Brain Differences in Children with Autism Spectrum Disorder

Annette Hurley, PhD, CCC-A
Inga Denman, B.S.
Dr. Annette Hurley is coauthor of Constraint Induced Auditory Therapy and has a very small financial interest (royalties) from the sale of this product.
Auditory complaints in children with autism are common and may be regarded as part of the high order cognitive disorder.

It is possible that the auditory difficulties may be in part due to structural brain differences.

This session will review anatomical differences and describe a deficit specific auditory training program based upon differences.
Definition of ASD

- First discovered by Kanner (1943)
- APA definition
  - “A syndrome presenting with impairment in social relatedness and communication and with repetitive routines and restricted interests”
- Includes a range of developmental disorders
  - Autism
  - Asperger's Disorder
  - PDD-NOS
Incidence and Prevalence

- Epidemic
  - Affecting 1 in 110 children
  - Affecting 1 in 94 boys

- That means approximately 1.5 million Americans have some degree of ASD, according to the 2006 Autism Prevalence Report from the Autism and Developmental Disabilities Monitoring Network at the Centers for Disease Control and Prevention.
Auditory Complaints and ASD

- Pure tone thresholds:
  Previous study of 199 ASD (Rosenhall et al 1999)
    ~8% had mild to moderate loss
    ~4% had severe to profound hearing loss
  Another study reported 13.3% of an ASD group (Gilberg et al (1991)
- Hypo and Hyper arousal/ Shared attention
- Sensitivity issues (hyperacusis)
- Understanding speech/communication – more difficult in background noise
- Ear deficits on Dichotic Listening Tasks
Electrophysiological Responses

The function and organization of sensory pathways can be assessed by evoked potentials.

Differences in transmission of the brainstem (Rosenhall et al 2003) review of 10 previous studies

- Auditory Brainstem Response (ABR)
  - A test of neural synchrony from the peripheral VIII CN to the upper brainstem.
  - Previous research show increased transmission time.
  - I-III, IIII-V, I-V, interaural differences

  “..Brainstem abnormalities suggest that the brainstem may be partly responsible for deviant language, cognitive and social development in children with ASD.”
Brain Differences (Cont.)

- Russo et al (2008) reported differences in subgroup of children with ASD, although the population did not differ in behavioral tests of receptive or expressive language but did differ in cABR.
  - Difficulty with deficient pitch tracking
  - Reduced phase-locking ability (inability of the neurons to fire synchronously)
    - May benefit from auditory training.
- Russo et al (2009) report children with ASD hear as if they are hearing in background noise
Auditory Cortical Response

P300- oddball paradigm

- Smaller amplitude in patients with ASD in comparison to control group (Bomba et al, 2004; Novic et al, 1979, 1980; Courchesne et al, 1984, 1985)
- May be related to failure to attach appropriate significance to novel stimuli or integrating past experiences to current stimuli.

Mismatch negativity

- Shorter latency and larger amplitude (Ferri et al, 2003; Gomot et al, 2002)
- Higher cerebral reactivity to the deviance which may reflect hypersensitivity to acoustic change
- MMN absent in speech syllables (Kuhl et al, 2005)
Neuroanatomical Brain Differences
Brain Stem

- Absence of Facial Nucleus (innervates the muscles of facial expression and the stapedius muscle)

- Differences in the Superior Olivary Complex

- Rodiger (1996) Significant structural differences to total absence
  - Important for Binaural information
    - Differences in MSO/LSO (Time and Intensity Differences)
    - Differences in Inferior Olive (integration of visual and auditory information)
Neuroanatomical Brain Differences

Imaging Studies

- Planum-temporale- is usually larger in the left hemisphere in typically developing individuals.

- This asymmetry was not seen in children or age-matched adults with ASD. (Rojas et al 2002, 2005; Gage et al, 2009, Knaus et al, 2009)

- Thicker gray matter in Heschl’s gyri and other areas of the brain including visual cortex, frontal lobes and parietal cortex showing this is not auditory specific (Gage et al, 2009). Thought to be involved in informational processing, social cognition and language.
Neuroanatomical Brain Differences

Imaging Studies

- Abnormalities in the cerebellum
  - May affect the individual’s ability to attend or shift attention from different modalities (Iarocci & McDonald, 2005)

- Neuronal differences
  - Synaptogenesis (connections)
  - Neural pruning (a regulatory process that produces a more efficient synaptic configuration by reducing the number of neurons)
  - Myelination (speed of transmission)
Neuroanatomical Brain Differences Imaging Studies

• “Microcolumnar organizational units of cortex are smaller and more tightly packed in frontal and temporal areas of patients with ASD. Widespread structural disconnectivity” (Cheung et al, 2009; Casanova et al, 2002)

• White matter tracts may not develop
  • 92 infants, 24 later diagnosed with ASD, differences in development of white matter tracts (Estes et al, 2012)
ASD and Sensory Processing Abnormalities

- Cerebral morphology
  - Cortical thickness may reflect dendritic arborization
  - ‘Local decreases of gray matter in the ASD group in areas belonging to the mirror neuron system (MNS), argued to be the basis of empathic behavior’ (Hadjikhan et al., 2006)
  - Variations in white and gray matter

- Corpus Callosum differences
Corpus Callosum and Auditory Function

- CC is a body of neural fibers connecting the right and left hemispheres
- CC is anatomically divided into several regions: genu, anterior body, posterior body, isthmus, and splenium

- Optimal and efficient processing occurs when the two hemispheres interact
ASD and Differences in Corpus Callosum

- Children with ASD have reductions in size of the body and posterior sub regions, anterior regions, splenium, isthmus, genu, rostrum (Harden et al, 2009)

- Decreased connectivity in inter and intra-hemispheric communication

- Abnormality of cortical connectivity leads to a disruption of integrative and interhemispheric processing

- Altered development of the CC may play in the social, emotional and communication deficits in autism.
Corpus Callosum and Auditory Function

- Different regions of the CC have specialized sensory functions
- Posterior portion, isthmus or sulcus is specialized for auditory information
- Splenium is sensitive to auditory function
- Optimal and efficient processing occurs when the two hemispheres interact
ASD and (C)APD

- ASHA Definition of (C)APD
  - “Deficit in the perceptual processing of acoustic stimuli and the neurobiologic activity that underlies those processes and gives rise to the auditory evoked potentials”

- Auditory Complaints in children with ASD may be regarded as part of the higher order cognitive disorder

- Label of CAPD is not appropriate
ASD and Auditory Processing Difficulties

- Auditory Difficulties may be due in part to organic brain differences

- Frazier & Harden (2009) report strong evidence the Corpus callosum is involved in the pathophysiology of autism.
- Therefore, targeting interventions which specifically seek to improve the efficiency of information transfer across the corpus callosum may be useful.

- Diagnosis of Autism may prevent referrals to qualified specialists who may be able to offer auditory training or remediation programs
Who can address these problems?

Audiology Must Take its Rightful Place on the Autism Team

“In my clinical practice, we have assessed approximately 600 adults and children for APD since 2004. Approximately 75 percent of patients diagnosed with APD in our clinic also have a diagnosis of Sensory Processing Disorder. About 40 percent of patients diagnosed with APD also had a diagnosis of ASD including high-functioning autism, Asperger’s syndrome, and pervasive developmental disorder- non-specific (PDD-NOS). Most of the children assessed were referred to us by occupational therapists specializing in SPD and developmental optometrists who specialize in visual processing.”
From C.A. Lau....

“ASD children benefit significantly from intense, appropriate auditory training, but may require longer intervention than children with only APD. I have treated approximately 80 children with ASD in our clinic, and have noted the profound effects of appropriate auditory training on those ASD children. We consistently see improvements such as increased verbal output, improved “presence” and engagement in conversations, and improved language pragmatics, attention, and ability to follow instructions.”
Dichotic Listening

- Previous studies have shown left ear deficits in dichotic listening tests in individuals with ASD.

- Anecdotal reports from this author
Dichotic Listening (DL): Interhemispheric Transmission

- Behavioral measure of interhemispheric function
- DL procedure is a measure of cerebral dominance for central auditory and language related functions
- Ear advantages can arise during DL tasks
- Evidence suggests that children with ASD are more likely to show a language-dominant hemispheric deficit (left ear deficit)
Auditory Training

- Frequency
- Intensity
- Duration
Dichotic Training

- Dichotic Interaural Intensity Difference Training. (Musiek)

- Dichotic Interaural Asymmetry Listening (Moncrief & Wertz, 2008)

- Constraint Induced Auditory Training (CIAT) (Hurley & Davis, 2011)
Dichotic Listening
Auditory Therapy

- Several training programs available to remediate APD and language processing deficits
- Efficacy is questionable
- Dichotic training is an innovative therapy for the remediation of the compromised central auditory pathway (i.e. corpus callosum)
- DL specifically targets central auditory processing via the CC that is often neglected in the treatment of autism
Auditory Therapy

- Recent studies show Dichotic training has improved a LED for children diagnosed with speech and language disorders.
- The same training also improved language processing in typically developing children.
  - Improved listening comprehension skills.
INTEGRATION/ INTERHEMISPHERIC (C)APD

- The two cerebral hemispheres are not working together.
- Difficulty transferring information from one part of the brain to another.
- Lag in maturation of the central nervous system auditory pathway (corpus callosum).
- Often left-ear deficits are found in dyslexia patients.
- Adults with lesions due to stroke or head injury.
Therapy for Integration/Inter-hemispheric (C)APD

Formal Auditory Training:

• Must be done in a clinic or laboratory

• Clinician routes 2 different signals (Dichotic) to each ear through an audiometer. Ear that is not performing well gets a stronger intensity, increases the opposite ear over time.
Formal Digits Auditory Training

4, 8
6, 1

Channel 1: 60 dB HL
Channel 2: 30 dB HL
Frequency: 1000 Hz
What is CIAT?

- Auditory Training Program Materials
- Pre-recorded to Addresses Deficit Ear
- Dichotic Auditory Training Exercises
  - Sentences (3,4,5,6 & 7 syllables)
  - Semantically Related Words (yes/no; sun/set; read/book)
  - Digits (1-9 with the exception of 7)
  - Consonant-Vowel Syllables (pa, ba, ga, da, ka, ta)
  - Stories (Public domain literature)
Key Point to Remember

• “…Select an intervention that appears well designed to treat the child’s auditory deficit” (Fey et al., 2011)
Early Reports

Single Subject Design
Study Design

- Multiple Baseline Across Subjects Design
  - Demonstrate
  - Verify
  - Replicate

- Rationale for this design
  - ABAB design not appropriate
    - teaching effect
    - ethical considerations
  - Group design not practical
Subject Recruitment

- 3 participants were recruited by networking with friends and family of LSUHSC, as well as current/former clients of Speech and Hearing clinic
- Consent and Assent were obtained from participants and their family
- Approval was obtained from the LSUHSC IRB prior to beginning study
Inclusion Criteria

- Ages 8-12
- Diagnosed with an ASD
- Absence of confounding neurological disorder
- Normal peripheral hearing
- Case history
- Significant interaural asymmetry due to poorer performance in the non-hemispheric dominant ear on dichotic digits test
## Profile of Participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age at onset of study</th>
<th>Diagnosis</th>
<th>Ear-Deficit for DL</th>
<th>Handed</th>
<th>Languages spoken at home</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>Female</td>
<td>11:8</td>
<td>Autism</td>
<td>Right</td>
<td>Left</td>
<td>English and Spanish</td>
</tr>
<tr>
<td>SB</td>
<td>Male</td>
<td>10:6</td>
<td>Autism</td>
<td>Left</td>
<td>Right</td>
<td>English</td>
</tr>
<tr>
<td>SC</td>
<td>Male</td>
<td>11:11</td>
<td>Autism</td>
<td>Left</td>
<td>Right</td>
<td>English</td>
</tr>
</tbody>
</table>
Pre-Intervention Measures

• Audiological Tests
  • Dichotic digits test
  • Subtests of the SCAN-3C
    • Filtered words
    • Auditory Figure Ground
    • Competing words-directed ear
    • Competing Sentences
  • ABR
  • Speech ABR (BioMARK recording)
• Language Tests
  • LPTE-3
Procedures
Baseline/Intervention Schedule

- SA was kept in base line conditions for three sessions, then had 18 intervention sessions
- SA entered intervention condition while SB and SC remained in baseline conditions
- SB remained in 7 baseline sessions before participating in 15 intervention sessions
- SC participated in 9 baseline sessions before participating in 12 intervention conditions
Rationale for Development of Language Probes

- Before beginning baseline sessions, participants were given subtests of the TAPS-3
  - Word discrimination*
  - Phonological Segmentation
  - Phonological Blending
  - Word Memory
  - Sentence Memory
  - Number Memory
- Performance on the subtests indicated the level for determining the language probes
- Unique set of language probes was designed for each participant at level of 50% correct
- 10 probes were delivered to each child at the end of every baseline and intervention sessions
- Tracking progress of the number of correct answers over sessions demonstrated when participant had reached a steady baseline, and showed progress during intervention
Baseline sessions

• No dichotic listening training
• Language enrichment activities
• Following every session, the child was asked 10 probes structured around subtests of the TAPS-3
• Tracking progress of the number of correct answers over sessions demonstrated when participant had reached a steady baseline
Intervention Conditions

- 30 minute auditory training sessions 2 times per week
- Child was positively reinforced for participation
- Training Material was dichotic listening stimuli
  - At onset of training, intensity from insert earphones was set to differ by 55dB HL
  - Number of correctly identified items was recorded
  - When deficit ear performance reached 70-100%, the intensity of material being presented to the non-deficit side was raised
  - If deficit ear performance dropped, either the intensity of material to the deficit side was raised or the intensity of the material to the non-deficit side was reduced
  - Across a session, child received dichotic presentations of digits, words and sentences
  - Goal was to continue intervention until intensity difference between L and R is 0dB with 70-100% correct responses
Intervention Conditions

- At the end of each intervention session, 10 language processing probes were delivered to the child
- Percent correct responses to probes was tracked to determine if DL training was improving Language Processing
Formal Auditory Training

4, 8

Digits

6, 1

Sentences

Words
Post-testing Assessments

- Audiological Assessments
  - Behavioral AP assessments
  - Electrophysiological AP assessments
- Language Assessments
  - LPT3-E
Results
### Results-Language Processing Test 3: E

<table>
<thead>
<tr>
<th>Participant</th>
<th>Associations Subtest</th>
<th>Categorization Subtest</th>
<th>Similarities Subtest</th>
<th>Differences Subtest</th>
<th>Multiple Meanings Subtest</th>
<th>Attributes Subtest</th>
<th>Total Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-pre intervention</td>
<td>&lt;53</td>
<td>89</td>
<td>N/A</td>
<td>95</td>
<td>63</td>
<td>77</td>
<td>63</td>
</tr>
<tr>
<td>SA- post intervention</td>
<td>110</td>
<td>72</td>
<td>64</td>
<td>87</td>
<td>98</td>
<td>78</td>
<td>77</td>
</tr>
<tr>
<td>SB- pre intervention</td>
<td>&lt;55</td>
<td>&lt;53</td>
<td>&lt;57</td>
<td>N/A</td>
<td>N/A</td>
<td>73</td>
<td>&lt;62</td>
</tr>
<tr>
<td>SB- post intervention</td>
<td>&lt;55</td>
<td>&lt;53</td>
<td>57</td>
<td>&lt;55</td>
<td>&lt;55</td>
<td>68</td>
<td>&lt;62</td>
</tr>
<tr>
<td>SC- pre intervention</td>
<td>&lt;53</td>
<td>&lt;55</td>
<td>&lt;54</td>
<td>&lt;54</td>
<td>&lt;57</td>
<td>57</td>
<td>&lt;61</td>
</tr>
<tr>
<td>SC- post intervention</td>
<td>&lt;53</td>
<td>72</td>
<td>&lt;54</td>
<td>&lt;54</td>
<td>&lt;57</td>
<td>65</td>
<td>&lt;61</td>
</tr>
</tbody>
</table>
## Results - Subject A

<table>
<thead>
<tr>
<th>Participant/Test</th>
<th>Pre-Intervention L ear</th>
<th>Post-Intervention L ear</th>
<th>Pre-Intervention R ear</th>
<th>Post-Intervention R ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA- Competing Words</td>
<td>27</td>
<td>50</td>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>SA-Competing Sentences</td>
<td>10</td>
<td>50</td>
<td>0</td>
<td>91</td>
</tr>
<tr>
<td>SA- Dichotic Digits</td>
<td>94</td>
<td>94</td>
<td>62</td>
<td>82</td>
</tr>
<tr>
<td>SA- Filtered Words</td>
<td>75</td>
<td>95</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>SA-Speech in Noise</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
# Results-Subject B

<table>
<thead>
<tr>
<th>Participant/Test</th>
<th>Pre-Intervention L ear</th>
<th>Post-Intervention L ear</th>
<th>Pre-Intervention R ear</th>
<th>Post-Intervention R ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB- Competing Words</td>
<td>27</td>
<td>60</td>
<td>43</td>
<td>60</td>
</tr>
<tr>
<td>SB-Competing Sentences</td>
<td>54</td>
<td>42</td>
<td>11</td>
<td>52</td>
</tr>
<tr>
<td>SB- Dichotic Digits</td>
<td>48</td>
<td>32</td>
<td>18</td>
<td>90</td>
</tr>
<tr>
<td>SB- Filtered Words</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td>SB-Speech in Noise</td>
<td>90</td>
<td>95</td>
<td>85</td>
<td>90</td>
</tr>
</tbody>
</table>
# Results-Subject C

<table>
<thead>
<tr>
<th>Participant/Test</th>
<th>Pre-Intervention L ear</th>
<th>Post-Intervention L ear</th>
<th>Pre-Intervention R ear</th>
<th>Post-Intervention R ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC- Competing Words</td>
<td>20</td>
<td>63</td>
<td>68</td>
<td>70</td>
</tr>
<tr>
<td>SC-Competing Sentences</td>
<td>63</td>
<td>94</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>SC- Dichotic Digits</td>
<td>0</td>
<td>88</td>
<td>48</td>
<td>88</td>
</tr>
<tr>
<td>SC- Filtered Words</td>
<td>75</td>
<td>70</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>SC-Speech in Noise</td>
<td>95</td>
<td>95</td>
<td>75</td>
<td>70</td>
</tr>
</tbody>
</table>
Electrophysiological Results

- All subjects had click ABRs within normal limits.
- All subjects had abnormal cABRs (speech ABRs)
- No change in pre and post training ABR or cABR
Results-Qualitative Outcome Measures

- SA Parental Report - Likert Scale
  - Less difficulty remaining in his/her seat when required to do so
  - Less difficulty awaiting his/her turn in games or group situations
  - Observed to “talk excessively” more often
  - Child interrupts more frequently
  - Child argues with adults more often
  - Child is not as easily annoyed
  - Child shows more interest in imaginative activities
  - Child has less difficulty initiating or carrying on a conversation
Results- Qualitative Outcome Measures

SA parental response: Post-Intervention Questionnaire

- “[my child] has finally started talking to my friend’s daughter… they have known each other for 7 years.”
- “[my child] has been talking more lately, and with more expression.”
- “[my child] talks to her little sister more, asks her what is wrong when she cries, [and] asks her to help her play a video game.”
Results-Qualitative Outcome Measures

- SB Parental Report- Likert Scale
  - Less difficulty sustaining attention to tasks or activities
  - Child listens more often to what is being said to him/her
  - Child has less difficulty with ball games
  - Child has less difficulty with physical activities
  - Child has less difficulty forming letters for printing or cursive
  - Child has more confidence when speaking
  - Child has less trouble pronouncing some sounds in words correctly
  - Child more often looks at the person they are speaking or listening to
Results- Qualitative Outcome Measures

SB parental response: Post-Intervention Questionnaire

- “[my child] seems to notice humorous things...he laughs more”
- “[my child] seems to listen better”
- “[my child] seems to do more things on his own, [such as] showering and brushing his teeth”
- “small things to most people. Huge to me!”
Results-Qualitative Outcome Measures

- SC Parental Report- Likert Scale
  - Child has less difficulty writing down his/her thoughts on paper
  - Child has less difficulty initiating or carrying on a conversation with others
  - Child has less trouble with left/right when giving or receiving directions
  - Child has less difficulty making friends his/her own age
  - Child shows less distress over changes in routine or environment
  - Child is less touchy or easily annoyed
  - Child more often interrupts or intrudes on others
  - Child is observed to more often “talk excessively”
Results, Conclusions, and Future Directions
Conclusions

- Based on visual inspection, language processing performance improved during dichotic listening training.
- Based on comparison of pre-and post-data, some improvement was seen in some areas of behavioral measurements of auditory processing (Competing Words and Competing Sentences).
- Little difference was seen in the standard scores obtained during language testing.
- No changes were seen in electrophysiological measures of auditory brainstem response.
- Parental response was overwhelmingly positive.
Limitations of Study

- Single subject design. Limited ability to generalize results to larger ASD population.
- Parental report obtained at end of study may have been influenced by positive rapport established with researcher.
Future Directions

- The results of this study merit a group design study/add control group
- Examine cortical potentials and brainstem electrophysiology measures
- Extend time frame of study
- Re-evaluate participants following a period without intervention/continue with a ‘maintanence’ program
THANK YOU!!

ahurle@lsuhsc.edu
References


References


