ABSOLUTE PITCH AND CALENDRICAL CALCULATION IN ASPERGER SYNDROME: A CASE STUDY

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Master of Psychology (Clinical Neuropsychology)
University of Melbourne

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Acknowledgements: Dr. Natasha Brown, Dr. Ian Stuart
Asperger Syndrome

- Developmental disorder characterised by social and behavioural difficulties

- Autism Spectrum Disorders (ASD; Wing and Gould, 1979)
  - ‘Triad’ of impairments
    1. Social interaction and relationships
    2. Language and communication
    3. Thought and imagination

- In adulthood, interests are often not shared by others and may lead to ‘savant skills’
Savant Syndrome

- ‘Island of genius’ in the context of intellectual disability (Treffert, 2009)
- Normatively superior performance in a specific area, plus a discrepancy with overall level of functioning (Miller, 1998)
- Most commonly associated with ASD (Heaton, 2004; Hill, 1977; Rimland, 1978)
- Domains of music, art, mathematics and spatial relationships
  - Two savants skills of interest in this study: absolute pitch and calendrical calculation
- Savants may have higher IQ than non-savants (O’Connor & Hermelin, 1991; Howlin et al., 2009)
- Conflicting evidence for whether savants demonstrate more restricted or stereotyped interests (O’Connor & Hermelin, 1988; 1991; Howlin et al., 2009)
Why do savant skills develop?

- **Central coherence model** (Frith, 1989)
  - ‘Central coherence’ is our tendency to form global percepts and extract higher level meaning
  - In ASD, weak central coherence leads to ‘piecemeal processing’

- **Support for the central coherence model**
  - Embedded figures (Shah & Frith, 1983)
  - Block design (Shah & Frith, 1983)
  - Sentence recall (Hermelin & O’Connor, 1967)
  - Word list recall (Tager-Flusberg, 1991)

- Perhaps the key feature is superior local processing as opposed to inferior global processing (Happé & Booth, 2008)
Object-Attribute model of auditory processing can provide neurobiological context to test the central coherence model (McLachlan & Wilson, 2010)

Both categorical and spatial pathways may require intact central coherence

A range of musical skills may reflect central coherence
- Identification of intervals in RP: higher level categorisation & reliance on tonal context
- Rhythmic processing: grouping mechanisms involve learnt hierarchical patterns
The Object-Attribute Model

(McLachlan & Wilson, 2010)
Testing the central coherence model

- Object-Attribute model of auditory processing can provide neurobiological context to test the central coherence model (McLachlan & Wilson, 2010)

- Both categorical and spatial pathways may require intact central coherence

- A range of musical skills may reflect central coherence
  - Identification of intervals in RP: higher level categorisation & reliance on tonal context
  - Rhythmic processing: grouping mechanisms involve learnt hierarchical patterns
Absolute Pitch (AP)

- The rare ability to identify or produce the pitch of any musical tone without using an external reference pitch (Takeuchi & Hulse, 1993; Wilson, Lusher, Wan, Dudgeon & Reutens, 2009)

- Extremely common in ASD, and also found in highly trained musicians (Rimland, 1978; Deutsch, Henthorn & Dolson, 2004)

- Thought to develop in the context of musical training during sensitive periods of development, paired with genetic predisposition (Baharloo et al., 1998, 2000; Gregersen et al. 2001; Wilson et al., 2009)

- Elevated prevalence of AP among blind musicians (Hamilton, Pascual-Leone & Schlaug, 2004)
Calendrical calculation (CC)

- Rapid naming of weekdays corresponding to dates in the past or future (Cowan, Staintorp, Kapnogianni, & Anastasiou, 2004; Heavey, Pring & Hermelin, 1999)

- Common in the context of savant syndrome

- Highly variable in terms of speed, accuracy and range

- Contributing factors: rote memory or calculation
Weak central coherence, AP & CC?

- Weak central coherence may favour AP & CC
  - Calendar and music are closed systems with internal rules
  - Encourages the salience of day-date combinations in memory
  - AP involves the categorisation of pitch at a local level
    - In RP, learning musical identities for intervals involves higher level categorical processing
Current study

- Issues to be addressed
  - Investigation of common underlying mechanisms should study savants with multiples skills
  - Substantial variability in savant skill calls for focus on individual cases
  - No studies of central coherence have used savant samples

- Current case study
  - Focus on RB, a 23 year old male with AP and CC in the context of Asperger syndrome and blindness
Aims

- Document the nature and extent of RB’s skills

- Investigate common underlying mechanisms through:
  - Generalisability of savant skills through analogous AP and CC tasks
  - Categorisation level
  - Multimodal associations

- Evaluate these findings against the central coherence framework

- Compare RB with group of congenitally blind, age-matched controls
Hypotheses

- **Savant skill**
  - Pitch naming ability in AP range, CC performance comparable with previously reported savants

- **General intellectual, musical and numerical aptitude**
  - At least average musical / numerical skill
  - At least Average verbal ability, with reduced executive function

- **Central coherence**
  - Performance on analogous tasks would not approximate the level of RB’s savant skills
  - RB would use lower level categorisation strategies in tonal, rhythmic and homograph judgments
    - Tonal classification: RB < controls
    - Tapping to rhythmic pulses: RB would use lower hierarchical grouping strategies compared to controls
    - Homograph reading: RB < controls
  - Recognition of perceptual contours across modalities: RB < controls
Case report: RB

- 23 year-old, L-handed male with Asperger syndrome, AP & CC
- Informed consent from RB and guardian

**Education**

**Medical Hx**
- Congenital blindness, temporal lobe epilepsy. MRI: abnormal bony structures around orbits, normal brain structure.

**Musical experience**
- Piano, guitar, harmonica, sings. Began piano at 4yo, completed grade 7 prac & grade 4 theory. Lead vocalist and guitarist for band.

**Mathematical background**
Neuropsychological assessment

**WAIS-III: verbal ability**

<table>
<thead>
<tr>
<th>Verbal subtests</th>
<th>RS</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>56</td>
<td>15</td>
</tr>
<tr>
<td>Similarities</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Information</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Comprehension</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Digit span</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>L-N sequencing</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>19</td>
<td>15</td>
</tr>
</tbody>
</table>

Verbal Comprehension Index = 100 (95% CI = 94-106, 50th percentile)

Working Memory Index = 130 (95% CI = 121-135, 98th percentile)

**Estimation of non-verbal ability**

- **Tactual Learning Test** (Stuart, personal communication)
  - Reproduction more difficult than recognition

- **Tactual 3D constructions test** (Stuart)
  - Difficulty with organisation and planning

- **Auditory spatial manipulation**
  - 100% accuracy
## Neuropsychological assessment

### WMS-III: Memory

<table>
<thead>
<tr>
<th>WMS-III subtest</th>
<th>RS</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical Memory I</td>
<td>69</td>
<td>18</td>
</tr>
<tr>
<td>Logical Memory II</td>
<td>44</td>
<td>18</td>
</tr>
<tr>
<td>VPA I</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>VPA II</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Word Lists I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List A total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 1 - List B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning slope</td>
<td>43</td>
<td>15</td>
</tr>
<tr>
<td>Trial 4 – Short delay</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Word Lists II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recall total Recognition</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Retention</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>15</td>
</tr>
</tbody>
</table>

Auditory Immediate Memory Index = 139 (95% CI = 128-143, 99th percentile)

Auditory Delayed Memory Index = 132 (95% CI = 119-137, 98th percentile)

### DKEFS: Executive function

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Component</th>
<th>RS</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal fluency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Letter fluency total correct</td>
<td>54</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Category fluency total correct</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Category switching total correct</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Category switching total switching accuracy</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Word context</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total consecutively correct</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Consistently correct ratio</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>Proverb Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free enquiry</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Multiple choice</td>
<td>32</td>
<td>100th percentile</td>
</tr>
</tbody>
</table>

(95% CI = 128-143, 99th percentile)

<table>
<thead>
<tr>
<th>MBEA subtest</th>
<th>Score</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale Discrimination</td>
<td>29</td>
<td>26 (2.63)</td>
</tr>
<tr>
<td>Different contour</td>
<td>29</td>
<td>26 (2.64)</td>
</tr>
<tr>
<td>Same contour</td>
<td>29</td>
<td>26 (2.80)</td>
</tr>
<tr>
<td>Rhythmic contour</td>
<td>31</td>
<td>27 (2.60)</td>
</tr>
<tr>
<td>Metric task</td>
<td>30</td>
<td>26 (4.12)</td>
</tr>
<tr>
<td>Incidental memory (recognition)</td>
<td>30</td>
<td>27 (2.43)</td>
</tr>
<tr>
<td>Average score</td>
<td>29.67</td>
<td>26 (1.88)</td>
</tr>
</tbody>
</table>

### Just noticeable difference

- Just noticeable difference
- Reliable detection = 75% correct
- RB could reliably detect 0.25% change (smallest difference level)
Experimental study: Method

- **Participants**
  - Case study: RB
  - Control group
    - Males (n=5)
    - Approximately age-matched
    - Congenitally blind, or blind before 18 months
    - No light or pattern sensitivity
    - Screened for ASD and other neurological and psychiatric conditions

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age (years)</th>
<th>Education (years)</th>
<th>Mathematical instruction (years)</th>
<th>Musical training (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls (mean)</td>
<td>25.8</td>
<td>15.2</td>
<td>10.8</td>
<td>7.28</td>
</tr>
<tr>
<td>RB</td>
<td>23</td>
<td>15</td>
<td>10</td>
<td>17</td>
</tr>
</tbody>
</table>
Method: Savant skill measures

- **Savant skills**
  - Calendrical calculation: Gregorian calendar task adapted from (adapted from Cowan, et al., 2003)
    - E.g. “What day of the week was it on the 12th June, 1986?”
    - Comparison with other calculators for speed, accuracy and range
  - Absolute pitch
    - Pitch naming task (Wilson et al., 2009)
      - 50 piano tones to be named. > 90% accuracy = AP
    - Key identification
      - Identifying the key of 30 of short musical phrases (MBEA)
Method: Central coherence measures

- Generalisability of savant skills
  - Julian calendar task
    - Today’s Julian Day Number is 2,455,371, abbreviated to 5,371
    - E.g. “What day of the week was it on Julian Day Number 4,273?”
  - Microtone naming task
    - Presentation of 5 blocks of 20 tones to name/describe
    - Tones were either semitones (chroma), halfway between two semitones, ¼ above/below or ⅛ above/below

<table>
<thead>
<tr>
<th>Block</th>
<th>Stimuli</th>
<th>Time-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 semitones</td>
<td>2,000ms</td>
</tr>
<tr>
<td>2</td>
<td>10 semitones + 10 ½ semitones</td>
<td>15,000ms</td>
</tr>
<tr>
<td>3</td>
<td>5 semitones + 5 ½ semitones + 5 ¼ semitones + 5 ⅛ semitones</td>
<td>30,000ms</td>
</tr>
<tr>
<td>4</td>
<td>5 semitones + 5 ½ semitones + 5 ¼ semitones + 5 ⅛ semitones</td>
<td>30,000ms</td>
</tr>
<tr>
<td>5</td>
<td>5 semitones + 5 ½ semitones + 5 ¼ semitones + 5 ⅛ semitones</td>
<td>30,000ms</td>
</tr>
</tbody>
</table>
Method: Central coherence measures

- **Categorisation level**
  - **Tonal classification task** (Wilson et al., 2009)
    - Arpeggiated dominant chord followed by a tone that is either a) the tonic of the key, or b) a semitone higher than the tonic.
    - Is the sequence is ‘tonal’ or ‘atonal’?
  - **Rhythmic task** (adapted from Drake, 1993)
    - Rhythms were simple – complex (including polyrhythms)
    - Reproduction phase
    - ‘Tapping’ phase
  - **Homograph task** (Happé, 1997)
    - e.g. “The scrap metal man first took the copper and iron and then he took the lead”.
    - Conditions: rare/before, rare/after, frequent/before, frequent/after

- **Multimodal associations**
  - Melodic contour recognition
  - Melodic contour reproduction
Method: Screening measures

- Screening measures for controls
  - Autism Spectrum Screening Questionnaire (ASSQ; Ehlers, et al., 1999)
  - Neurological screening questionnaires
  - Musical experience questionnaire
  - WAIS-III verbal subtests
Results

- **Statistical analyses:** all comparisons used modified independent sample t-test, and those not meeting assumptions of normality used single-sample t-test (Crawford & Garthwaite, 2002).

- **Screening measures for controls**
  - No ASD features on ASSQ
  - No significant neurological hx
  - Musical experience: 4 self-reported AP
  - Mean VIQ = 122.8 (VCI = 117, WMI = 116.4)
Results: Gregorian Calendar task
Results: AP assessment

1. Pitch Naming task: Accuracy for RB and controls

2. Key identification: RB achieved 100% accuracy
Results: Julian calendar task

Accuracy (% correct) / median response latency (s)

Time period:
- 1995-1997
- 1995-1997
- 2006-2012
- 2017-2022

Accuracy

Latency
Results: Microtone naming task

RB’s error (% frequency) for naming of microtones, divided into types according to proportion of semitone presented; whole, half, quarter, or eighth.
Results: Experimental tasks

- Tonal classification task (Wilson et al., 2009)
  - RT consistent with other AP’s
  - No difference between RB (100%) and controls (M=72.86%, SD=25.76) on accuracy

- Rhythmic task
  - No differences between RB and controls for rhythm reproduction, or tapping to the beat

- Homograph task
  - No differences between RB and controls in accuracy of homograph pronunciation in any condition

- Multimodal associations
  - No difference between RB (100%) and controls (M=84.72%, SD=31.45) on melodic contour recognition, or on melodic contour reproduction (RB=11.5, controls M=9.1, SD=3.92).
Discussion: Summary of results

- Savant skills confirmed with AP and CC tasks
- General intellectual, musical and numerical ability
  - Average verbal ability, no deficit in executive function
  - Strengths in working memory and long term memory
  - Superior musical and arithmetical skill
- No deficit in central coherence on any measure
  - Evidence of generalisability of skills
  - No differences between RB and controls in level of categorisation (tonal classification, rhythmic grouping, homograph reading)
  - No differences between RB and controls in multimodal processing
Discussion: Results in context

- Conceptualisation of savant skill
  - Results argue against the notion of an ‘island of genius’ in the context of intellectual disability (Treffer, 2009), and Miller’s (1989) definition
  - RB’s skills fit with descriptions of AP and CC
  - Consistent with reports of higher IQ in savants (O’Connor & Hermelin, 1991; Howlin et al., 2009)

- Calendrical calculation: Rote memory + extensive practice?
  - RB was not practiced
  - Pattern of response latency suggests working memory
  - Often used an anchor (e.g. Birthday)
  - Memory skill and practice are not useful for Julian calendar task: evidence of understanding of calendrical regularity and calculation skill
Discussion: results in context

- **Absolute pitch**
  - All AP/QAP participants began training before 8yo, but none had family hx of AP
  - Shift in template during the microtonal task suggests temporary ‘paracusis’ described by Tsuzaki (1992)
  - Role of blindness in the development of AP

- **Is there evidence for a common underlying mechanism?**
  - No support for weak central coherence on any measures
  - No evidence of superior local processing
  - We were unable to replicate Happé’s (1997) homograph findings
  - Support for Hoy et al (2004) of no effects in homograph reading in Asperger samples

- **If not central coherence, what factors might contribute to savant skill?**
Conclusions

- This was the first study to investigate the central coherence model in savant samples
  - Single-case study reduces generalisability of findings
- Future studies should further investigate multi-skilled savant samples, with various subtypes of ASD, levels of IQ, and severity of restricted interests
- Future studies should utilise a firm neurobiological and cognitive grounding, such as the Object-Attribute model, for systematic investigation
- fMRI studies might assist in the investigation of common underlying processes
- In conceptualising savant skill, perhaps biases in perceptual processing are not strong explanatory variables