Assessing Attention While Driving Using Cardiac Measures of Autonomic Control

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What is Attention?

William James (1890) *Principles of Psychology*

- Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called *distraction*, and Zerstreutheit in German.

• Distracted driving is any non-driving activity a person engages in that has the potential to distract him or her from the primary task of driving and increase the risk of crashing.

• There are three main types of distraction:
  – Visual — taking your eyes off the road
  – Manual — taking your hands off the wheel
  – Cognitive — taking your mind off what you’re doing
While all distractions can endanger drivers’ safety, texting is the most alarming because it involves all three types of distraction.

Other distracting activities include:

- Using a cell phone
- Eating and drinking
- Talking to passengers
- Grooming
- Reading, including maps
- Using a PDA or navigation system
- Watching a video
- Changing the radio station, CD, or Mp3 player.
What Is Distracted Driving?

www.distraction.gov

• 20 percent of injury crashes in 2009 involved reports of distracted driving. (NHTSA).

• Of those killed in distracted-driving-related crashed, 995 involved reports of a cell phone as a distraction (18% of fatalities in distraction-related crashes). (NHTSA)

• In 2009, 5,474 people were killed in U.S. roadways and an estimated additional 448,000 were injured in motor vehicle crashes that were reported to have involved distracted driving. (FARS and GES)

• The age group with the greatest proportion of distracted drivers was the under-20 age group – 16 percent of all drivers younger than 20 involved in fatal crashes were reported to have been distracted while driving. (NHTSA)

• Drivers who use hand-held devices are four times as likely to get into crashes serious enough to injure themselves. (Source: Insurance Institute for Highway Safety)
Divided Attention and Dual-Tasks

• Resources must be shared when multiple tasks are performed simultaneously

• Attention in dual-tasks is influenced by component task structure
  Tasks that require common resources require greater attention in proportion to their demands upon these shared resources, regardless of their difficulty
Many-to-One Psycho ($\Psi$) - Physiological ($\Phi$) Mapping Between Task Demands and Heart Period

- Monitoring Difficulty
- Mental Arithmetic
- Verbal Working Memory Load
- Manual Control
- Dividing Attention

$\Psi \rightarrow \Phi$

Shorter Heart Period
## Modes of Autonomic Control for Heart Period from Berntson, Cacioppo, & Quigley (1991; 1993)

<table>
<thead>
<tr>
<th>Control Mode</th>
<th>Sympathetic Input</th>
<th>Parasympathetic Input</th>
<th>Heart Period Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reciprocally-Coupled Modes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympathetic Activation/</td>
<td>Increase</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
<tr>
<td>Parasympathetic Inhibition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parasympathetic Activation/</td>
<td>Decrease</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Sympathetic Inhibition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nonreciprocally-Coupled Modes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coactivation</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase, Decrease, or No Change</td>
</tr>
<tr>
<td>Coinhibition</td>
<td>Decrease</td>
<td>Decrease</td>
<td>Increase, Decrease, or No Change</td>
</tr>
<tr>
<td><strong>Uncoupled Modes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympathetic Activation</td>
<td>Increase</td>
<td>---</td>
<td>Decrease</td>
</tr>
<tr>
<td>Sympathetic Inhibition</td>
<td>Decrease</td>
<td>---</td>
<td>Increase</td>
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<tr>
<td>Parasympathetic Activation</td>
<td>---</td>
<td>Increase</td>
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<td>---</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
</tbody>
</table>
Modes of Autonomic Control for Heart Period from Berntson, Cacioppo, & Quigley (1993)

\[ HP = \beta - 230 \times S_i + 1713 \times P_j + I_{ij} + \varepsilon \]

A = Uncoupled Sympathetic Activation

B = Reciprocally-Coupled Sympathetic Activation/Parasympathetic Inhibition

C = Uncoupled Parasympathetic Inhibition
Autonomic Space

![Diagram of Autonomic Space]

- Uncoupled Sympathetic Inhibition
- Uncoupled Parasympathetic
- Activated Sympathetic
- Activated Parasympathetic
- Coupled Reciprocal
- Coupled Nonreciprocal

 activates

 inhibits

 activations

 inhibitions

 Uncoupled Sympathetic

 Uncoupled Parasympathetic

 Coupled Reciprocal

 Coupled Nonreciprocal
Dependent Variables

- **Heart period** (ms)
- **PNS**: Respiratory Sinus Arrhythmia / 0.12-0.49 Hz HF-HRV (ln(ms²))
- **SNS**: Pre-ejection Period (ms)
- Respiration (breaths/min)
- Analyzed as reactivity scores from resting baseline
Desktop Simulator
Car–Following (Tracking) Task

D = Simulated Driving
### Car–Following (Tracking) Task (N = 30)

<table>
<thead>
<tr>
<th>Measure</th>
<th>1-D Driving</th>
<th>2-D Driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Period (ms)</td>
<td>-47.89***</td>
<td>-41.24**</td>
</tr>
<tr>
<td>PEP (ms)</td>
<td>-1.50</td>
<td>0.21</td>
</tr>
<tr>
<td>RSA (ln(ms²))</td>
<td>-0.55*</td>
<td>-0.85**</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .001 compared to baseline

![Graph showing Sympathetic Activity and Parasympathetic Activity](image)
Tasks

- Simulated driving at constant velocity on straight, 2-lane road with no ambient traffic
- The n-back task –
  - A verbal working memory task
  - Attentional resources required increase as n increases
  - 0-back – is the current letter the same as the first letter presented?
  - 3-back – is the current letter the same as the one presented three trials previously?

\[ D = \text{Simulated Driving} \]
\[ N = n\text{-back} \]
Single-Task Results (N=32)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Driving</th>
<th>n-back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Period (ms)</td>
<td>3.74</td>
<td>-27.99***</td>
</tr>
<tr>
<td>PEP (ms)</td>
<td>-1.79</td>
<td>-2.17*</td>
</tr>
<tr>
<td>RSA (ln(ms²))</td>
<td>-0.26***</td>
<td>-0.19*</td>
</tr>
</tbody>
</table>

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### Single to Dual-Task Results (N=32)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Driving only</th>
<th>Dual-task 0-back</th>
<th>Dual-task 3-back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Period (ms)</td>
<td>3.74</td>
<td>-19.00*</td>
<td>-56.24**</td>
</tr>
<tr>
<td>PEP (ms)</td>
<td>-1.79</td>
<td>-2.40</td>
<td>-3.85*</td>
</tr>
<tr>
<td>RSA (ln(ms²))</td>
<td>-0.26*</td>
<td>-0.25*</td>
<td>-0.51*</td>
</tr>
</tbody>
</table>

* * p<.05  ** p<.01  *** p<.001

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Many-to-One Psychological ($\Psi$) - Physiological ($\Phi$) Mapping Between Task Demands and Heart Period

- Monitoring Difficulty
- Mental Arithmetic
- Verbal Working Memory Load
- Manual Control
- Dividing Attention

Shorter Heart Period
Many-to-Many Mapping Between Proposed Cardiac Modes of Control and Task Demands

- Transformation of $\Phi$ to $\Phi'$
  - the *autonomic mode of control* responsible for shorter heart period
- Many-to-many mapping between $\Psi$ and $\Phi'$
One-to-One Mapping Between Proposed Cardiac Modes of Control and Processing Resources

- Transformation of $\Psi$ to a possible model of attentional processing resources
- One to-one mapping between $\Psi'$ and $\Phi'$
Participants

- 246 students
- 70% (n = 171) women and 30% men (n = 75)
- $M$ age 18.7 years-old ($SD = 1.06$)
- 91% Caucasian, 0.4% American Indian, 4.1% African-American, 2.4% Hispanic, 0.4% Asian, 1.7% other
- 4% (n = 10) reported taking prescriptive medications including drugs used in the treatment of ADHD and mood disorders (e.g., Adderall and Lexapro)
Negative Emotions & Safe Driving Behavior

**Negative Emotions**

\[ \beta_1 = .52^{**} \]

**Driving Anger**

\[ \beta_1 = .48^{**} \]
\[ \beta_2 = .47^{**} \]

**Attention Disorder Symptoms**

\[ \beta_1 = -.21^{**} \]

**Emotion Control**

\[ \beta_1 = -.33^{**} \]

*p < .05, **p < .01

\( \beta_1 \) = zero-order correlation

\( \beta_2 \) = partial standardized regression coefficient with one mediator
Negative Emotions & Safe Driving Behavior

- **Negative Emotions**
  - $\beta_1 = .48^{**}$

- **Attention Disorder Symptoms**
  - $\beta_1 = .52^{**}$

- **Emotion Control**
  - $\beta_1 = -.21^{**}$
  - $\beta_2 = .18$

- **Driving Anger**
  - $\beta_1 = -.33^{**}$
  - $\beta_2 = -.29^{**}$

*p < .05, **p < .01

- $\beta_1$ = zero-order correlation
- $\beta_2$ = partial standardized regression coefficient with one mediator
Negative Emotions & Safe Driving Behavior

**Negative Emotions**

\[ \beta_1 = .52^{**} \]

**Attention Disorder Symptoms**

\[ \beta_1 = -.21^{**} \]

**Driving Anger**

\[ \beta_1 = .48^{**} \]
\[ \beta_2 = .47^{**} \]
\[ \beta_3 = .45^{**} \]

**Emotion Control**

\[ \beta_1 = -.33^{**} \]
\[ \beta_2 = -.29^{**} \]
\[ \beta_3 = -.24^{**} \]

*\( p < .05 \), **\( p < .01 \)

\( \beta_1 \) = zero-order correlation
\( \beta_2 \) = partial standardized regression coefficient with one mediator
\( \beta_3 \) = partial standardized regression coefficient with both mediators
Summary

• High anger and low emotion control ability account for the problems of maladaptive driving anger, NOT attention disorder symptoms:
  – Individuals with high symptoms of attention disorders experience and express their anger in more aggressive ways.
  – Individuals with attention disorders are unable to regulate their anger.
Method

• Participants
  – 42 students (10 male, 32 female) \( M \) age = 20.54 (\( SD = 1.52 \))
  – 20 (15 females) had “high” ADHD symptoms and 22 (17 females) had no ADHD symptoms
  – There were no group differences in age, years of driving history or miles per year driven.

• Performance on the Driving Simulator
  – Practice drive
  – Baseline driving condition
  – Frustration driving condition
AAA Michigan Driving Simulator
Frustration Events During Simulated Driving

Event log0001
Driving Performance for Low (n = 22) and High (n = 20) ADHD Symptom Groups

<table>
<thead>
<tr>
<th></th>
<th>Baseline Condition</th>
<th>Frustration Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Total No. running red stop light</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Total no. of collisions</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Total no. multiple (&gt;1) collisions</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>M Frustration Scale (0-100)</td>
<td>28.21</td>
<td>40.81</td>
</tr>
<tr>
<td>M Lane Excursions</td>
<td>7.95</td>
<td>8.52</td>
</tr>
</tbody>
</table>

* p<.05  ** p<.01

# Cardiac Data for Low (n = 22) and High (n = 20) ADHD Symptom Groups

<table>
<thead>
<tr>
<th>Event</th>
<th>Variable</th>
<th>Baseline Driving</th>
<th>Frustration Driving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low Group</td>
<td>High Group</td>
</tr>
<tr>
<td>Intrusion</td>
<td>Heart Period (ms)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>RSA (ln[ms²])</td>
<td>-0.52**</td>
<td>-0.51*</td>
</tr>
<tr>
<td></td>
<td>PEP (ms)</td>
<td>0.5</td>
<td>-1</td>
</tr>
<tr>
<td>Construction</td>
<td>Heart Period (ms)</td>
<td>-16</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>RSA (ln[ms²])</td>
<td>-0.48*</td>
<td>-0.64**</td>
</tr>
<tr>
<td></td>
<td>PEP (ms)</td>
<td>1</td>
<td>-1</td>
</tr>
</tbody>
</table>

* p<.05  ** p<.01
Autonomic Space for Low (n = 22) and High (n = 20) ADHD Symptom Groups

Intrusion

Parasympathetic Activity

Activation

0.5

1.5

High Baseline

High Frustration

Low Baseline

Low Frustration

Construction

Parasympathetic Activity

Activation

0.5

1.5

0.5

1.0

1.5

1.0

1.5

1.0

1.5

0.5

1.0

1.5
Conclusions

• High ADHD symptom group had more anger than low ADHD symptom group:
  – When provoked by frustrating events results in hostile and aggressive behaviors during simulated driving

• Driving performance differed between high and low ADHD symptom groups:
  – In *tactical* driving skills (decision making skills used while driving and adjusting to changing traffic conditions)
  – NOT in *operational* driving skills (fundamental skills such as vehicular control)

• High ADHD symptom group did not differ from low group in cardiac parasympathetic inhibition, but showed more sympathetic activation during frustration