Sensory Processing From Bedside to Brain Training
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Disclaimers/Conflicts

• Akili Interactive Labs: I provide consultation for the development of cognitive training tools for children.

The hour’s Objectives:

Objectives:
1) Understand what is meant by the term “Sensory Processing Disorder ( SPD)”
2) Understand the causes of sensory processing dysfunction
3) Update on research regarding clinical assessment of sensory processing
4) To understand the similarities and differences in brain connectivity between SPD and Autism
5) Understand the role of brain training in SPD and cognitive disorders
What’s the big deal, anyway?

• Three Stories show the many faces of SPD:
  – Touchy Tommie
  – Fragile Frankie
  – Happy Heidi

Touchy Tommy

• y.o. male could only wear one pair of shorts.
  • Tactile: At intake in August of 2015 had one and only one pair of shorts and shirt that he had worn daily for the past year
  • Auditory: Bothered by loud and novel noises
  • Receiving OT support for fine motor dyspraxia
  • Birth, Medical, Surgical and/or Family history is notable for meatal stenosis repair and nasal turbinate repair, mom with mild tactile sensitivity
  • Medications: To be determined

Fragile Frankie

• y.o. male with a neurodevelopmental disorder characterized by
  – Strengths in gross motor (zip line, climbing)
  – Challenges with fine motor (ADLS and handwriting), receptive language (est 3-4y); social limited by language and arousal; attention (working on this with teachers)
  – Comorbid conditions include: none
  • Examination is notable for hypertelorism, course facial feature: triangular face, short stature
  • Etiologic evaluations at referral included: psychology label of autism, no genetic evaluation
  • Activities include: hippotherapy, swimming and paddle boarding
  • Therapies include: ST/OT/ABA
Happy Heidi

- y.o. female with a neurodevelopmental disorder characterized by
- strengths in social drive and reading
- challenges with gross/fine motor, visual spatial, processing speed, feeling anxiety, Sensory OverResponsivity auditory only; social finesse
- Examination is notable for immature affect, non-dysmorphic and non-focal
- Etologic evaluations to date include: Clinical MRI showed no evidence of abnormality, high resolution chromosomes, fragile X and Array were normal. Whole Exome Sequencing was revealing.
- Activities include: horse back riding, martial arts
- Current Therapies include: social skills group

So do they have SPD?

A description? A label? or A diagnosis?

What is SPD?

- Neuroscience/Neurologists (BROAD)
  - The disruption of information perception, encoding, integration from one or multiple sensory systems leading to clinically relevant cognitive and behavioral deficits.
- Occupational Therapy (SPECIFIC)
  - A singular condition that exists when sensory signals don’t get organized into appropriate responses (SPDfoundation.net)
- Psychology/Psychiatry (NON-EXISTANT)
  - A disorder that doesn’t exist (not included in the DSM 5) but now included in Autism Spectrum Disorders Criteria
- Pediatricians (TAG ALONG)
  - When sensory problems are present, health care providers should consider other developmental disorders, including autism spectrum disorders, attention deficit/hyperactivity disorder, developmental coordination disorder and anxiety disorder (www.aap.org)
Auditory OverResponsive (AOR)

Tactile OverResponsive (TOR)

The Add On’s
- Dysgraphia (fine motor control)
- Emotional Dysregulation (emotional Control)
- Inattention (Cognitive Control)
In the word of Rachel Schneider

What’s it like to have SPD - SMD? It depends on the SPDer’s individual experiences and specific subtype.

“For example, the sight of light may be perceived as painful, problematic, and supremely bright for those who are over-responsive. A person who is sensory-seeking might crave light and turn on every lamp in the house. Someone who is under-responsive might not even notice light and leave lamps on, even as they sleep…”

www.rachel-schneider.com

SPD Subtypes

- Sensory Overresponsivity: Avoiding Sensory input
  - Underresponsive: non-responsive to sensory input
- Dyspraxia/Motor Planning
- Postural Control Disorders

Lucy Miller: Spdfoundation.org

Whatever it is, research is on the rise...
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Etiologies of SPD

- Utero
- ? Genetics
- Injury
- Environment

Genetic disorders with reported SPD

- Turner’s (XO) and 47,XXX
- (included Triplet Repeats)
  - 16p11.2 Deletions and Duplications
  - Fragile X
Fragile Frankie

ArhGEF9 (Rho Guanine Nucleotide Exchange Factor 9)
- collybistin
- Molecular switch that is pivotal in the role of post synaptic glycine and GABA receptor clusters
- Global NDD and auditory hypersensitivity (startle)

Single Genes Associated with SPD

MBD5 (methyl-CpG-Binding Domain Protein 5)
- 2q23.1
- de novo mutation in a pilot series of 10 trios with SPD
- Found in 0.18% of patients with ASD, no controls
- Cognitive impairment, epilepsy, sleep and & behavioral challenges (3 case reports)
- Our patient:
  - WISC VCI 106, PRI 79, WM 99, PSI 65
  - Social Communication Questionnaire total = 7
  - Sensory Profile DD in all categories
  - Vanderbilt Parent: meets ADHD cut scores
  - Clinical MRI unrevealing

Happy Heidi
Injury/Brain malformation can lead to “sensory processing differences”

- Fetal Alcohol Syndrome
- Prematurity
- Stroke
- Infection
- Agenesis of the corpus callosum
- Migraine?

Prematurity

<table>
<thead>
<tr>
<th>Agenesis of Sensory Behavior in Premature Infants using the Sensory Profile</th>
<th>N (%) with scores &gt;2 SD from the mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadrants</td>
<td></td>
</tr>
<tr>
<td>Low Registration</td>
<td>10 (10)</td>
</tr>
<tr>
<td>Sensory Seeking</td>
<td>11 (11)</td>
</tr>
<tr>
<td>Sensory Sensitivity</td>
<td>10 (10)</td>
</tr>
<tr>
<td>Sensory Avoiding</td>
<td>11 (11)</td>
</tr>
<tr>
<td>S E C T I O N S</td>
<td></td>
</tr>
<tr>
<td>Auditory Processing</td>
<td>96 (96)</td>
</tr>
<tr>
<td>Visual Processing</td>
<td>80 (80)</td>
</tr>
<tr>
<td>Tactile Processing</td>
<td>80 (80)</td>
</tr>
<tr>
<td>Oral Motor Processing</td>
<td>105 (105)</td>
</tr>
<tr>
<td>Total Sensory Processing</td>
<td>155 (155)</td>
</tr>
</tbody>
</table>


Agenesis of the Corpus Callosum

Images courtesy of Dr. Elliott Sherr
Agenesis of the Corpus Callosum: Low Registration

Individuals with agenesis of the corpus callosum show sensory processing differences as measured by the sensory profile.


Environment (Experience over Time)
- Sensory Deprivation v. Engagement/Experience
- Trauma/Conflict v. Comfort
- Screen Time: passive v. active, addictive v. stimulating

The interaction of marital conflict and stress reactivity on externalizing and internalizing symptoms: the role of laboratory stress.
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So how does one define SPD for research?

Isolated SPD
Our Lab approach (it’s a start)

- Community diagnosis/suspicion of “SPD”
- Sensory Profile with > 2 SD (Definite Difference) bias toward hypersensitivity
  - Auditory, Tactile, Visual, Oral/Olfactory, Vestibular, Multisensory Processing
- Evaluate for Autism Criteria
- Evaluate for Cognitive Ability
- Evaluate for Attention/Hyperactivity
- R/o for Clinical MRI findings
- R/o for known Genetic conditions
- (Future: Assess for Dyslexia and Autonomic Arousal)

Bedside

Auditory and Tactile Assessment

- 54 boys (ASD 20, SPD 15, TDC 19)
- Auditory processing: Differential Screening test for Processing (DSTP)
  - Dichotic listening (number to both ears)
  - Temporal Patterning (order of high/low tones)
  - Auditory Discrimination (Filtering-nonsense in noise)
- Tactile Processing
  - Tactile detection “Von Frey hairs”
  - Sensitivity “two point discriminator”
  - Form Discrimination “von boven domes”
  - Proprioception/WM “SIPT graphesthesia”
Tactile

- Tactile detection
  - Weaker detection in SPD group than ASD or TDC
- Sensitivity
  - No difference noted
- Form Discrimination “von boven domes”
  - No differences noted
- Proprioception/WM “SIPT graphesthesia”
  - Right Hand: ASD = SPD < TDC

Auditory

- ASD < SPD = TDC
Bedside Summary

- Measurable bedside tactile differences in children with isolated SPD
- Auditory processing differences become apparent when moving to a correlational approach

*But where is it in the brain?*

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Structural Neuroimaging in SPD

- TBSS Data Driven Approach SPD boys 8-12y compared to Controls

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- Right handed boys
  - SPD n=16
  - Controls n=25
- Age Matched
  - 8 to 11 years old
- FSIQ matched
  - SPD mean 113 (100-131)
  - Control mean 115 (97-130)
Then, we looked for lesions...

<table>
<thead>
<tr>
<th>Group</th>
<th>SPD (n=16)</th>
<th>Controls (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corpus Callosum</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decreased White matter</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grey Matter Injury</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Posterior Fossa Cyst</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
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Next, we looked for volume...

<table>
<thead>
<tr>
<th>Free Surfer</th>
<th>p</th>
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<tbody>
<tr>
<td>Total Cortex</td>
<td>.87</td>
</tr>
<tr>
<td>Intracranial</td>
<td>.63</td>
</tr>
<tr>
<td>Total White</td>
<td>.49</td>
</tr>
<tr>
<td>Left White</td>
<td>.58</td>
</tr>
<tr>
<td>Right White</td>
<td>.42</td>
</tr>
<tr>
<td>Left Cortex</td>
<td>.94</td>
</tr>
<tr>
<td>Right Cortex</td>
<td>.81</td>
</tr>
</tbody>
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Finally, we looked at white matter integrity using diffusion tensor imaging
Fractional Anisotropy & Radial Diffusivity

Based on water movement under the influence of a gradient:

FA = Degree of directionality
RD = rate of movement perpendicular to the WM tract.

The differences were striking!

Follow up Study

- SPD n=41 (m 28, f 13)
- TDC n=41 (m 33, f 8)
- 8-12 years
- Age and IQ matched
- Big tracts:
  - Posterior Thalamic Radiations
  - Posterior Corpus Callosum
  - Posterior Internal Capsule
  - Anterior Thalamic Radiation

White matter microstructure is associated with auditory and tactile processing in children with and without sensory processing disorder.

*Marco*; Fonseca in Neuroscience (submitted and pending review)
Brain Training
(focus on cognitive control/attention)

Our 3 step approach...
Marco + Gazzaley + Akili Interactive

- Step 1: Assess Challenges
  - Parent report, direct assessment, Neuroimaging/EEG
- Step 2: Train with Engaging Platform
  - COLLABORATION WITH PROFESSIONALS!
- Step 3: Reassess for Performance and Plasticity
  - Direct game behavior
  - Transfer skills
  - Neurophysiologic and Structural Change

Step 1: Assess Challenges

- Parent report: Sensory Profile & Vanderbilt
- Direct Assessment:
  - Motor Speed, TOVA, Flanker, Neuroracer
- Neuroimaging: DTI
- Neurophysiology: EEG/Neuroracer
Step 2: Play EVO

- **Kids**
  - n=18 SPD; n=19 NT
  - Age 8-12 y
  - PIQ > 70

- **Play**
  - 7 rounds a day (30 min)
  - 20 days of training with driving and targeting
  - Challenge assessment at each new world
  - 4 worlds total

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Shoot Only NeuroRacer Condition
Direct Game Behavior

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TOVA RTV
(transfer of skills)

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Vanderbilt Average Inattention (real world change?)

![Graph](image)

Step 3: Performance and Plasticity Midline Frontal Theta Power

**NeuroRacer Shoot Only Condition (240-360ms)**
- 19 Healthy Controls
- 13 Children with SPD (No ADHD)
- 14 Children with SPD/ADHD

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy Controls</td>
<td>8 Children with SPD (No ADHD)</td>
</tr>
</tbody>
</table>

So what ever happened to Touchy Tommy?

- Stay Tuned.
Many Hands:
- Kasra Khatibi
- Anne Bernard
- Monica Arroyo
- Heidi Kirsch
- Anna Findlay
- Suzanne Homna
- Julia Owen
- Shin Chang
- Mathilde Graciot
- MAC
- Bruce Miller
- Joel Kramer
- John Neuhaus
- Sensory Processing Foundation
- Lucy Miller
- Sarah Schoen
- EVO Team
- Adam Gazzaley
- Joaquin Anguera
- Shivani Desai
- Ashley Antovich
- Cammie Rolle
- John Gibbons
- Annie Aiken
- Sasha

Thank you for your multisensory attention!