Human Factors & Advanced Vehicle Technologies

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University of Toronto

Located in Toronto, Ontario, Canada
**Mechanical Engineering**
- Biomedical
- Energy, environmental
- Thermal, fluid sciences
- Applied mechanics, design
- Advanced materials, manufacturing
- Robotics, mechatronics, instrumentation

**Industrial Engineering**
- Human Factors
- Information engineering
- Operations research

50 faculty members

~ 1200 undergraduate & 450 graduate students
HFASt: Human Factors & Applied Statistics Lab

Director
Birsen Donmez

Postdoctoral Fellow
Winnie Chen

PhD Students
Wayne Giang
Maryam Merrikhpour
Dengbo He
Farzan Sasangohar, Texas A&M
Patrick Stahl, Apple

MS students
Neil Sokol
Jeanne Xie
HFASt: Human Factors & Applied Statistics Lab

**OPERATOR**
Intentions, attention, adaptation, state

**TECHNOLOGY**
Decision support tools
Feedback mechanisms

**EVALUATION**
Measures
Statistics

Application areas:
Surface Transportation
Healthcare
Mining
Supervision of unmanned vehicles
...

**Funding sources:** Toyota, Qualcomm, MDA, Barrick Gold, Ornge, Skymeter, Kangeroo Design, NSERC, CFI, ORF, Ontario MRI, Federal Development of Ontario, MITACS, Connaught, Auto21 Network Centres of Excellence, Transport Canada
Our methods in the driving domain

• Crash data analysis
• Surveys
• Simulator
Methods: On-road studies
Naturalistic Studies: Conduct and Analysis (SHRP2)

- Headway noncompliant
- Speed noncompliant
- Yellow light: noncompliant

Driving Report Overview:

- Changes in percentage time spent over the speed limit since the start of the study:
  - 22% overall improvement
  - Urban: 29%
  - Rural: 12%
  - School: 22%

Oh no! You've increased the time you drive over the limit by 22% since the start of the study.
Driving task is changing

• Infotainment and carried-in technologies
  – Need for connectivity
  – Concern for distraction

• Smarter vehicle/traffic technologies
  – Traffic info
  – Collision avoidance systems
  – Driver state detection

• Driving task becoming highly automated
  – Ironies of automation
At risk populations (e.g.)

• Younger Drivers
  – Less skilled
  – Tend to engage in numerous high risk situations (Williams 2003; Ferguson 2003)
    • More likely to engage in distractions, be severely injured when distracted by phones (Neyens and Boyle, 2008), be in rear-end crashes when distracted (Neyens, Boyle, 2007)

• Older Drivers
  – Information processing impairments (Barr, Eberhard 1991; Evans 1988)
    • Diminished perceptual, cognitive, motor skills
    • Slower response times, more restricted field of attention, reduced time-sharing abilities
GDL evaluation in Iowa

\[ y_t - y_{t-12} = \phi(y_{t-1} - y_{t-13}) + e_t - \theta e_{t-1} - \Theta e_{t-12} + GDL + LRAG \]

Neyens, Donmez, Boyle (2008). *Journal of Safety Research*
Anticipation

• Anticipation of familiar situations as necessity for skill- and rule-based behaviour (Onken, 1993)

• Frequently mentioned in driving research:
  – Risk Avoidance Model: Anticipatory avoidance response to eliminate danger (Fuller, 1984)
  – Anticipatory neuronal programs to explain response to familiar events (Tanida & Poeppel, 2006)
  – Anticipation of other drivers’ behaviours in traffic flow modelling (Treiber & Kesting, 2007)
Definition

“Anticipatory Driving is a high-level cognitive competence that describes the identification of stereotypical traffic situations on a tactical level through the perception of characteristic cues, and thereby allows for the efficient positioning of a vehicle for probable, upcoming changes in traffic.”

Stahl, Donmez, Jamieson, 2014, IEEE THMS
Experience and anticipation

Number of participants

Years of licensure

Mileage (km/year)

- Low
  - $\leq 2$
  - Low $\leq 10,000$

- Medium
  - $\geq 10$
  - Medium $< 10,000$

- High
  - $\geq 10$
  - High $> 50,000$

Number of pre-event actions

Anticipation support helps novices

Attention is central to driving

• Distraction affected (subset of inattention):
  – 10% of fatalities (3,154) and 18% of injuries (424,000) in 2013 (NHTSA 2015)
  – 1.4% of fatalities associated with cell phones

• Observable distraction 51% of baselines (Dingus et al 2016)
  – Tech-distractions in ~10% of baselines
  – %15 interaction with adult/teen passenger
Visual-manual most detrimental

<table>
<thead>
<tr>
<th>Observable distraction*</th>
<th>OR (p&lt;.05)</th>
<th>Baseline prevalence %</th>
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<tbody>
<tr>
<td>In-vehicle device total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio</td>
<td>1.9</td>
<td>2.21</td>
</tr>
<tr>
<td>Climate control</td>
<td>2.3</td>
<td>0.56</td>
</tr>
<tr>
<td>Other</td>
<td>4.6</td>
<td>0.83</td>
</tr>
<tr>
<td>Cell total (handheld)</td>
<td>3.6</td>
<td>6.40</td>
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<tr>
<td>Browse</td>
<td>2.7</td>
<td>0.73</td>
</tr>
<tr>
<td>Dial</td>
<td>12.2</td>
<td>0.14</td>
</tr>
<tr>
<td>Reach</td>
<td>4.8</td>
<td>0.58</td>
</tr>
<tr>
<td>Text</td>
<td>6.1</td>
<td>1.91</td>
</tr>
<tr>
<td>Talk</td>
<td>2.2</td>
<td>3.24</td>
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<tr>
<td>Reading/writing</td>
<td>9.9</td>
<td>0.09</td>
</tr>
<tr>
<td>(includes tablet)</td>
<td></td>
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</tr>
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</table>

*From 6-second pre-crash and baseline sample video segments; Dingus et al 2016
How common is model driving?

“The risks associated with all contributing factors were then evaluated through a comparison with alert, attentive, and sober driving episodes (operationally defined herein as “model” driving).”
Why distraction happens

• Automaticity
  – lane keeping, car following, vision for action; not pedestrian detection, vision for identification
  – Allows for parallel processing (not always optimal)

• Under arousal
  – Drivers seek out stimulation when driving demands are low (Shinar 2008)

• Continual visual attention and intermittent manual input
  – Expectancy, uncertainty
  – Single channel processing; Inopportune short glances are a common crash, near crash problem (Victor et al 2014)
A continuum of intentionality (Lee et al 2008)

- Involuntary
- Voluntary

- Increasing display functionality for infotainment
- 70% of distraction associated with crashes were voluntary (Beanland et al 2013)
- We found that glance frequency correlated with self-reported everyday attentional failures (CFQ; Broadbent et al 1982)
- Not enough focus on self-paced paradigm (Caird et al 2008)
Implications for Distraction Mitigation

• Target behavioural modification for voluntary distraction

• Function lockouts may be more effective for involuntary distraction
  – Cell-phone blocker technology frequently bypassed – Michigan DOT volunteers (Funkhouser and Sayer, 2013)
  – Worse rejection for teens; dramatic dropout (Benden et al. 2012)
  – Connectivity is important

• Smart-driver monitoring/assistance for both
Machine Learning

SMART DRIVER MONITORING

VEHICLE MEASURES
- Steering angle
- Throttle position
- Brake position
- Braking intensity
- Vehicle heading
- Acceleration
- Velocity
- Headway distance
- Speed limit detection
- Over/under speeding
- Time-to-lane crossing
- Lane detection
- Lane deviation
- Jerk

FACIAL & BODY EXPRESSION
- Gaze direction
- Eye movements
- Eye blinks
- Eyes opening/closure
- Yawning
- Head movements

PHYSIOLOGICAL MEASURES
- Skin conductivity
- Respiratory activity
- Heart activity
- Brain activity

DRIVER FEEDBACK
- Audio
- Visual
- Vibration
- Break/rest reminder
- Device lockout
- Adaptive cruise control
- Collision avoidance
- Lane keeping assistance

Aghaei, .., Donmez, Plataniotis (in review) IEEE Signal Processing Magazine
Distraction mitigation

limited **attentional resources**

real-time feedback

**driving**

**secondary tasks**

**memory** on driving, real-time feedback and secondary tasks

**Post-drive feedback**

**mental model** of safe driving

**personality**

**social norms**

during driving

post driving

Feng, Donmez (2013) *Proc. of Driver Assessment Conference*
Original equipment (OE) in-vehicle electronic devices used by the driver to perform secondary tasks through visual-manual means.

Android Auto will be available on your phone.
Distraction mitigation

limited attentional resource

real-time feedback
driving

secondary tasks

memory on driving, real-time feedback and secondary tasks

mental model of safe driving
during driving

personality

social norms

Post-drive feedback

post driving

Feng, Donmez (2013) Proc. of Driver Assessment Conference
Mitigation with Real-time, Post-drive Feedback

Donmez, Boyle, Lee (2008) *Accident Analysis and Prevention*
Donmez, Boyle, Lee (2010) *Journal of Transportation Engineering*
Voluntary distraction – TPB

Self-reported voluntary distraction engagement frequency function of attitudes, perceived control, social norms

Chen, Hoekstra-Atwood, Donmez (2016) Transportation Research Part F
Online Survey

Susceptibility to Driver Distraction Questionnaire (Feng, Marulanda, Donmez, TRR 2014)

- hold phone conversations
- manually interact with a phone
- adjust the settings of in-vehicle technology (e.g., radio or GPS)

Distraction engagement frequency
  When driving, you...

Attitudes
  I think it is alright to drive and...
  You think you can drive well and...

Descriptive social norms
  Most drivers around me drive and...

Injunctive social norms
  Most people important to me think it is alright to drive and...

Technology inclination (Reimer et al 2013)
  Level of experience with technology
  Readiness to adopt new technology

Risk/Sensation seeking
  Impulsiveness and Venturesomeness scales (Eysenck & Eysenck 1978)
  Sensation seeking scale (Arnett 1994)
Attitude most important among tested (TPB predictors, personality, technology inclination)
  • Need to emphasize/calibrate risk perception of driver distraction
• For older drivers, sensation/risk seeking personality seems more relevant than norms
  • Also likely more susceptible to involuntary distraction
• Younger drivers more susceptible to social norms, especially injunctive norm
  • Leverage social norms for feedback

Chen, Donmez (2016). *Accident Analysis and Prevention*
Teenage driver distractions

• Survey findings:
  - Parents behavior predictive of teenagers’ distracted driving (Carter et al 2014)
  - Teens may overestimate their parents’ distraction engagement and approval of distraction
  - Parents may underestimate their teens’ distraction engagement

Social norms feedback based on parents’/peers’ engagement in distractions
Parental norms: Number of unsafe glances (>2 seconds)
Feedback and rewards on speeding and tailgating:

- Three phases (37 drivers)
  - Baseline – 2 weeks
  - Intervention – 12 weeks
  - Post-intervention – 2 weeks

Green light: compliant
- Headway compliant
- Speed compliant

Yellow light: noncompliant
- Headway noncompliant
- Speed noncompliant

Merrikhpour, Donmez, Battista (2014) *Transportation Research Part F*
Average linkage hierarchical clustering

- N = 21, (12 females; 9 males)
- Speed compliance = 89%
- Headway compliance = 90%

- N = 16, (5 females; 11 males)
- Speed compliance = 79%
- Headway compliance = 70%

Merrikhpour, Donmez, Battista (2014) *Transportation Research Part F*
Similar effect for headway but only significant for higher risk group

Merrikhpour, Donmez, Battista (2014) *Transportation Research Part F*
16 weeks; 60 participants

- Real-time

- Real-time + incentives: Up to $300 based on speed limit compliance

- Real-time + post-drive + cumulative feedback

Driving Report Overview

Changes in Percentage Time Spent Over the Speed Limit Since the Start of the Study

- Urban: 29%
- Rural: 12%
- School: 22%
- Overall: 22%

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How might attention be affected when action stage gets automated?
Action stage automated

• **Meta-analysis** *(de Winter et al 2014)*
  – drivers of a highly automated car and to a lesser extent ACC drivers are likely to engage in non-driving tasks.
  – when they are not engaged in non-driving tasks, they are more likely to get fatigue compared to manual driving.

• **Driver state detection for transfer of control**
Distrionic Adaptive Cruise Control is no substitute for active driving involvement. It does not react to stationary objects, nor recognize or predict the curvature and lane layout of the road or the movement of the vehicles ahead. It is the driver's responsibility at all times to be attentive to traffic and road conditions, and to provide the steering, braking and other driving inputs necessary to retain control of the vehicle. After braking the car for stopped traffic ahead, the system resumes automatically only if traffic pauses for less than 3 seconds. Drivers are cautioned not to wait for the DISTRONIC Proximity Warning System before braking, as that may not afford sufficient time and distance to brake safely. Braking effectiveness also depends on proper brake maintenance, and tire and road conditions.
The highest levels of trust in ACC were exhibited when awareness of the systems’ limitations was lacking (Dickie, Boyle 2009)
Volvo to test autonomous cars with ordinary drivers on public roads by 2017

Participants in the trial will have to be sober and competent to take over controls at any time. Volvo claims its Drive Me system is capable of handling a range of driving conditions including “smooth commuting to heavy traffic and emergency situations” although its test roads will be without pedestrians, cyclists or oncoming traffic.

“It is relatively easy to build and demonstrate a self-driving concept vehicle, but if you want to create an impact in the real world, you have to design and produce a complete system that will be safe, robust and affordable for ordinary customers,” said Erik Coelingh one of Volvo’s technical specialists. “Making this complex system 99% reliable is not good enough. You need to get much closer to 100% before you can let self-driving cars mix with other road users in real-life traffic.”
The **Vanier Canada Graduate Scholarship** helps Canadian institutions attract highly qualified doctoral students.

- $50,000/year x 3 years
- 3 equally weighted criteria: academic excellence, research potential, and leadership