. Intervention – 20 weeks with feedback. Second baseline – 2 weeks immediately after intervention, no feedback. **Study groups**: (i) Feedback off-line only to parents, (ii) in-vehicle to teens and off-line to parents, (iii) in-vehicle in all cases and off-line only if no immediate improvement in behavior, (iv) control. **Results**: *Impact* – Reduction of up to 43% in events, up to 98% in seat belt non-use, up 37% in speeding during interventions (i, ii and iii) compared to control. Most are not statistically significant. Within intervention, initially large reduction in events, and then gradual increase. *After intervention* – No large change from intervention to second baseline. *Group effects* – Lower impact for feedback off-line only group within intervention and second baseline. *Feedback access* – Average of one login per week. Added email notifications to participants during experiment. Login values reduced to 0.5 logins per week.
Musicant and Lampel, 2010	**Sample size and composition**: N=32, 17-24 years old drivers in UK. **Measurement system**: G-force events, speeding **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – web-based reports and weekly emails to parents only.

	Experiment phases and duration: Baseline – 14 weeks, no feedback. Intervention – up to 22 weeks with feedback. **Study groups**: Treatment only (no control). **Results**: *Impact* – Reduction of 59% in event rates during intervention compared to baseline. Reduction is higher for drivers with high scores in baseline.
Prato et al., 2010	**Sample size and composition**: N=62, 17 years old drivers in Israel within first year of driving. **Measurement system**: G-force events, speeding **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – web-based reports to parents and teens. **Experiment phases and duration**: Baseline – 18 weeks, no feedback. Intervention – 35 weeks with feedback. **Study groups**: Treatment only (no control). **Results**: *Impact* – Event rates lower by 15% if both parents and novice drivers access feedback, and 21% higher if only novice drivers access feedback compared to when only the parents access feedback. *Feedback access* – 49% only parents, 22% only novice driver, 28% both.
McGehee et al., 2013	**Sample size and composition**: N=90, 14.5-15.5 years old school license drivers, 16-17 years old drivers with and without prior school license in Iowa. **Measurement system**: Video-based recording of events that are triggered by g-force conditions, seat belt and cellphone use, passengers in the vehicle. **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – weekly mail summaries of events and video clips to parents who were asked to discuss them with the teens.

	Experiment phases and duration: Baseline – 4 weeks, no feedback. Intervention – 16 weeks with feedback. Second baseline – 4 weeks immediately after intervention, no feedback. **Study groups**: (i) School license drivers, (ii) regular license drivers with and (iii) without previous school license driving experience. There is no control group with respect to the feedback. School licenses allow younger teens to drive only to and from school. **Results**: *Impact* – Reduction of 84%, 58%, and 68% in event rates for school license drivers, regular license drivers with and without prior experience compared to the first baseline, respectively. *After intervention* – increase in event rates for school drivers in second baseline compared to intervention (still 61% lower compared to first baseline). No significant change with regular license holders.
Simons-Morton et al., 2013	**Sample size and composition**: N=88, novice drivers in Michigan with under 4 weeks of unsupervised driving experience. **Measurement system**: Video-based recording of events that are triggered by g-force conditions. **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – weekly emails to parents and teens, website access with video clips. **Experiment phases and duration**: Baseline – 2 weeks, no feedback. Intervention – 13 weeks with feedback. **Study groups**: (i) Feedback in-vehicle only, (ii) both in-vehicle and off-line. No no-feedback control group. **Results**: *Impact* – Reduction of 54% in event rates with both in-vehicle and off-line feedback compared to in-vehicle only. *Feedback access* – 91% of parents accessed feedback at least once. Average of 0.78 logins per week. Logins on last week about fourth of first week.
Farah et al., 2014	**Sample size and composition**: N=217, 17-22 (mean 17.5) years old drivers in Israel with less than 1.5 month of driving experience.

	Measurement system: G-force events, speeding **Feedback**: *Real-time* – in-vehicle LED lights. *Off-line* – web-based reports to parents and novice drivers. **Experiment phases and duration**: 52 weeks with feedback. Covers 3 months of supervised and 9 months unsupervised driving within Israeli GDL program. **Study groups**: (i) offline Feedback to novice drivers only, (ii) offline feedback to both novice drivers and parents, (iii) training to parents in addition to feedback, (iv) control. **Results**: *Impact* – Reduction of 10% in event rates to feedback groups and 29% to group with additional training over the control during unsupervised driving. No differences in supervised driving period. *Group effects* – Differences between training and feedback only groups are only for drivers with higher initial event rates (Musicant et al. 2013). *Feedback access* – Initially high access rates. Decline by 60% within 6 months, and 90% within 12 months.

Individually, the studies summarized in the table suffer from limitations on the experimental design and small sample sizes. In fact, Farah et al. (2014) is the only study with more than a hundred participants. Most of the studies did not include control groups and so relied only on within-subject analysis. The two exceptions are Carney et al. (2010) and Farah et al. (2014). Interestingly, the feedback effects in these two studies are among the lowest reported. Most of the studies showed large reductions (over 50%) in safety-related event rates when feedback was provided. Farmer et al. (2010) found 43% reductions. Farah et al. (2014) and Prato et al. (2010) found lower reductions, less than 20%. The studies with lower reductions were all based on g-force events. This approach may generate more false events that are not affected by the feedback compared to video-based events. McGehee et al. (2007) and Farmer et al. (2010) also found reductions in seat-belt non-use. Feedback provided both in the vehicle and off-line yields lower event rates compared to providing only one of the feedback types (Farmer et al. 2010, Simons-Morton 2013). This seems to indicate that both types are useful and complementary. Off-line feedback provided to both parents and novice drivers is the most useful to reduce event rates, followed by feedback to the parents only, and then to the novice drivers only (Farah et al. 2014). Observations of feedback access (through web logins or self-reports) indicate that most participants access the feedback and use it for intra-familial communications (Carney et al. 2010, Farmer et al. 2010, Simons-Morton et al. 2013, Farah et al. 2014). However, the rates of feedback access decline drastically from the beginning to the end of the experiments (Simons-Morton et al. 2013, Farah et al. 2014). Within the intervention periods, the reductions in event rates are maintained over the entire period (McGehee et al. 2007, 2013, Carney et al. 2010). However, when a second baseline was used at the end of the intervention, event rates did not increase substantially in this period (Carney et al. 2010, Farmer et al. 2010, McGehee et al. 2013). An exception to this is a group of 14.5-15.5 years old drivers (McGehee et al. 2013). Among the participants, McGehee et al. (2007), Carney et al. (2010) and Musicant and Lampel (2010) found that the reductions in event rates are proportionally larger for drivers that initially had high event rates than for drivers who had lower event rates. This may be partially a result of regression to the mean. But, drivers that initially had low event rates did not exhibit increase in the event rates. They generally had small or negligible reductions in event rates.

4. How far are we from wide dissemination?

Feedback technologies for young drivers have been around for almost a decade. Their effectiveness has been demonstrated in a number of studies, showing reductions in event rates and (although in a limited number of cases) a connection to crash rates. Nevertheless, we are still far away from wide dissemination.

There are two major target audiences to be considered when investigating acceptance and usage of feedback technologies: the young drivers' population and their parents. Clearly those two groups have very different views on acceptance and usage, especially in non-symmetric situations, when parents are exposed to the driving feedback of their teen driving and not vice versa. In this section we discuss barriers to acceptance as well as mechanisms to overcome them through incentives and positive motivation.

4.1 Barriers to acceptance and usage

Views of teen drivers regarding in-vehicle feedback technologies were qualitatively studied in Gesser-Edelsburg and Guttman (2013). Personal individual interviews were conducted with 26 teens that had used the technology. Eighteen focus group interviews were conducted with teens that had not. The main findings were that the teens' views of feedback technologies were analogous to their negative views on actual parental accompaniment, namely: invasion of privacy and restriction of independence. Other issues that were raised by teens referred to lack of trust and fear that the feedback will become an instrument for punishment and limitation of car use. However, teens also attributed positive functions to the technology as an "objective" indicator that would be acceptable to both parents and teen drivers when they perform well or need to improve in particular driving maneuvers. Yet, the overriding perceptions of the technology were negative and viewed as an extension of parental supervision that could introduce tensions and frictions into the parent–young driver relationship. Another finding was that teens had mixed and contradictory views of their parents as role models. This has implications for their acceptance of parental authority regarding safer driving advice. The feedback from a more "objective" technological device could thus be viewed as more credible. These findings indicate that parents' involvement through use of feedback technologies requires guidance. It is hence recommended that parents' "accompaniment" both directly and through use of feedback technology must be branded not as means for parents to employ sanctions but rather as means to enhance driving skills.

Guttman and Lotan (2011) report on parents' attitudes and views regarding the use and ethics of driver-monitoring technologies. The study is based on phone interviews of 906 parents of young drivers. Most believed that parents should feel morally obligated to install it. When cost was not a consideration, most said they would, and believed other parents would also be willing to install the technology. About half of the respondents expressed willingness to install the technology after being told about its estimated cost. The rest saw the monetary cost as a barrier to installation. Considerations of the family relations were viewed as an incentive. Parents that supported the installation believed it would serve as a trigger for parent–young driver communication. Those that did not support installation thought it would erode trust in the parent–young driver relationship. Parents that expressed great concern about their teen driving were also more likely to state that they would be willing to install the technology regardless of its monetary cost. Most said parents should have access to the monitoring data.

Guttman and Gesser Edelsburg (2011) conducted interviews with 79 young drivers and their parents who experienced driving with a feedback system. The main concerns raised were related to privacy, parent-young driver relationship, self-esteem and confidence, constructive use of the feedback data, and the limitations of the documentation that can be provided by the technology.

It is important to mention that although parents seem to be very positive when told about the technology and state that they will definitely use it for their teens – once they were offered to do so – even at no cost and with monetary incentive, in a research setting – they often chose not to.

4.2 Overcoming the barriers: incentives and motivations

It is evident that there are many barriers to the acceptance and usage of feedback systems by its two major target audiences: parents and teens. In order to reach wide dissemination these barriers have to be dealt with. Some of the barriers, mentioned in the previous section, have been addressed with varying degrees of success, other still need to be recognized and addressed:

Technology improvement. This is probably the easiest barrier to tackle as it requires dealing with equipment rather than with human perceptions and behavior.

Indeed feedback systems are becoming friendlier in several aspects, specifically regarding their ease of installation and de-installation. Some systems include a direct connection to the car's OBD (On-Board Diagnostics) which can be self-installed, requires only simple calibration, and provides smartphone-based feedback and even stand-alone smartphone apps.

Monetary incentives. Probably the most promising direction in this category is usage-based insurance, also known as Pay-As-You-Drive or Pay-How-You-Drive. In these schemes, car insurance costs also depend on dynamic driving parameters, such as: actual extent of driving, driving locations, time of driving, and the telematics-based measures of the quality/safety of driving. Several insurance companies, mostly in the US, are already implementing telematics usage-based insurance, with specific programs for young drivers (Bolderdijk et al. 2011). Understanding the effect of the various premium structures offered on different drivers (e.g. those with base high and low risk driving behavior) to enroll in these programs and on their behavior are still open research questions.

Parents remain the key agents for the introduction, effective usage and long term maintenance of safe driving with the help of feedback systems. However, research findings and market behavior show that typically parents do not adopt this role voluntary and need guidance and motivation to do so. Several programs have been suggested to involve parents in their teen driving using contracts, agreements and structured processes. Some of the programs include use of feedback systems (e.g. McGehee et al. 2007, Farah et al. 2013 2014). Research suggests that useful parental involvement is crucial to enhance their teens' safe driving (Prato et. al 2010, Farah et. al. 2014, Shimshoni et. al. 2015). Feedback systems provide a validated tool to help parents perform their role. However, their involvement needs to be legitimized (mostly by their teens), clarified and structured, as well as sustained over time.

Incentive-based systems. Ultimately, teens will choose whether or not to install a feedback system and use the feedback it provides. However their acceptance requires clear motivation or incentives. Recently, there have been some attempts to generate such feedback systems. A good example is the standalone smartphone app RefuelMe. When activated, it accumulates safe mileage (mileage driven with no unsafe events) and reports to a sponsor (typically the parent) who in turn provides the teen with a pre-specified reward. In this way teens are driving to earn desired rewards. Two pilot studies (Lotan et. al. 2014, Musicant et. al forthcoming) used this system with group rewards. These rewards are decided by the group members that accumulate the required mileage together. In the experiments, this scheme led to high levels of use of the system by the group members and even others in their social networks. But, once the rewards were achieved the use of the app practically stopped. Hence the question of how to move from external rewards to intrinsic motivation remains, and cannot be answered by incentives only.

Positive positioning. Feedback systems should be positively positioned as steering young drivers, not spying on them. In order to avoid one of the major barriers to acceptance, namely: privacy intrusion, the systems should be presented as helping young drivers and not as spying on them. Hence they should be informative with focus on recommended tips to achieve safe behavior rather than on emphasis of unsafe behaviors (Guttman and Lotan 2011). This is in agreement with findings from other public health domains (e.g. illness prevention, smoking cessation, and physical activity) according to which gain-framed messages appear to be more effective than loss-frame messages (Gallagher and Updegraff 2012).

User friendliness. Feedback systems compete in today's highly digital and over-stimulated world, hence they have to be attractive. Successful design of effective feedback needs to build on comprehensive understanding of the driver, the feedback and their interactions (Lee 2007, Feng and Dommez 2013). In order to make the systems attractive to teens and encourage their effective usage even without tangible rewards, special attention should be devoted to development of advanced user interfaces, learning capabilities, user-specific adjustments, dynamic scores and comparisons, competitions, gaming and social network implementations.

Privacy protection. A major concern regarding the use of feedback systems is intrusion of privacy. Several guidelines have been suggested to address this issue (Guttman 2012). First, use of the system has to be transparent and clear between the parent and teen, meaning that teens are fully aware of the information that is being collected. Second, data collection has to be minimal and limited to safety related driving. For example, location data was available in the study of Shimshoni et al. (2015), but it was not reported to parents since teens expressed concerns about their parents being exposed to their location. Hence the message from parents to teens was: 'I don't care where you drive, I care how you drive', which contributed to acceptance by teens. Third, exposure to the data collected can be dynamic and conditioned on actual driving behavior; as long as there is no indication of unsafe driving behavior – data is not transferred to parents, but once certain thresholds are reached – parents are notified. Fourth, even the extreme case, in which privacy is fully protected and only the young drivers are exposed to their driving information, feedback can be effective. In Farah et al. (2014) an experimental group with this type of feedback performed better than the control group.

Legislation can naturally contribute to wide use of feedback systems. These systems can, for example, be incorporated into the Graduated Driver Licensing (GDL) process as an intermediate stage between accompanied and independent driving. It may also be used to verify adherence to other restrictions or as means to allow controlled driving bypassing the restrictions. For example, the system can monitor night driving, or night driving may be allowed when the system is functional. To the best of our knowledge, such measures have not been implemented. Legislation would need to address obstacles regarding standardization and validation of the systems as well as enforcement mechanisms and guarantee of availability to all.

Change of media discourse. A major obstacle to wide dissemination of feedback systems lies in their positioning and marketing. Most news items and media coverage target the parents and position these technologies as 'big brother', tracking, monitoring and even spying. They are rarely presented as driving assistance tools, teaching and learning aids or safety enhancing systems. Clearly, this framing does not encourage young drivers to install feedback technologies with monitoring capabilities.

Timing of installation. Young drivers are eager to drive. Hence, it is recommended that the feedback system be installed before they start their independent driving. It is expected that the objection of young drivers to the feedback systems would be lower if it is pre-installed before they start independent driving. Furthermore, if installed early it can be used as a monitoring and learning tool during the learners' phase.

5. Summary

It is expected that advanced technological systems will become more widely used and accepted. Feedback monitoring systems can lead to significant decreases in the frequencies of undesired behaviors that they monitor and provide feedback on. This is in particular important for young drivers that exhibit high crash rates during their first year of driving.

Research clearly shows that correct implementation of feedback systems to young drivers can bring to large reductions (over 50%) in safety related event rates. Although, the evidence is still limited, there seems to be a connection between these behaviors and crash risks. Thus, feedback systems have a potential to improve the safety of young drivers if accepted and implemented correctly. Currently, feedback systems are still far away from being widely accepted and used. A number of barriers to acceptance by young drivers exist including: invasion of privacy, restriction of independence, lack of trust and limitations of the feedback systems. In order to reach wide dissemination the technological aspects of the systems have to be optimized and simplified, but more importantly, clear motivation and incentives (monetary or other) must be put in place in order to overcome the basic objection of young drivers to being monitored. Additionally, the feedback systems need to be positively positioned and marketed in order to help young drivers use them as an acceptable tool to increase their safety.

Finally, it should be kept in mind that as with many advanced new technologies, there might be deterioration in proper and effective usage of the system over time. Hence processes to encourage sustainable effective use must be put in place to ensure the safety of young drivers and their environment in the long run.

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