Acute Pain and Sustained Attention

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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

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

Conceptual Overview of Our Research Program

- Executive Functions
- Goal Attainment
- Negative Outcomes
How Do You Put Someone In Pain?
Prospective Memory

Laboratory Task

Time

Prospective Memory Performance

DV: proportion “/” responses

House

Word

Waiting

Spacebar

Doctor

Word

Waiting

“/” key

Prang

Non-Word

Cue Detection

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
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

Watch the red target.
Hit space bar when red circle skips a position.
The Psychomotor Vigilance Task
3 Lapses > 500 ms
3 Lapses > 500 ms
Mu = 292.99
Sigma = 11.12
Tau = 45.64
Mu + Tau = 337.86

Table 1
Descriptive statistics and reliability estimates for all measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
<th>α</th>
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</thead>
<tbody>
<tr>
<td>µ</td>
<td>279</td>
<td>24</td>
<td>168</td>
<td>NA</td>
</tr>
<tr>
<td>σ</td>
<td>21</td>
<td>12</td>
<td>73</td>
<td>NA</td>
</tr>
<tr>
<td>τ</td>
<td>71</td>
<td>33</td>
<td>221</td>
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</table>
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
2 x 5 mixed ANOVA on RTs

**Main effect of block**
\[ F(4, 420) = 25.36, \quad p < .001 \]

**Main effect of condition**
\[ F(1, 105) = 9.05, \quad p = .003 \]

**No block x condition interaction**
\[ F(4, 420) = 1.61, \quad p = .17 \]
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>$t$-test</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mu</td>
<td>Control</td>
<td>258.40</td>
<td>1.69</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>242.03</td>
<td></td>
</tr>
<tr>
<td>sigma</td>
<td>Control</td>
<td>36.46</td>
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<tr>
<td></td>
<td>Pain</td>
<td>60.13</td>
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<tr>
<td>tau</td>
<td>Control</td>
<td>74.05</td>
<td>-2.95</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>113.45</td>
<td></td>
</tr>
</tbody>
</table>
Experiment 2

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.
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
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
\[ F(4, 684) = 1.00, \ p = .40 \]
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Pain</th>
<th>t-test</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>mu</td>
<td>255.98</td>
<td>242.03</td>
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<td>.15</td>
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<tr>
<td>sigma</td>
<td>61.51</td>
<td>81.96</td>
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<td>.02</td>
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<td>tau</td>
<td>122.32</td>
<td>150.53</td>
<td>-2.16</td>
<td>.03</td>
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</table>
E2 - Thought Probe Responses

The diagram shows the number of responses (out of 20) for different probe responses under two conditions: control and pain. The conditions are represented by bars in red for control and yellow for pain. The probe responses are:

- on-task
- task-related interference
- finger in device
- mind-wandering
- mind- blanking

The error bars indicate the variability in the responses.
Consistency in Arousal while Sustaining Attention

We can measure the pupils during vigilance tasks...
Tonic Changes in Pupil (Arousal) Over Time

Figure 1. Prettrial 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 prettrial 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
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**
\[ F(4, 576) = .41, p = .80 \]
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Pain</th>
<th>t-test</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>mu</td>
<td>271.73</td>
<td>253.54</td>
<td>1.57</td>
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<tr>
<td>sigma</td>
<td>54.81</td>
<td>79.10</td>
<td>-2.56</td>
<td>.01</td>
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<tr>
<td>tau</td>
<td>112.51</td>
<td>143.85</td>
<td>-2.15</td>
<td>.03</td>
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</tbody>
</table>
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**
\[ F(4, 560) = 1.40, p = .23 \]
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
\( t(142) = 2.55, p = .011 \)
There is a correlation between final subjective pain rating and tau...

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