Introduction to Temporal Processing and Its Application to CAPD and Other Aspects of Neuroaudiology

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Outline/Agenda

• Introduction:
  – Definition
  – Test battery
  – Types temporal processing
• Auditory Patterns
  – Background and administration
  – Mechanism
  – Common errors
  – Clinical impact
• Gaps in noise
  – Background & administration
  – Mechanisms
  – Clinical impact
• Comment: Audition – cognition
• Future directions
• Take home message
Temporal Processing: The perception of time alteration or influence on an audible acoustic event(s). – Musiek (2016)

**CENTRAL AUDITORY TEST CATEGORIES**

- **Temporal**
  - Patterns*, 2 element seq., Gap/fusion detection*, temp. Integration, temp masking

- **Electrophysiologic**
  - ABR*, MLR*, N1, P2, P300 cABR, MMN

- **Dichotic**
  - Digits*, CVs, Words, Sentences*, DSI, SSW*, Rhyme*

- **Monaural Low Redundancy**
  - LPFS, Comprsd Spch Spch in Noise, Spch vs. Spch

- **Bin. Interaction**
  - MLDs, Fused image tracking, LISN

- **Discrimination ?**
Types of Temporal Processing

- Integration (brief tone Freq. DLs)
- Sequencing (Patterns)
- Resolution (Gaps in Noise)
- Masking (Backward, Forward)

FOCUS

Answers from the past but not acknowledged
Briefly; Brief tone Freq. DLs

- Cranford’s work
  - Brief tone thresholds (temp. Integration)
  - Frequency discrimination for brief tones
  - Animal & human data
  - Clinical application?

Brief Tone Freq. DLs: Controls vs CANS
Auditory Patterns

Frequency and Duration Patterns

Key Processes: temporal sequencing & frequency discrimination

(Musiek)

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Frequency Patterns

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*** BE SURE YOU HAVE THE RIGHT TEST !!!
Duration Patterns

1. Long  Long  Short
2. Long  Short  Short
3. Short  Short  Short
4. Short  Long  Short
5. Short  Short  Long
6. Short  Short  Long

Underlying Mechanisms for Pattern Perception
Site of Dysfunction & Interpretation

A = RT. CORTEX
B = CORPUS CALLOSUM
C = LT. CORTEX

Common Errors
Administration of Pattern Perception Tests

- Verbal explanation
- Use the correct version of the test!
- Visual cues with voiced patterns
- Practice items
- Monaural vs. binaural or sound field
- Humming response
- 30 test item minimum
- Half lists
- Sound field, diotic testing

Scoring of Pattern Perception Tests

- Reversals
- Extra element responses
- Supplemented responses
- Musicians
### Children’s Norms (cut off scores)

**Frequency Patterns**

<table>
<thead>
<tr>
<th></th>
<th>LE</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 y.o.</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>9 y.o.</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>10 y.o.</td>
<td>72%</td>
<td>72%</td>
</tr>
<tr>
<td>11 y.o.</td>
<td>75%</td>
<td>75%</td>
</tr>
</tbody>
</table>

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**Significant diagnostic findings for neurologically based group studies using pattern tests**

- Pinheiro 1977 (neuro -1)
- Musiek, Wilson, Pinheiro, 1980 (neuro -1)
- Musiek, Pinheiro, Baran, 1987 (neuro -1)
- Musiek, Baran, Pinheiro, 1990 (neuro -1)
- Musiek, 1994 (neuro -1)
- Hurley & Musiek, 1997 (neuro -1)
- Bamiou et al. 2006 (neuro -1)
- Meneguello et al. 2006 (TL Epilepsy)
- Amaral et al. 2015 (TL Epilepsy)

Musiek, 2016
Significant diagnostic findings for neurologically based group studies using pattern tests, con’t

- Han et al. (2011) (TL Epilepsy)
- Jafari, et al. (2016) (MS)
- Valadbeigi et al (2014) (MS)
- Bruner, & Pereira, (2009)*
- Camarinha, et al. (2011) (neurotoxic)
- Teixeira, et al. (2002) (neurotoxic)
- Dutra et al. (2010) (neurotoxic)
- Zamydlowska-Szmytke et al. (2009) (neurotoxic)
- Fluente, McPherson, (2007) (neurotoxic)

Musiek, 2016

ROC Curves: Central Auditory Tests

From Hurley and Musiek, 1997
Based on Weihing et al 2015, Musiek et al. 1987, (modified)
Mean Correct Scores for Frequency Patterns in Children w. CAPD

Other learning disabilities

- Dias, 2005
- Engelmann & Ferreira,
Mean percent performance on frequency patterns across auditory sites
N= 120, 50, 22, 29

Controls cochlears b.s. cerebrals

Patterns and Split Brains

Musiek
Frequency Patterns & Dyslexia

FROM Lewandowska ET AL. 2013
MODIFIED

\[ \text{CONTROLS} \]
\[ \text{DYSLEXIA} \]

\[ \text{P < 0.01} \]

\[ \text{N = 40} \]
\[ \text{N = 57} \]

(MUSIEK)

Patterns & Dyslexia (con’t)

FIGURE 1. Bar graph of the percentage of occurrence of each category on the speech-in-noise, dichotic digit, and frequency pattern tests for the dyslexia group.

See also: *** Pinheiro, 1977 | Frota, 2003 Machado et al. 2011
Soares et al. 2011
Gaps in Noise (GIN)
Why are the perception of “silent intervals” & transitions to and from silence important?

- Critical in the perception of speech
  - The ball was thrown by the quarterback
  - I want my quarter back!
- Provides insight into temporal resolution of the auditory system
- It can be reliably measured psychoacoustically and now clinically
  
  **Noise - fills in gaps!**

Word recognition in noise: poorer speech recognition correlates with poor gap detection – Snell, 2000; Snell et al. 2002

Stimulus

- CD
- 50 dB SL re: PTA
- 6 second broadband uniform white noise segments
- 0-3 silent intervals
- 5 second ISI
- Durations: 6 each of:
  - 2, 3, 4, 5, 6, 8, 10, 12, 15, 20 msec = 60 items/ list
  - No rise – fall
1. 3870.3 20
2. 1303.2 2
4357.6 10
3.
### Scoring

<table>
<thead>
<tr>
<th>Threshold</th>
<th>2 msec</th>
<th>3 msec</th>
<th>4 msec</th>
<th>5 msec</th>
<th>6 msec</th>
<th>8 msec</th>
<th>10 msec</th>
<th>12 msec</th>
<th>15 msec</th>
<th>20 msec</th>
<th>Total % Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>List 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Ear</td>
<td>0/6</td>
<td>1/6</td>
<td>3/6</td>
<td>4/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
<td>45/60</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>17%</td>
<td>50%</td>
<td>67%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>75%</td>
</tr>
</tbody>
</table>

A. Th = 5 msec
75% Correct
**Normative Data for GIN Across Countries & Languages**

<table>
<thead>
<tr>
<th>Study</th>
<th>Language</th>
<th>Age (yrs)</th>
<th>GIN A.th (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musiek et al. 2005, English</td>
<td></td>
<td>24.6</td>
<td>RE- 4.8, LE- 4.9</td>
</tr>
<tr>
<td>Sanchez et al. 2010, Portuguese</td>
<td></td>
<td>29.7</td>
<td>4.7</td>
</tr>
<tr>
<td>John et al. 2012, English</td>
<td></td>
<td>25.6</td>
<td>4.7</td>
</tr>
<tr>
<td>An et al. 2014, Korean</td>
<td></td>
<td>42.2</td>
<td>4.97</td>
</tr>
<tr>
<td>Wong &amp; McPherson, Cantonese</td>
<td></td>
<td>24.8</td>
<td>RE- 4.6, LE- 4.9</td>
</tr>
<tr>
<td>Hover et al., 2015, English</td>
<td></td>
<td>24.6</td>
<td>4.53</td>
</tr>
<tr>
<td>Rabelo et al. 2015, Portuguese</td>
<td></td>
<td>25</td>
<td>RE- 4.6, LE- 4.7</td>
</tr>
<tr>
<td>Amaral et al. 2015, India ‘dil.’</td>
<td></td>
<td>10.6</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Range = 4.5 – 4.97 msec

Acknowledge: Bamiou Lab
Mean Gap Detection Values for Each Ear & 1 S.D. (-) (based on Shinn et al.)

Self-Report: Hearing Handicap Inventory – Adult

- 25-item questionnaire addressing the impact of hearing-related problems on emotional and social functioning

63% of blast-exposed report moderate or severe hearing handicap

(Gallen et al.)
Test Efficiency of GIN on Patients with Neurologic Based Lesion

Musiek, 2016

In brief........

**Significant effects of Age on GIN or GD Procedures**

- Martin and Jerger, 2005;
- Humes et al, 2010;
- Harris et al, 2010;
- John et al, 2012
- Palmer & Musiek, 2014
- Hoover et al, 2015
- Vaidyanatha and Yathiraja, 2015
A comment on audition, cognition

Pearson r Values comparing the degree of association Between CAPD tests and WISC Scores

<table>
<thead>
<tr>
<th></th>
<th>LPFS</th>
<th>CS</th>
<th>DD</th>
<th>FP</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full I.Q.</td>
<td>-0.06</td>
<td>0.15</td>
<td>0.17</td>
<td>0.28*</td>
<td>0.25</td>
<td>-0.01</td>
</tr>
<tr>
<td>Verb comp.</td>
<td>-0.16</td>
<td>0.02</td>
<td>-0.05</td>
<td>-0.07</td>
<td>-0.09</td>
<td>-0.05</td>
</tr>
<tr>
<td>Percep. Reason</td>
<td>-0.13</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.17</td>
<td>0.12</td>
<td>-0.17</td>
</tr>
<tr>
<td>Process speed</td>
<td>-0.12</td>
<td>-0.13</td>
<td>-0.13</td>
<td>-0.16</td>
<td>-0.23</td>
<td>-0.03</td>
</tr>
<tr>
<td>Work Memory</td>
<td>0.01</td>
<td>0.06</td>
<td>0.01</td>
<td>-0.05</td>
<td>0.03</td>
<td>0.07</td>
</tr>
</tbody>
</table>

# Since there was no diff. between R and L ear scores were collapsed
*Once alpha level was adjusted for the number of correlations by WISC this was not significant C1, C2 = test combinations

(see Weihing et al. 2015) Also Sharma et al. 2009; Gyldenkaerne et al. 2014)
Future Directions

EP GIN
N1, P2

(Palmer and Musiek, 2013)
Partially-Filled Gap Detection aka Decrement Detection

- “the smallest detectable duration of a brief decrement in the intensity of a noise as a function of the depth of the decrement” (Plack & Moore, 1991).
- two stimulus variables are of interest:
  - decrement depth, or the change in stimulus intensity relative to the rest of the stimulus (noise, tone),
  - decrement duration, the duration of the partially-filled gap.

Ceruti et al. 2014
Thank you