# Acute Pain and Sustained Attention

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MACLab
The Memory & Attention Control Laboratory

# Arizona State University Team Overview

# Everybody Hurts

## Psychological Cost

Human Performance, Impoverished Social Relationships, Psychopathology, Addiction

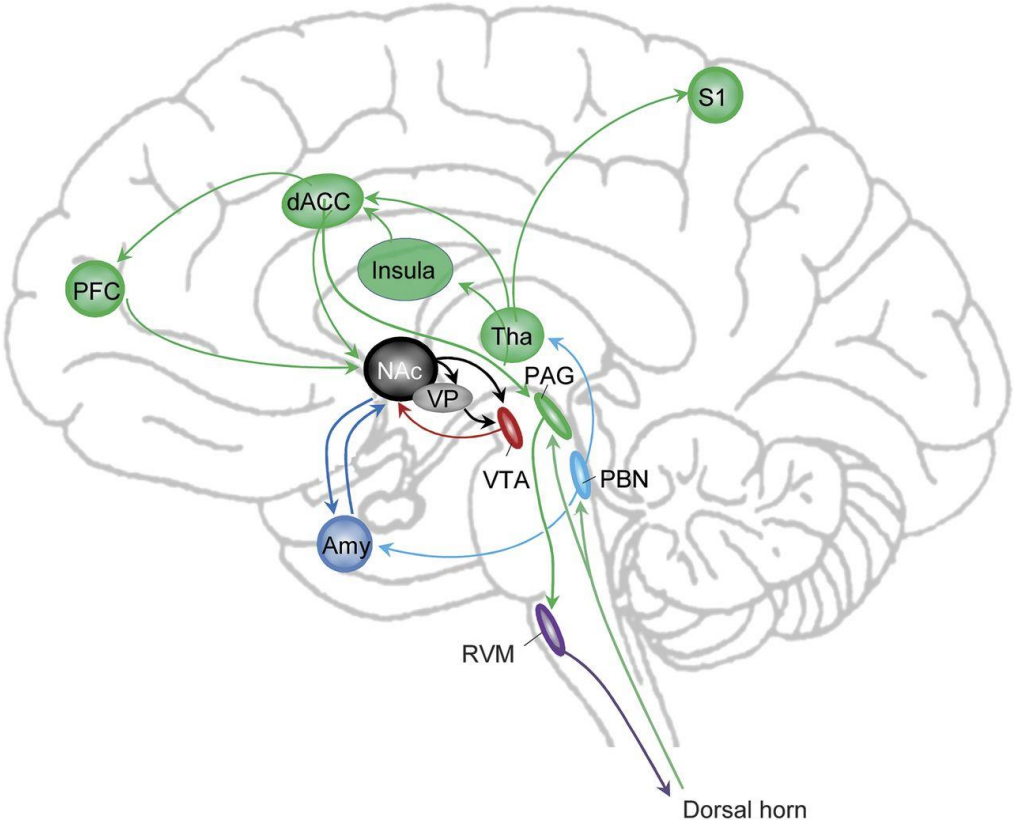
## Societal Cost

“The annual **cost** to the national economy associated with chronic **pain** is estimated to be $560 to $635 billion. That is more than heart disease, cancer, and diabetes combined! (This estimate includes the **cost** of health care for those with **pain** and the **cost** of lost productivity attributed to **pain**.)”

## What about the Transition from Acute to Chronic Pain?

Have you ever thought about where chronic pain comes from?

# Transition from Acute Pain to Chronic Pain




Benarroch, E. E. (2016)

# Our Theoretical Framework

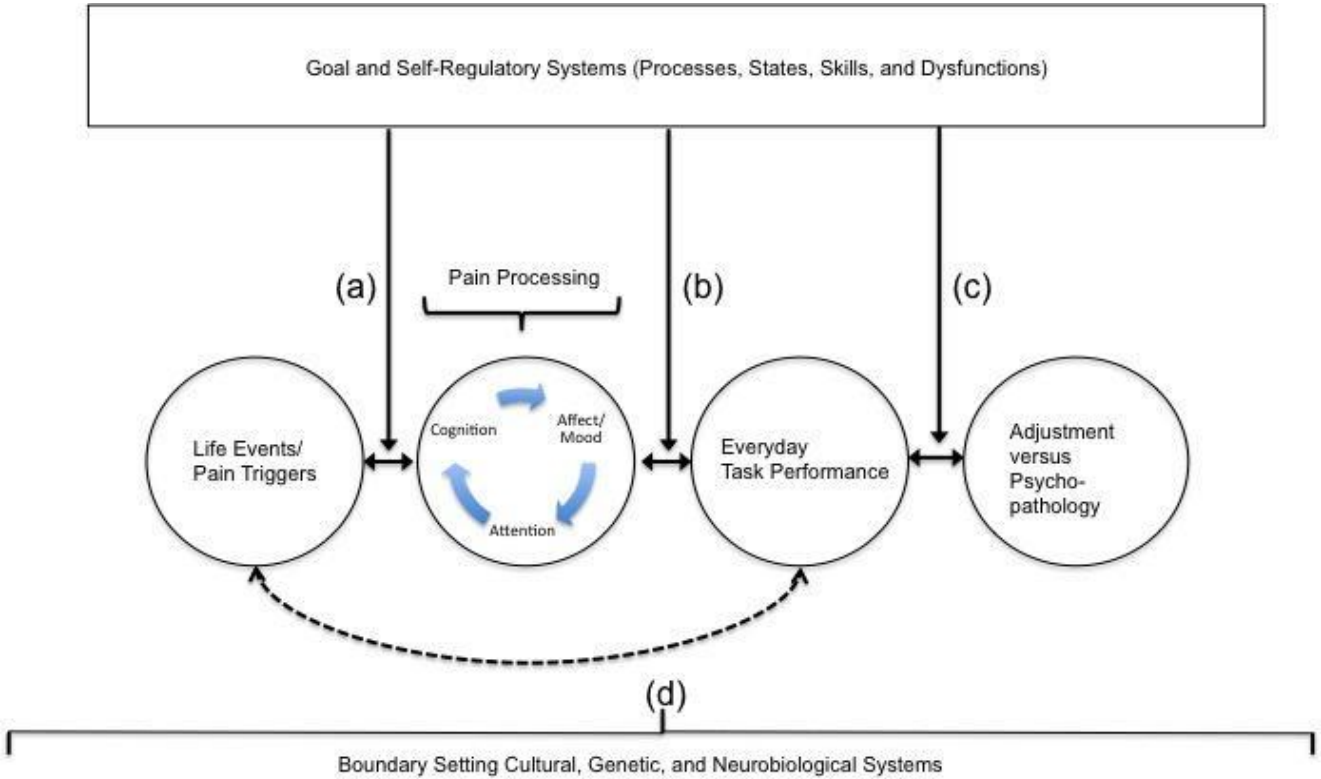
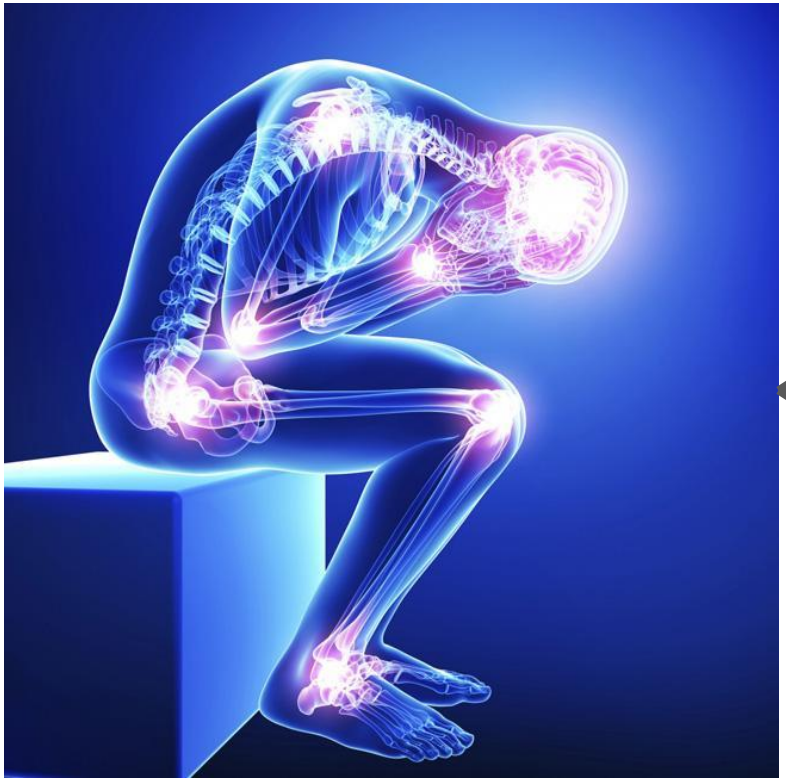



Figure 1. Goal-Centered Self-Regulatory Processes Moderating the Pain-Processing-Performance (PPP) Link to Adjustment and Maladjustment

Karoly, P. (2018)

# Conceptual Overview of Our Research Program

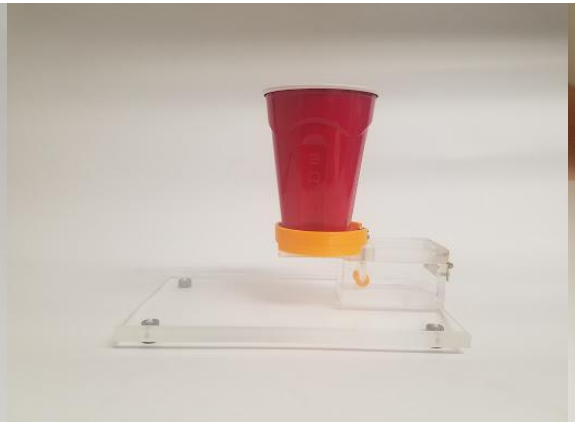


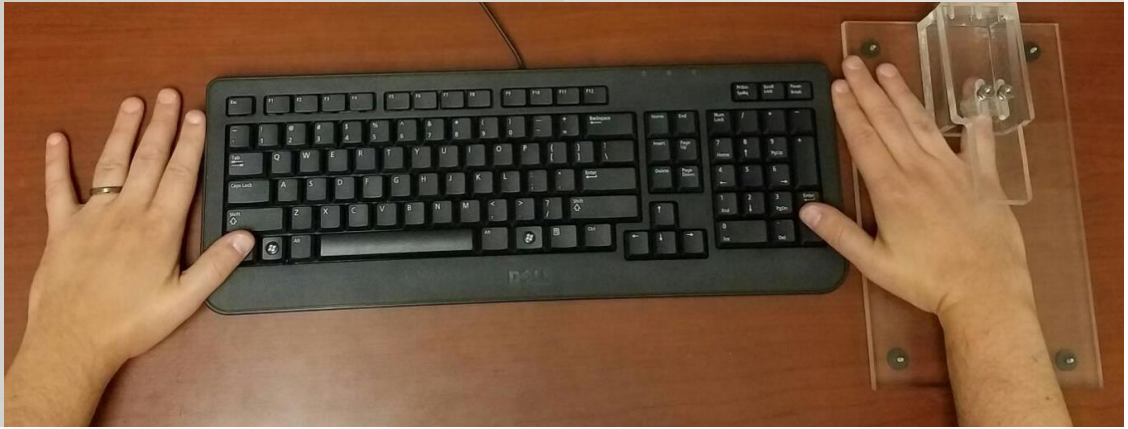
Executive Functions

Goal Attainment

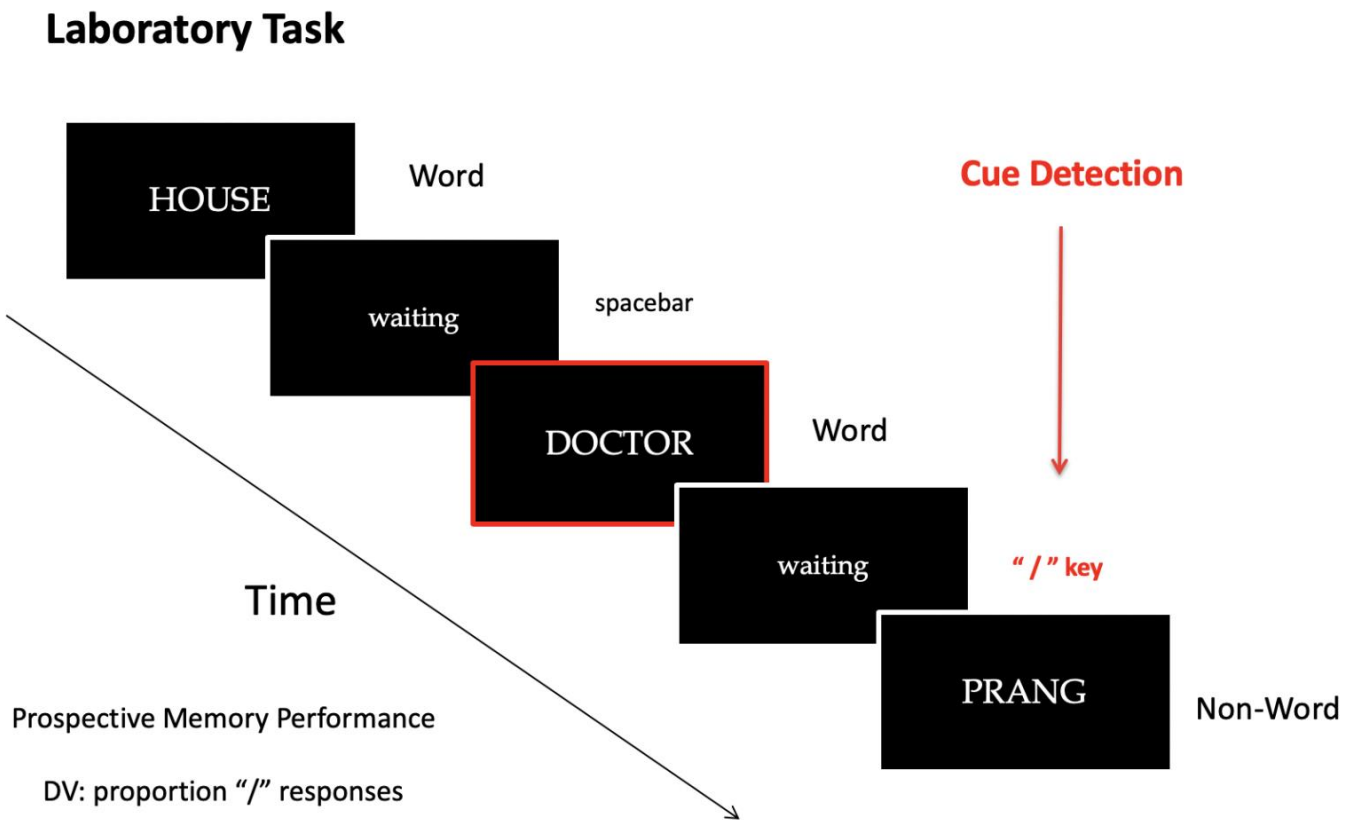
Negative Outcomes

# How Do You Put Someone In Pain?



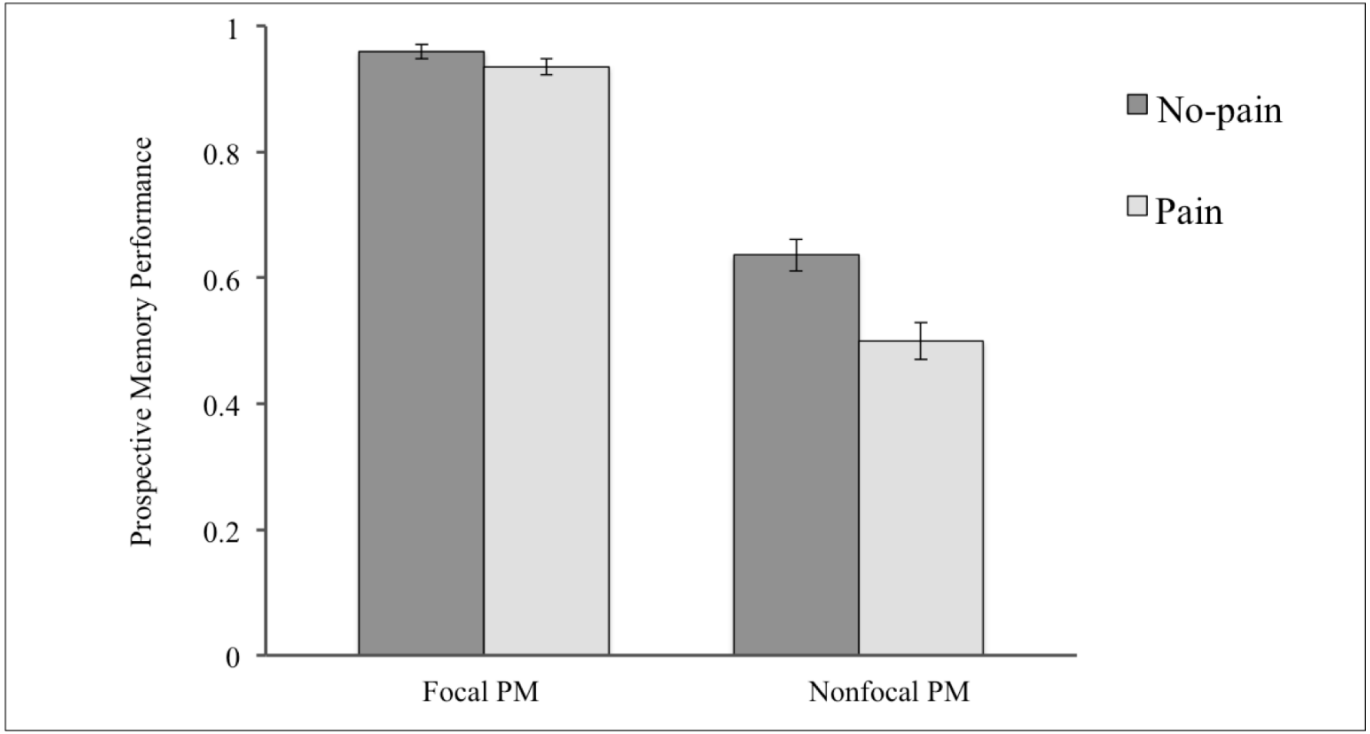


# Prospective Memory



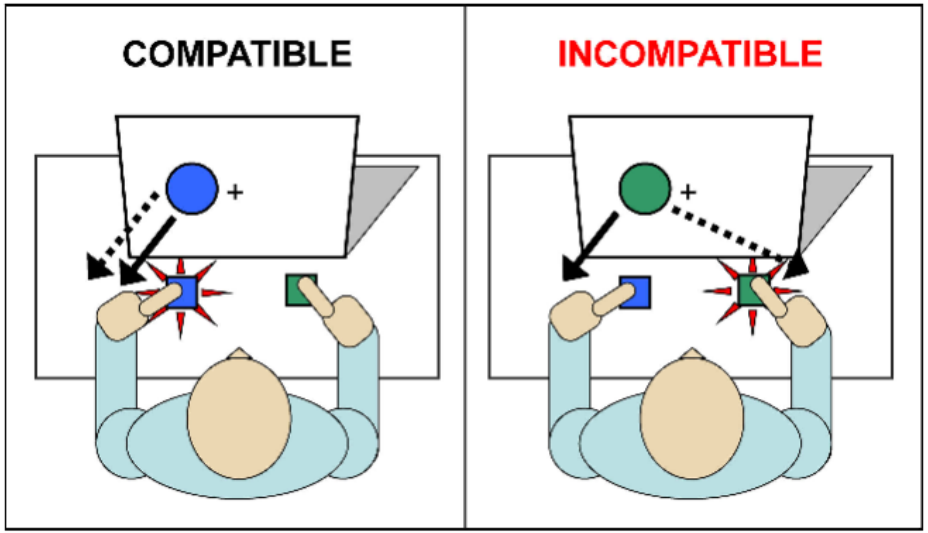

Pitaes et al. (2018)

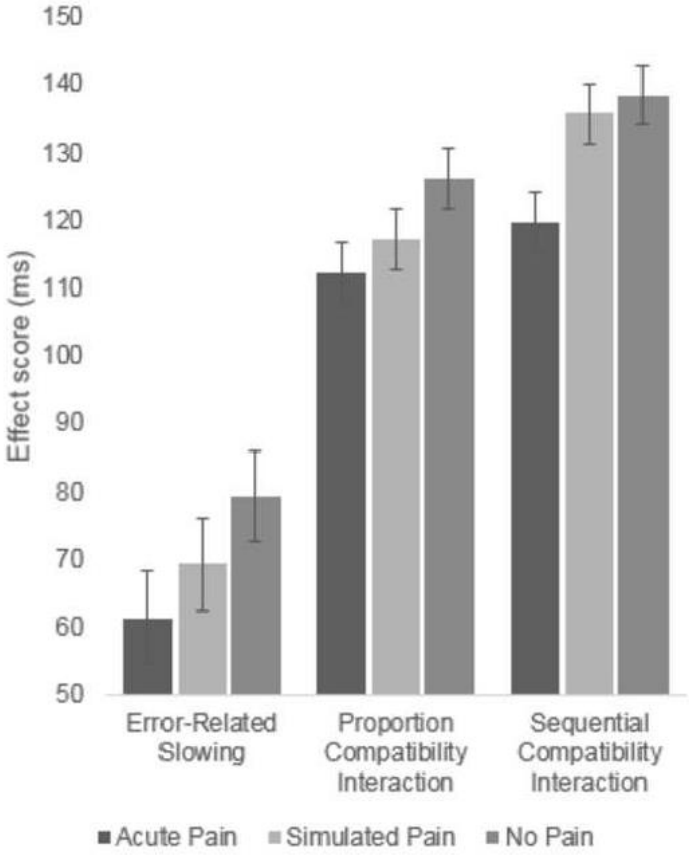
# Prospective Memory



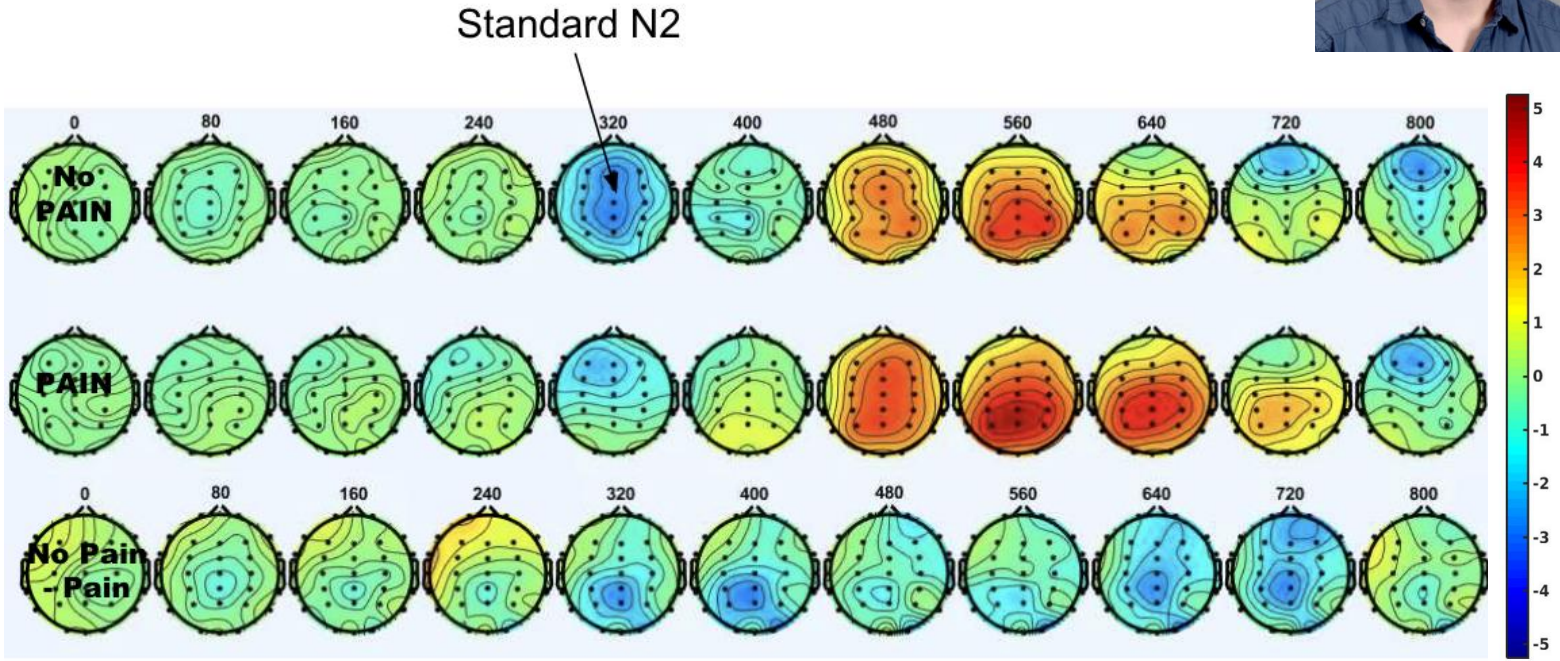

Pitaes et al. (2018)

# Acute Pain Disrupts Neural Markers of Cognitive Control



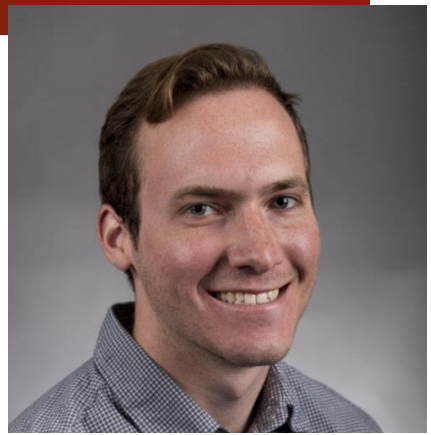



# Acute Pain Disrupts Neural Markers of Cognitive Control




Blais et al. (In Prep)

# Acute Pain & Sustained Attention

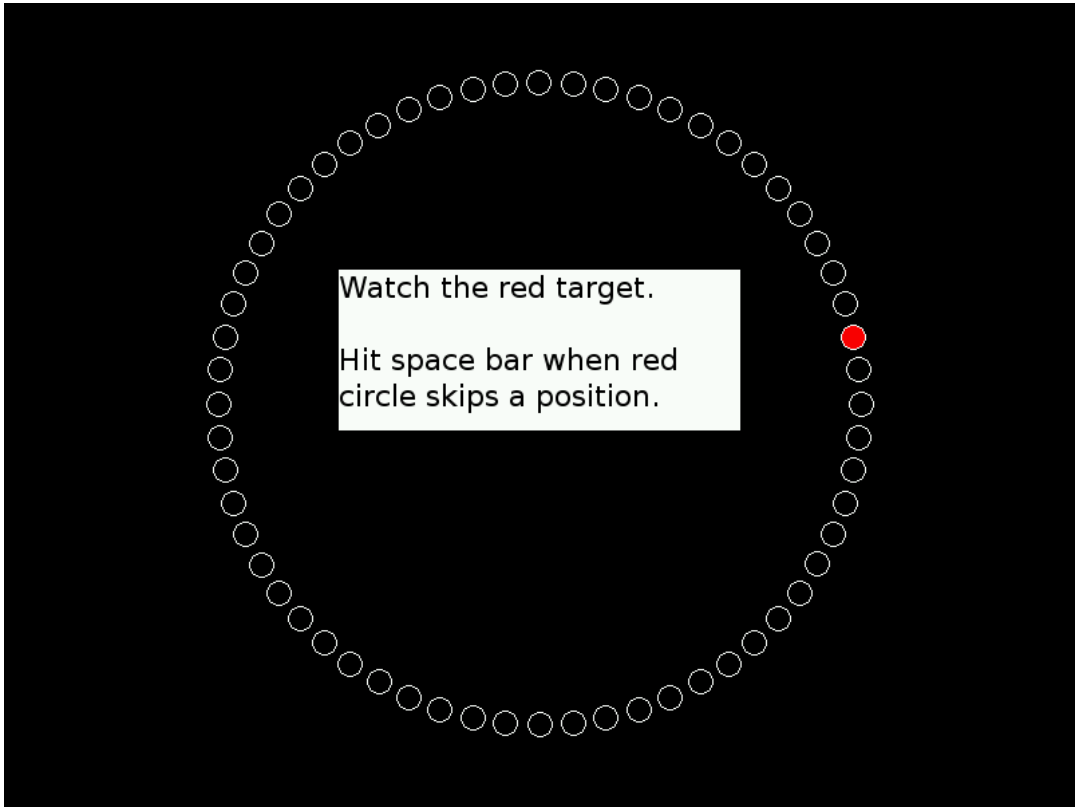


We have become increasingly interested in how deep into basic cognitive processing the effects of pain reach...

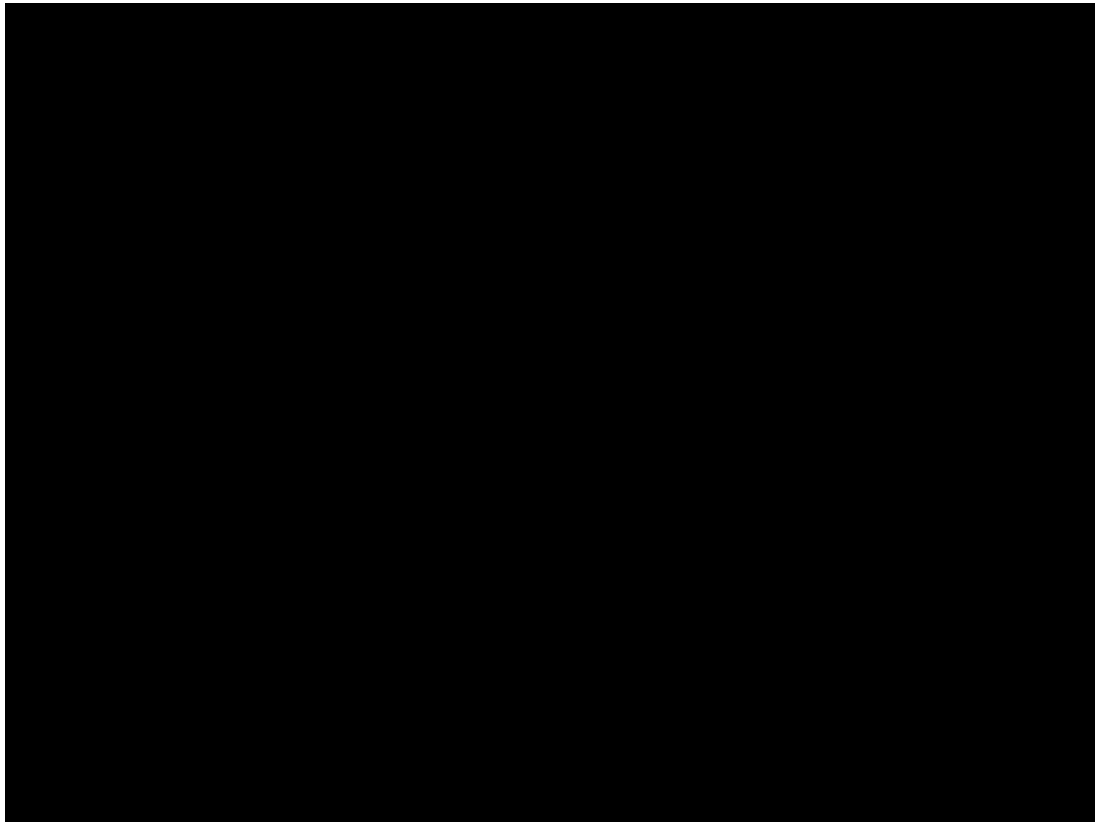
What are the most basic cognitive mechanisms influenced by pain?

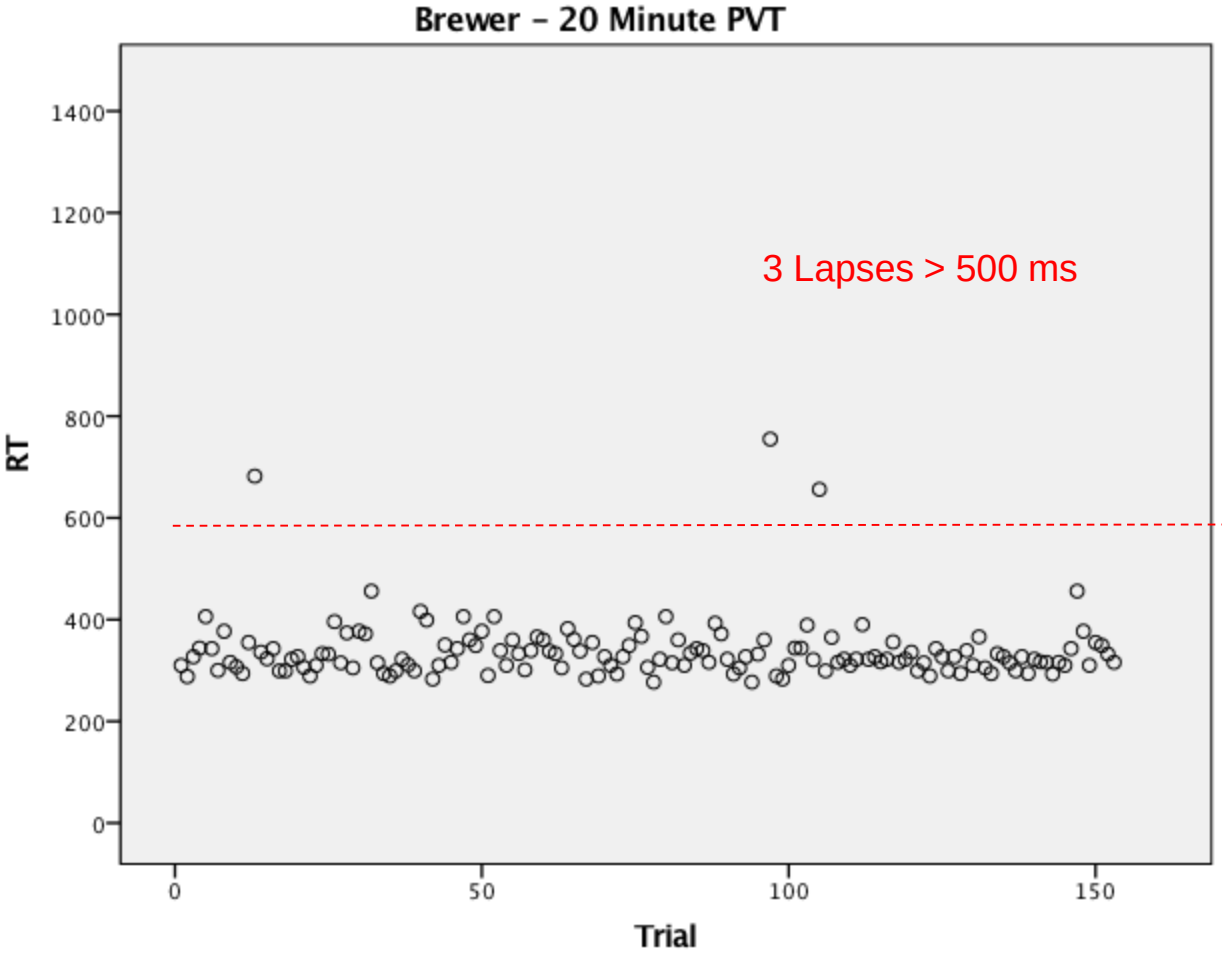
The work I'll present today is examining how pain influences behavioral performance in *simple reaction time tasks.*

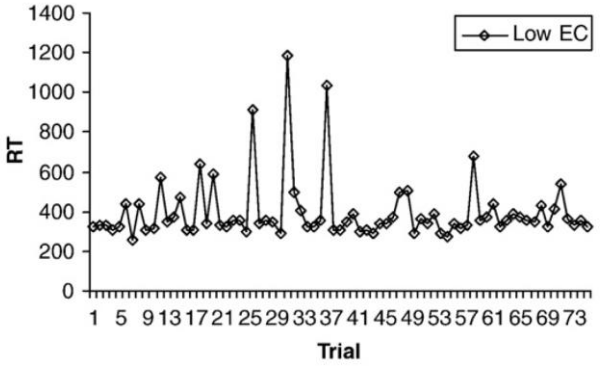
# History of Studying Human Vigilance

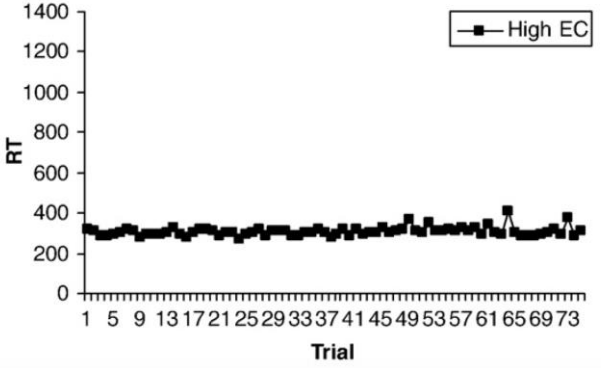


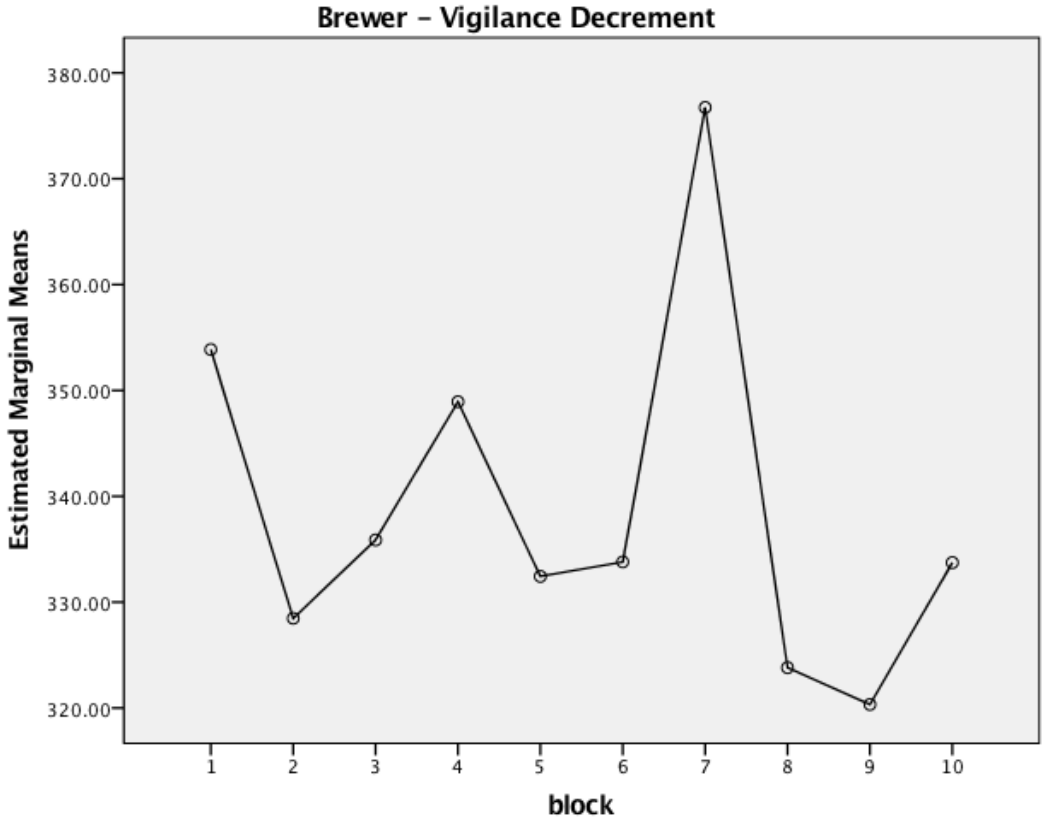
# The Psychomotor Vigilance Task

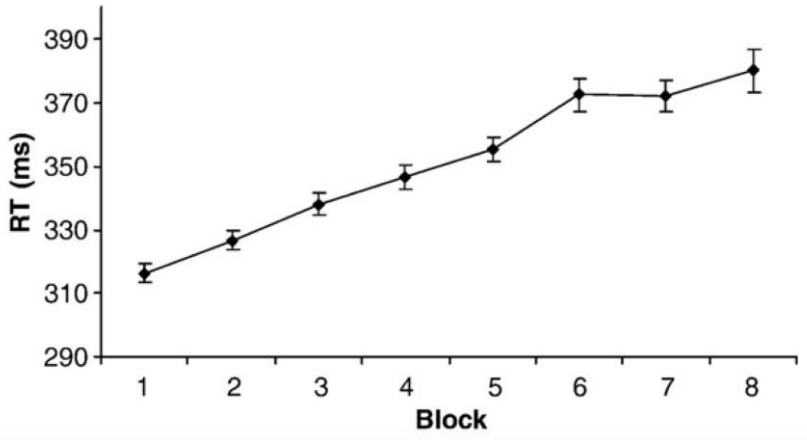


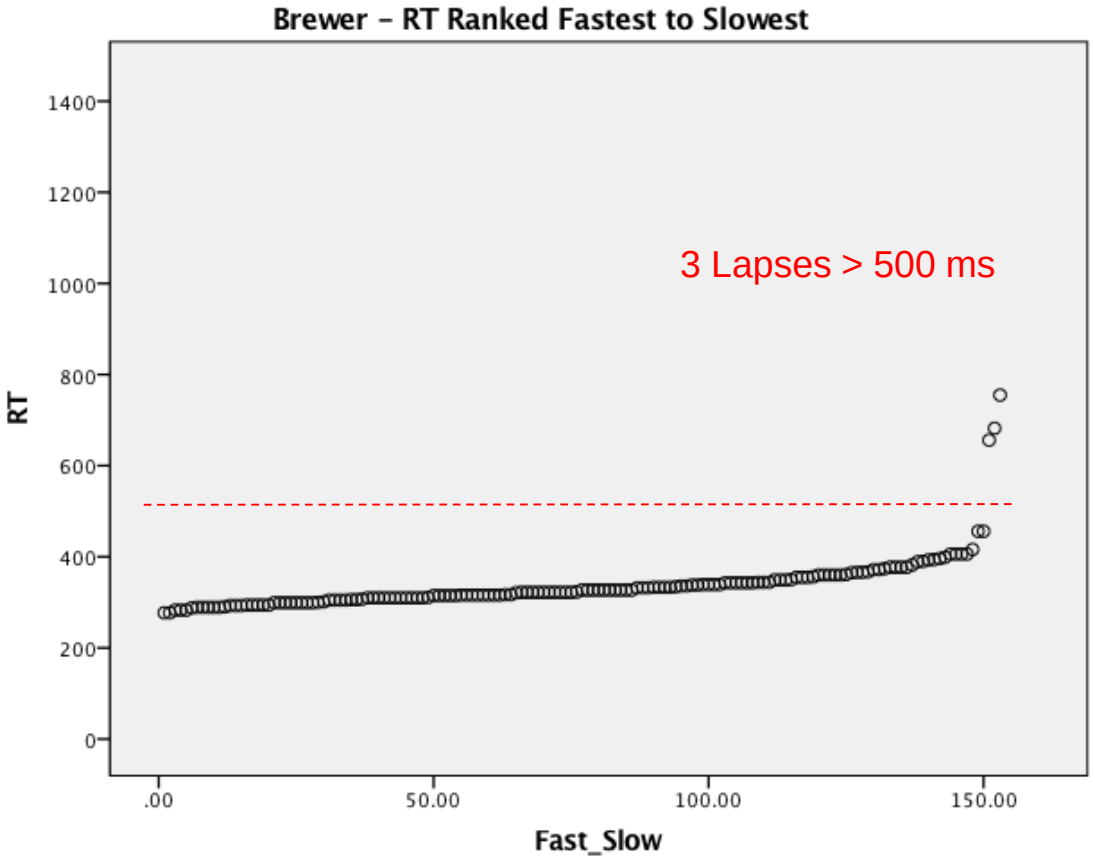

Brewer – 20 Minute PVT
3 Lapses > 500 ms
RT
Trial
1400
1200
1000
800
600
400
200
0
0
50
100
150

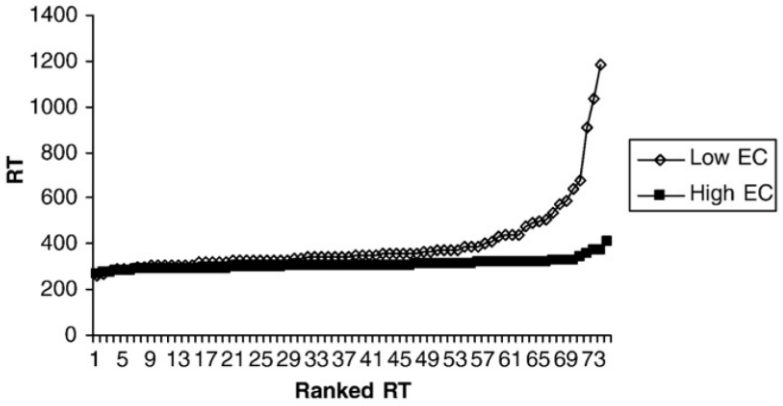

Low EC
RT
Trial
1400
1200
1000
800
600
400
200
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73


High EC
RT
Trial
1400
1200
1000
800
600
400
200
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73

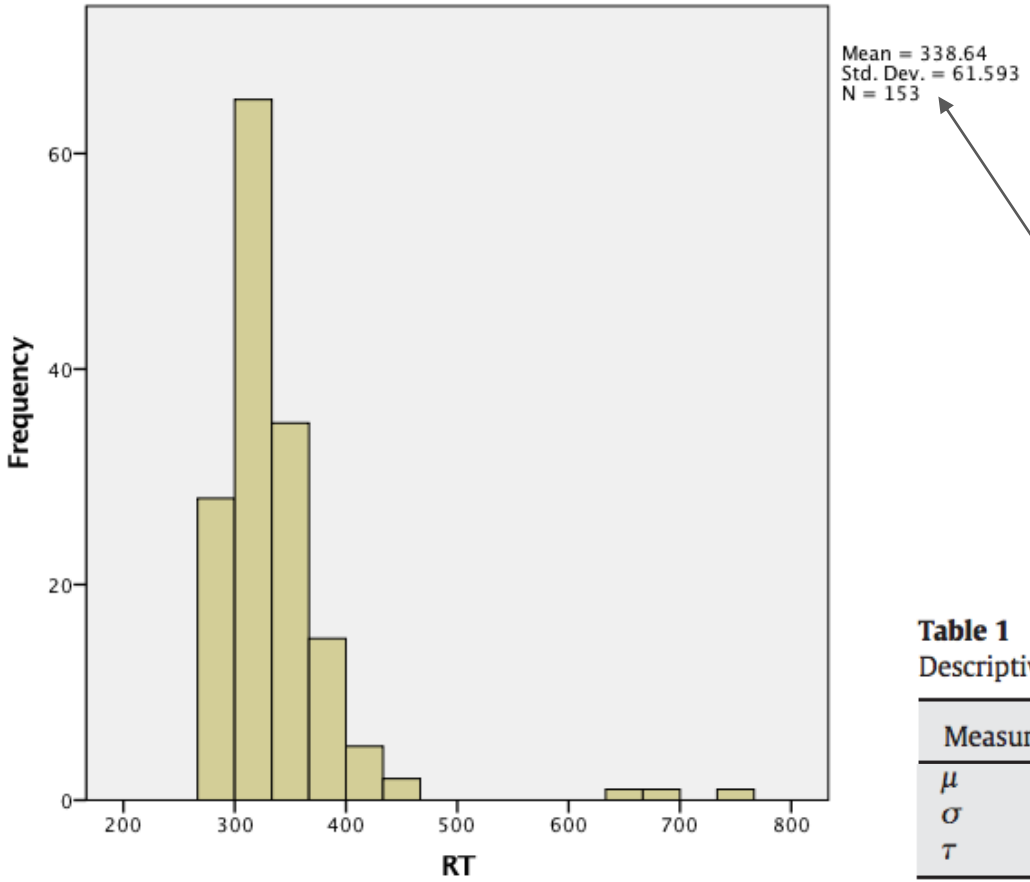

Brewer – Vigilance Decrement
Estimated Marginal Means
380.00
370.00
360.00
350.00
340.00
330.00
320.00
1
2
3
4
5
6
7
8
9
10
block


RT (ms)
390
370
350
330
310
290
1
2
3
4
5
6
7
8
Block


Brewer – RT Ranked Fastest to Slowest
3 Lapses > 500 ms
RT
1400
1200
1000
800
600
400
200
0
.00
50.00
100.00
150.00
Fast_Slow


RT
1400
1200
1000
800
600
400
200
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73
Ranked RT
Low EC
High EC

**Brewer – RT Histogram**




Mu = 292.99

Sigma = 11.12

Tau = 45.64

Mu + Tau = 337.86

**Table 1**
Descriptive statistics and reliability estimates for all measures.

| Measure | *M* | SD | Range | $\alpha$ |
|---|---|---|---|---|
| $\mu$ | 279 | 24 | 168 | NA |
| $\sigma$ | 21 | 12 | 73 | NA |
| $\tau$ | 71 | 33 | 221 | NA |

# Experiment 1 - Task & Procedure

Participants completed a ~20 minute sustained attention task (psychomotor vigilance) in either acute pain or a control condition

In the acute pain condition, we placed participants' non-dominant pinky finger in an algometer. We gradually added weight to the algometer until participants reported being at a pain level of 7 on a 1 to 9 scale. We then removed weight until they reported being at a level of 5.

Participants then completed 115 trials of the PVT

# Experiment 1 - Design & Participants

Two between-subjects conditions:

Pain versus No Pain

Final samples, after outlier deletion

Pain: N = 52

Control: N = 56

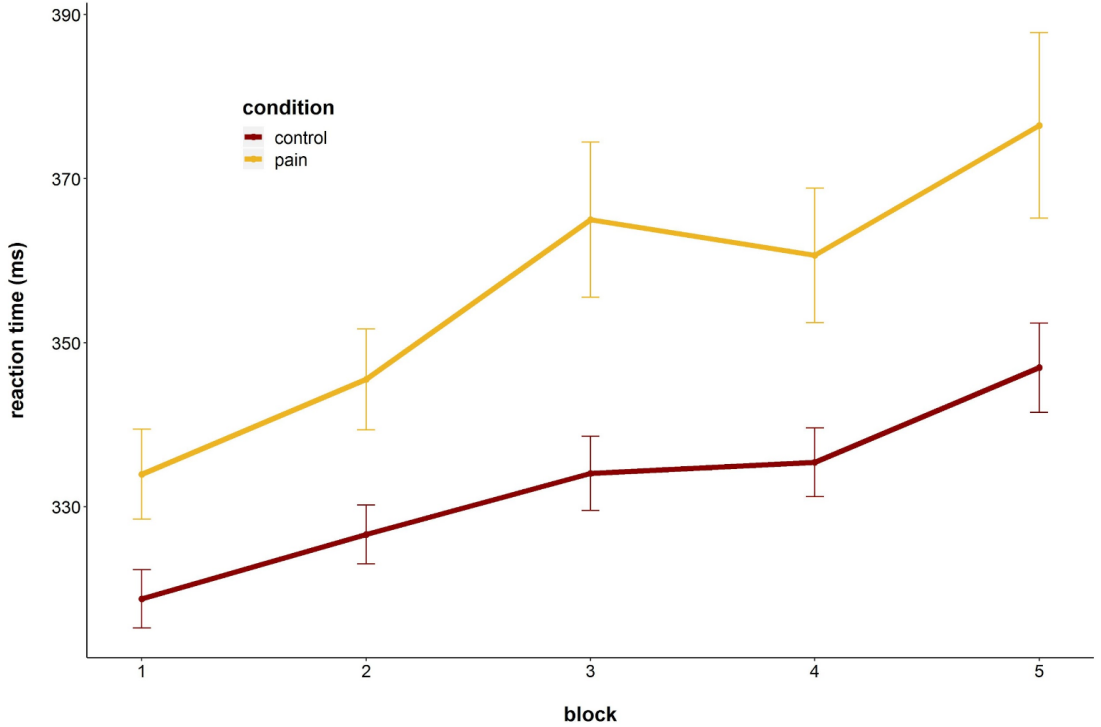
# E1 - Vigilance Decrements

2 x 5 mixed ANOVA on RTs

**Main effect of block**
$F(4, 420) = 25.36$, $p < .001$

**Main effect of condition**
$F(1, 105) = 9.05$, $p = .003$

**No block x condition interaction**
$F(4, 420) = 1.61$, $p = .17$



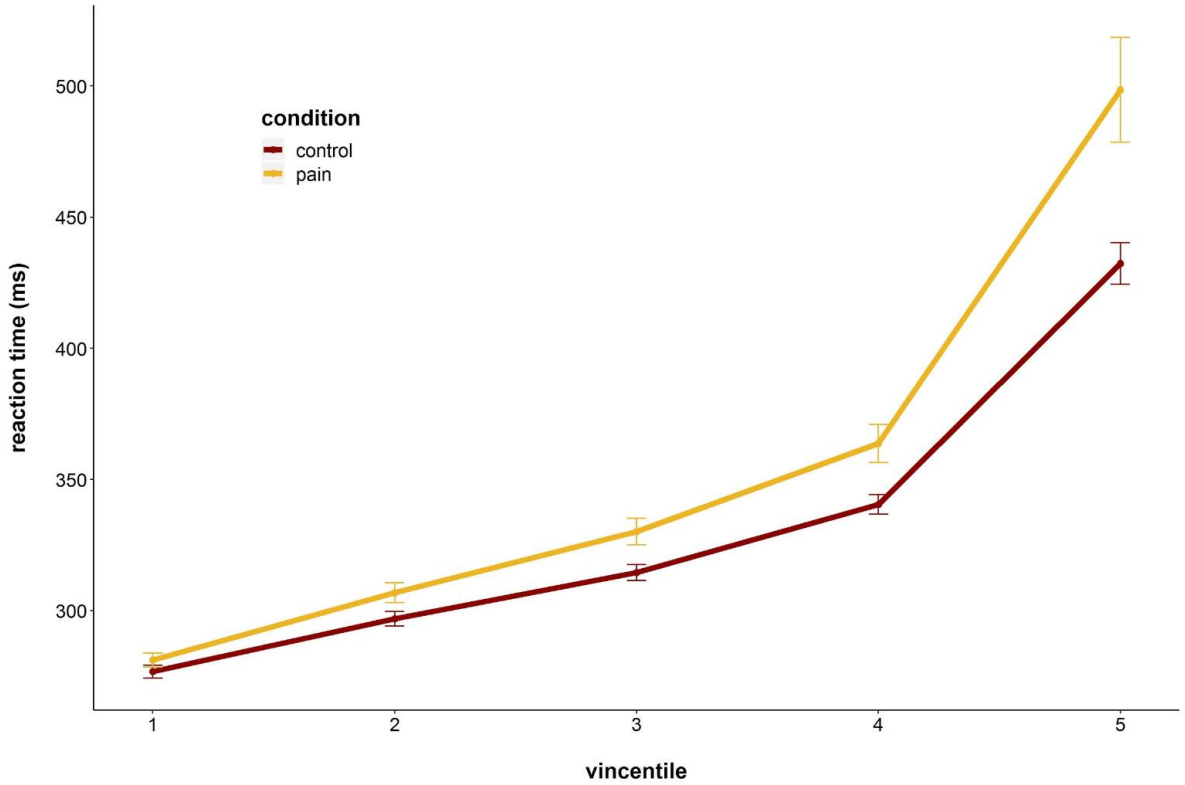
# E1 - Vincentile Plots

2 x 5 mixed ANOVA on RT

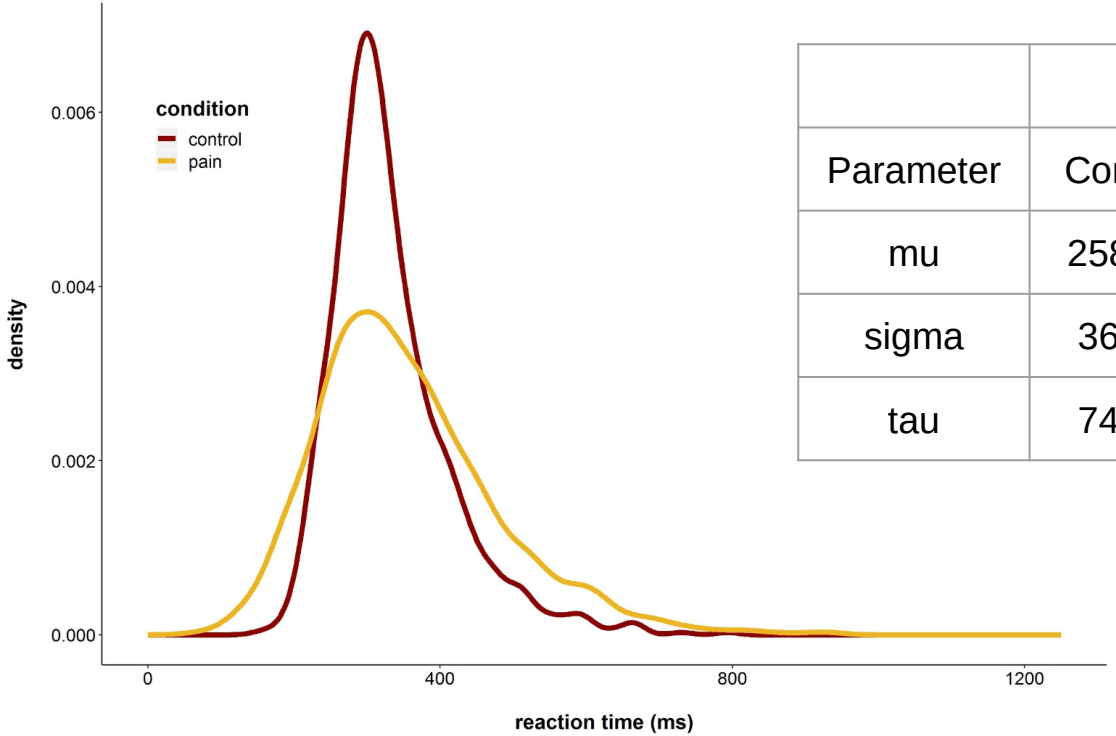
**Main effect of bin**
$F(4, 420) = 320.98$, $p < .001$

**Bin x condition interaction**
$F(4, 420) = 9.25$, $p < .001$

*Pain effect larger at slower RT bins*

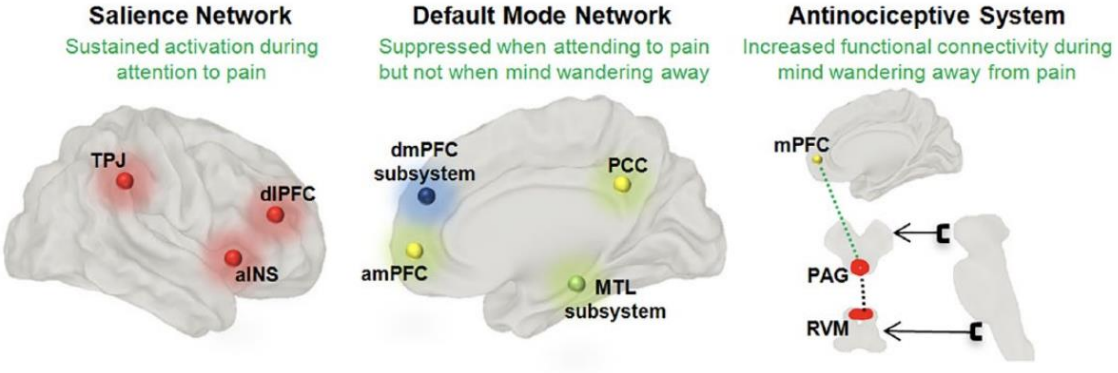


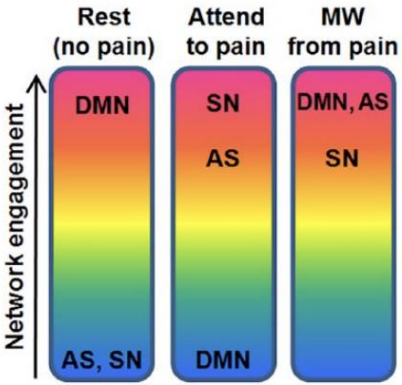
# E1 - Ex-Gaussian Analysis

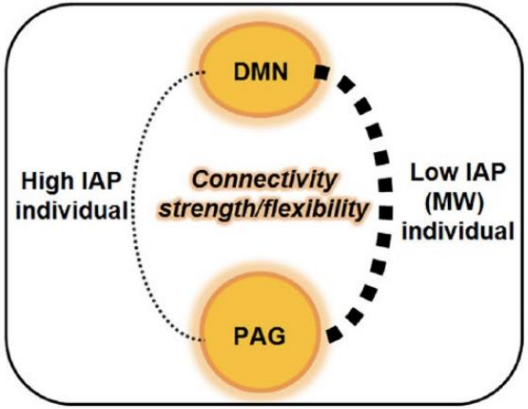



| | Condition | | *t*-test | |
|---|---|---|---|---|
| Parameter | Control | Pain | *t*(103) | *p* |
| mu | 258.40 | 242.03 | 1.69 | .09 |
| sigma | 36.46 | 60.13 | -2.56 | .01 |
| tau | 74.05 | 113.45 | -2.95 | .003 |

# Experiment 2




Kucyi, A., & Davis, K. D. (2017)

# Experiment 2 - Task & Procedure

Participants completed a ~20 minute sustained attention task (psychomotor vigilance) in either acute pain or a control condition

In the acute pain condition, we placed participants' non-dominant pinky finger in an algometer. We gradually added weight to the algometer until participants reported being at a pain level of 7 on a 1 to 9 scale. We then removed weight until they reported being at a level of 5.

Participants then completed 115 trials of the PVT

# Experiment 2 - Thought probes

After 20 trials, participants were asked to report their current attentional state with 5 options

What were you thinking about in the few seconds prior to this screen appearing?

1) I was totally focused on the current task.

2) I was thinking about my performance on the task.

3) I was thinking about my finger in the device.

4) I was thinking about things unrelated to the task (i.e., day-dreaming).

5) My mind was blank.

# Experiment 2 - Design & Participants

Two between-subjects conditions:

Pain versus No Pain

Final samples, after outlier deletion

Pain: N = 84

Control: N = 90

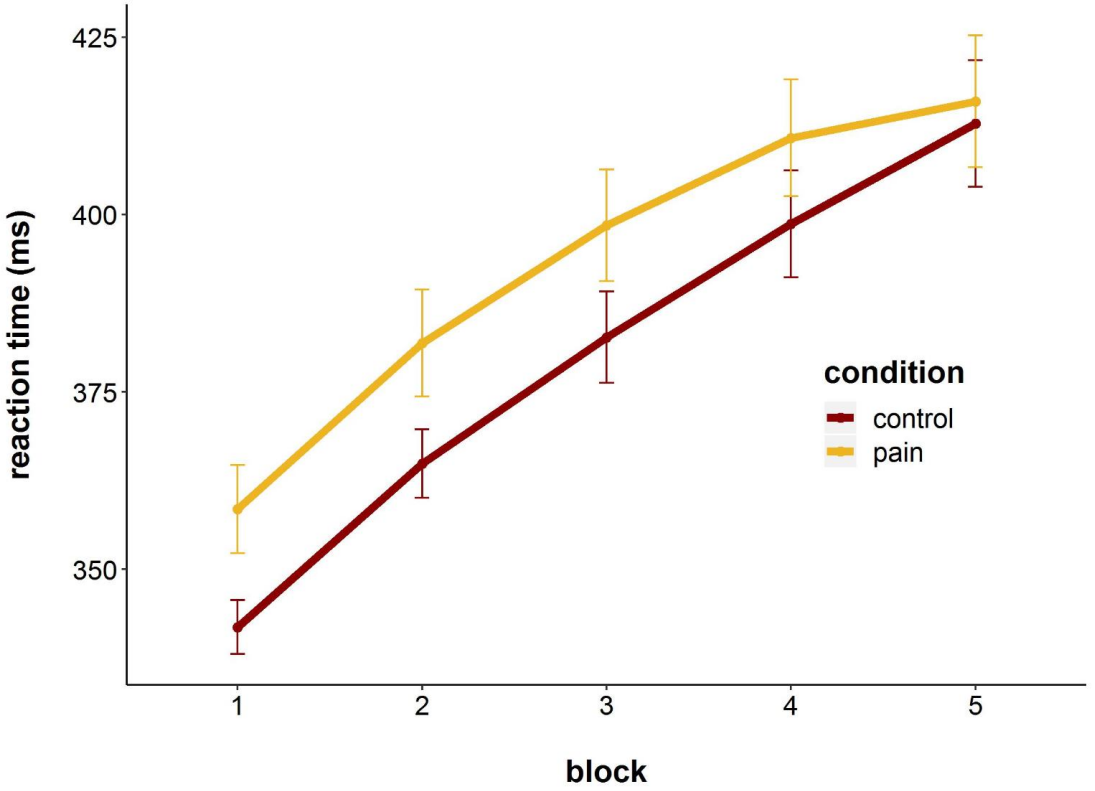
# E2 - Vigilance Decrement

2 x 5 mixed ANOVA on RTs

**Main effect of block**
*F*(4, 684) = 78.25, *p* < .001

**No main effect of condition**
*F*(1, 171) = 2.15, *p* = .14

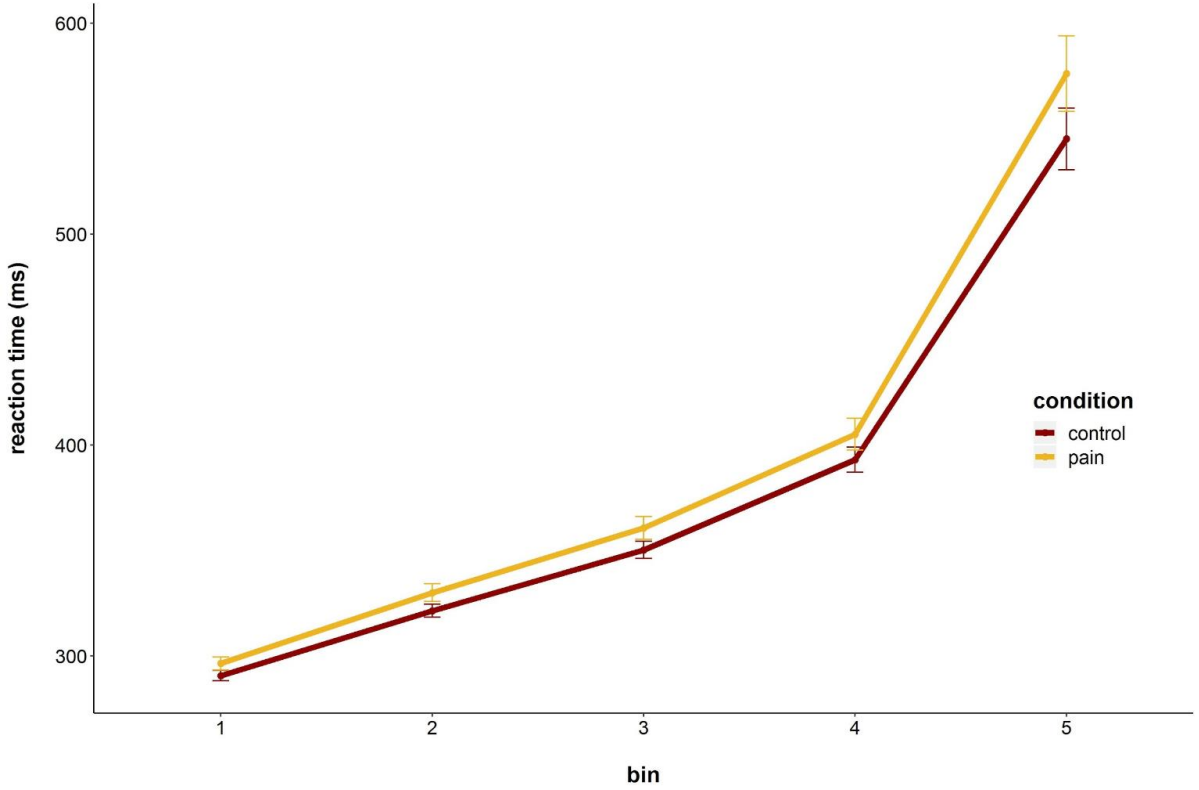
**No bin x condition interaction**
*F*(4, 684) = 1.00, *p* = .40



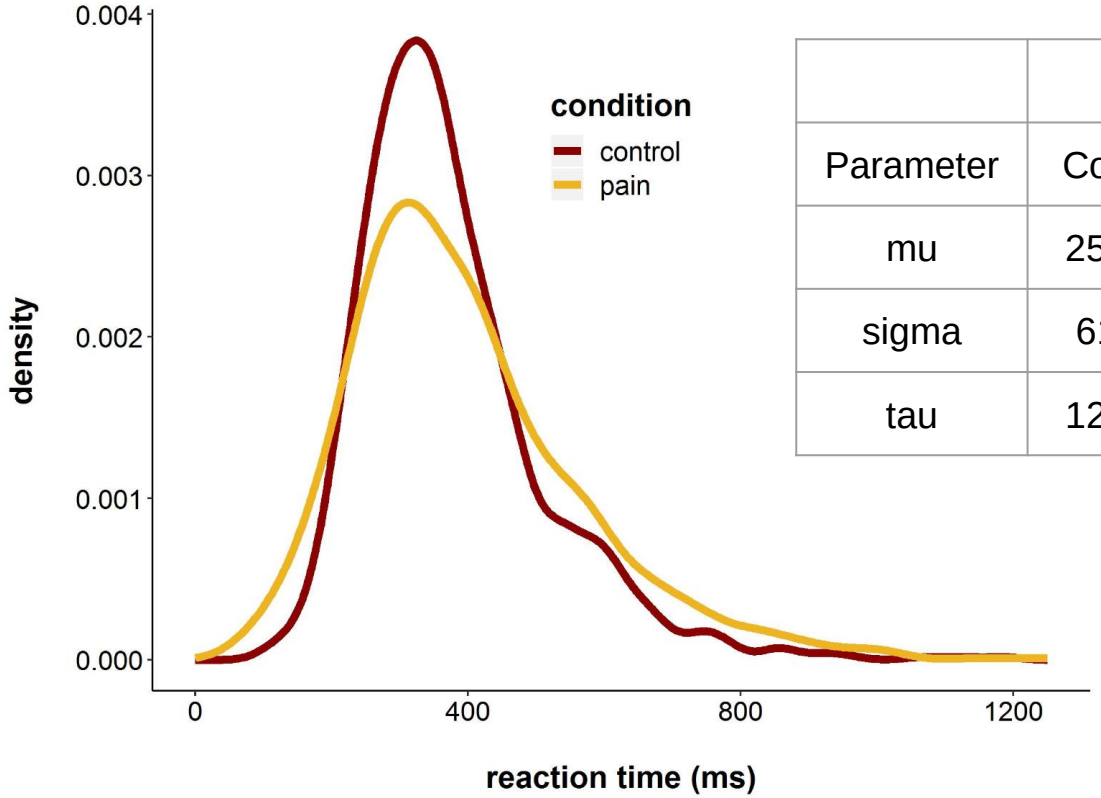
# E2 - Vincentile Plots

**Main effect of bin**
$F(4, 684) = 554.46$, $p = .001$

**No bin x condition interaction**
$F(4, 684) = 1.27$, $p = .28$

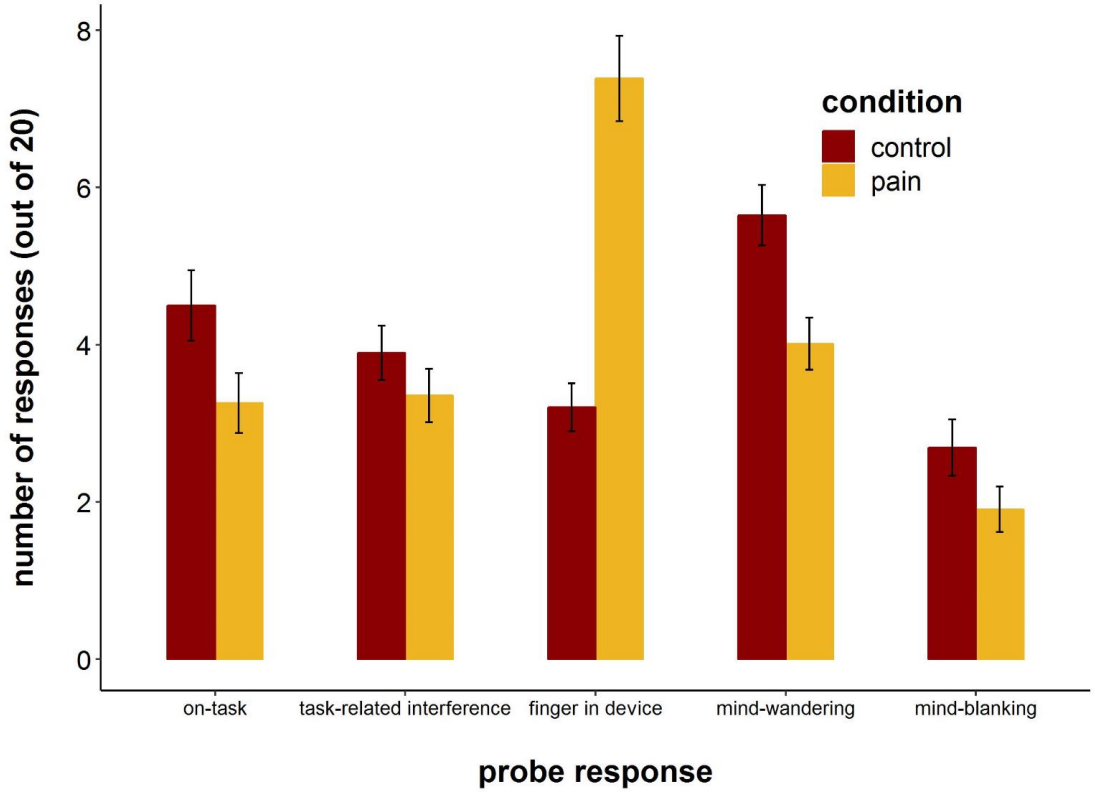


# E2 - Ex-Gaussian Analysis

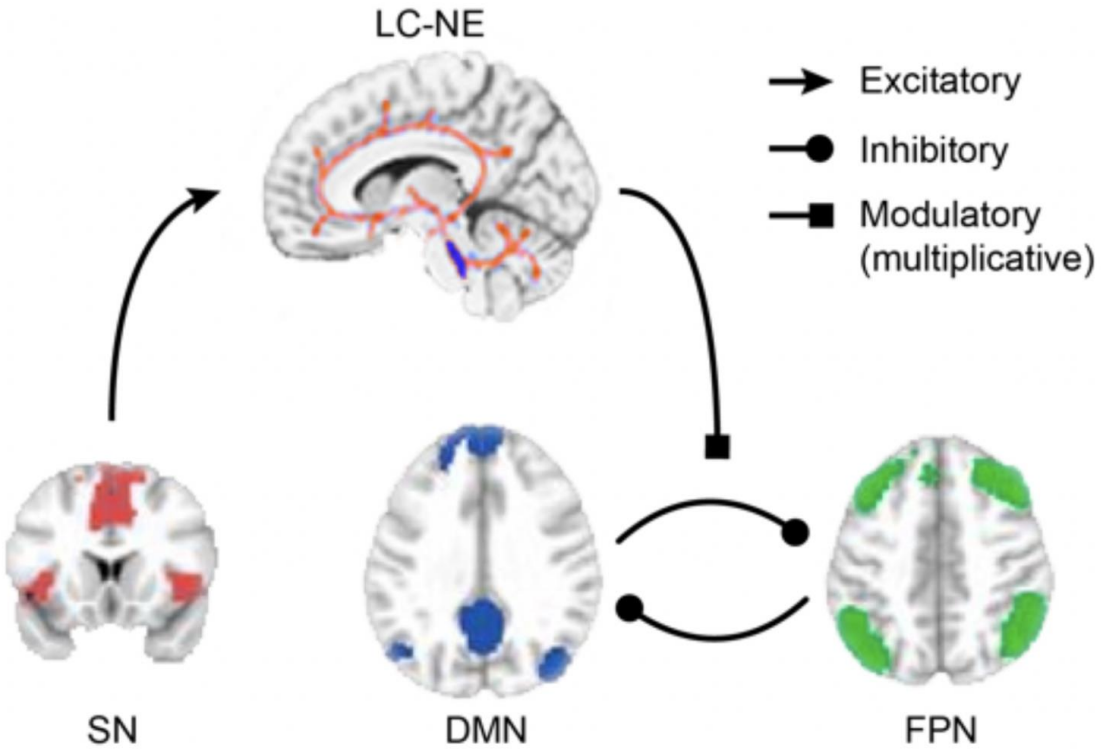



| | Condition | | *t*-test | |
|---|---|---|---|---|
| Parameter | Control | Pain | *t*(167) | *p* |
| mu | 255.98 | 242.03 | 1.43 | .15 |
| sigma | 61.51 | 81.96 | -2.35 | .02 |
| tau | 122.32 | 150.53 | -2.16 | .03 |

# E2 - Thought Probe Responses

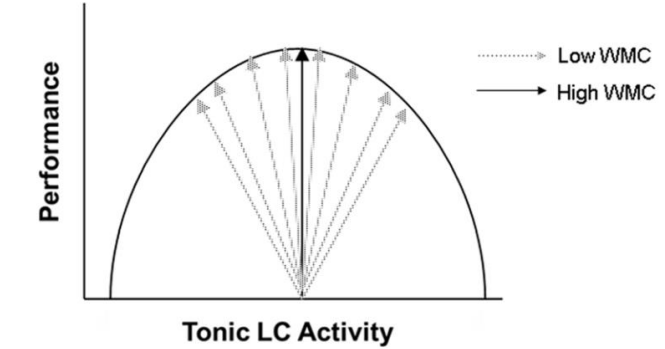


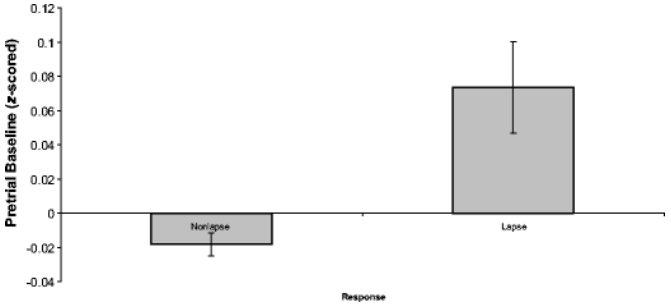
# Experiment 3



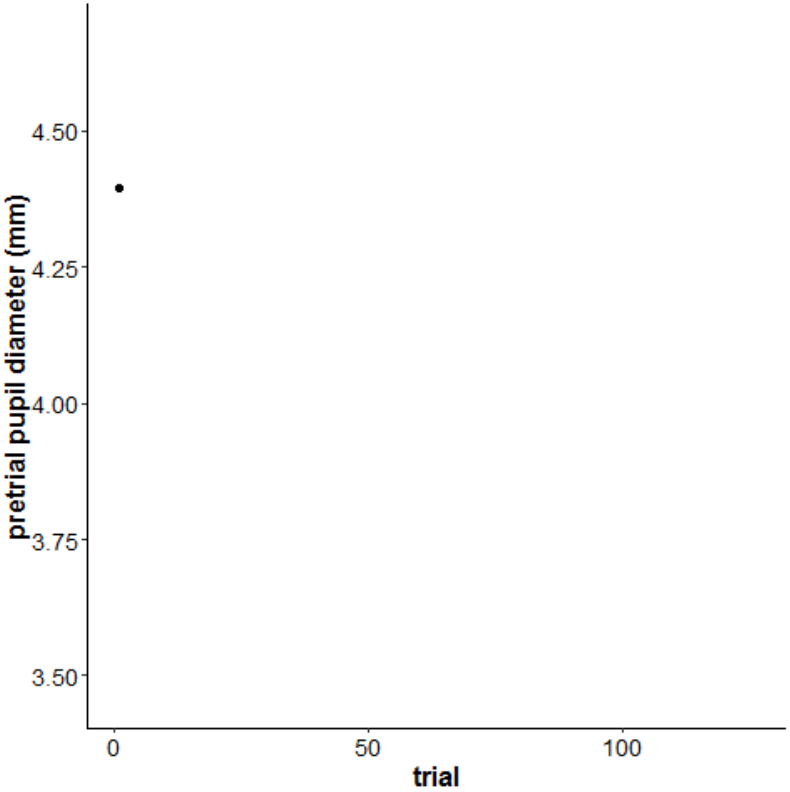
# Consistency in Arousal while Sustaining Attention

We can measure the pupils during vigilance tasks...



# Tonic Changes in Pupil (Arousal) Over Time



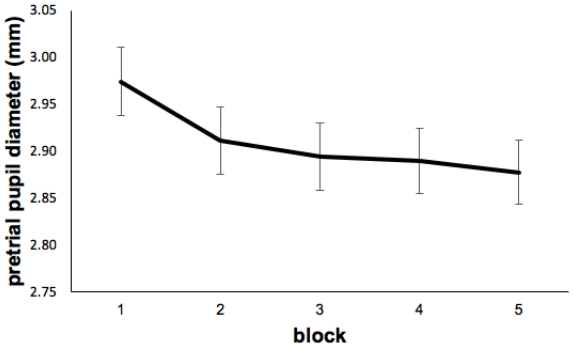




**Figure 1.** Pretrial pupil diameter, a measure of arousal, as a function of time in the psychomotor vigilance task. Data from Robison (2018).

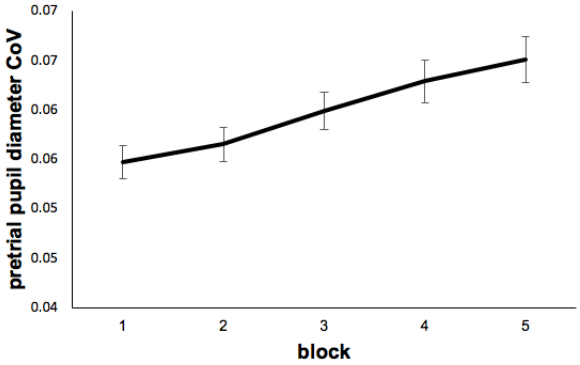
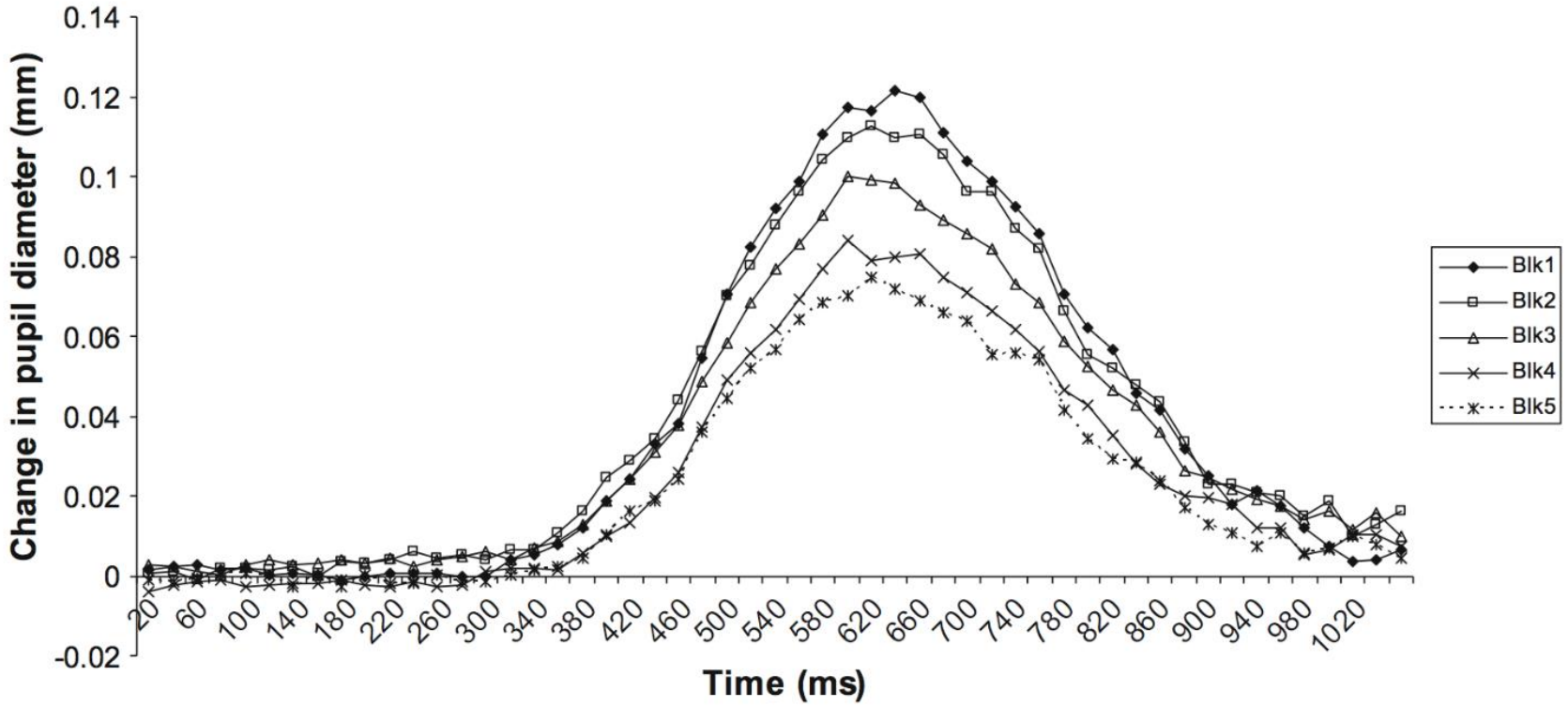



**Figure 2.** Intra-individual variability (CoV) in pretrial pupil diameter, a measure of fluctuations in arousal, as a function of time in the psychomotor vigilance task. Data from Robison (2018).

# Phasic Change in Task Evoked Pupillary Responses



# Experiment 3 - Task, Procedure, & Pupillometry Details

Participants completed the PVT (without probes) while their pupil diameter was continuously recorded at 50 Hz

In the acute pain condition, we placed participants' non-dominant pinky finger in an algometer. We gradually added weight to the algometer until participants reported being at a pain level of 7 on a 1 to 9 scale. We then removed weight until they reported being at a level of 5.

Dependent measures:

Reaction time across blocks, Pretrial pupil diameter (arousal), Task-evoked pupillary response (task engagement)

# Experiment 3 - Design & Participants

Two between-subjects conditions:

Pain versus No Pain

Final samples, after outlier deletion

Pain: N = 72

Control: N = 73

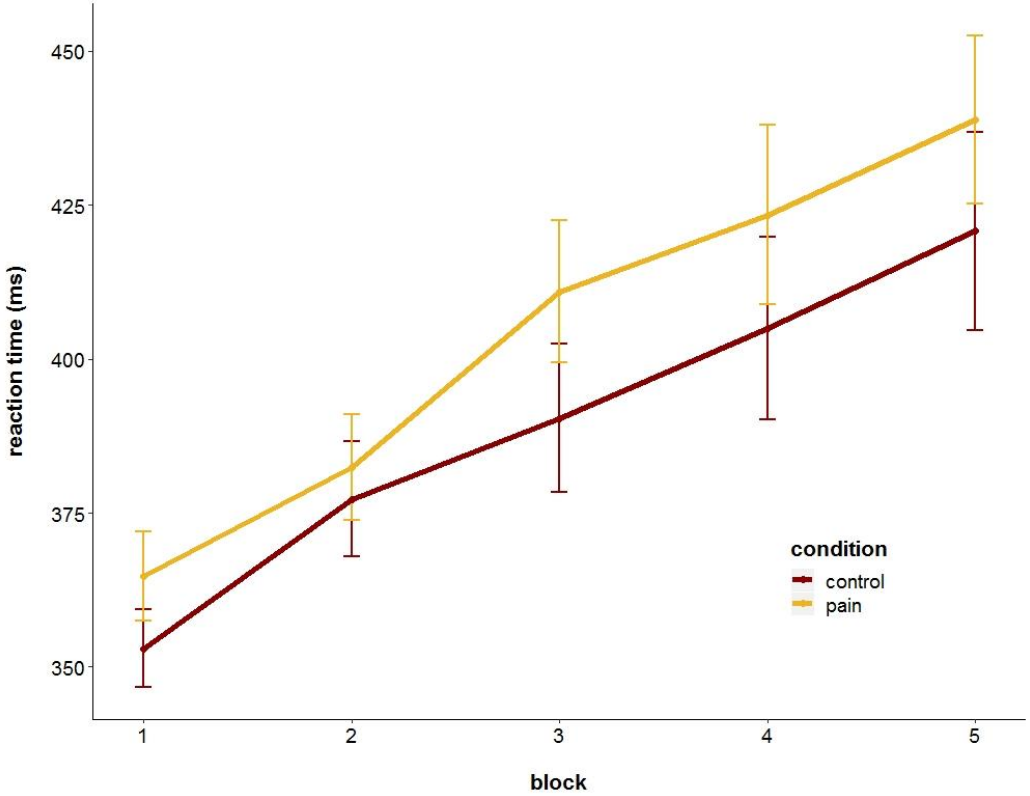
# E3 - Vigilance Decrement

2 x 5 mixed ANOVA on RTs

**Main effect of block**
*F*(4, 576) = 68.27, *p* < .001

**No main effect of condition**
*F*(1, 144) = 1.11, *p* = .30

**No block x condition interaction**
*F*(4, 576) = .41, *p* = .80

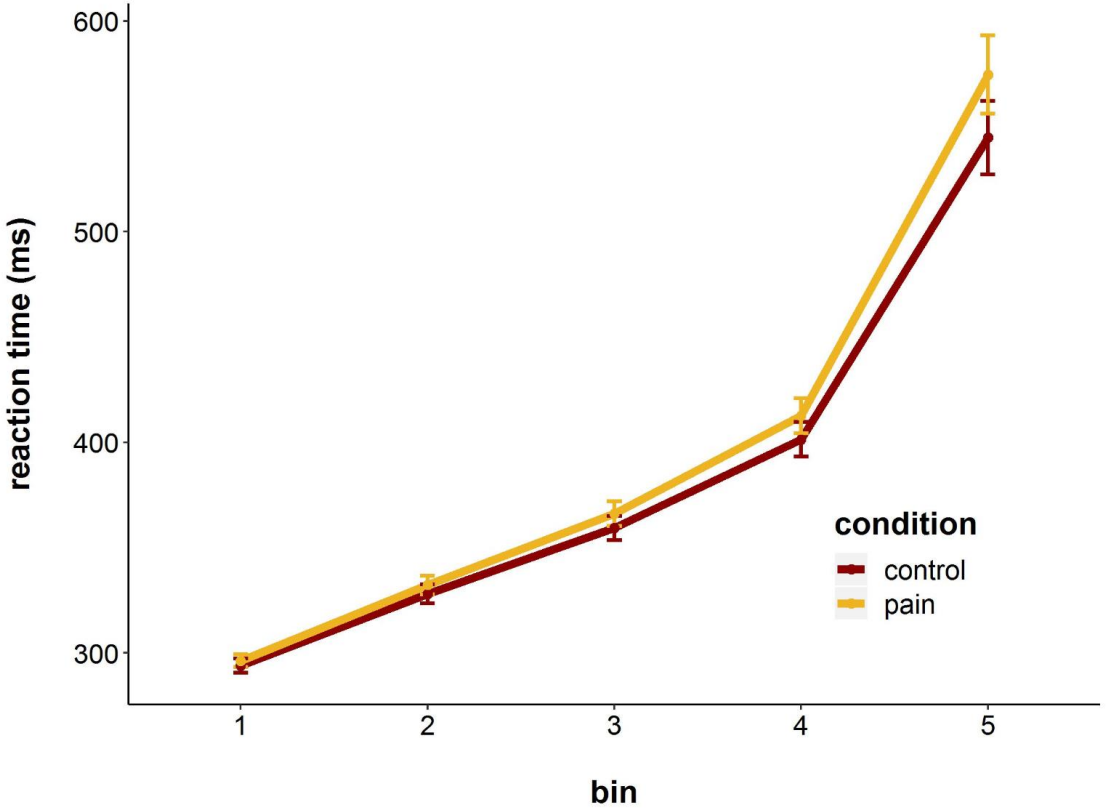


# E3 - Vincentile Plots

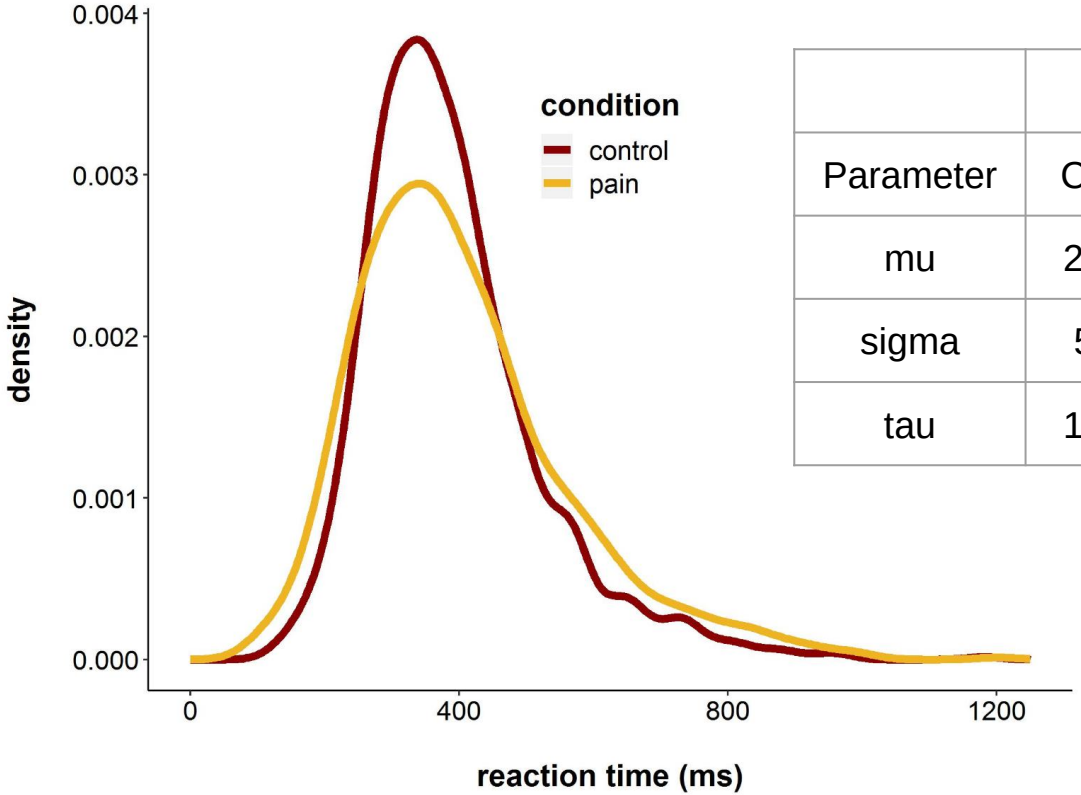
2 x 5 mixed ANOVA on RTs

**Main effect of bin**
$F(4, 572) = 448.76$, $p < .001$

**No bin x condition interaction**
$F(4, 572) = 1.32$, $p = .26$



# E3 - Ex-Gaussian Analysis




| | Condition | | *t*-test | |
|---|---|---|---|---|
| Parameter | Control | Pain | *t*(167) | *p* |
| mu | 271.73 | 253.54 | 1.57 | .12 |
| sigma | 54.81 | 79.10 | -2.56 | .01 |
| tau | 112.51 | 143.85 | -2.15 | .03 |

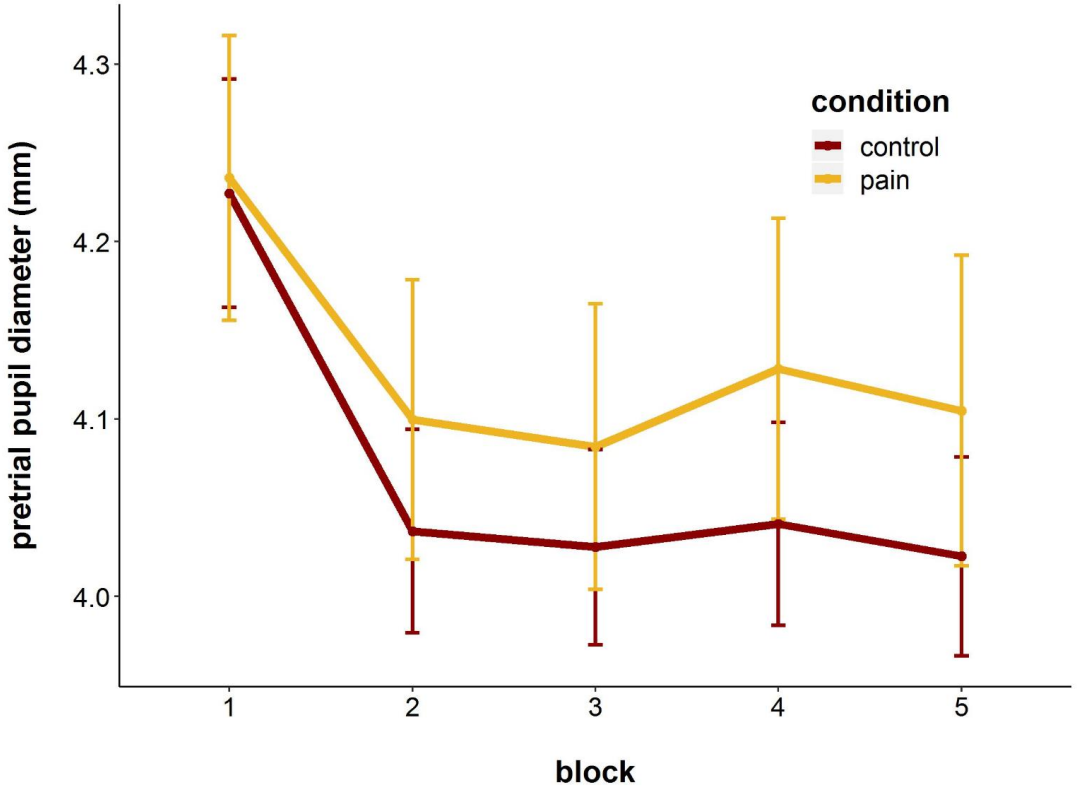
# E3 - Pretrial Pupil Measures (Diameter)

2 x 5 mixed ANOVA on mean pretrial pupil diameter

**Main effect of block**
*F*(4, 560) = 23.39, *p* < .001

**No main effect of condition**
*F*(1, 140) = .38, *p* = .54

**No block x condition interaction**
*F*(4, 560) = 1.04, *p* = .39



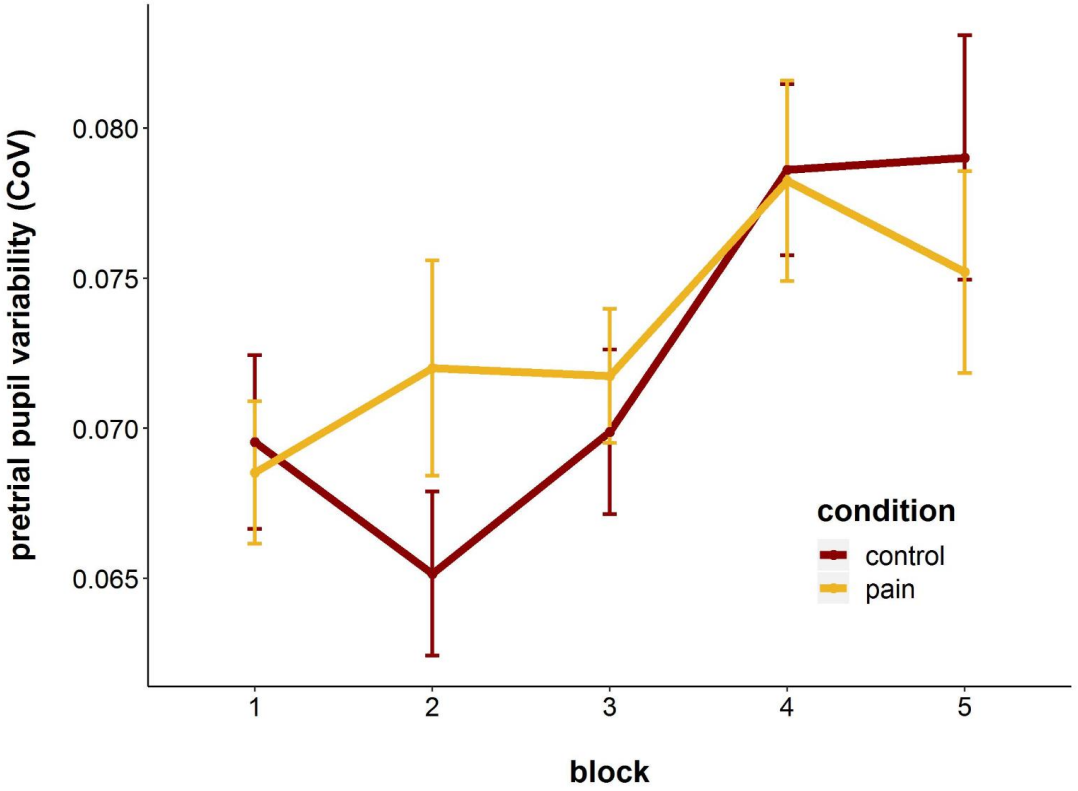
# E3 - Pretrial Pupil Measure (CoV)

2 x 5 mixed ANOVA on mean pretrial pupil diameter

**Main effect of block**
*F*(4, 560) = 7.61, *p* < .001

**No main effect of condition**
*F*(1, 140) = .05, *p* = .82

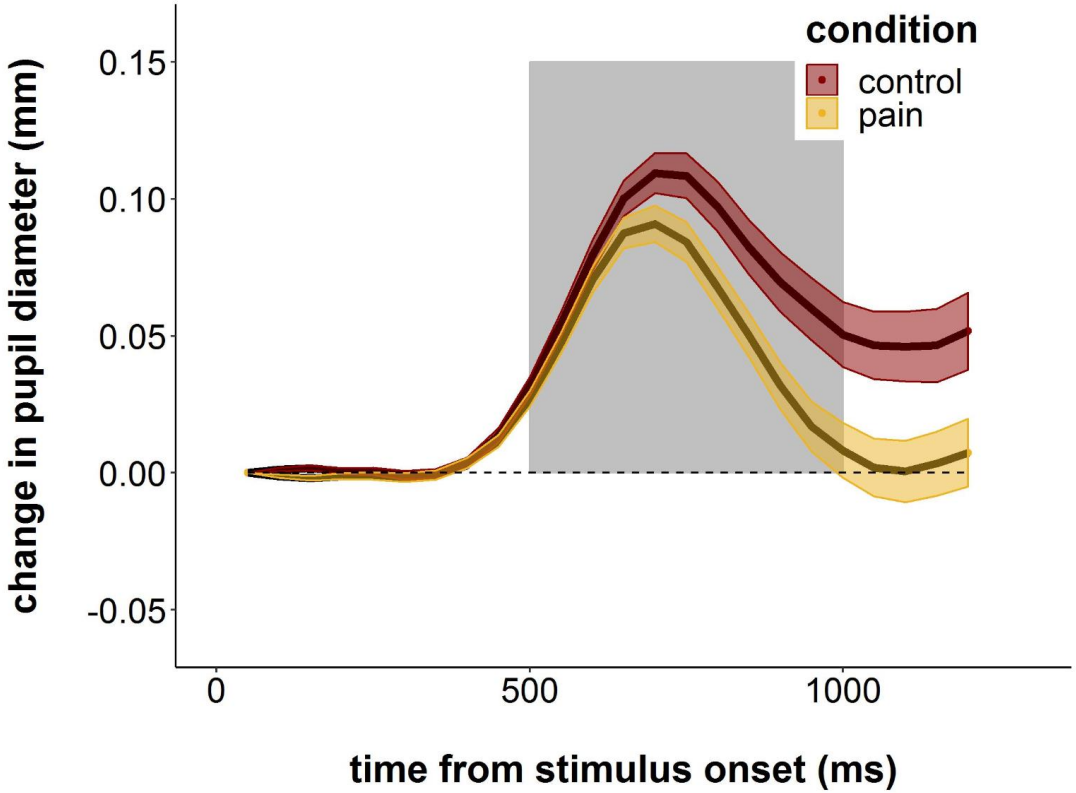
**No block x condition interaction**
*F*(4, 560) = 1.40, *p* = .23



# E3 - Task-Evoked Pupillary Responses

**Task-evoked pupillary response =** Change in pupil diameter from baseline over window 500 to 1000-ms post stimulus onset

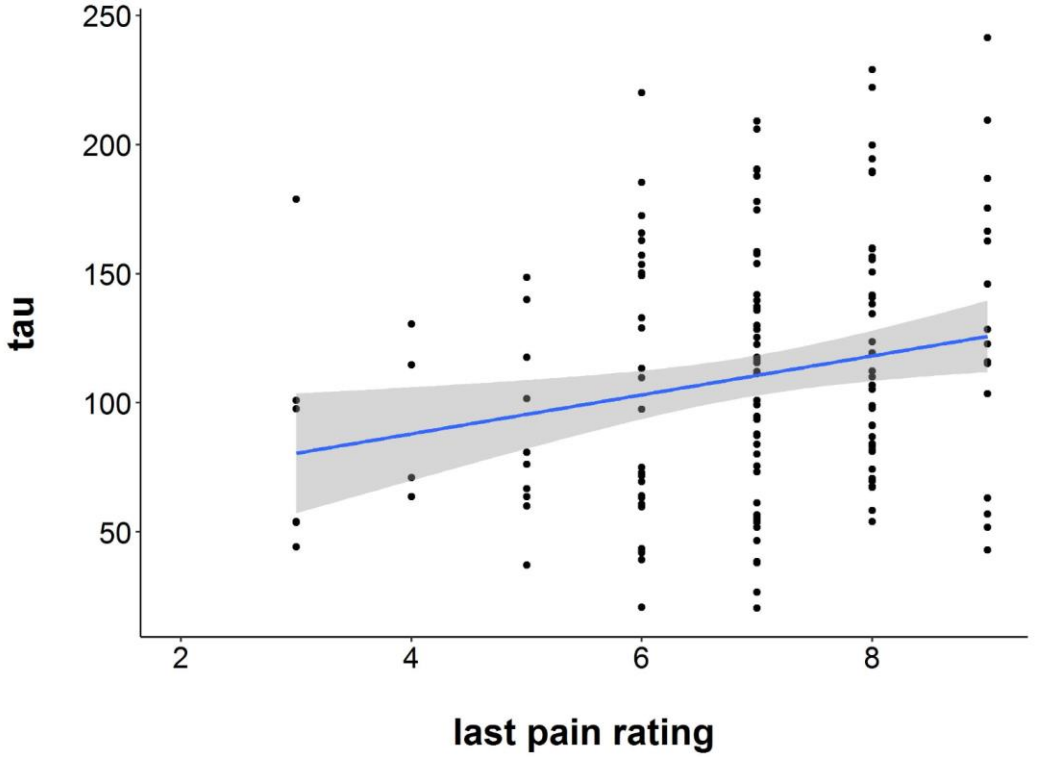
**Significantly larger TEPR in control condition**
*t*(142) = 2.55, *p* = .011



# Combined Correlational Analysis

There is a correlation between final subjective pain rating and tau...

$r(153) = .19$, $p = .02$



# Summary

Experiment 1 showed a significant difference in RT distributional profiles due to acute pain.

Experiment 2 showed that participants report fewer ‘on-task’ thoughts due to exteroceptive thoughts (thinking about their finger in the device).

Experiment 3 showed that participants in pain condition did show smaller task-evoked pupillary responses -- usually an indicator of task engagement.

More generally, this research contributes to our growing understanding of how acute painful events influence moment-to-moment control over goal-oriented behavior potentially leading to deficits across many domains.

# Thank You

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# Questions?

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