Examining Neural Activity to Pitches and Feedback at the Plate: Psychological and Performance Implications

Jason Themanson, Ph.D.
Illinois Wesleyan University
https://works.bepress.com/jason_themanson/
Hitting: A Dynamic and Interactive Psychological Process
Existing Neural Research

- Seeing/hitting the pitch
- Pitch classification processes\(^1\text{-}^3\)
  - Neural profiles of correct vs incorrect pitch classifications
  - Specific timing, neural activity, and neural networks utilized in identifying different types of pitches

Hitting: A Dynamic and Interactive Psychological Process
Current Research Project

- Pitch-by-pitch influences
  - Pitches per plate appearance continues to increase
  - 1991 = 3.68
  - 2019 = 3.93 (BaseballReference.com)

- Highlights the open dynamic processes that exist beyond a single pitch during a hitter’s plate appearance
  - Self-regulation (monitoring performance)
  - Learning (strike zone)
  - Improving (performance)

Self-Regulation

- **Cognitive control**
  - Processes that underlie the ability to coordinate thoughts and actions with internal goals\(^5\).
    - Swing at strikes, don’t swing at balls
  - Self-Regulation – monitoring of one’s behavior to ensure executed actions match intended outcomes\(^6\).
    - Crucial for successful learning and adjusting behavior to meet goals\(^7-11\)
      - Work better at bats

Self-Regulation and the ACC

- The anterior cingulate cortex (ACC) is crucial for self-regulatory processes.
  - ACC activation is related to compensatory alterations in behavior following errors, incorrect feedback, and the execution of difficult task trials⁷,¹²-¹⁵

Event-Related Brain Potentials (ERPs)

- Neural activity time-locked to a specific event.
- Events are repeated so that trials of the same event can be averaged together.
- Components of the ERP can often be associated with a particular cognitive function.
Event-Related Brain Potentials (ERPs)
Feedback-Related Negativity (FRN)

- Generated by ACC\textsuperscript{16-17}
- Reflects a reward prediction error (RPE)\textsuperscript{18-19}
  - Expectations/Confidence
  - Knowing the strike zone
  - Initiates adjustments in behavior\textsuperscript{20}
  - Take off-speed pitches

---

Fronto-Central Positivity (FCP)

- Associated with attentional orienting processes
  - Paying attention to umpire feedback
  - Related to learning\textsuperscript{21-22}
    - Pitch was low, don’t swing next time

Anterior N2

- Generated by ACC\textsuperscript{11, 23-24}
- Associated with response inhibition and response conflict processes\textsuperscript{25}
  - Ball/Strike decision
  - Swing/Take decision

N450/Medial Frontal Negativity (MFN)

- Associated with cognitive conflict monitoring and adaptation processes\(^{26-27}\)
  - Conflict between swing/take options
  - Index proactive cognitive control processes\(^{27}\)

Participants

- Two groups:
  - College students (novices)
  - College baseball players (experts)
- Task: Act as a hitter making ball/strike decisions
Procedure

- Pitch video presented
- Participants needed to decide “ball” vs “strike” during pitch.
- Following pitch and response, feedback given on correctness of decision.
- Next pitch video presented.
Instructions

Watch these pitches.

If the pitch is a Ball, press the left button.  
If the pitch is a Strike, press the right button.

Try to respond as quickly and as accurately as possible.
Neural Activity During Task

- Strike stimulus
- Ball low stimulus
- Ball response
- Correct ball feedback
- Correct Strike feedback
- Error strike feedback
- BLINK
- BLINK

Time stamps:
- Strike stimulus: 00:00:47, 00:00:50
- Ball low stimulus: 00:00:49, 00:00:51
- Ball response: 00:00:48, 00:00:52
- Correct ball feedback: 00:00:49, 00:00:51
- Correct Strike feedback: 00:00:50, 00:00:52
- Error strike feedback: 00:00:48, 00:00:49
- BLINK: 00:00:47, 00:00:50
Task Performance Findings

- **Response Accuracy (% Correct) by Participant Group**
  - Players: 50%
  - Non-Players: 45%

- **Response Time (ms) by Participant Group**
  - Players: 350 ms
  - Non-Players: 340 ms
Post-Feedback Performance Findings

Response Accuracy (% Correct) Following Error Feedback and Correct Feedback

- Post-error feedback
- Post-correct feedback

<table>
<thead>
<tr>
<th>Group</th>
<th>Players</th>
<th>Non-Players</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Accuracy (% Correct)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing response accuracy for players and non-players following error and correct feedback.]
FRN and FCP by Expertise and Feedback Type

Amplitude (µV) vs Time (ms)

- Error feedback - college players
- Correct feedback - college players
- Error feedback - novices
- Correct feedback - novices
FRN and FCP by Expertise and Feedback Type

FRN Amplitude to Performance Feedback by Feedback Type and Group

FCP Amplitude to Performance Feedback by Feedback Type and Group

* indicates significant difference between groups.
N2 and MFN by Expertise and Post-Feedback Trial Type

Amplitude (µV)

Time (ms)

-100 0 100 200 300 400 500 600

Post-error feedback - college players
Post-correct feedback - college players
Post-error feedback - novices
Post-correct feedback - novices

FCz

N2

MFN

*
### Relationships between Neural Activity and Measures of Task Performance

#### Players

<table>
<thead>
<tr>
<th>Variable</th>
<th>FRN-Error</th>
<th>FCP-Error</th>
<th>FRN-Correct</th>
<th>FCP-Correct</th>
<th>N2</th>
<th>MFN-All</th>
<th>P-Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>-.56**</td>
<td>-.49*</td>
<td>-.66**</td>
<td>-.55**</td>
<td>.31</td>
<td>.19</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>.49*</td>
<td>.53**</td>
<td>.55**</td>
<td>.65**</td>
<td>-.55**</td>
<td>-.55**</td>
<td></td>
</tr>
<tr>
<td>P-ER RT</td>
<td>-.51*</td>
<td>-.42</td>
<td>-.62**</td>
<td>-.52*</td>
<td>.28</td>
<td>.17</td>
<td></td>
</tr>
<tr>
<td>P-ER PC</td>
<td>.57**</td>
<td>.54**</td>
<td>.64**</td>
<td>.56**</td>
<td>-.25</td>
<td>-.18</td>
<td></td>
</tr>
<tr>
<td>P-MC RT</td>
<td>-.61**</td>
<td>-.50*</td>
<td>-.71**</td>
<td>-.56**</td>
<td>.36</td>
<td>.22</td>
<td></td>
</tr>
<tr>
<td>P-MC PC</td>
<td>.03</td>
<td>.28</td>
<td>.11</td>
<td>.47*</td>
<td>-.60**</td>
<td>-.70**</td>
<td></td>
</tr>
</tbody>
</table>

#### Non-Players

<table>
<thead>
<tr>
<th>Variable</th>
<th>FRN-Error</th>
<th>FCP-Error</th>
<th>FRN-Correct</th>
<th>FCP-Correct</th>
<th>N2</th>
<th>MFN-All</th>
<th>P-Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>.06</td>
<td>.08</td>
<td>.10</td>
<td>.10</td>
<td>-.36</td>
<td>-.46*</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>.17</td>
<td>.07</td>
<td>.07</td>
<td>.01</td>
<td>-.12</td>
<td>-.31</td>
<td></td>
</tr>
<tr>
<td>P-ER RT</td>
<td>.04</td>
<td>.05</td>
<td>.10</td>
<td>.05</td>
<td>-.32</td>
<td>-.40</td>
<td></td>
</tr>
<tr>
<td>P-ER PC</td>
<td>-.03</td>
<td>.13</td>
<td>.26</td>
<td>.18</td>
<td>-.42</td>
<td>-.47*</td>
<td></td>
</tr>
<tr>
<td>P-MC RT</td>
<td>.07</td>
<td>.12</td>
<td>.18</td>
<td>.18</td>
<td>-.44</td>
<td>-.53**</td>
<td></td>
</tr>
<tr>
<td>P-MC PC</td>
<td>.25</td>
<td>-.14</td>
<td>.06</td>
<td>-.23</td>
<td>.17</td>
<td>.16</td>
<td></td>
</tr>
</tbody>
</table>

**p < .05; * p < .10**
### Relationships Among Measures Of Neural Activity for Players

<table>
<thead>
<tr>
<th>Variable</th>
<th>FRN-Error</th>
<th>FCP-Error</th>
<th>FRN-Correct</th>
<th>FCP-Correct</th>
<th>N2-All</th>
<th>MFN-P-Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRN-Error</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>FCP-Error</td>
<td>.86**</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>FRN-Correct</td>
<td>.81**</td>
<td>.65**</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>FCP-Correct</td>
<td>.79**</td>
<td>.95**</td>
<td>.66**</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>N2-All</td>
<td>-.16</td>
<td>-.30</td>
<td>-.39</td>
<td>-.54**</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MFN-P-Error</td>
<td>-.05</td>
<td>-.14</td>
<td>-.20</td>
<td>-.49*</td>
<td>.72**</td>
<td>—</td>
</tr>
</tbody>
</table>

** $p < .05$; * $p < .10$
Player Conclusions - FRN

- Reward prediction error/performance expectations (indexed by FRN to feedback):
  - Correlated with overall task performance and post-error adjustments in behavior
    - Smaller FRN to negative feedback was related with improved task learning and performance
    - Reflects faster and more efficient learners

Player Conclusions – FCP

- Attentional orienting to performance feedback (indexed by FCP to feedback):
  - Correlated with task performance and self-regulatory measures for players
    - More attention to feedback was related with improved task performance (RT and accuracy) and learning
  - More attention to correct feedback was also associated with greater inhibitory control and more proactive control throughout the task.

Player Conclusions – N2

- Response inhibition/inhibitory control (indexed by N2 during pitch):
  - More inhibitory control correlated with greater accuracy
  - Correlated with more attention to correct feedback and greater response accuracy following correct feedback
    - Inhibitory control may be one candidate mechanism underlying learning and performance enhancements.
Player Conclusions – MFN

- Response conflict detection/adaptation (indexed by MFN during pitch):
  - Better conflict adaptation correlated with better response accuracy and more inhibitory control
  - Correlated with response accuracy following correct feedback
    - Conflict adaptation may be another candidate mechanism underlying learning and performance enhancements.
Implications

- Neural activity during feedback and/or between pitches can influence hitting behavior.
- Neural measures index player expectations, motivation, and attentional allocation
  - More objective measures for psychological/cognitive variables.
  - Data point for coaches/instructors/scouts
- Increase efficiency, effectiveness, and communication in coaching, training, scouting, and player development processes.
Future Directions

- Examine relationships with in-game performance/metrics
- Explore different levels of play/expertise
  - A, AA, AAA, etc.
- Obtain longitudinal data to look at player across time
- Expand paradigm
  - Different decisions, game contexts, etc.
- Consult, partner, collaborate with teams/organizations
Acknowledgments

- Illinois Wesleyan University
- Students and colleagues
- Family and friends
- SABR
- All of you
Questions?