The hour’s Objectives:

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1) Understand what is meant by the term “Sensory Processing Disorder (SPD)”
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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

- Tommy is a 9 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
  - **Receptive:** Frequent Meltdowns at home but not school
  - **Distraction:** Distractible but not significantly interfering with learning

- **Birth, Medical, Surgical and/or Family history** is notable for meatal stenosis repair and nasal turbinate repair, mom with mild tactile sensitivity

- **Activities include:** trouble with bike, swimming/trampoline

- **Therapies include:** OT

- **Medications:** To be determined

### Fragile Frankie

- 13 y.o. male with a neurodevelopmental disorder characterized by
  - **Strengths in gross motor:** zip line, climbing
  - **Challenges with fine motor:** ADLs and handwriting, rec/expressive language (est 3-4y); social limited by language and arousal, attention (working on this with teachers), Sensory OverResponsivity auditory and tactile.

- **Birth, Medical, Surgical and/or Family history** is notable for twin delivery, overseas adoption, early neglect, ear tubes

- **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

- 11 y.o. female with a neurodevelopmental disorder characterized by
  - **Strengths in social drive and reading**
  - **Challenges with gross/fine motor, visual spatial process, processing speed, feeling anxiety, Sensory OverResponsivity auditory only; social finesse**

- **Examination is notable for immature affect, non-dysmorphic and non-focal**

- **Etiologic 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)

- Image of a blender

Tactile OverResponsive (TOR)

- Image of a hand touching a sensory stimulator

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 Modulation Disorder (SMD)
  – Sensory Craving: Seeking sensory input
  – Sensory Overresponsivity: Avoiding Sensory input
  – Sensory Underresponsive: non-responsive to sensory input

• Sensory-Based Motor Disorder
  – Dyspraxia/Motor Planning
  – Postural Control Disorders

• Sensory Discrimination Disorder

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Etiologies of SPD

- Known Genetic Factors
- In Utero Exposures
- Brain Injury related to Prematurity
- Toxic Stress?

Genetic disorders with reported SPD

- Chromosomal Disorders
  - Turner’s (XO) and 47,XXX
- Copy Number Variations (included Triplet Repeats)
  - 16p11.2 Deletions and Duplications
  - Fragile X

Fragile Frankie

ArhGEF9 (Rho Guanine Nucleotide Exchange Factor 9)

- Xq11.1-q11.2
- Protein: collybistin
- Molecular switch that is pivotal in the role of post-synaptic glycine and GABA receptor clusters
- Global NDD and auditory hypersensitivity (startle)
Happy Heidi

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, WMI 99, PSI 65
  - Social Communication Questionnaire total = 7
  - Sensory Profile DD in all categories
  - Vanderbilt Parent: meets ADHD cut scores
  - Clinical MRI unrevealing

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>Quadrants</th>
<th>N</th>
<th>% with scores &gt; 2 SD* from the mean</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Low Registration</td>
<td>91</td>
<td>24</td>
<td>&lt;0.01</td>
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<tr>
<td>Sensory Seeking</td>
<td>85</td>
<td>11</td>
<td>0.02</td>
</tr>
<tr>
<td>Sensory Sensitivity</td>
<td>90</td>
<td>10</td>
<td>0.03</td>
</tr>
<tr>
<td>Sensory Avoiding</td>
<td>87</td>
<td>11</td>
<td>0.01</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Sections</th>
<th>N</th>
<th>% with scores &gt; 2 SD* from the mean</th>
<th>p-value</th>
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<td>Auditory Processing</td>
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<td>Visual Processing</td>
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<td>0.19</td>
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<tr>
<td>Tactile Processing</td>
<td>86</td>
<td>10</td>
<td>0.02</td>
</tr>
<tr>
<td>Vestibular Processing</td>
<td>102</td>
<td>13</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Oral Sensory Processing</td>
<td>88</td>
<td>9</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*Children born prematurely have atypical sensory profiles.*


Agenesis of the Corpus Callosum

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


Environment (Experience over Time)

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

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So how does one define SPD for research?

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)...

Isolated SPD

Bedside

Shared and Divergent Auditory and Tactile Processing in Children with Autism and Children with Sensory Processing Dysfunction Relative to Typically Developing Peers.
Demopoulos C, Brandes-Aitken AN, Desai SS, Hill SS, Antovich AD, Harris J, Marco EL.
J Int Neuropsychol Soc. 2015 Jul 6:1-1
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”

Parent report & Direct Assessment

- Auditory Processing
- Graphesthesia Right
- Sensory Profile Auditory
- Sensory Profile Tactile
- Sensory Profile Total

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

r = -.34, p = .045)
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?*

Structural Neuroimaging in SPD

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

![Image of brain scan](image)

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>
</table>

- 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)
Next, we looked for volume...

<table>
<thead>
<tr>
<th></th>
<th>p</th>
</tr>
</thead>
<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>
</table>

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!

http://brain.oxfordjournals.org/content/128/11/2562/F7.large.jpg
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

Correlating Bedside & Structure
Tactile

Bedside with Structure
Auditory

Correlations – Sustained Attention
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
Shoot Only NeuroRacer Condition
Direct Game Behavior

TOVA RTV
(travel of skills)

Vanderbilt Average Inattention
(real world change?)

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
So what ever happened to Touchy Tommy?

• Stay Tuned.

Many Hands:

❖ The kids and their parents!
❖ SPD MEG/DTI Team
❖ Srikant Nagajaran
❖ Pratik Mukherjee
❖ Elliott Sherr
❖ Leighton Hinkley
❖ Carly Demopoulos
❖ Shivani Desai
❖ Ashley Antovich
❖ Julia Harris
❖ Susannah Hill
❖ Richard Hill
❖ Angelina Jocson

❖ MAC
❖ Kasra Khatib
❖ Anne Bernard
❖ Monica Arroyo
❖ Heidi Kirsch
❖ Anne Findlay
❖ Suzanne Homna
❖ Julia Owen
❖ Shin Chang
❖ Mathilde Gratiot
❖ Srikantan Nagarajan
❖ Pratik Mukherjee
❖ Elliott Sherr
❖ Leighton Hinkley
❖ Carly Demopoulos
❖ Shivani Desai
❖ Ashley Antovich
❖ Julia Harris
❖ Susannah Hill
❖ Richard Hill
❖ Angelina Jocson
❖ 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
❖ Johno Gibbons
❖ Annie Aiken
❖ Sasha

Thank you for your multisensory attention!