Teens have the highest crash rate of any group in the United States.

# The Transition to Unsupervised Driving

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## About the Sponsor

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## Summary

Although crash rates increase substantially when teens make the transition to unsupervised driving, little is known about the changes that occur during this critical period. The present study examined how the internal driving environment (e.g., passengers, belt use), external driving environment (e.g., time of day, traffic density), and the nature of driving incidents differs between the first four months of the learner period and the first six months of unsupervised driving. An event data recorder (Drivecam) was installed in the vehicles of 50 families of beginning teenage drivers at the outset of the learner stage. The recorders were re-installed in the vehicles of 38 of these families when the teen obtained an intermediate license. The analyses in this report are based on these 38 teens. The availability of event-based data from the same families during both the learner permit stage and the intermediate licensing stage provided a unique opportunity to explore how the driving environment and driving behaviors differ during these two periods. The findings suggest that driving conditions do appear to differ between the learner stage and the high risk initial period of unsupervised driving. During the intermediate license stage, a greater percentage of driving clips occurred in darkness or inclement weather than during the learner stage. In addition, loud, potentially distracting music was noticeably more common after teens obtained an intermediate license. The presence and composition of passengers also changed dramatically, shifting from parents and siblings during the learner stage to primarily friends. Notably risky or worrisome driving incidents were rare during both the learner and intermediate license stages. A relatively small number of teens accounted for many of the incidents during the intermediate license stage. Although this study provides important, new evidence on how the driving circumstances and conditions change when teens begin driving without a supervisor, there are inherent limitations of the study due to the sample size and underlying methods that are described in the study.

## Background

Previously, we conducted a study to investigate how parents approach the task of supervising a novice teen driver during the learner stage of graduated driver licensing (Goodwin, Foss, Margolis & Waller, 2010). The study involved regular interviews with parents to obtain detailed information about their experiences during the year-long learner stage. In addition, event-based data recorders were placed in the vehicles of participating families so parent and teen behaviors during practice sessions could be directly observed.

In the present project, we continued to follow these same families as teens made the transition to unsupervised driving. Data recorders were re-installed in teens' vehicles for the first six months following licensure. The primary objective was to accumulate data for future analyses concerning distracted driving, the risks associated with carrying teenage passengers, and other issues such as the similarities between parents' driving style and that of their teens'. However, the video data also permitted an examination of the transition from supervised driving to the high risk initial period of driving without a parent in the vehicle. Crash rates increase 12-fold when teens first begin driving unsupervised (Mayhew, Simpson & Pak, 2003), but the reasons behind this sharp increase are not well understood. Research has clearly shown the risks associated with nighttime driving (Williams, 2003), passengers (Chen et al., 2000) and alcohol (Mayhew et al., 1986). However, additional research is needed to probe the complex interaction of factors that contribute to crashes and "close calls" among newly licensed drivers.

It is strongly suspected by researchers that supervised driving is a somewhat unnatural driving condition because the parent is present. Their mere presence discourages many kinds of expressive, impulsive behaviors in which teenagers might otherwise engage (cf., Steinberg, 2008). Parental presence also alters travel times and locations, as well as the kinds of passengers and their behaviors in the vehicle. In brief, supervised driving is a substantially constrained experience, with the explicit goal of providing a safe condition in which a novice driver can learn. Thus, although supervised driving can provide experience with vehicle handling and the roadway environment – including both the physical infrastructure and the behaviors of other drivers – it cannot provide the experience of being fully in charge of a motor vehicle. The ability to manage oneself, handle potential distractions such as peer passengers, and deal with a variety of other potential behaviors and situations remains to be learned when a teenager begins driving without an adult in the vehicle.

This project provided a unique opportunity to obtain information that should increase our understanding of how the driving circumstances and conditions change when teens begin driving without a supervisor. By following teens through this critical transition period, we hoped to identify and document what conditions and behaviors change, and how, from the early learner stage to the initial months of unsupervised driving. The purpose for this part of the teenage driver study was to collect data during the initial six months of unsupervised driving. Initial analyses are provided here to describe similarities and differences in teens' driving during the learner and intermediate phases of licensing.

In this report, we first describe several characteristics of the internal driving environment, such as the presence of passengers, occupant belt use and music volume, and how these changed from the learner stage to the intermediate license stage. We then examine changes in the external driving environment, including the time/day of driving, ambient light, weather and traffic density. Finally, we consider how triggering events, g-forces, and driving incidents changed once teens obtained a license to drive unsupervised.

**North Carolina's Graduated Driver Licensing (GDL) System**

All new drivers under the age of 18 in North Carolina are required to hold a learner permit for 12 months before they are eligible for an intermediate (restricted) license. The earliest age at which teens can obtain an intermediate license is 16. Teens must hold the intermediate license for 6 months, during which they must have no violations or at-fault crashes to become eligible for a full, largely unrestricted license.

The following table shows restrictions covering the learner and intermediate stage in North Carolina at the time the study was conducted.[1]

| | Minimum entry age | Holding period | Restrictions |
|---|---|---|---|
| **Learner stage** | 15 | 12 months | • Teen must be supervised at all times by a parent or guardian<br>• No cell phone use while driving |
| **Intermediate license stage** | 16 | 6 months | • Between 9 p.m. and 5 a.m., driver must be supervised by a parent or guardian (exception when driving to/from work)<br>• Driver may carry no more than one person younger than 21 unless supervised (exception for family members)<br>• No cell phone use while driving |

[1] After the study was completed, North Carolina added a requirement that teens obtain 60 hours of supervised driving during the learner stage (10 of which must be at night), and 12 hours during the intermediate stage (6 of which must be at night).

## Methods

Fifty families were recruited through two Division of Motor Vehicles (DMV) offices in central North Carolina at the time teens applied for a learner permit.[2] Of the 50 families, 38 agreed to continue participating when the teen obtained an intermediate license. The reasons for declining to continue participation varied. Most commonly, it was the teen (rather than a parent) who decided not to continue once the teen obtained an intermediate license. However, some families were lost from the study when they moved out of state or the teen turned 18 and "aged out" of the GDL system.

Event-based data recorders were installed in the vehicle most often driven by the newly licensed teen driver. Recorders were usually installed within one week of the date of licensure and remained in the vehicle for six months. As in the previous study, the event-based data recorders were obtained from DriveCam. The DriveCam recorder is a palm-sized camera that captures video, audio and g-force information that describes vehicle movements. The camera is mounted on the windshield behind the rearview mirror and has two lenses – one is forward-facing to capture the scene in front of the vehicle, and the second faces rearward to record activity inside and behind the vehicle. Although the recorder runs continuously, it only saves information when a triggering "event" such as sudden braking or an abrupt turn occurs. Once triggered, it saves the 10 seconds preceding and 10 seconds following the event. Thus, the nature of the triggering event, as well as occupants' responses, can be viewed. The sensitivity of the data recorder (i.e., the change in g-force required to trigger the unit to record) is adjustable. The thresholds employed for the present study were 0.40 for longitudinal (forward/rearward) g-forces and 0.45 for lateral (sideways) g-forces. These matched the sensitivity settings employed during the initial phase of the study when teens were driving under supervision.

Teens were paid $200 for participating in this second phase of the study. This incentive was distributed in four graduated payments to encourage teen participation for the full six months. All aspects of the study were approved by the University of North Carolina Institutional Review Board.

### Selection of Video Clips

During the 228 total months data recorders were installed in vehicles during the intermediate license stage (6 months x 38 vehicles), 29,920 individual driving clips were recorded. The vehicles were sometimes shared with other family members. Hence, each driving clip was screened to identify the driver as well as the number and configuration of passengers. In total, 19,363 driving clips were recorded for the 38 teen drivers. In the remaining clips, the driver was a parent, sibling, friend, or someone else.[3] On average, there were 510 clips per teen driver

[2] See Goodwin et al. (2010) for a detailed description of the recruitment procedures.

[3] Because we had tracked families from the beginning of the learner stage, we were able to identify whether the vehicle occupants were siblings, parents, or non-family members. "Teenage peer" was defined as a non-sibling passenger between the ages of 13 and 20. The relationship between the driver and teenage peers was not known. They may have been close friends, casual acquaintances, or relative strangers.

from the intermediate license stage, ranging from 17 to 1,028. The configuration of passengers in all teen driver clips is presented in Table 1.

**Table 1**

Observed Passenger Configuration, Intermediate License Stage

| | N | % |
|---|---|---|
| No passengers | 12,567 | 65% |
| One teenage peer | 2820 | 15% |
| Two or more teenage peers | 913 | 5% |
| One sibling | 1,985 | 10% |
| Two or more siblings | 42 | < 1% |
| Teenage peer(s) & sibling(s) | 400 | 2% |
| Parent or other adult present* | 636 | 3% |

*Any clip where an adult passenger was present; may also include siblings, teenage peers or other passengers.

Because coding clips is a labor-intensive, time-consuming process, a sample of teen driver clips from the intermediate license stage was selected for coding. To ensure the findings were not biased toward the teens who recorded the most clips, a cap was set on the total number of clips selected for each of the participating drivers. Table 2 shows the maximum number of clips selected from any driver, based on the configuration of passengers in the vehicle. Clips with passengers were oversampled to ensure an adequate sample of cases with peer or sibling passengers for analysis in subsequent studies.

**Table 2**

Maximum Number of Driving Clips Selected per Driver by Passenger Configuration, Intermediate License Stage

| | Maximum no. sampled |
|---|---|
| No passengers | 60 |
| One teenage peer | 50 |
| Two or more teenage peers | 100 |
| One sibling | 50 |
| Two or more siblings | 70 |
| Teenage peer(s) & sibling(s) | 50 |
| Parent or other adult present | 35 |

Driving clips were randomly selected within each passenger configuration for each participating teen driver up to the pre-determined maximum number of cases. If a driver had fewer than the maximum number of clips for a certain passenger configuration, all clips with that configuration were selected. The median number of clips selected per teen was 154 (ranging from 10 to 235). In total, 5,859 driving clips from the 38 teen drivers were selected for full coding.[4]

**Data Weighting and Analysis**

Because clips with passengers were oversampled from the intermediate license stage, it was necessary to weight the final dataset of coded clips. The case weights are simply the inverse of the probability of selection based on the known passenger configurations of the full sample of teen driver clips (N=19,384). Because multiple clips were coded for each driver, all analyses took this clustering of measures within driver into account to ensure that standard errors (hence, confidence intervals) were correctly estimated.

The 5,859 driving clips were compared with the driving clips obtained from the learner permit stage, as reported in Goodwin et al. (2010). The learner stage included a total of 2,068 clips from 52 teen drivers; however, only 1,750 clips from the 38 teen drivers who continued to participate once they received an intermediate license are reported here. Although teens in North Carolina must hold the permit for a full year, cameras were only installed for the first four months of the learner stage; consequently, the two time periods being compared were separated by a minimum of eight months. In addition, because the duration of the observation periods differed (four months for the learner period, six months for the intermediate stage), comparisons between the two licensing stages should be based on percentages presented in the tables rather than the number of clips. Finally, in some cases data are missing due to darkness of the clip or other circumstances that prevented clear determination of passenger presence or characteristics, so the counts in the tables do not always total 5,859 and 1,750.

[4] This approach produced a stratified, cluster sample. Each driver represents a cluster; within each cluster the clips were stratified by passenger configuration to ensure an adequate number of each configuration was sampled to enable configuration-specific analyses.

## Results

### Participant Characteristics

Table 3 shows the characteristics of the 38 teens who had the camera re-installed when they obtained an intermediate license.

**Table 3**

Characteristics of Participating Teen Drivers

| | N | % |
|---|---|---|
| Age at licensure | | |
| 16 | 33 | 87% |
| 17 | 5 | 13% |
| Sex | | |
| Male | 12 | 32% |
| Female | 26 | 68% |
| Year in school | | |
| Sophomore | 16 | 42% |
| Junior | 18 | 47% |
| Senior | 4 | 11% |
| Primary vehicle driven by teen | | |
| Passenger car | 21 | 55% |
| Minivan | 7 | 18% |
| SUV | 6 | 16% |
| Pick-up truck | 4 | 11% |
| Vehicle access | | |
| Owned (or unlimited access) by teen | 12 | 32% |
| Vehicle shared with parent or sibling | 26 | 68% |

The 38 teens who had the camera re-installed did not significantly differ from the 14 who did not participate in terms of age, sex, or year in school (all *p*'s > .16). However, the 38 participants did record more driving clips during the learner stage (Median=40.5), on average, than teens who refused to participate (Median=19.0) (Median test, p<.01).

**Internal Driving Environment**

We first examined characteristics of the internal driving environment visible or audible in the driving clips. These included the presence of passengers, occupant belt use and music volume. These characteristics were then compared for the learner and intermediate license stages to see how the internal driving environment changed.

***Passengers.*** Information about the number and age of passengers carried is presented in Table 4.

**Table 4**

Presence and Composition of Passengers, by License Stage

| | Learner permit | | Intermediate license | |
|---|---|---|---|---|
| | Number of clips | % of clips | Number of clips | % of clips |
| Parent/adult presence | | | | |
| Present | 1,736 | 99% | 202 | 3% |
| Absent | 14 | 1% | 5,656 | 97% |
| Young passenger (<18) presence | | | | |
| Present | 599 | 34% | 2,016 | 36% |
| Absent | 1,138 | 66% | 3,627 | 64% |
| Number of passengers | | | | |
| Zero (driver was alone) | 2 | < 1% | 3,566 | 62% |
| One | 1,087 | 63% | 1,676 | 29% |
| Two | 496 | 29% | 368 | 6% |
| Three | 134 | 8% | 128 | 2% |
| Four or more | 19 | 1% | 46 | 1% |

As would be expected, the presence of a parent/adult dropped substantially, from 99% of clips during the learner stage to just 3% after teens obtained a license to drive unsupervised. The percentage of clips involving a young passenger did not differ between the learner and intermediate license stages (33% versus 36%; OR=0.97, 95% CI=0.90, 1.04). During the learner stage, nearly all of these young passengers were siblings. By comparison, young passengers during the intermediate license stage were often peers. When passengers were present during the intermediate stage, at least one of those passengers was a peer in 61% of the driving clips. By comparison, a sibling was present in 36% of clips with passengers.

***Belt use.*** Belt use among teen drivers and their passengers is shown in Table 5.

**Table 5**

Belt Use Among Teen Drivers and Passengers, by License Stage

| | Learner permit | | Intermediate license | |
|---|---|---|---|---|
| | Number of clips | % of clips | Number of clips | % of clips |
| Teen driver belt use | | | | |
| Belted | 1,677 | 99% | 5,349 | 98% |
| No belt | 19 | 1% | 107 | 2% |
| Right-front seat passenger | | | | |
| Belted | 1,648 | 99% | 1,959 | 94% |
| No belt | 22 | 1% | 135 | 6% |

During the learner stage, seat belt use was nearly universal among both teen drivers and their right-front seat passengers. Belt use remained high among teen drivers after they obtained an intermediate license. Among right-front seat passengers, however, belt use was lower during the intermediate license stage than during the permit stage (94% versus 99%; OR=0.95, 95% CI=0.94, 0.96). During the intermediate license stage, right-front seat passenger belt use was 92% among teenage peers, 96% among siblings, and 96% among parents. During the learner stage, the right-front seat passenger was a parent or adult in all but a handful of clips.

***Music or other audio.*** Table 6 displays the presence and volume of music or other audio[5] during the learner and intermediate license stages.

**Table 6**

Presence and Volume of Music, by License Stage

| | Learner permit | | Intermediate license | |
|---|---|---|---|---|
| | Number of clips | % of clips | Number of clips | % of clips |
| Music and volume | | | | |
| None | 966 | 55% | 963 | 17% |
| Low | 349 | 20% | 841 | 15% |
| Medium | 392 | 22% | 3,121 | 54% |
| High | 38 | 2% | 825 | 14% |

[5] Throughout the report, “music” is used as a generic term and also includes talk radio or any other audio playing in the vehicle. The source of the audio (CD player, radio, iPod, etc.) could not be reliably determined from the driving clips.

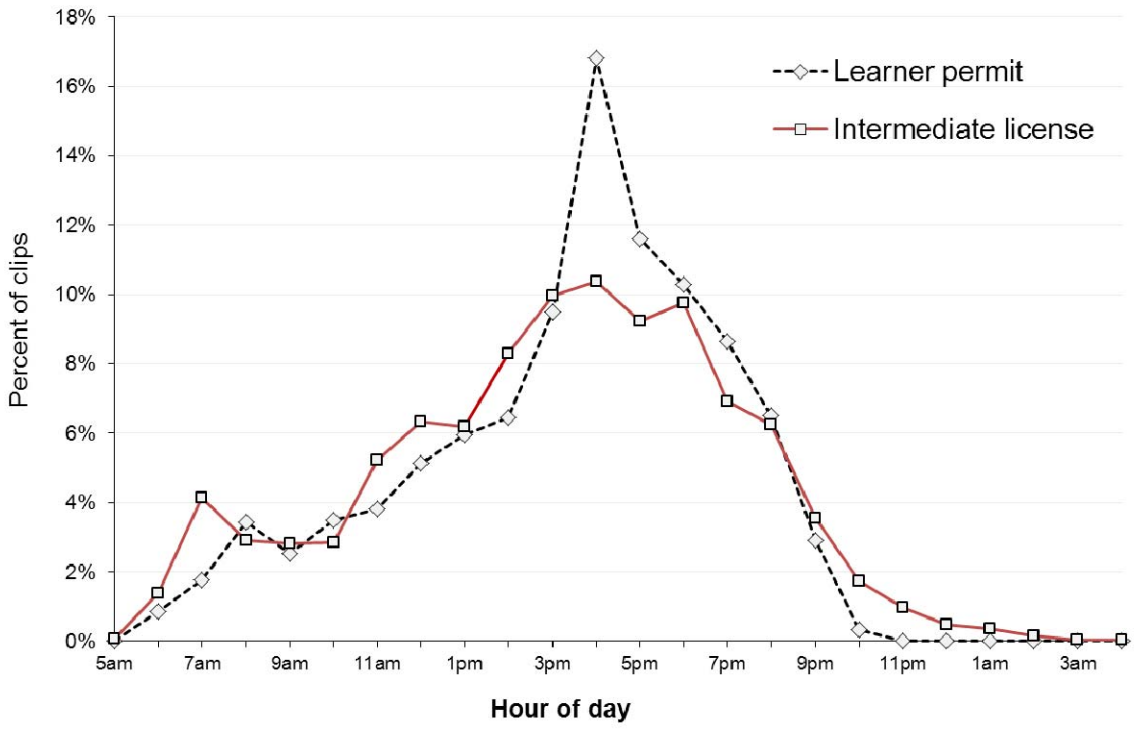
During the learner stage, music could be heard playing in about half of all clips. When present, the volume was usually judged to be either low (barely audible) or medium. Audible music was substantially more common after teens obtained an intermediate license (83% versus 45%; OR=1.87, 95% CI=1.77, 1.97). When present, music was generally louder in the clips of intermediate drivers. Particularly loud music (i.e., music judged to be high enough that it was (1) potentially distracting and (2) may have masked the sound of horns, sirens, etc.) was present in one of every six clips recorded for intermediate drivers. The likelihood of loud music was seven times greater during the intermediate license stage than during the permit stage (14% versus 2%; OR=6.58, 95% CI=4.78, 9.09).

**External Driving Environment**

We also looked at several characteristics of the external driving environment, including the time/day of driving, ambient light, weather and traffic density. These characteristics were compared to see how they changed from the learner stage to the intermediate license stage.

***Time and Day of Driving***. The distribution of recorded clips by time of day and driver license stage is shown in Figure 1.

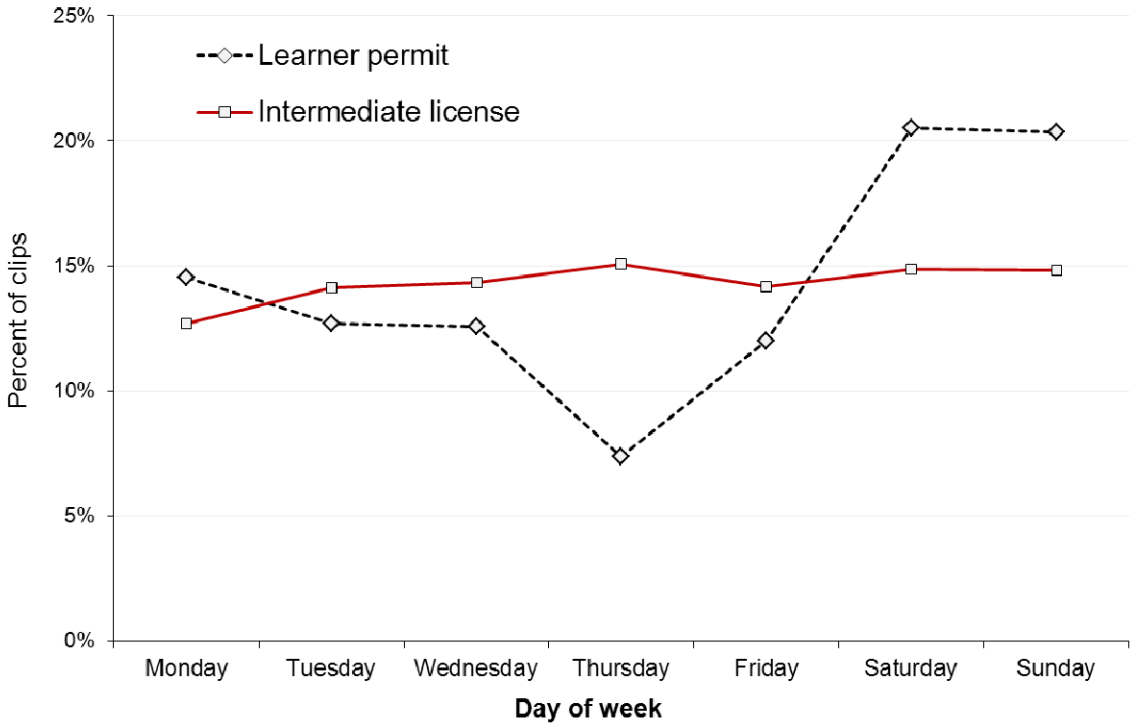
**Figure 1. Hour of day clip was recorded by license type**



Regardless of license type, most driving clips were recorded in the afternoon. Among those with a permit, driving after school accounted for a larger percentage of driving clips. On the other hand, somewhat more driving clips were recorded in the early morning and at night after teens were licensed to drive without supervision. For example, driving clips between 9 p.m. and 5 a.m. were more than twice as likely when teens had an intermediate license as when they had a learner permit (7.3% versus 3.3%; OR=2.25, 95% CI=1.72, 2.95).

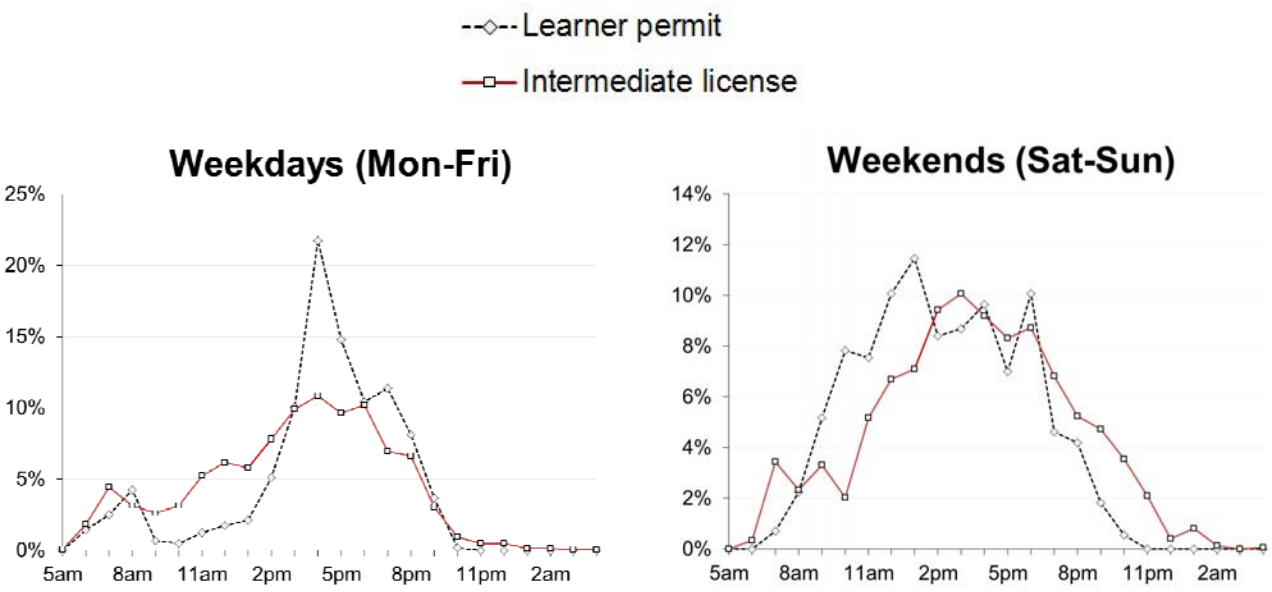
Figure 2 shows the distribution of clips by day of week. Among teens with a learner permit, driving clips were most commonly recorded on the weekend. Forty-one percent (41%) of clips occurred on either a Saturday or Sunday. Once teens began driving unsupervised, clips were distributed evenly across days of the week.

**Figure 2. Day of week clip was recorded by license type**




Finally, we examined the time of day of recorded clips separately for weekdays and weekends. The findings are shown in Figure 3.

**Figure 3. Hour of day clip was recorded by weekday/weekend and license type**




On weekends (chart to the right), the driving pattern was similar for teens with a learner permit and those with a license. The distribution of intermediate driver license clips shifted about two hours later. The pattern was quite different on weekdays (chart to the left). For teens with a learner permit, many weekday driving clips were recorded in the afternoon, particularly after school. For teens with an intermediate license, somewhat more clips were recorded during the late morning hours than for teens with a learner permit.

***Driving Conditions.*** Table 7 shows the characteristics of the driving conditions observable in the recorded clips.

**Table 7**

Observed External Driving Conditions in Clips, by License Stage

| | Learner permit | | Intermediate license | |
|---|---|---|---|---|
| | Number of clips | % of clips | Number of clips | % of clips |
| Ambient light | | | | |
| Good light | 1,154 | 66% | 3,535 | 61% |
| Degraded light (e.g., dusk; rain) | 306 | 17% | 1,042 | 18% |
| Dark | 290 | 17% | 1,216 | 21% |
| Pavement condition | | | | |
| Dry | 1,609 | 93% | 5,151 | 89% |
| Wet (no wipers) | 67 | 4% | 391 | 7% |
| Raining (wipers on) | 50 | 3% | 246 | 4% |
| Amount of traffic | | | | |
| None | 375 | 22% | 1,655 | 29% |
| Light | 492 | 28% | 2,890 | 50% |
| Moderate | 744 | 43% | 884 | 15% |
| Heavy | 40 | 2% | 21 | < 1% |
| N/A (e.g., parking lot, driveway) | 89 | 5% | 342 | 6% |
| External driving environment difficulty/stressfulness | | | | |
| 1 Low | 1,400 | 80% | 3,911 | 67% |
| 2 | 308 | 18% | 1,843 | 32% |
| 3 | 29 | 2% | 38 | 1% |
| 4 High | 3 | < 1% | 0 | 0% |

There are several small, but notable, differences in the observed driving conditions in the clips recorded among learner stage and intermediate stage drivers. A greater percentage of clips occurred in darkness for intermediate drivers (21% versus 17% for learners; OR=1.27, 95% CI=1.13, 1.42). Clips from intermediate license stage were also about 60% more likely than learner stage clips to involve wet or rainy conditions (11.0% versus 6.8%; OR=1.62, 95% CI=1.34, 1.96). On the other hand, traffic was judged to be either moderate or heavy more often during the permit stage than when teens had an intermediate license (45% versus 16%; OR=2.88, 95% CI=2.66, 3.12).

In addition to recording observable conditions, coders assigned a global rating of the difficulty/stressfulness of the external driving environment as it would likely be perceived by an experienced driver. This rating included factors such as the amount and speed of traffic, behavior of other vehicles, weather, the presence of pedestrians or bicycles, road construction, and a variety of other factors. As shown in Table 7, most of the clips were judged to occur in low difficulty/stress driving environments. Nonetheless, clips for teens with an intermediate license were more likely than those for teens with a learner permit to involve conditions that were judged to involve more than "low" stress (33% versus 20%; OR=1.66, 95% CI=1.50, 1.84).

**Triggering Event and Incidents**

Another question that can be addressed with the present data is how triggering events, g-forces, and driving incidents changed from the learner stage to the intermediate license stage of driving.

***Triggering events.*** From the driving clips, it was possible to determine what vehicle action triggered the camera to record. Table 8 displays this information.

**Table 8**

Vehicle Action that Triggered Event Recording, by License Stage

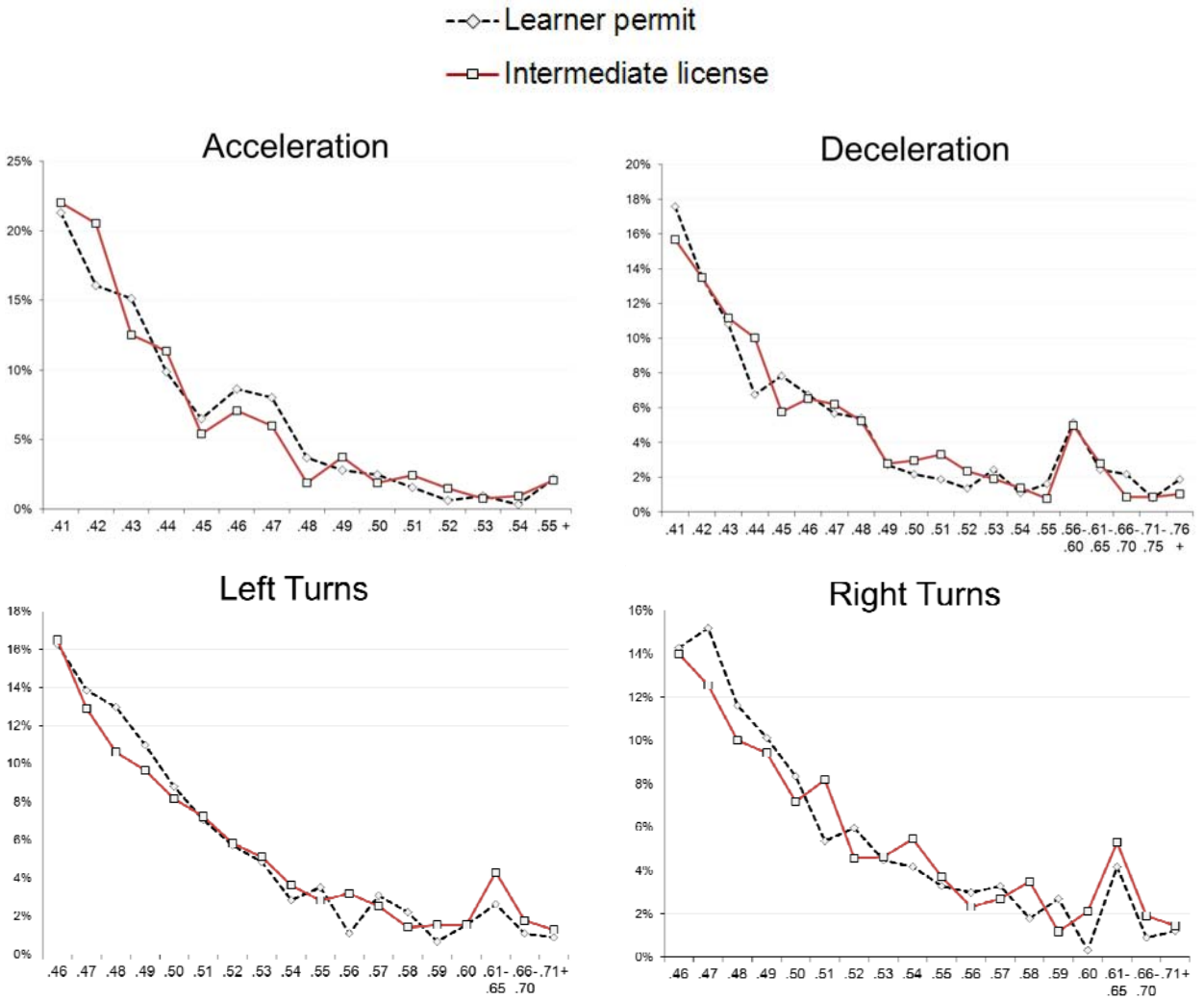
| | Learner permit | | Intermediate license | |
|---|---|---|---|---|
| | Number of clips | % of clips | Number of clips | % of clips |
| Vehicle action | | | | |
| Acceleration | 324 | 19% | 545 | 9% |
| Deceleration | 370 | 21% | 1,161 | 20% |
| Left turn | 455 | 26% | 1,636 | 28% |
| Right turn | 336 | 19% | 1,391 | 24% |
| Hit bump (e.g., speed bump, pothole) | 226 | 13% | 930 | 16% |
| U-turn | 5 | < 1% | 35 | 1% |
| Stalled vehicle[H] | 10 | 1% | 3 | < 1% |
| Triggered manually | 6 | < 1% | 20 | < 1% |
| Swerve | 0 | 0% | 21 | < 1% |
| Collision | 0 | 0% | 3 | < 1% |

[H]Vehicle with manual transmission

The cameras were triggered more often by hard acceleration during the learner stage (19% versus 9%; OR=1.99, 95% CI=1.75, 2.26). During the license stage more clips resulted from right turns (24% versus 19%; OR=1.24, 95% CI=1.11, 1.38). Otherwise, triggering events were generally similar in the learner and intermediate license stages.

***G-forces***. We also examined the g-forces involved during events and whether the g-forces recorded by the event-data recorders differed from the learner stage to licensure. Figure 4 displays the maximum g-force that was recorded for each event, based on whether the camera was triggered by a change in longitudinal g-force (acceleration/deceleration) or lateral g-force (turns).

**Figure 4. Maximum recorded g-force for four different vehicle movements, by license stage**




Note: *p*-values for a Kolmogorov-Smirnov test of the distributions were .26 for acceleration, .82 for deceleration, .42 for left turns, and .20 for right turns.

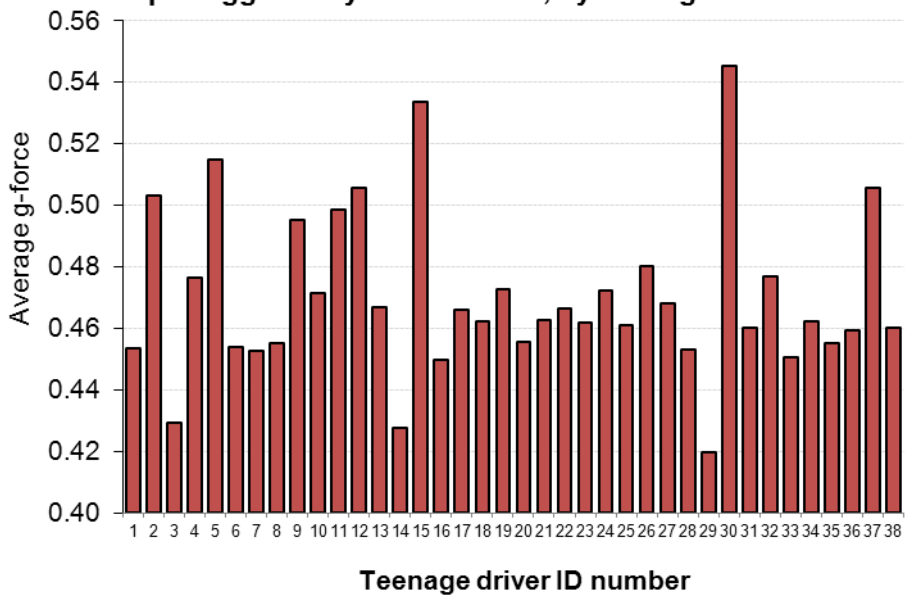
Inspection of the figures indicates there are few, if any, clear differences in the g-force distributions during the learner and intermediate license stages.[6] Because the g-force distributions were highly skewed, we conducted Kolmogorov-Smirnov tests to determine whether the distributions differed meaningfully between the learner and intermediate driving stages.[7] No statistically reliable findings emerged.

[6] The apparent spike in g-forces at higher values in 3 of the 4 charts is an artifact of grouping of low frequency values into 5-unit intervals.

[7] The K-S is a non-parametric test that assesses the likelihood two distributions represent different populations. It makes no assumption about the shape of the distribution.

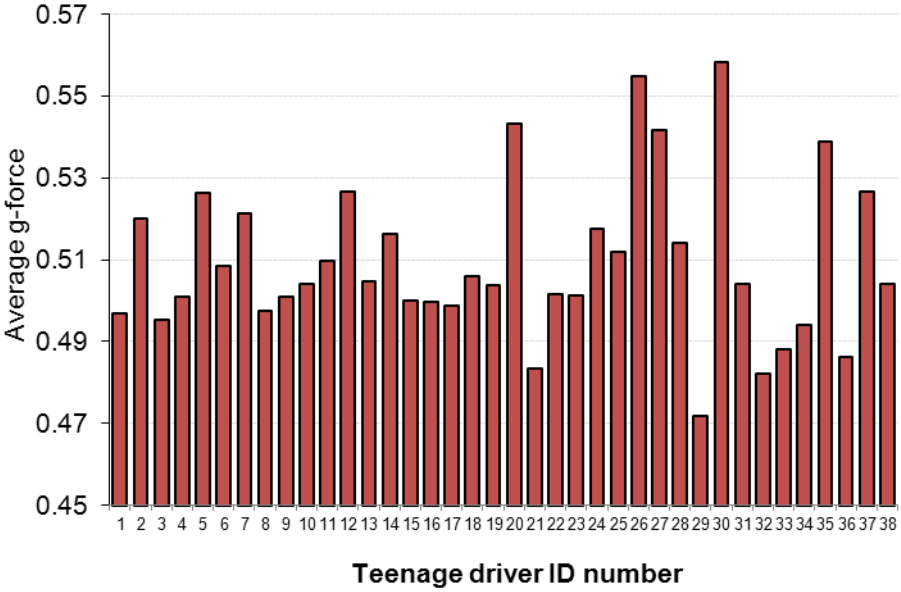
The g-forces recorded in clips varied noticeably by teen driver. For example, Figure 5 shows the average maximum longitudinal g-force for events triggered by deceleration for each of the 38 teenage drivers during the intermediate license stage. The average maximum lateral g-force for events triggered by left turns is shown in Figure 6.

**Figure 5. Average maximum longitudinal g-force for clips triggered by deceleration, by teenage driver**




Note. A g-force of at least .40 was required to trigger recording of a deceleration.

**Figure 6. Average maximum lateral g-force for clips triggered by left turns, by teenage driver**

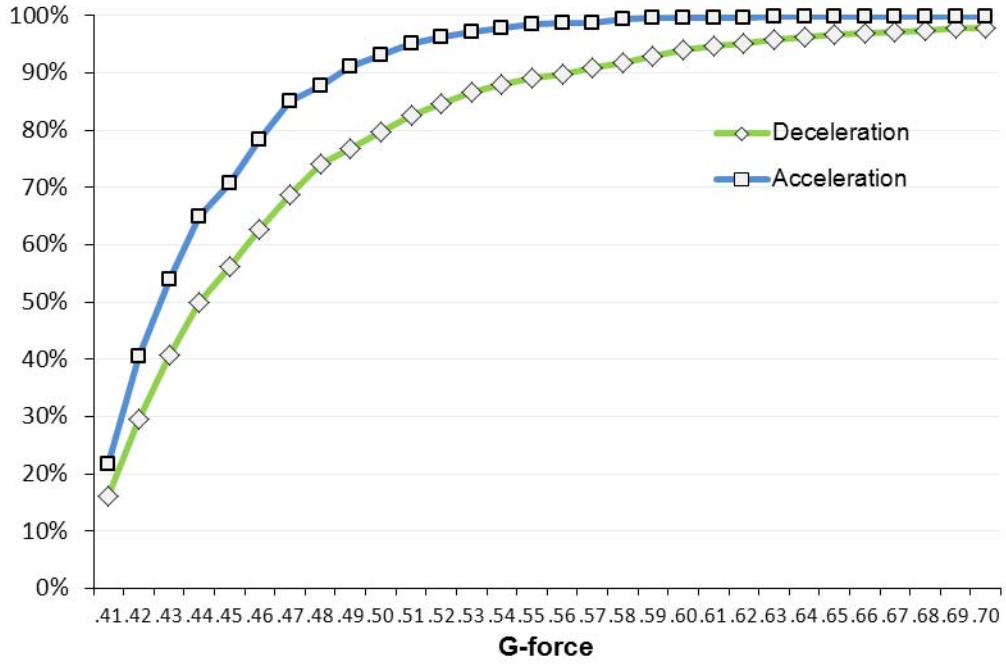



Note. A g-force of at least .45 was required to trigger recording of a left turn.

Teen 30 was notable for recording relatively high average g-forces for events triggered by deceleration and also left turns. Teen 29, by comparison, recorded relatively low g-forces for both types of events. The correlation between average maximum g-forces for deceleration and left turns was .23 (Spearman's rho). Similarly, there were moderate to small correlations between acceleration and right turns (.37), acceleration and left turns (.17), and deceleration and right turns (.13). The correlation between left turns and right turns was high (.57). Acceleration and deceleration were not correlated (.03).

Comparing the different g-force distributions suggests some differences in the nature of the events that triggered recordings, regardless of driver license type. First, a greater proportion of hard accelerations was concentrated among the lowest g-forces necessary to record an event. About 71% of hard starts produced forces below .46g and almost none exceeded .55g. In contrast, hard decelerations involved a greater proportion of substantially higher g-forces. About 56% of hard deceleration events involved forces less that .46g, and about 11% exceeded .55g (see Figure 7). There were no meaningful differences in the distributions for maximum g-forces recorded for right versus left turns.

**Figure 7. Cumulative distribution of deceleration vs acceleration g-forces, learner and intermediate combined**



***Incidents.*** Finally, we examined the frequency and nature of noteworthy driving incidents identified among the sampled clips, and whether these differed between the learner and intermediate stages. A noteworthy incident was defined as a driving event that involved at least one of the following:

- Collision
- Near collision – evasive maneuver by teen
- Near collision – other driver avoids crash
- Other serious incident, such as losing control or leaving the roadway

During the learner stage, only 10 clips (representing just 0.6% of all clips) met one of these criteria. None of these events was a collision. Among the clips recorded for intermediate licensees, 42 met at least one of the criteria for an incident (0.7% of all clips). Three of these clips involved a collision. Each of the incidents was reviewed to identify factor(s) that appeared to lead to the incident. The findings are shown in Table 9.

**Table 9**

Nature of Driving Incidents, by License Stage

| | Learner permit | | Intermediate license | |
|---|---|---|---|---|
| | Number of clips | % of clips | Number of clips | % of clips |
| Nature of incident | | | | |
| Teen driver mistake – vehicle handling | 3 | 30% | 5 | 12% |
| Teen driver mistake – judgment/perception | 4 | 40% | 23 | 55% |
| Other driver at fault | 3 | 30% | 7 | 17% |
| Deliberate dangerous maneuver by teen | 0 | 0% | 7 | 17% |

During the learner stage, most of the incidents were precipitated by the teen driver. These incidents were split about equally between errors in vehicle handling and errors in judgment/perception. The former includes mistakenly applying the gas instead of the brake or having difficulty negotiating a turn. Examples of the latter include failure to see another vehicle or misjudging gaps when making a turn.

The small number of incidents during both the learner and intermediate license periods means the percentage estimates are unstable, so comparisons must be made with caution. Nonetheless, a somewhat different pattern appears to emerge after teens obtained an intermediate license. Judgment errors and deliberate risky maneuvers became more common when teens were driving without adult supervision. Judgment/perception errors usually involved rapid deceleration after not realizing traffic had slowed. A relatively small number of teens accounted for many of the incidents during the intermediate license stage. Of the 35 incidents precipitated by a teen driver, 16 (46%) could be attributed to just four teen drivers. Eight drivers accounted for 24 (69%) of these incidents. The most at-fault incidents recorded by a teen driver was six.

## Discussion

The primary objective of this project was to collect event-based data from a group of teen drivers – whose supervised driving had been extensively documented – during their first six months of unsupervised driving. The availability of event-based data from the same families during both the learner permit stage and the intermediate (restricted) licensing stage provided a unique opportunity to explore how the driving environment and driving behaviors differ during these two periods.

The findings suggest that driving conditions do appear to differ between the learner stage and the high risk initial period of unsupervised driving. During the intermediate license stage, a greater percentage of driving clips occurred in darkness than during the learner stage. Additionally, driving clips from the intermediate license stage revealed wet or rainy conditions somewhat more often than clips from the permit stage. The goal of supervised driving should not necessarily be to mimic the conditions teens will encounter once licensed. Rather, it is important teens have considerable exposure to a wide range of potentially challenging driving situations/conditions. It is currently unknown how much practice is needed in different settings for teens to be well prepared. However, the fact that teens are driving less often in darkness and inclement weather during the learner stage is cause for some concern. The findings suggest more varied supervised experience is highly desirable to ensure teens develop the competence and confidence needed to handle these situations well. Presently, much of teen practice during the learner stage appears to come in routine trips to or from school (Goodwin et al., 2010). Obtaining practice in other, more challenging situations may require special trips on the part of parents and teens, and should produce noticeable benefits.

The internal environment differed more dramatically than the external environment between the learner stage and the initial stage of unsupervised driving. Music or other audio in the vehicle was noticeably more common after teens obtained an intermediate license. Moreover, the likelihood of loud, potentially distracting music was substantially greater during the intermediate license stage. The presence and composition of passengers also changed dramatically. Not unexpectedly, parents were much less likely to be in the vehicle of teens who had an intermediate license. Instead, when these teens carried passengers, they most commonly carried friends. Studies have shown higher crash rates among young teenage drivers when young passengers are present (Chen et al., 2000; Ouimet et al., 2010), which is one reason that most state GDL legislation includes passenger restrictions, and regardless of state laws, which AAA and other organizations recommend such restrictions. The reasons for this are not known. It is assumed passengers directly influence teen driver behavior, but there is presently no evidence to support this assumption. It is suspected, further, that passengers may distract the driver through loud conversation, horseplay or other means. Passengers may also increase the likelihood of risky driving behaviors via overt statements or more subtle pressure. We have attempted to obtain evidence about some of these issues in a follow-up analysis of data collected as part of the present project (Goodwin, Foss, O'Brien, 2011).

A majority (65%) of driving clips during the intermediate stage occurred with *no* passengers in the vehicle. Passenger restrictions for teenage drivers are widely assumed to be highly inconvenient for families. The present study and others (e.g., Ehsani et al., 2010) suggest teens usually do not usually carry passengers. Moreover, approval for passenger restrictions is relatively strong among parents, teens and the general public (Block & Walker, 2008; Ferguson et al., 2001; Williams, 2011). In light of this, the common assumption that passenger restrictions are difficult or disruptive for teens appears questionable.

Finally, only a few differences in driving behavior were observed after teens began driving unsupervised. During the permit stage, a relatively large percentage of clips were triggered by acceleration. Generally, it appeared teens inadvertently applied too much pressure when first stepping on the gas pedal. This was a common mistake among beginners that declined during the initial months of driving. Interestingly, and somewhat surprisingly, there were no meaningful differences in the distributions for maximum g-forces recorded between the learner and intermediate license stage. Hence, even though we cannot know whether unsupervised teens had more or fewer recordable events per unit of travel, when they did occur they were comparable to those during the supervised driving period.

The underlying reasons for events probably represent something a bit different for learners than for drivers who have progressed to an intermediate license. Given that all the events for learners occurred during the first 4 months driving and with a parent in the vehicle, we assume that for the most part they represent errors, or lack of understanding, rather than intentionally rough starts, stops and turns. Among drivers with an intermediate license, it seems unlikely that many of these higher g-force events represent lack of knowledge about vehicle handling. Rather, they seem more likely to represent the teen's driving style. Regardless of the underlying reasons, it is noteworthy that the forces involved in "hard" starts, stops, and turns by teens driving without an adult in the vehicle are essentially no different from those that occurred when teens were accompanied by a parent.

Notably risky or worrisome driving incidents were relatively rare during both the learner and intermediate license stages. Noteworthy incidents on the part of intermediate drivers were most commonly the result of judgment errors. Some anecdotal evidence suggests inexperienced drivers are more likely to be involved in crashes resulting from errors or risky actions of other drivers. Novices seem less able to avoid crashes by recognizing this possibility and effectively anticipating – then avoiding – problems caused by the actions of other drivers (Foss, Smith, & Goodwin, 2010). The present data are among the few available to clearly indicate the prevalence of such incidents, and we hope that this new information will get integrated into driver education materials and programs, including those that target parents of teen drivers. It is also noteworthy that a sizable proportion of incidents from the intermediate license stage came from a relatively small subset of drivers. This is consistent with previous research employing event data recorders with newly licensed teenage drivers (Carney, McGehee, Lee, Reyes, & Raby, 2010).

Several limitations of this study should be noted. First, the sample size was small and potentially unrepresentative. As noted in Goodwin et al. (2010), many of the families who participated in the study were highly educated and relatively affluent. In addition, female participants outnumbered males by more than 2 to 1. The event data recorders employed in the present study also have limitations. For events recorded at night, for example, darkness sometimes prevented clear determination of passenger presence, seat belt use, and other elements of the driving setting. The recorders also did not capture information about driving exposure – that is, how often and how far teens drove. Exposure information would be helpful for giving context in interpreting some of the measured phenomena. Although the number of driving clips recorded provides some indication of driving exposure, it is not a satisfactory measure since the number of clips recorded depends not only on how much a person drives, but also on the individual's driving style. More recent versions of the event-based technology employed in this study have addressed many of these limitations.

It should also be noted the study compared the first four months of the learner permit stage with the first six months of the intermediate license. Because teens in North Carolina must hold a permit for 12 months, the two periods being compared were separated by at least eight months (or longer, for teens who did not obtain their intermediate license as soon as they were eligible). This leaves open the possibility that driving behaviors may have differed later in the learner stage when the cameras were not installed. This concern is mitigated, to some degree, by the findings of Goodwin et al. (2010) – periodic interviews with parents over the course of the year-long learner stage suggested little change in how often teens drove in more challenging situations such as highways, heavy traffic or rain. Nonetheless, the sizeable gap between the two measurement periods could potentially account for other differences in driving behaviors or conditions.

In summary, the analyses presented here provide some basic comparisons of the internal and external driving environments as well as the actions that triggered recording of an elevated g-force event for teenage drivers in their first several months of supervised and unsupervised driving. Follow-up investigations will examine several important issues in greater detail, including the nature and prevalence of distracted driving among teenagers, and the nature of passengers' influence on teen driving.

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