In Vehicle Technology to Correct Teen Driving Behavior:
Addressing Patterns of Risk

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Outline

- Background – Teen crash statistics
- Mechanisms of unsafe driving behavior
- Method of intervention
  - Forcing, Feedback, and Reporting Functions
- Enabling technologies – Teen Driver Support System (TDSS)
- Examples of current teen systems on the market
- Our vision for the future
Teen Driving Fatalities: Current Trends

- In last decade, have seen an increase in teen fatalities.
- Teen drivers have a higher fatality risk than any other driver age group on the road.
- Although teenagers (16-19 years old) make up only 4.7% of all licensed drivers, they are involved in 13% of all fatal crashes.

**Teen (13-19 year old) Fatalities, 1975-2004**

![Graph showing teen driving fatalities from 1975 to 2004]

Source: IIHS, FARS data
Teen Driver Crash Risk on a Per Mile Basis

- Teen drivers are almost **twice as likely** to be involved in a fatal crash than the next youngest age group... 20-24 year olds.

- 16 year olds are **most likely** to be involved in a fatal crash,... and almost **6 times more likely** than drivers aged 30-59.

No. of Fatal Driver Crash Involvements per Million Miles Traveled, 2001-2002, Passenger vehicles

Source: IIHS Teenager Fatality Facts
Driver Fatalities by Crash Type:
For Most Crash Types, Higher for Teens

Driver Fatalities per 100,000 licensed drivers:

Data provided by: Alan Rodgers, Research Analyst for the Minnesota Dept. of Public Safety
Teen Fatality Contributing Factors: Speed Kills


All FATAL Crashes

- Illegal/Unsafe Speed: 28%
- Failure to Yield ROW: 16%
- Driver Inattention/Distraction: 13%
- Driving left of center: 11%
- Physical Impairment: 9%
- Disregard of traffic control: 7%
- Driver Inexperience: 6%
- Improper/Unsafe Lane use: 4%
- Other: 6%

Data provided by: Alan Rodgers, Research Analyst for the Minnesota Dept. of Public Safety
On the national level, 38% of male teen (15-20) driver fatalities had excessive speed as a contributing factor.

Source: 2004 NHTSA Traffic Safety Facts
Teen Fatality Contributing Factors: Seatbelt Use

In Minnesota, seatbelt use is lowest among teenagers.

Source: Minnesota Motor Vehicle Crash Facts, 2004
Alcohol Use: For every age group, existing approaches to mitigation have hit a brick wall

Percent of fatally injured passenger vehicle drivers with BACs >= 0.08 %, 1982-2004

Source data: IIHS Teenager Fatality Facts

% of all 16-17 year olds who were fatally injured


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## Behavioral Mechanisms of Unsafe Driving

<table>
<thead>
<tr>
<th>Factor</th>
<th>Explanation</th>
<th>Feature</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning Factors</strong></td>
<td>Novice teen drivers initially do not have enough experience in a diverse range of situations with appropriate feedback to develop accurate perceptions of prevailing conditions and unsafe limits for driving.</td>
<td>Lack of experience; inadequate feedback.</td>
<td>Drive fast in curve due to misperception of own speed and unfamiliarity with curve negotiations.</td>
</tr>
<tr>
<td><strong>Social Factors</strong></td>
<td>The social environment of teen drivers and their peers may engender motivations to drive recklessly and increased exposure to risky driving situations (e.g., driving late at night), without a counteracting social agent to promote safe motivations.</td>
<td>Motivation; exposure.</td>
<td>Driving fast in curve (late at night) to impress peers.</td>
</tr>
<tr>
<td><strong>Person Factors</strong></td>
<td>The development stage and personality of teen drivers may inherently dispose these drivers to seek risk (sensation seeking) and engage risky behaviors.</td>
<td>Age; personality.</td>
<td>Driving fast in curve because of thrill and perceived invulnerability.</td>
</tr>
<tr>
<td><strong>Skill / Knowledge</strong></td>
<td>Novice teen drivers may not have developed sufficient skills to control the vehicle nor adequate knowledge to interpret and respond to new or ambiguous situations.</td>
<td>Skills; knowledge.</td>
<td>Driving fast in curve due to poor speed control and lack of knowledge about safe curve speeds.</td>
</tr>
<tr>
<td><strong>Risk Assessment</strong></td>
<td>The assessment of risk may be defective for teen drivers due to lack of awareness of hazards and biased perception of risk (by underestimating negative consequences).</td>
<td>Awareness, perception; decision making.</td>
<td>Drive fast in curve as a result of decision that probability of a crash is low.</td>
</tr>
</tbody>
</table>
Relationship between mechanisms leading to Unsafe Behavior

Model of Teen Driver’s Crash Involvement (Adapted from Gregersen et al., 1995).
Behavioral Modification: Functions

In-vehicle technology has the ability to address these issues by forcing behavior, providing driver feedback, and reporting driving behavior of teenagers.

- **Forcing Behavior.**
  
  *Some unsafe actions (risks) may be habitual.* Forcing requires specific behavior to occur prior to or during vehicle operation.

- **Driver Feedback.**
  
  *Drivers may not be aware of risks.* Real-time warnings can alert the driver in case of poor driving behavior or potential risks.

- **Reporting Behavior.**

  *Some drivers may purposely take risks because they feel anonymous.* Vehicle parameters can be saved for inspection by parents (or other authorities).
Mechanisms of Unsafe Driving: Beyond “Reporting”

<table>
<thead>
<tr>
<th>Forcing</th>
<th>Feedback</th>
<th>Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior</td>
<td>Learning</td>
<td>Personality</td>
</tr>
<tr>
<td>Skill</td>
<td>Skill</td>
<td>Social</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Knowledge</td>
<td>Risk Assessment</td>
</tr>
</tbody>
</table>

Mechanisms:
- Learning Factors
- Social Factors
- Person Factors
- Skill/Knowledge
- Risk Assessment

- Alcohol Ignition interlocks to deal with impairment (which affect Perception, Behavior, & Skill)
Behavior Interventions

Seatbelt interlock
Requires all occupants to engage seatbelt prior to starting vehicle. (Forcing)

Alcohol interlock
Prevents teen driver from starting vehicle if alcohol is detected. (Forcing)

Intelligent Speed Adaptation (ISA)
Discourages driver from exceeding road’s posted speed limit. Achieved through combination of Global Positioning System (GPS) and digital road map. In some systems, speed is limited by link with elements of vehicle's power train, such as throttle or fuel system. (Feedback/Forcing)
Current legislation (FMVSS 208; Federal Register 1974, 42,692–42,693) prohibiting NHTSA from requiring new seat belt use technologies other than the ineffective 4- to 8-second belt reminder is outdated and unnecessarily prevents the agency from requiring effective technologies to increase belt use.

Negative reaction indicated by ... NHTSA interviews and focus groups and hesitancy of industry to reintroduce interlock systems ... suggest that, for the moment, their use be considered only for certain high-risk groups (e.g., drivers impaired by alcohol, teenage drivers) who are overrepresented in crashes.

NHTSA and the private sector should strongly encourage research and development of seat belt interlock systems for specific applications.
On Interlocks and Seatbelt Monitoring

- "Observational studies indicated that despite their low acceptance, interlocks were effective in increasing seatbelt use in the 1970’s. Belt use was 59% in cars with interlocks as compared to 28% in cars of prior model years. (Robertson, 1975)

- "Teenagers have high crash risk but low belt use, which add to their injury problem. Avenues to address this include:
  - Strong belt use laws and their enforcement,
  - Building belt use requirements into graduated licensing systems,
  - Keeping young beginners out of high risk driving situations, and
  - Finding ways to influence parents and other adults to ensure that their teenage passengers use seatbelts.” (Williams, McCartt and Geary, 2003)
Intelligent Speed Adaptation (ISA) Summary

- Location
  - ISA has been evaluated in simulation and field studies in Australia and several European countries including, Belgium, France, Germany, England, Netherlands, and Sweden.

- Observations
  - In general, these projects have shown consistent reductions in speed levels, better awareness of speed limits, and improved compliance with speed limits (Besseling, 2003; Carsten & Fowkes, 2000; Vagverket, 2003).

- Impact
  - It has been estimated that speed control systems such as ISA have the potential for achieving almost 60% fatality reduction (Carsten & Fowkes, 2000).
ISA Summary

Three types of ISA systems:

- Advisory – in vehicle warning, driver ultimately limits speed.
- Mandatory – active control, vehicle limits speed, overrides driver.
- Voluntary – advisory with option of mandatory.

Three notification levels possible:

- Fixed – posted speed limit only.
- Variable – site specific limits, ex: construction zones, school zones, curves.
- Dynamic – limits based on hazard potential, e.g. weather, time of day, traffic congestion, pavement condition.
ISA: Compensation for “Lost Time”

When drivers have speed restricted by a mandatory or variable system, there may be a tendency for them to compensate by accepting shorter gaps in crossing traffic and closer following distances in traffic compared to baseline driving (or only an advisory system). This is believed to result from a perceived need to make up for limited mobility and time.
ISA: Complacency
We relax our responsibility and let the system take over

Adaptive Speed Control

- Speed limit
- Mand, fixed
- NSL (off)
- Advisory
- Mand, dynamic

In expt, subjects drove a simulator in traffic conditions with heavy fog. Note that drivers drove at a speed lower than the speed limit with no speed control, and in response to the advisory and dynamic system. However, drivers with the mandatory system seemed to be complacent and drive to the system limit rather than use their own judgment to slow down. As a result, drivers tended to drive toward the speed limit even though conditions suggest a lower speed to be safe.

(courtesy of Q. Carsten, ITS, Leeds)
Modifying Behavior: Feedback

- Need static and dynamic context
- Auditory or other sensory signals triggered by unsafe vehicle operation
  - Excessive speed for local conditions, e.g. speeds incompatible with road curvature, can lead to lane departure.
  - “Hassles” driver until behavior is corrected.
- Prediction of road curvature can inform the driver of necessary upcoming maneuvers (especially useful in rural areas at night).
Reporting Behavior: Consequences, Incentives, & Rewards

- Record vehicle parameters such as speed, acceleration, braking, throttle use, distance, location, time of day.

- Parents can be notified in real-time of unsafe driving behavior. Parents can also inspect “report card” of data to review teen driving behavior offline.

- Attempt to address difficulty in enforcing compliance.

- Review possible by insurance (insurance premium, rebates), and/or DPS (license progression, awards).
TDSS Components: Enabling Technologies

- Intelligent Speed Adaptation (ISA)
  - Speed Limits
  - Curve speed
  - Weather related speed
- Seatbelt Interlock
- Alcohol Interlock
- Biometric Fingerprint Identification
- Real-time Feedback
  - Auditory Warning
- Real-time and Off-line Reporting
  - Automated cell phone dialing
TDSS Prototype

Vehicle

Ignition Switch
On/Off

Seatbelt Status

GPS Position
GPS device

Vehicle Speed
OBD-II

Auditory Warning

Buzzer/Speaker

Computer (QNX)

Driver ID

Fingerprint Sensor

Alcohol Interlock

Driver Report

Weather Data

Wireless Modem
How ISA Works

[Diagram of ISA operation process]

1. **GPS receiver**
2. **Vehicle Speed**
3. **Map Match Models**
4. **Digital Map Database**
5. **Street Location**
6. **Speed Limit Database**
7. **Speed Limit**
8. **Is Vehicle Speed greater than Speed Limit?**
9. **YES**
   - Initiate Warning
10. **NO**

[Map showing different areas and roads with a star indicating the location of a device]

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Curve Speed

Example
- CSAH 15 at Cottonwood Ln – Lake Minnetonka
- Speed Limit: 30mph
- Advisory Speed: 15mph

Photo source: maps.google.com
Road Weather Information System (RWIS) Data

rwis.dot.state.mn.us
Alcohol Interlock

171.305 Ignition interlock device. Subdivision 1. Definition. "Ignition interlock device" or "device" means breath alcohol ignition equipment designed to prevent a motor vehicle’s ignition from being started by a person whose alcohol concentration exceeds the calibrated setting on the device.

- Commercially available option
  - Expensive (?): $795 or $60/mo.
  - Could be reserved as optional component for previous offenders.
  - Interlock tolerance level can set to 0% BAC.

ADS Determinator Interlock by Alcohol Detection Systems
Enabling Technology: Biometric Fingerprint ID

Benefits:

- Enables the system to recognize who is driving so parents can opt out.
- Enables individual settings for parents of multiple teen drivers.
- Enables logging of Graduated Driver’s License (GDL) provision on number of driving hours (day/night) logged with a parent.
Design Opportunities

<table>
<thead>
<tr>
<th></th>
<th>Speed</th>
<th>Inexperience</th>
<th>Inattention/Distraction</th>
<th>Alcohol</th>
<th>Seatbelts</th>
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</thead>
<tbody>
<tr>
<td>Forcing</td>
<td></td>
<td></td>
<td></td>
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<td>X</td>
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<tr>
<td>Feedback</td>
<td>X</td>
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<tr>
<td>Reporting</td>
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<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Indirectly

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When needed?
Crash rate by cumulative miles driven after licensure and by gender

- First 250 miles crash involvement rate: 3.2 (per 10K miles); next 250 miles rate is 1.3 (per 10K miles) (1)
- For novice drivers, crash rates decrease dramatically from the 1st to the 7th month (41%), then gradually decrease through the 24th month after licensing (60% overall reduction) (2)

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Road Safety: RS-1000

Summary

- Records driving characteristics for later viewing on PC by guardian.
- Audible alert parameters defined by user.
  - Speed, driver seatbelt, acceleration, braking, erratic driving, throttle use.
- Connects via OBD-II
- Relatively low cost: $280
Davis Instruments: CarChip

Summary

- Records driving data saved for later viewing on home PC.
  - Time and date for each trip, distance, speed, hard accelerations and decelerations.
- Data logger will start collecting data as soon as car is started.
- Connected via OBD-II port (available on model years 1996+)
- Cost: $179.
Geofencing: SignalTrac

http://www.signaltrac.com/

**Summary**

- Real-Time e-mail notification via cellular connection each time driver enters a *zone*.
- *Zone(s)* are user-defined.
- Also includes real-time position, speed, seatbelt*, and passenger* notification.
  (*Optional)

Cost: $499 + $399/yr
Teen Arrive Alive

**Summary**

- Subscription plan for phone tracking.
- Uses technology from GPS enabled cell phone.
- Works with selected Motorola phones and Nextel calling plans.
- Subscription cost: ~$20/month (in addition to standard Nextel service plan fees of ~$40/month).
- Phone location, speed, direction of travel, and time of day are reported every 2 minutes.
- Reports are accessible by parents via website or by placing a call to secure line.
Video Monitoring: DriveCam
http://www.drivecam.com/drivecam-videos.asp

Features:
- Two lenses: Forward and Interior.
- 20 second buffer records 10s prior to, and 10s after event.
- Records both Video & Audio.

Limitations:
- User defined threshold - false positives.
- Difficult to record speed or impairment.
- Feedback to driver behavior provided after event (not real-time)
- Review of footage is time consuming.

Cost: $1200
## Existing teen driving aids

<table>
<thead>
<tr>
<th>Product</th>
<th>RS-1000</th>
<th>CarChip E/X</th>
<th>DriveRight 600</th>
<th>SignalTrac</th>
<th>NetworkCar</th>
<th>SmartDriver</th>
<th>DriveCam</th>
<th>TeenArriveAlive</th>
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</thead>
<tbody>
<tr>
<td>Manufacturer website</td>
<td>RoadSafety</td>
<td>Davis Instruments</td>
<td>SignalTrac</td>
<td>NetworkCar</td>
<td>SmartDriver</td>
<td>DriveCam</td>
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<tr>
<td>base price ($)</td>
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<td>179</td>
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<td>service fee ($)</td>
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<td>399/yr</td>
<td>108/yr</td>
<td>100/yr</td>
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<td>240/yr</td>
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</table>

### Data Collected

<table>
<thead>
<tr>
<th>Feature</th>
<th>RS-1000</th>
<th>CarChip E/X</th>
<th>DriveRight 600</th>
<th>SignalTrac</th>
<th>NetworkCar</th>
<th>SmartDriver</th>
<th>DriveCam</th>
<th>TeenArriveAlive</th>
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</table>

### Notification

<table>
<thead>
<tr>
<th>Feature</th>
<th>RS-1000</th>
<th>CarChip E/X</th>
<th>DriveRight 600</th>
<th>SignalTrac</th>
<th>NetworkCar</th>
<th>SmartDriver</th>
<th>DriveCam</th>
<th>TeenArriveAlive</th>
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</thead>
<tbody>
<tr>
<td>real-time GPS</td>
<td>R**</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>FE</td>
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### Additional Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>RS-1000</th>
<th>CarChip E/X</th>
<th>DriveRight 600</th>
<th>SignalTrac</th>
<th>NetworkCar</th>
<th>SmartDriver</th>
<th>DriveCam</th>
<th>TeenArriveAlive</th>
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<tbody>
<tr>
<td>1,3</td>
<td>2,3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*feature is optional
**feature is not yet available
(1) broadcasts via cellular connection
(2) LCD display on dashboard
(3) auditory feedback

### FUNCTIONS

- **FO - FORCING**
- **FE - FEEDBACK**
- **R - REPORTING**
- **N - NOT AVAILABLE**
Existing system deficiencies


- Current systems are too passive. None of the systems:
  - Modify speed threshold based on individual road’s local speed limit, or upcoming road curvature (as per ISA), time of day or weather (RWIS).
  - Force behavior such as using seatbelt or maintaining sobriety.
  - Recognize current driver.

- Digital maps can be updated with speed limits; real-time wireless access for pavement condition and weather already available in Minnesota.

- Need teen driver-parent centric system, designed to modify dangerous teen driving behavior and empower parents.
Driver Reporting Systems: The issue is not only “technology”

- What are the tests? The performance criteria?
  - Speed violation? Stability of accel/decel, headway? Lane wandering? Distraction measure?
- What thresholds does one set for pass/fail on each?
- How does one come up with an overall “grade”?
- Does one exam (ie report card) fit every state? …every teen?
- Feedback mechanism? Auditory? Incentive?
Technical Caveats

- Technology may redistribute risk rather than reduce risk overall.
- By changing the nature of the driving/operational task, we need to verify that the technology not introduce new risk factors.
- The question always is: What are the unintended consequences of using technology?
Our Vision:
A Three-Phased Approach

- Phase 1 – System Development

Design, develop, and validate in-vehicle technology to force safe behavior, report unsafe behavior, and provide feedback to help teens help themselves. Key focus areas of Teen Driver Support System (TDSS) are:

- Excessive speed based on location.
- Alcohol.
- Seatbelt use.
Our Vision: A Three-Phased Approach

- Phase 2 – *Driver Interface Design and Validation*

Driving simulator study to evaluate the response of teen drivers to different feedback modalities for effectiveness and driver acceptance.

- **Study 1 - System Feedback (Illegal Speeds)**

<table>
<thead>
<tr>
<th>Speed Threshold</th>
<th>Tone</th>
<th>Icon</th>
<th>Haptic Pedal</th>
<th>Haptic Seat</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mph</td>
<td>N1 = 24</td>
<td>N1 = 24</td>
<td>N1 = 24</td>
<td>N1 = 24</td>
</tr>
<tr>
<td>10 mph</td>
<td>N2 = 24</td>
<td>N2 = 24</td>
<td>N2 = 24</td>
<td>N2 = 24</td>
</tr>
</tbody>
</table>
Our Vision:
A Three-Phased Approach

- **Study 2 - System Feedback (Unsafe Speeds)**

<table>
<thead>
<tr>
<th>Timing</th>
<th>Modality</th>
<th>Icon</th>
<th>Haptic Pedal</th>
<th>Haptic Seat</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 seconds</td>
<td>N1 = 24</td>
<td>N1 = 24</td>
<td>N1 = 24</td>
<td>N1 = 24</td>
</tr>
<tr>
<td>7 seconds</td>
<td>N2 = 24</td>
<td>N2 = 24</td>
<td>N2 = 24</td>
<td>N2 = 24</td>
</tr>
</tbody>
</table>

- **Study 3 - Evaluation Based System**

<table>
<thead>
<tr>
<th>No Evaluation</th>
<th>Real time</th>
<th>Post hoc</th>
</tr>
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<tbody>
<tr>
<td>N1 = 24</td>
<td>N2 = 24</td>
<td>N3 = 24</td>
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</tbody>
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Our Vision: A Three-Phased Approach

- **Phase 3 - Field Operational Test:**
  - 4 years, 400 vehicles.

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice teens</td>
<td>50 TDSS</td>
<td>50 TDSS</td>
</tr>
<tr>
<td></td>
<td>50 Control</td>
<td>50 Control</td>
</tr>
<tr>
<td>Teens driver &gt; 24 months</td>
<td>50 TDSS</td>
<td>50 TDSS</td>
</tr>
<tr>
<td></td>
<td>50 Control</td>
<td>50 Control</td>
</tr>
</tbody>
</table>

- **Year 0** - In-vehicle hardware finalized. (TDSS & vehDAQ).
- **Year 1** - Prepare study and fleet.
- **Year 2 & 3** - Collect data.
- **Year 4** - Analyze data and prepare report.
The End