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.*

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What Is Distracted Driving? www.distraction.gov

- 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

What Is Distracted Driving? www.distraction.gov

- 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.

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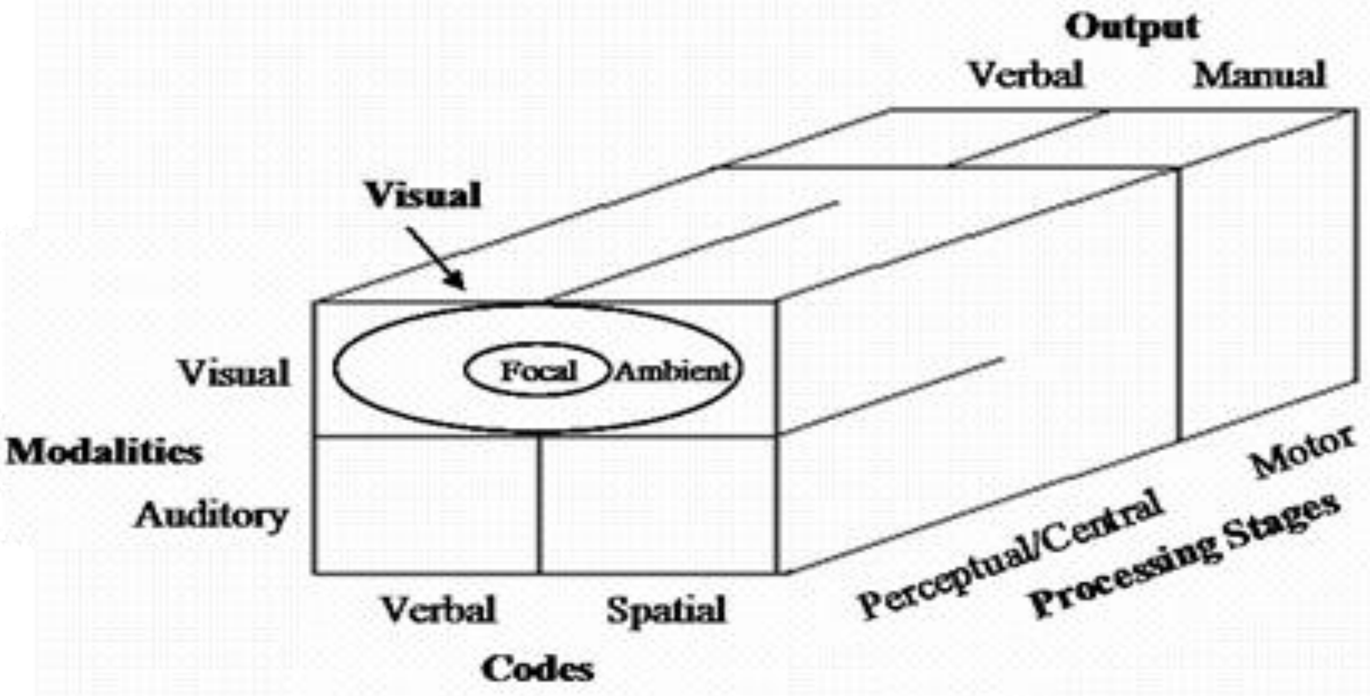
What Is Distracted Driving?
www.distraction.gov

- 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)

Wickens (2002) Multiple Resource Model of Attention



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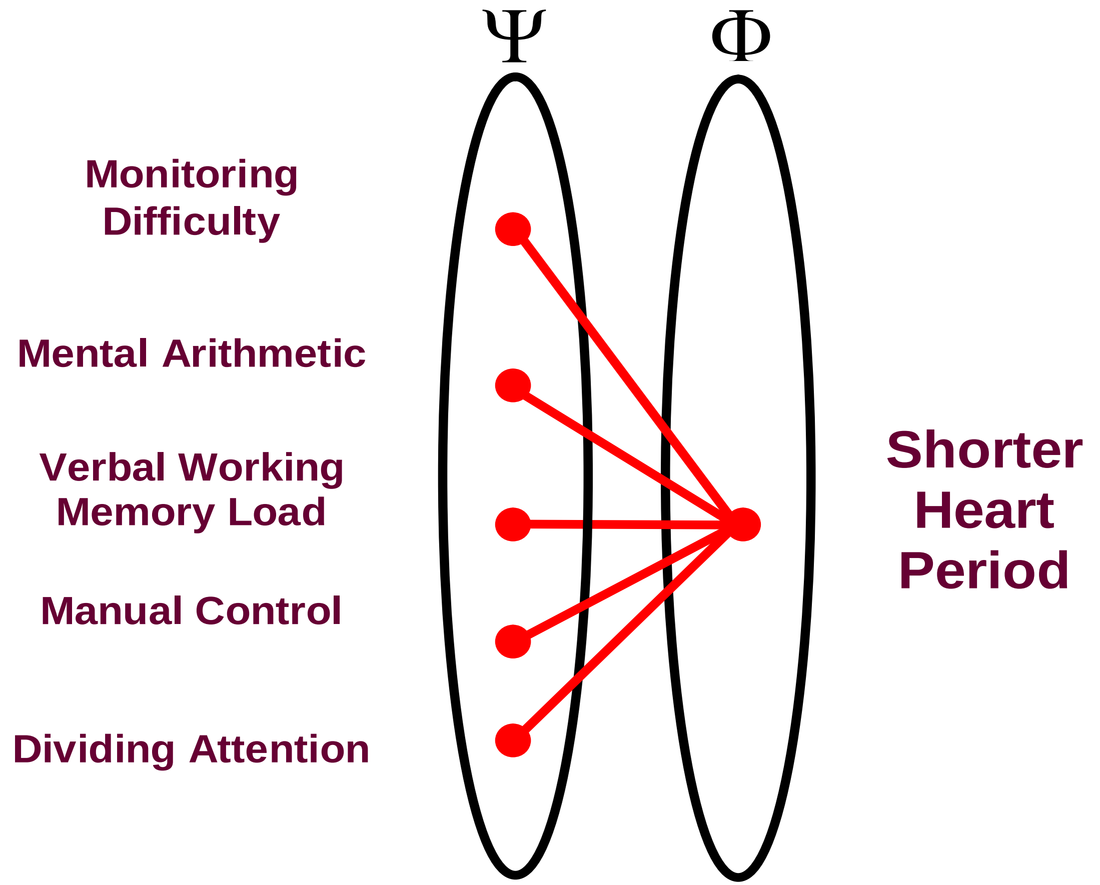
Divided Attention and Dual-Tasks

- 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 (Ψ) - Physiological (Φ) Mapping Between Task Demands and Heart Period



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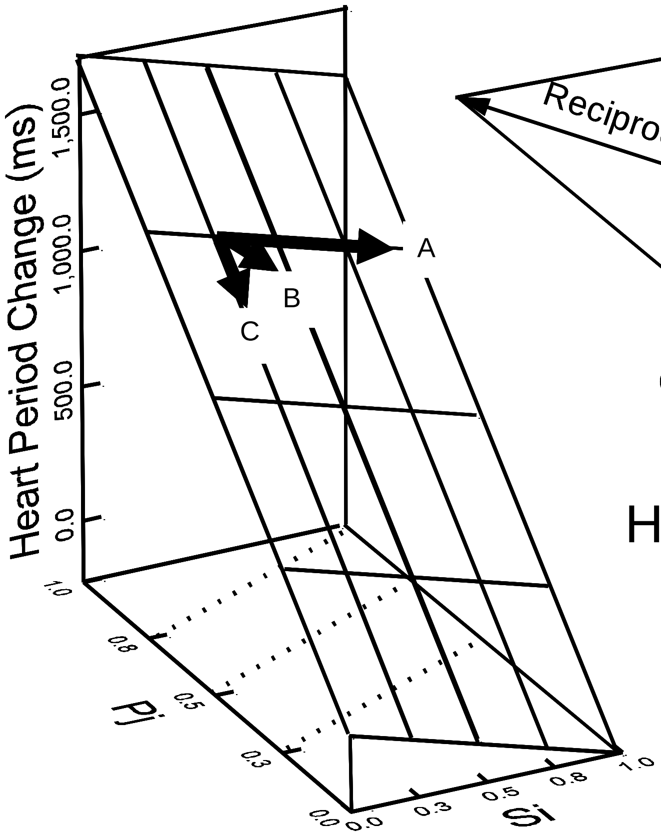
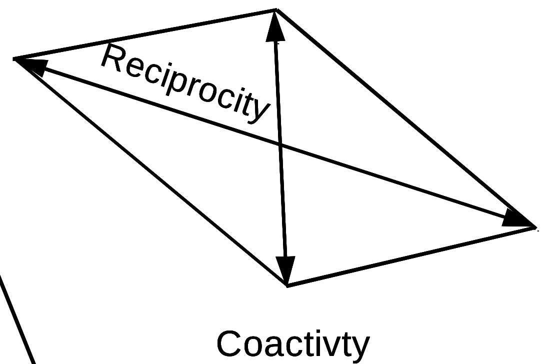
Modes of Autonomic Control for Heart Period from Berntson, Cacioppo, & Quigley (1991; 1993)

Control Mode	Sympathetic Input	Parasympathetic Input	Heart Period Response
Reciprocally-Coupled Modes			
Sympathetic Activation/ Parasympathetic Inhibition	Increase	Decrease	Decrease
Parasympathetic Activation/ Sympathetic Inhibition	Decrease	Increase	Increase
Nonreciprocally-Coupled Modes			
Coactivation	Increase	Increase	Increase, Decrease, or No Change
Coinhibition	Decrease	Decrease	Increase, Decrease, or No Change
Uncoupled Modes			
Sympathetic Activation	Increase	---	Decrease
Sympathetic Inhibition	Decrease	---	Increase
Parasympathetic Activation	----	Increase	Increase
Parasympathetic Inhibition	----	Decrease	Decrease

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





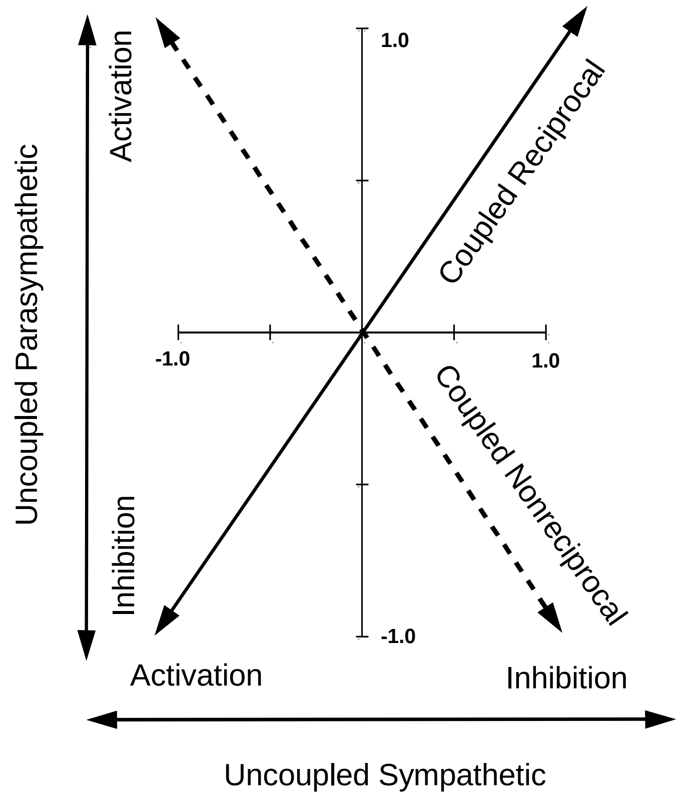
$$HP = \beta - 230 * S_i + 1713 * P_j + I_{ij} + \varepsilon$$

A=Uncoupled Sympathetic Activation

B=Reciprocally-Coupled Sympathetic Activation/Parasympathetic Inhibition

C=Uncoupled Parasympathetic Inhibition

Autonomic Space



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Dependent Variables

- **Heart period** (ms)
- **PNS:** Respiratory Sinus Arrhythmia / 0.12-0.49 Hz HF-HRV (ln(ms^2))
- **SNS:** Pre-ejection Period (ms)
- Respiration (breaths/min)
- Analyzed as reactivity scores from resting baseline

Control Panel
Auto Analysis
Working On File
drivingbaseline1_1_1.mw
Current Segment
4
Write (F7)
Done (F10)
Edit R's (F1)
R Peak & Artifact
Computing
Writing
Reading
Edit
HR/HRV
ECG
Volts
Time
IBI
Milliseconds
IBI #
ECG Ensemble Elements
Calculation Method
Entire
Interval Period
10.00
HR
61.92
Resp Rate
17.2283
Resp Peak Frequency
0.2871
Resp Signal
Z0
Resp Amplitude
1.13E-2
Resp Power
0.0134
Mean HR
61.92
Mean IBI
969.07
IBI Series
978.00
Intervals
0.00
R Peaks
62
R Peak Amplitudes
0.34
Heart Period Time Series
HR Power Spectrum
Frequency
Respiratory Time Series
Resp Power Spectrum
VLF Power
7.60
VLF Peak Frequency
0.020
VLF Band (Hz)
0.003
0.040
LF Power
101.18
LF Peak Frequency
0.091
LF Band (Hz)
0.040
0.120
HF/RSA Power
181.15
HF/RSA Peak Frequency
0.291
HF/RSA Band (Hz)
0.120
0.400
LF/HF Ratio
0.5585393
Windowing Function
Hamming
RSA
5.20

Control Panel
Auto Analysis
Current Segment
4
File Name
drivingbaseline1_1_1.mw
Write (F7)
Done (F10)
Edit R's (F1)
Edit Systolic Points (F2)
R Peak & Artifact
Computing
Writing
Reading
EDIT
IMPEDANCE
ECG & dZ/dt
Volts
Time (sec)
IBI
Milliseconds
IBI #
Ensemble Averages
Time (ms)
ECG Ensemble Elements
LVET
288.00
SV
19898.21
CO
1232.00
Zo
0.88
HR
61.92
PEP
120.00
Dz/dt Max
0.64
MAP
-1.00
TPR
-1.00
Q location
71.00
R location
100.00
B location
191.00
X location
479.00
Q value
-0.003
R value
0.173
B value
0.026
X value
-0.115
R Peak Amplitudes
0.17
R Peak
62
dZ/dt Source
measured
IBI Series
978.00
Mean IBI
969.07
Detrend Dz/dt
B point calculation method
max slope change
Q point calculation method
max slope change

Desktop Simulator

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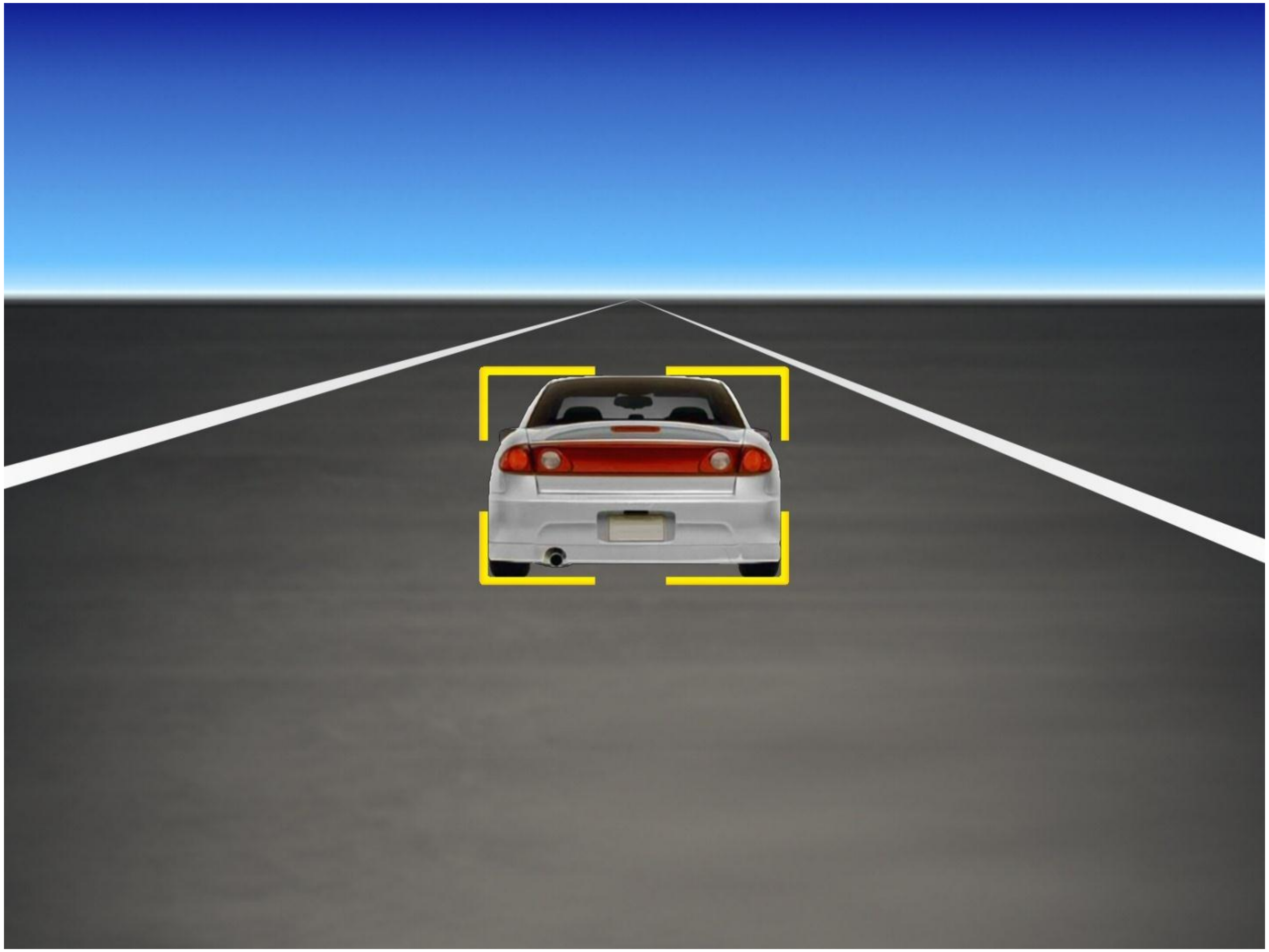
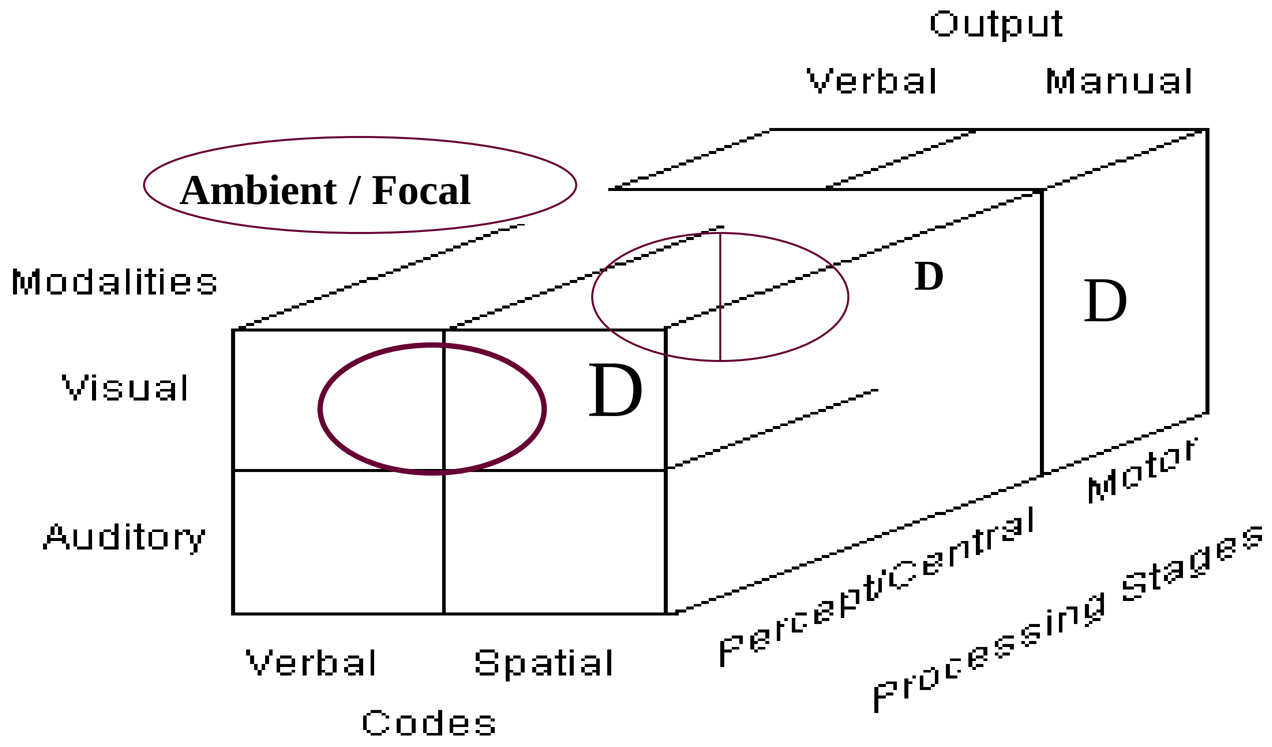
Car–Following (Tracking) Task



Wickens (2002) Multiple Resource Model of Attention

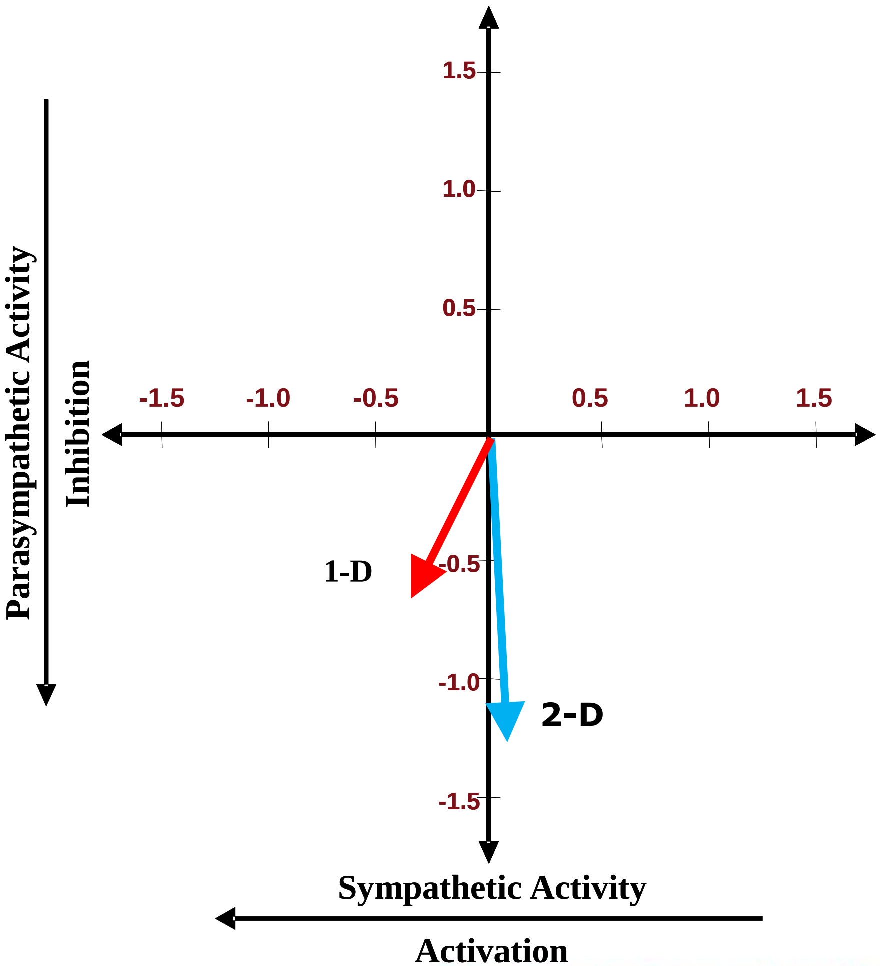
D = Simulated Driving



Car–Following (Tracking) Task (N = 30)

Measure	1-D Driving	2-D Driving
Heart Period (ms)	-47.89***	-41.24**
PEP (ms)	-1.50	0.21
RSA (ln(ms^2))	-0.55*	-0.85**

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



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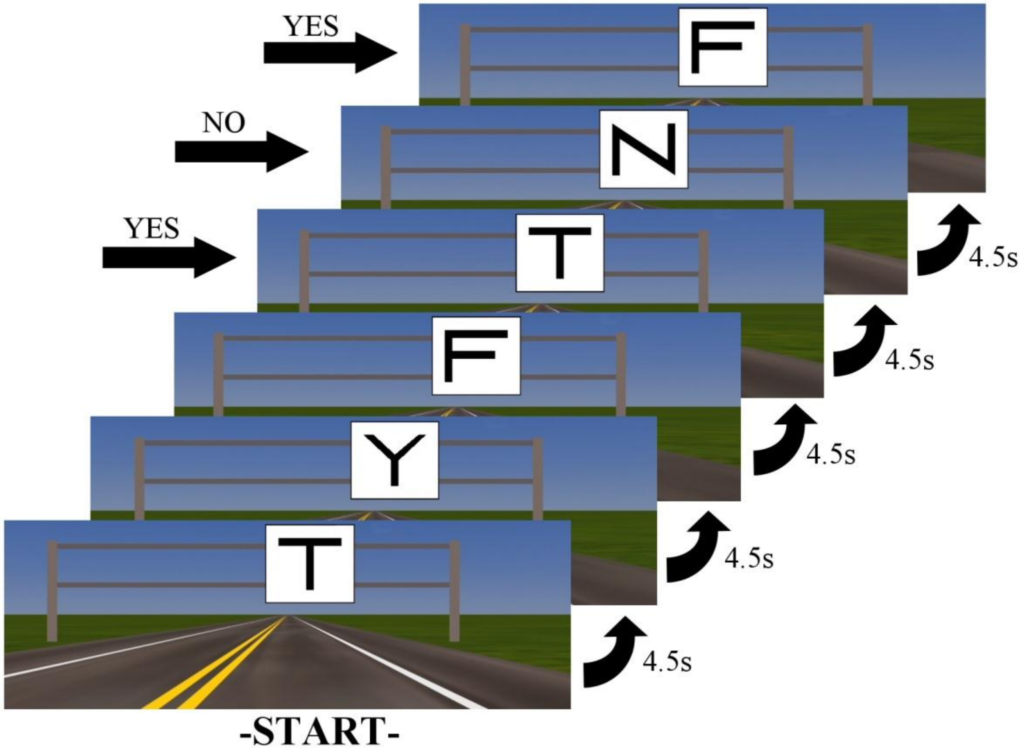
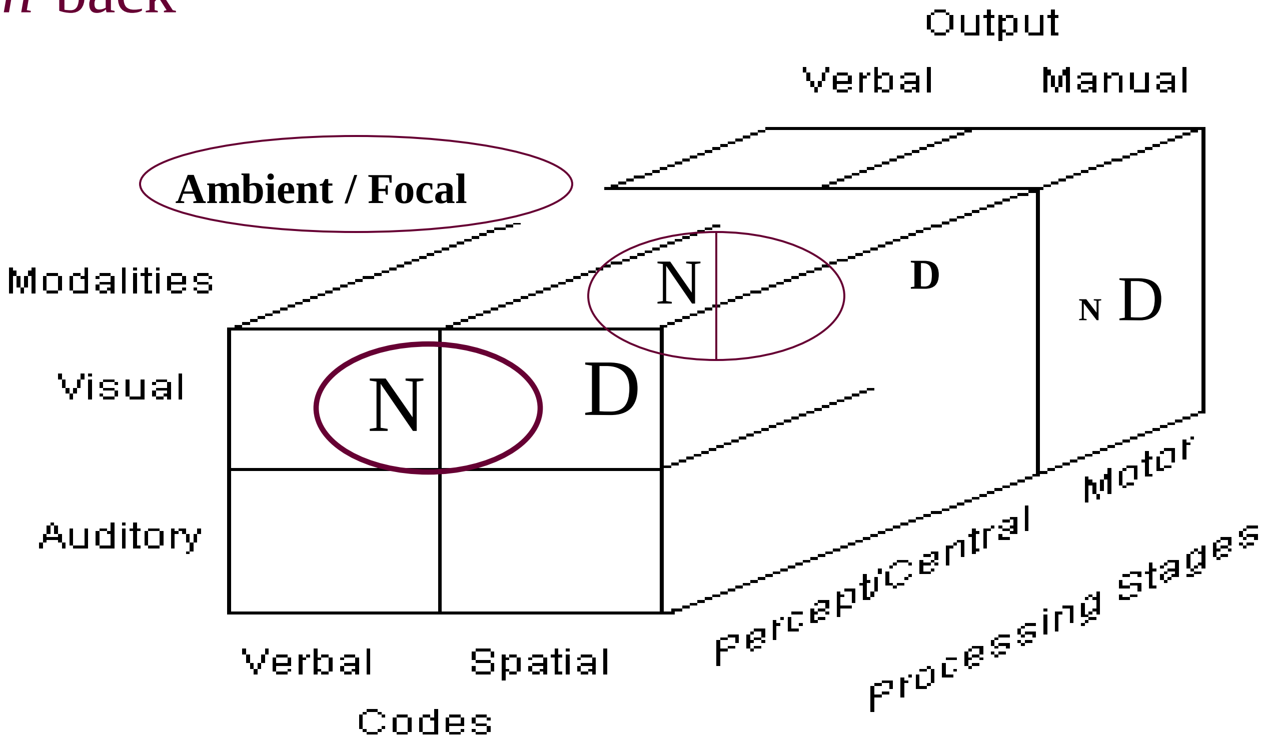
Tasks

- 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?



Wickens (2002) Multiple Resource Model of Attention

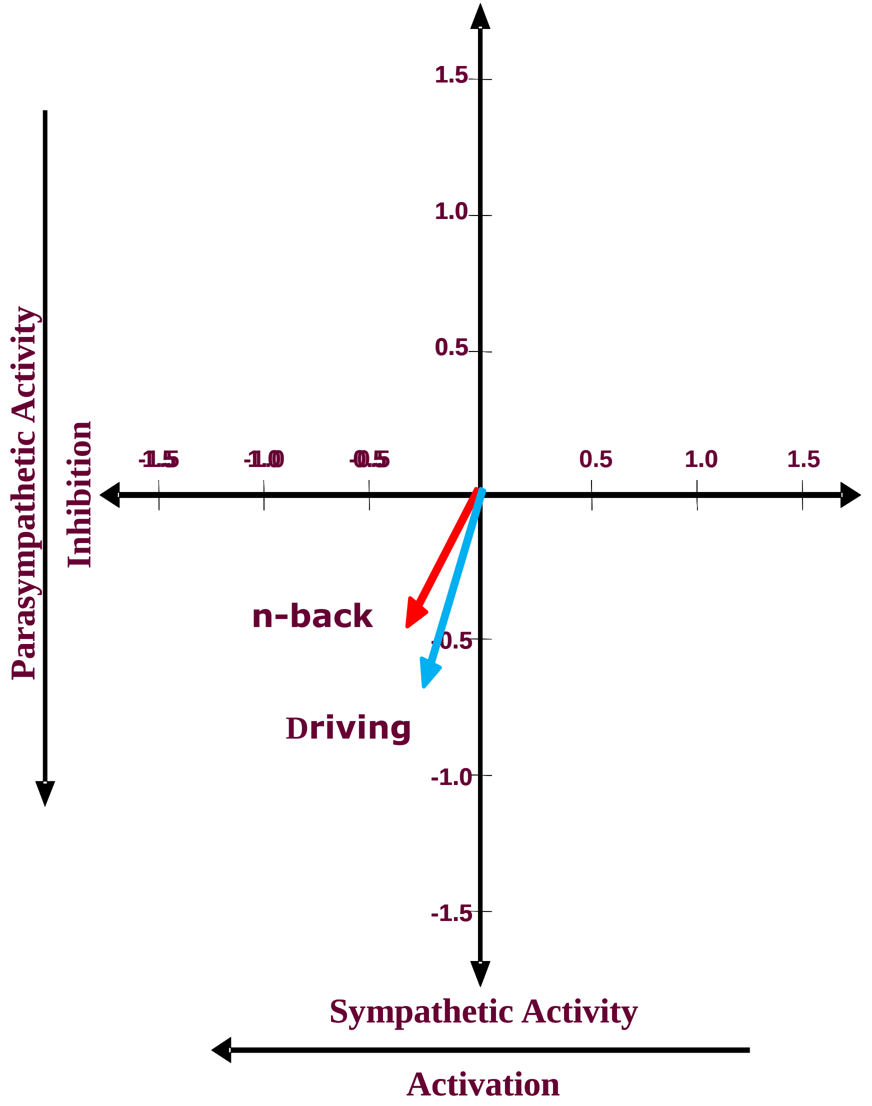
D = Simulated Driving
N = *n*-back



Single-Task Results (N=32)

Measure	Driving	n-back
Heart Period (ms)	3.74	-27.99***
PEP (ms)	-1.79	-2.17*
RSA (ln(ms^2))	-0.26***	-0.19*

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



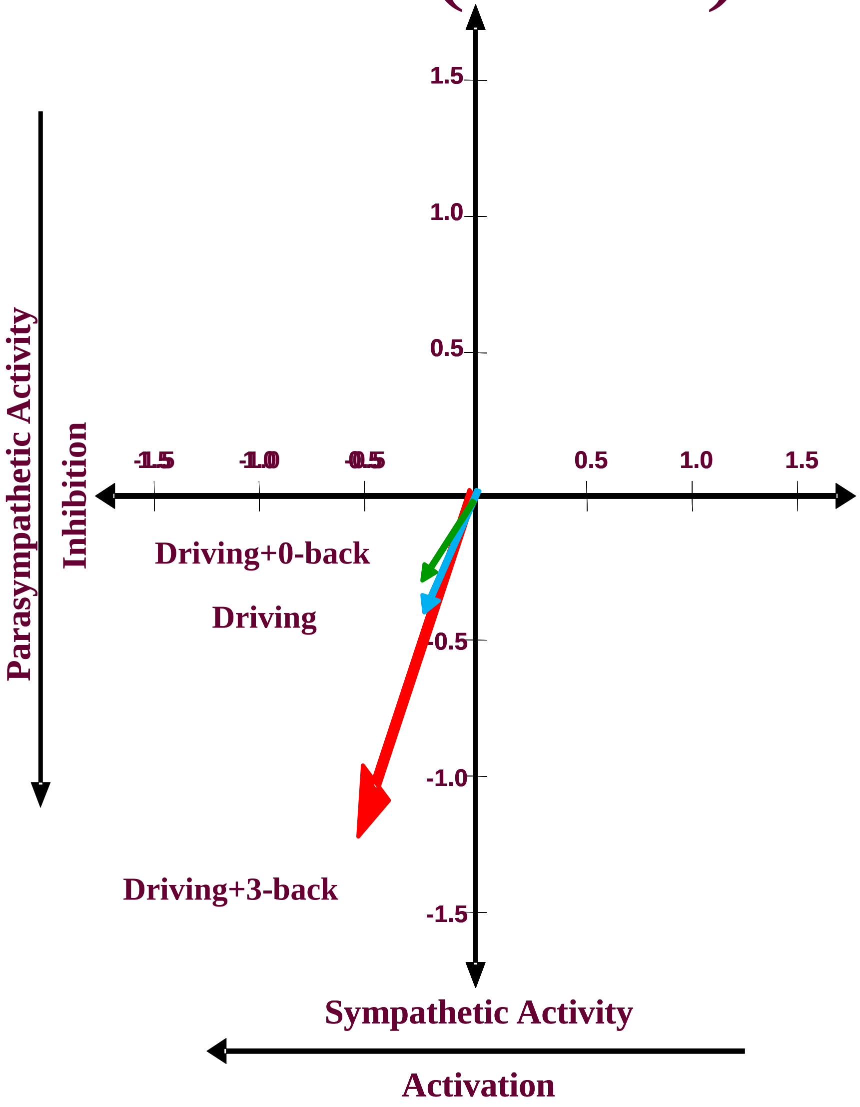
Lenneman, J. K., Tuttle, S.J., Oliver, M.L., & Backs, R. W. (2006). Cardiac autonomic control during dual-task performance of simulated driving and a verbal working memory task. *Proceedings IEA2006 Congress*. O xford, U.K.: Elsevier, Ltd.

Single to Dual-Task Results (N=32)

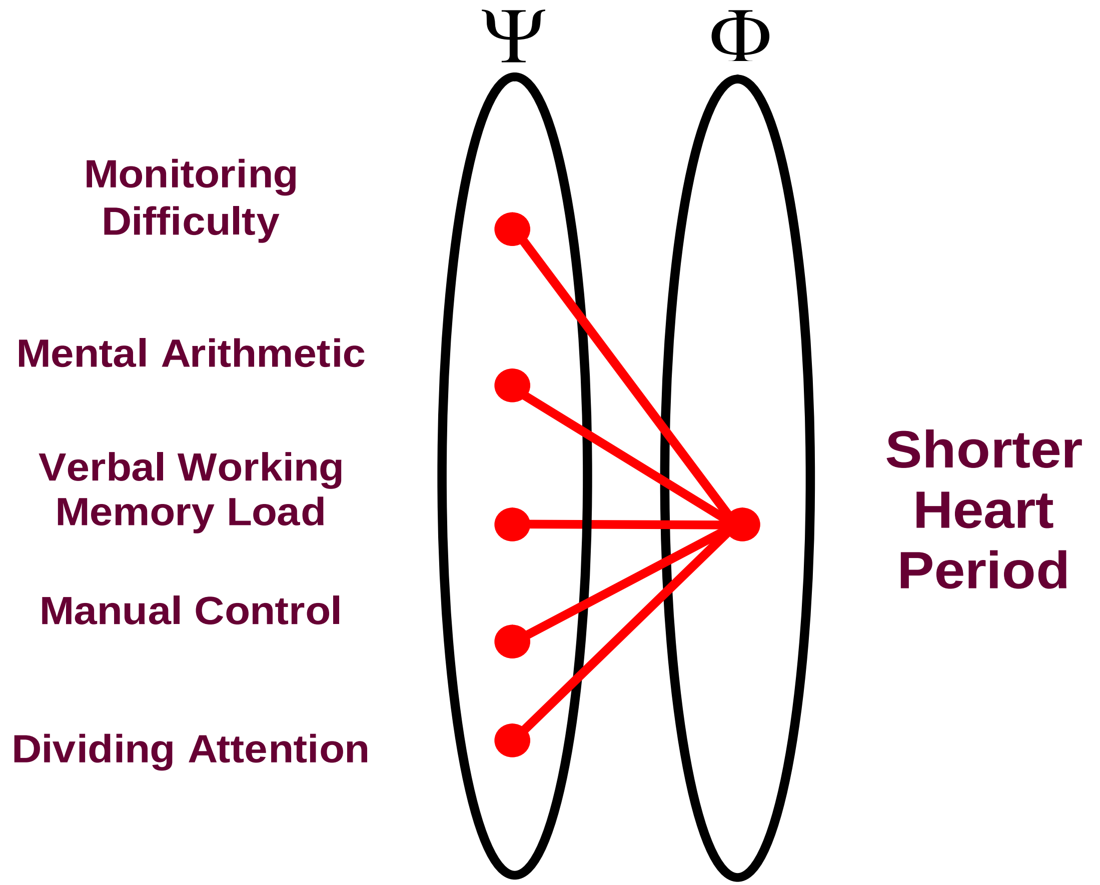
Measure	Driving only	Dual-task 0-back	Dual-task 3-back
Heart Period (ms)	**3.74**	**-19.00***	**-56.24****
PEP (ms)	**-1.79**	**-2.40**	**-3.85***
RSA (ln(ms^2))	**-0.26***	**-0.25***	**-0.51***

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

Lenneman, J. K., & Backs, R. W. (2009). Cardiac autonomic control during simulated driving with a concurrent verbal working memory task. *Human Factors, 51*, 404-418.



Many-to-One Psychological (Ψ) - Physiological (Φ) Mapping Between Task Demands and Heart Period



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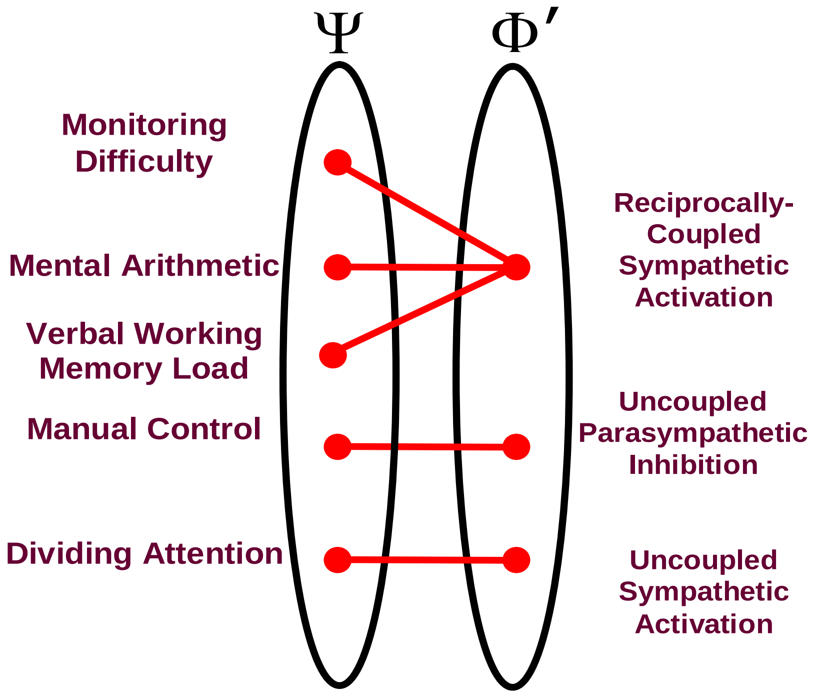
Many-to-Many Mapping Between Proposed Cardiac Modes of Control and Task Demands

- Transformation of Φ to Φ´ the *autonomic mode of control* responsible for shorter heart period
- Many-to-many mapping between Ψ and Φ´



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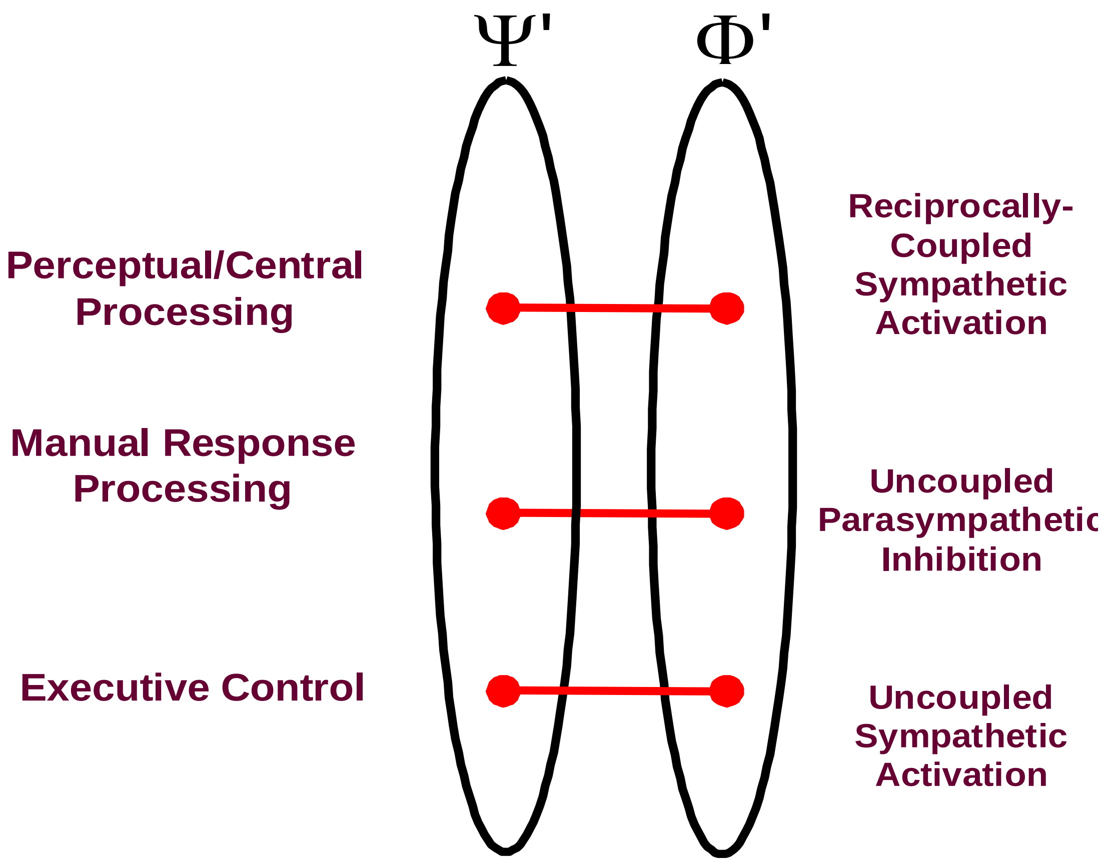
One-to-One Mapping Between Proposed Cardiac Modes of Control and Processing Resources

- Transformation of Ψ to a possible model of attentional processing resources
- One to-one mapping between Ψ´ and Φ´



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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)

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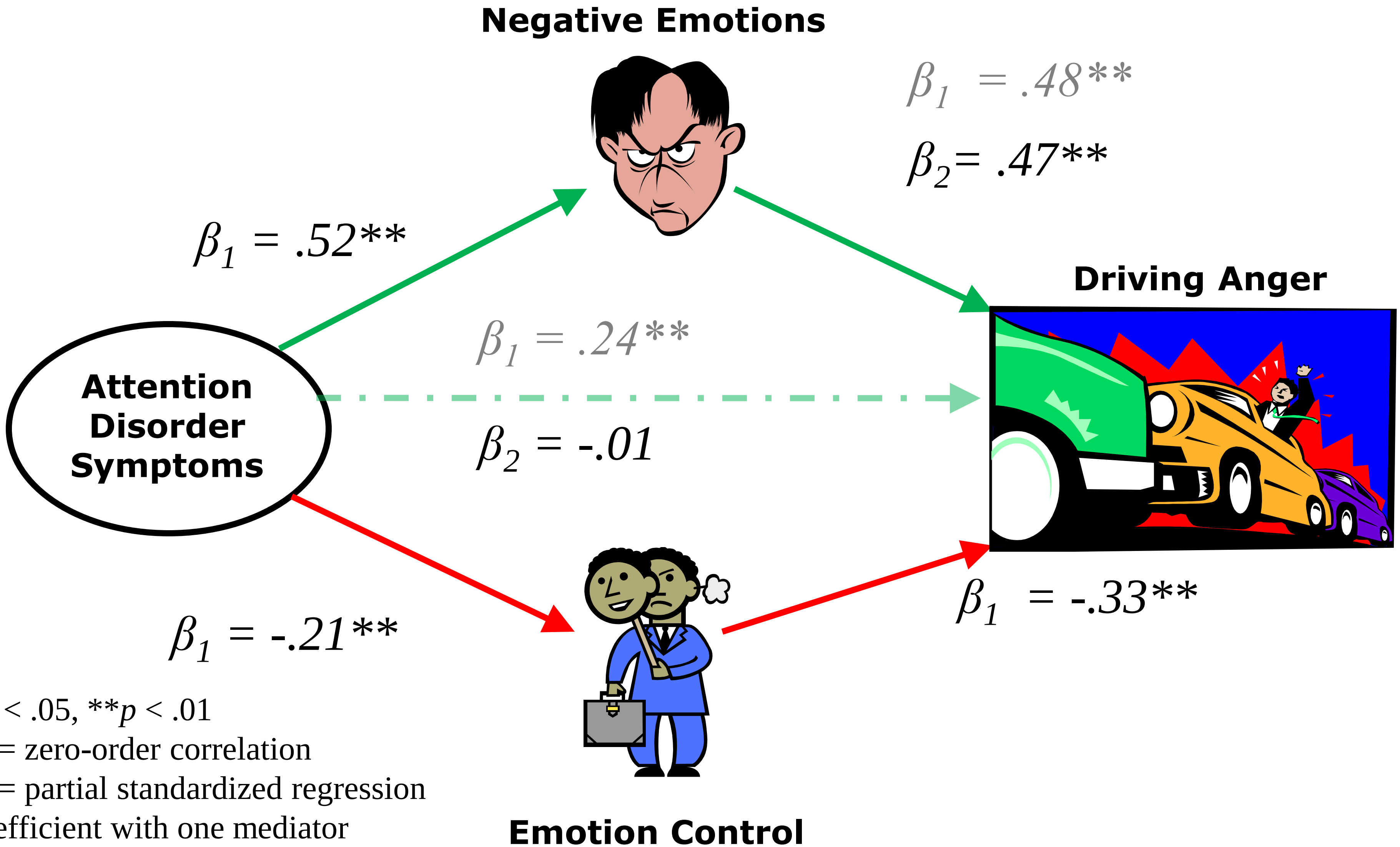
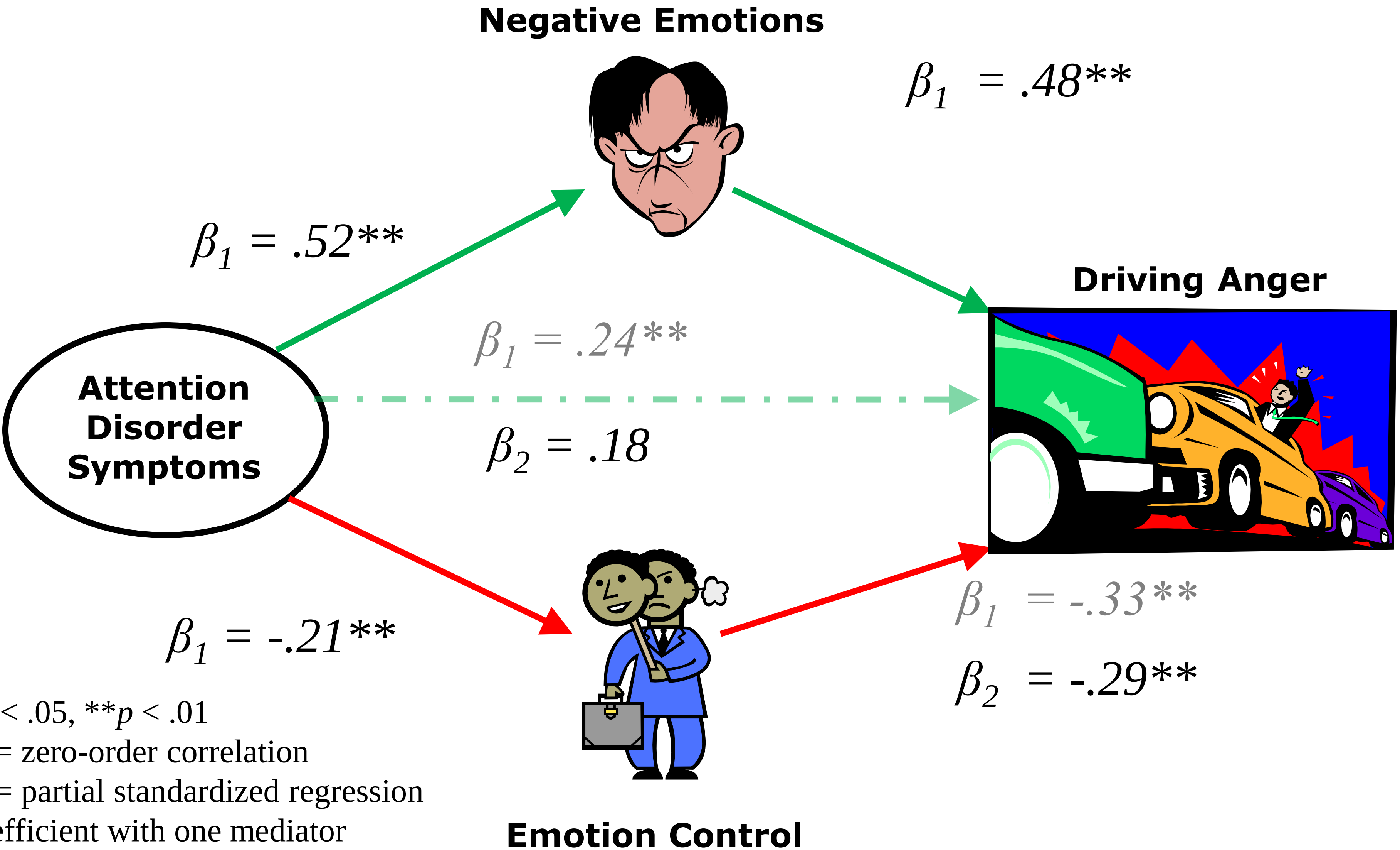
Negative Emotions & Safe Driving Behavior



$^{*}p < .05$, $^{**}p < .01$
β_1 = zero-order correlation
β_2 = partial standardized regression coefficient with one mediator

Negative Emotions & Safe Driving Behavior



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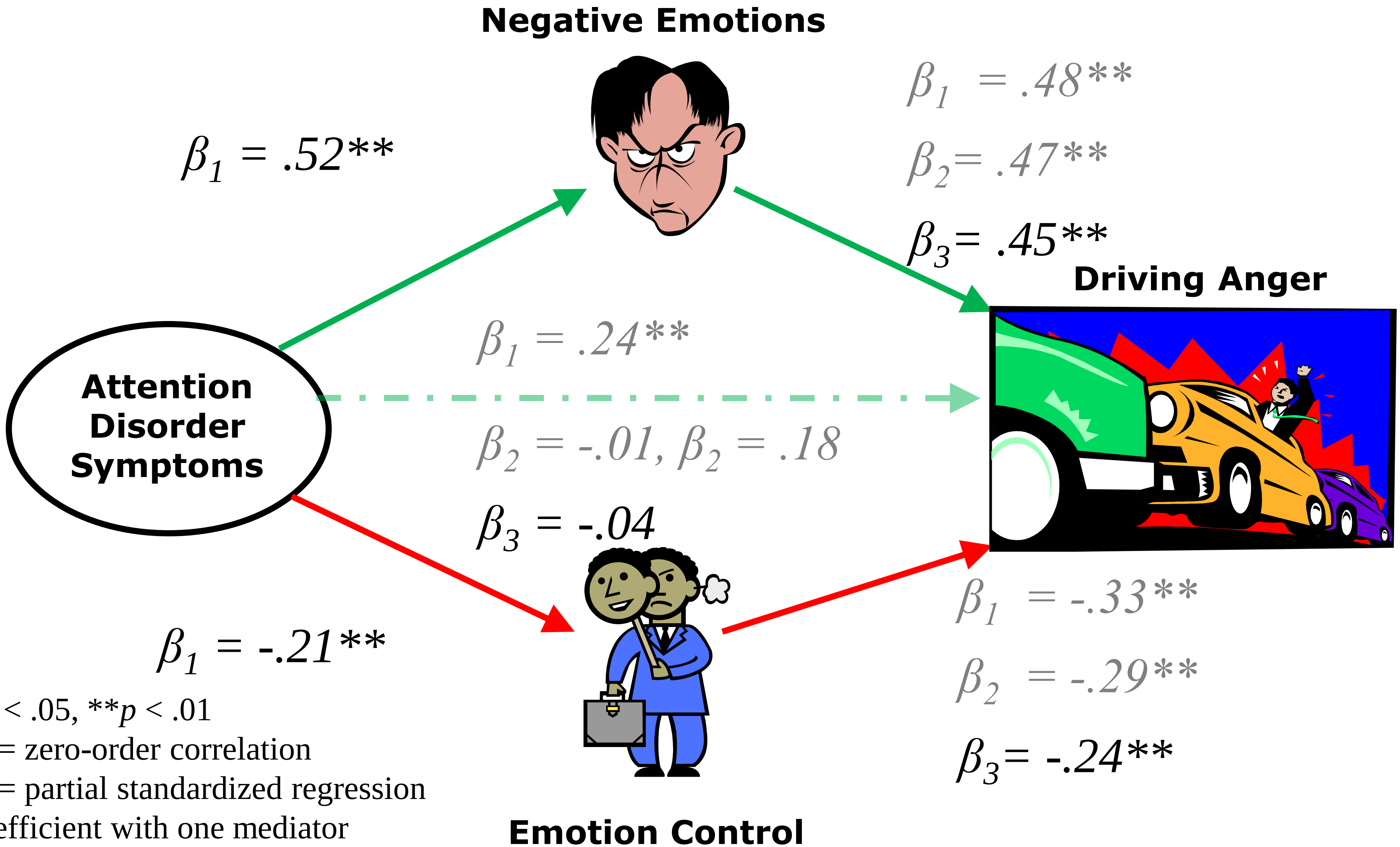
Negative Emotions & Safe Driving Behavior



$^{*}p < .05$, $^{**}p < .01$

β_1 = zero-order correlation

β_2 = partial standardized regression coefficient with one mediator

β_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

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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

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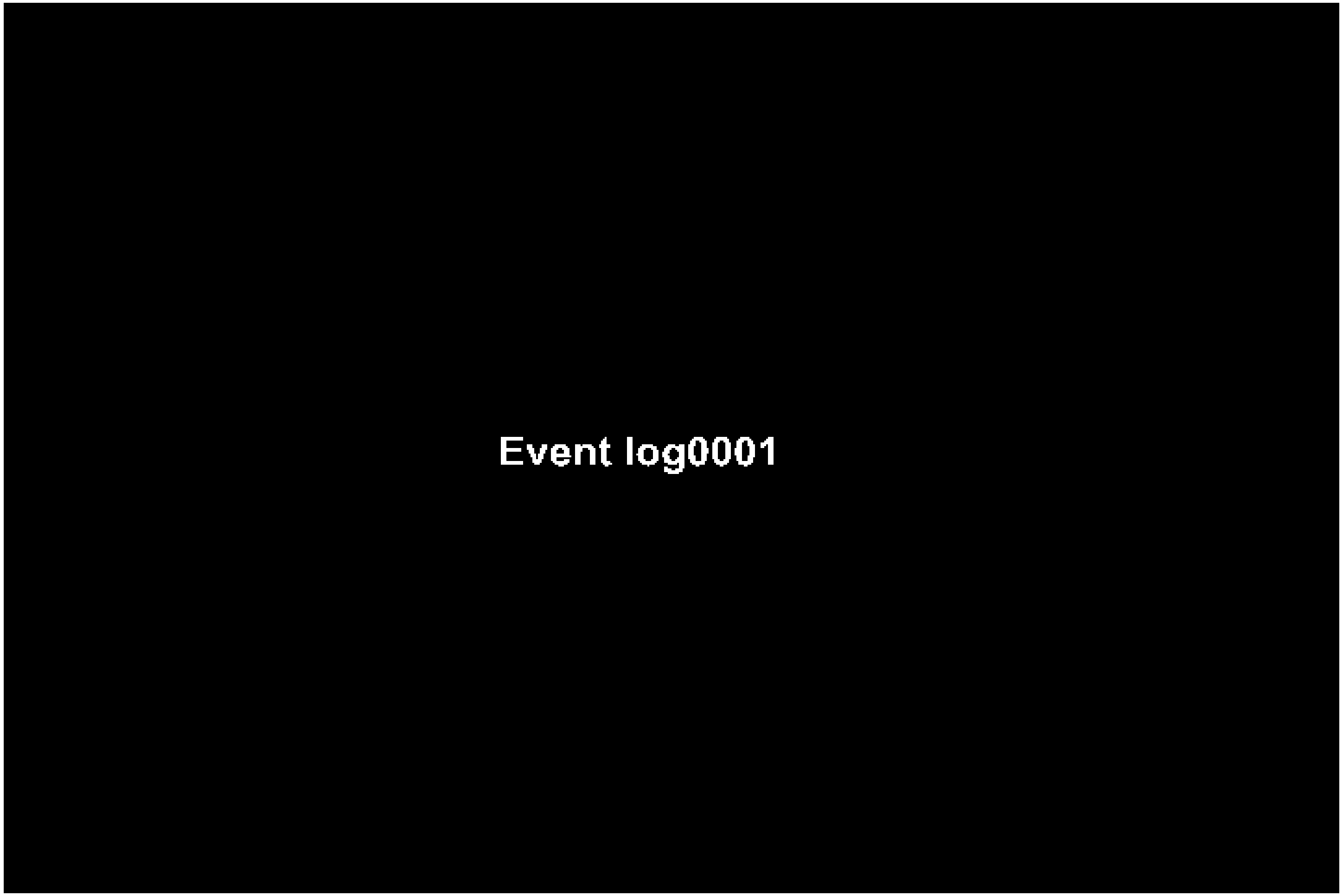
Frustration Events During Simulated Driving



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

	Baseline Condition		Frustration Condition	
	Low	**High**	**Low**	**High**
Total No. running red stop light	–	–	1	9**
Total no. of collisions	5	1	14	29*
Total no. multiple (>1) collisions	2	1	1	8**
M Frustration Scale (0-100)	28.21	40.81	52.79	70.81
M Lane Excursions	7.95	8.52	7.50	6.89

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

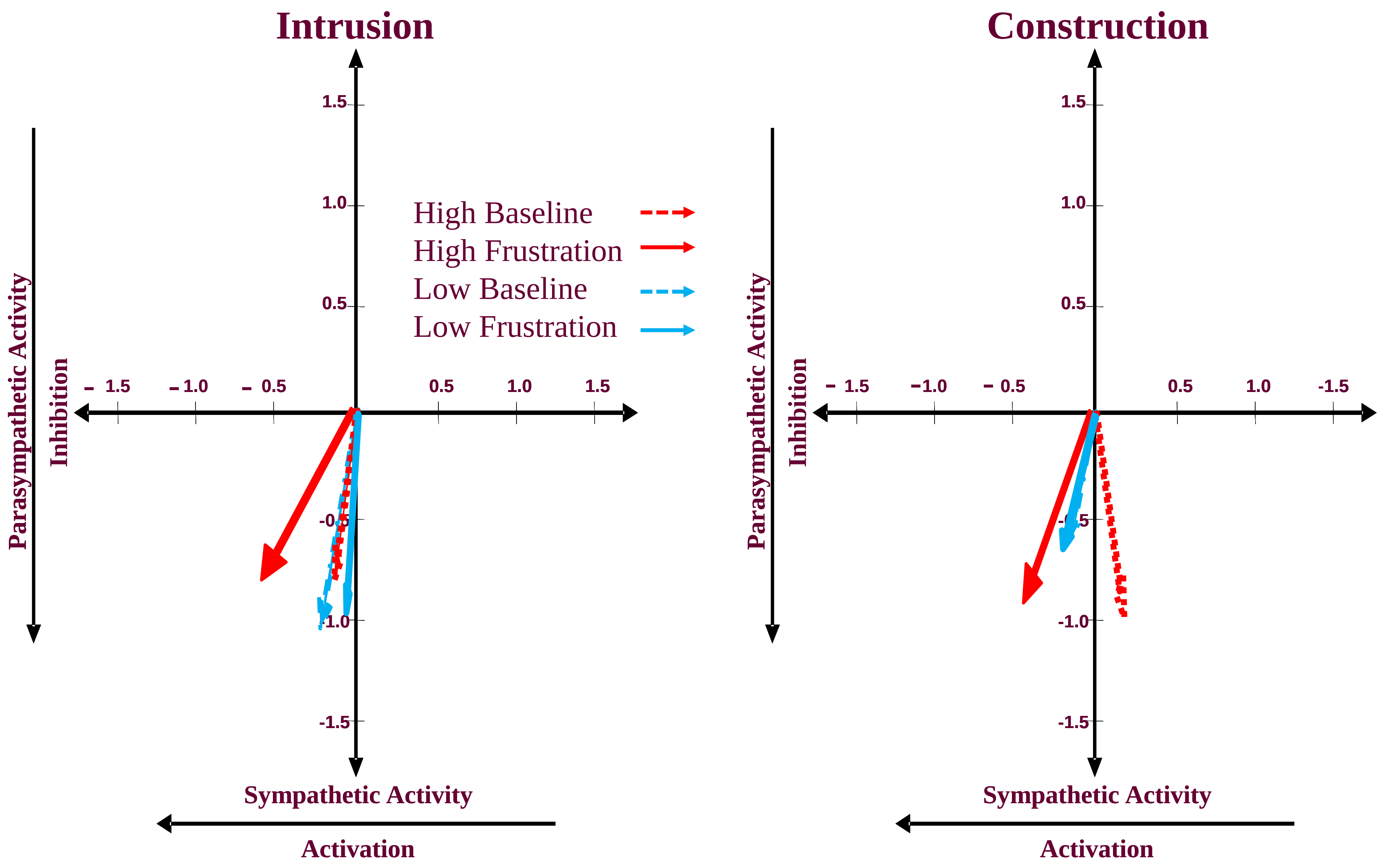
Oliver, M. L., Nigg, J.T., Cassavaugh, N. D., & Backs, R. W. (in press). Behavioral and cardiovascular responses to frustration during simulated driving tasks in young adults with and without attention disorder symptoms. *Journal of Attention Disorders*.

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

		Baseline Driving Condition		Frustration Driving Condition	
Event	**Variable**	**Low Group**	**High Group**	**Low Group**	**High Group**
Intrusion	Heart Period (ms)	**4**	**1**	**7**	**7**
	RSA ($\ln[ms^2]$)	**-0.52****	**-0.51***	**-0.42****	**-0.44***
	PEP (ms)	**0.5**	**-1**	**-1**	**-4**
Construction	Heart Period (ms)	**-16**	**-2**	**11**	**-7**
	RSA (ln[ms2])	**-0.48***	**-0.64****	**-0.49***	**-0.69****
	PEP (ms)	**1**	**-1**	**-1**	**-3**

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

Autonomic Space for Low (n = 22) and High (n = 20) ADHD Symptom Groups



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

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