Paved with good intentions:

*Why driver assistance and child restraint systems (CRS) don’t always work as intended…*

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Outline:

• Issue: why DON’T they work like we thought they would?
  – Definition of “behavioural adaptation”
• Examples of in-vehicle technologies that don’t work as well as they ‘should’
• Theory of behavioural adaptation
• Child restraint system (CRS) usability
• Conclusions / future research

Behavioural adaptation:

• Describes the collection of behaviours that occurs following a change to the road traffic system that was not intended by the initiators of that change

• Usually those with negative impacts on safety are of particular interest…
Engineering safety interventions…

Seat belts

• Required equipment in passenger vehicles as of 1964 (Victoria); 1971 (Canada)
  – Lower the probability of serious injury or death by about 40% for front outboard occupants
  – However, the enforcement of their use has resulted in much more modest effects on fatalities ...selective recruitment?
  – Belted habitual ‘non-wearers’ drive faster than belted ‘wearers’  
    (Janssen, 1994)
Air bags

- Fleet study of taxis → no effect of airbags on driver behaviour (Sagberg et al., 1997)
- May occur on strategic level (less likely to wear seat belt)
- Study based on insurance data found more aggressive driving in cars with airbags (Peterson et al., 1995)

Centre high-mounted brake lights

- Mandated in Australia since 1990 (Canada since 1986)
  - Fleet studies: 50% reduction in rate of rear-end collisions
  - Drivers show shorter reaction times than with typical brake light configurations
- But…
  - Insurance claims for rear-end collisions only reduced by 3-12% (‘85/86 vs. ‘86-91) (Farmer, 1996)
Studded tyres

- Used primarily in countries with ice- and snow-covered roads; not required equipment

- With studded tyres, drivers drove faster in icy conditions (Rumar et al., 1976)

- Possible that these same effects occur with (more common) snow tyres

Antilock brakes

- Initial predictions = 10-15% reduction in collisions

- Fleet studies of taxis → shorter headways, more aggressive, no reduction in collision frequency (Schenbrenner & Biehl, 1992, Sagberg et al., 1997)

- Insurance data: same frequency and cost (Highway Loss Data Institute, 1994)

- When drivers shown effects of ABS → drive faster and use higher brake pedal forces (Grant & Smiley, 1993)
Electronic Stability Control (ESC)

- Advertising / promotion of ESC may encourage drivers to drive ESC-equipped vehicles in an irresponsible / dangerous manner
- General public survey (2006)
- Survey owners of ESC-equipped vehicles (2008)
- Differences in their driving since using the system

<table>
<thead>
<tr>
<th>Notice Changes to Driving Behaviour</th>
<th>Length of Time Changes Lasted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling more confident (24%)</td>
<td></td>
</tr>
<tr>
<td>Feeling safer (18%)</td>
<td></td>
</tr>
<tr>
<td>Driving more carefully (18%)</td>
<td></td>
</tr>
<tr>
<td>Driving more slowly (13%)</td>
<td></td>
</tr>
<tr>
<td>Being better able to ‘handle’ vehicle (11%)</td>
<td></td>
</tr>
<tr>
<td>Driving faster (9%)</td>
<td></td>
</tr>
<tr>
<td>Improved ability to drive in adverse weather (8%)</td>
<td></td>
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</tbody>
</table>
In-vehicle Intelligent Transport Systems (ITS)  
(Advanced Driver Assistance Systems; ADAS)

Navigation systems

• Glances to roadway ahead:
  ➢ with system = 57%
  ➢ with paper map = 78%
  ➢ from memory = 84%

  (Antin et al., 1990)
Navigation systems

- If dynamic route guidance, congestion in residential areas (Kubota et al., 1995)

Vision enhancement systems

- Installed in some luxury vehicles (e.g., Cadillac Night Vision system); also head-up displays (HUD)
  - increases range and sensitivity of driver’s visual capabilities
  - reduces target detection for peripheral targets (Bossi et al., 1997)
  - may result in:
    - increases in speed
    - increased exposure (i.e., older drivers)
    - reallocation of attention
Forward collision warning systems

- problem of false alarms
- drivers may ignore warnings if too many false positives
- however, there is talk of incentives being offered

Fatigue warning systems

- Now in Volvo, Mercedes models (Driver Alert Control™, Attention Assist™)
  - no effect of FWS on break-taking behaviour (Vincent et al., 1998)
  - warnings may be redundant, ∴ no intrinsic value to driver
Lane departure warning systems

- Currently on the market (available since 2001 in Japan)
- Many heavy trucks equipped (Freightliner; Scania)

Lane departure warning system studies

- Simulator (N=30) vs test-track (N=26)
- 3 groups performed secondary task while driving
  - No warnings
  - Accurate warnings
  - Inaccurate warnings
- Hypotheses:
  1. drivers would learn to rely on accurate warnings to keep them in the lane, \( \therefore \) improve performance on secondary task
  2. drivers would not trust inaccurate warning system
  3. *locus of control* and *sensation-seeking* as potential personality variables
Lane departure warning system study--Results

- Accurate system improved lane keeping
- When using an inaccurate system, only drivers who trusted the system made complete lane departures
  - trust does contribute to behavioural adaptation
- ‘Externals’ and ‘low sensation-seekers’ more likely to trust system
  - certain people may be more likely to develop “automation complacency”

Adaptive cruise control (ACC)

- Currently available on some luxury vehicles, estimated to reduce number of rear-end collisions by 7.5% (Chira-Chavala & Yoo, 1994)
  - goal: reduction of driver workload BUT…will drivers use it as collision warning device?
  - with ACC → drive faster, shorter minimum headway, larger brake pedal forces (Hoedemaeker & Brookhuis, 1998)
  - with ACC → perform in-vehicle tasks they would not normally do (Fancher et al., 1998)
  - experience reduced visual demand of driving (Hoedemaeker & Kopf, 2001)
  - show impaired lane-keeping (Ward et al., 1995; Hoedemaeker & Brookhuis, 1998)
ACC study

(Rudin-Brown & Parker, 2004)

ACC study -- Results

- Main effect of ACC on number of prices found per minute (ACC reduces workload)

- Reaction time to brake lights was longer when drivers used ACC, especially in high sensation-seekers (ACC increases driver distraction)
Intelligent speed adaptation (ISA)

- Can be
  - Advisory (provide warnings)
  - Intervening (actively prevent)
- Effectiveness estimates range from 7-37%, if all vehicles were equipped
- Drivers accept shorter gaps; follow lead vehicle more closely (Comte, 2000)
- Reductions in % time spent over speed limit with time (Warner & Åberg, 2008)

Back ing Aids

- Assist drivers in performing low-speed backing and parking manoeuvres.
- May help to reduce collisions
- Perception and marketing of backing aids
  - “Collision avoidance” vs “parking aid”? (Jenness, et al., 2008)
**Backing Aids**

- **42 parent-aged participants (25-60 years)**
  - 60 days use
- **3 groups:**
  1. Dashboard mounted video (visual system only) n=15
  2. Rearview mirror mounted video (visual system only) n=12
  3. Sonar (audio system only) n=15

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**Graphs:**

- **Number of In-Vehicle Scans:**
  - Pre-Test Device Off: 1.5
  - Post-Test Device Off: 2

- **Unexpected Obstacles:**
  - Video: 80%
  - Rear View: 70%
  - Radar: 60%
Theory of behavioural adaptation:

- **DRIVING TASK:**
  - **SYSTEM:**
    - **PERSONALITY**
      - locus of control
      - sensation-seeking
    - **MENTAL MODEL**
    - **TRUST**
  - **ADAPTIVE DESIGN**
  - **OTHER FACTORS**
    - gender
    - state
    - age

- **BEHAVIOUR**
- **OBJECT**
- **CONTROL LOOP**
- **FEEDBACK** (direct and indirect/inferred)

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Child Restraint System (CRS) Usability
CRS Harness usability

• 42 participants installed 4 CRS rear- and forward-facing (in-vehicle and out-of-vehicle)
• Error severity scores determined in consultation with experts

<table>
<thead>
<tr>
<th>Score</th>
<th>Effect on Child Safety</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>No Effect on Safety</td>
</tr>
<tr>
<td>1</td>
<td>Hardly Noticeable Effect on Safety</td>
</tr>
<tr>
<td>2 - 3</td>
<td>Insignificant Failure</td>
</tr>
<tr>
<td>4 - 6</td>
<td>Moderate Failure</td>
</tr>
<tr>
<td>7 - 8</td>
<td>Severe Failure</td>
</tr>
<tr>
<td>9 - 10</td>
<td>Very High Severity Failure</td>
</tr>
</tbody>
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- Risk Priority Number (RPN):
  - (# of error occurrences) x (severity score)
- RPN > 42 = likely to compromise CRS effectiveness
ISOFix / LATCh / UAS usability

• Since 2002, all new vehicles and CRS are required (in Canada) to be equipped with lower anchorage, and top tether, attachments.

• Designed to make installing CRS in vehicles easier, with fewer opportunities for misuse.

• Study to assess how well users install a forward-facing CRS using different types of UAS connectors (lower anchorages, top tethers) in both a school bus and a passenger car.
**ISOFix / LATCh / UAS usability**

- **General:**
  - raise awareness of UAS
  - educate users regarding safety consequences of installation errors
- **School buses:**
  - use maximum seat spacing
  - develop effective installation / inspection procedures for bus drivers / monitors
  - limit CRS to one per bus seat

### Percentage of correct installations:

<table>
<thead>
<tr>
<th>CRS</th>
<th>Car</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRS A</td>
<td><img src="image1" alt="Car" /></td>
<td><img src="image2" alt="Bus" /></td>
</tr>
<tr>
<td>CRS B</td>
<td><img src="image3" alt="Car" /></td>
<td><img src="image4" alt="Bus" /></td>
</tr>
<tr>
<td>CRS C</td>
<td><img src="image5" alt="Car" /></td>
<td><img src="image6" alt="Bus" /></td>
</tr>
</tbody>
</table>

85%

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**Conclusions**

- **Design in-vehicle systems with end users (drivers) in mind**
  - Personality
  - Trust in device
  - Feedback from device (direct *and* indirect)
- **Design CRS with end users (parents / carers) in mind**
  - Usability
  - Feedback / clarity
  - Potential for severe consequences of errors (↑ RPN) and ‘False positives’
Future research: “Children in vehicles”

- Naturalistic study of child behaviour in cars
- Objectively document and describe how children behave within CRS, within vehicles
- How they interact with other occupants (e.g., driver)
- Effectiveness of current CRS in keeping children in a safe position within the vehicle
- Ways to enhance the design of vehicle rear seats and CRS

*Information session 25 May*