Auditory Comprehension, Verbal Encoding and Cognitive Flexibility: Insights from Neuroscience for Language Intervention in Autism Spectrum Disorders

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Autism Spectrum Disorder DSM-5 Criteria (APA, 2013)

- Persistent deficits in social communication and social interaction across contexts, not accounted for by general developmental delays.

- Restricted, repetitive patterns of behavior, interests, or activities.

Other Descriptors

- Type of onset
- Intellectual impairment
- Verbal impairment (level of spoken language)
- Co-morbid conditions

Differentiated by level of support needed

<table>
<thead>
<tr>
<th>Severity</th>
<th>Social Communication</th>
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<tbody>
<tr>
<td>Level 1 <em>Requiring support</em></td>
<td>Without supports in place, deficits in social communication cause noticeable impairments.</td>
</tr>
<tr>
<td>Level 2 <em>Requiring substantial support</em></td>
<td>Masked deficits in verbal and nonverbal social communication skills; social impairments apparent even with supports in place; limited initiation of social interactions; and reduced or abnormal responses to social overtures from others.</td>
</tr>
<tr>
<td>Level 3 <em>Requiring very substantial support</em></td>
<td>Severe deficits in verbal and nonverbal social communication skills cause severe impairments in functioning, very limited initiation of social interactions, and minimal response to social overtures from others.</td>
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</tbody>
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Levels of Causation of ASD

- Abnormalities in the Genetic Code for Brain Development
- Abnormal Mechanisms of Brain Development
- Structural and Functional Abnormalities of Brain
- Cognitive and Neurological Abnormalities
- Behavior
**Autism Spectrum Disorder (ASD):**

- A neurodevelopmental disorder
- In ASD, the way in which the brain responds to environmental input results in a cascade of problems in learning and social functioning.

**Basic Assumptions about the Effect of ASD:**

- Individuals with ASD learn and act differently because their brains function differently.
- Environment can influence their learning but cannot change the underlying neurophysiological differences.

**Typical Brain Development**

The brain is organized in response to environmental input during the early years of a child’s life.

**ASD is a neural systems disorder**

Abnormal connectivity occurs:

- At the level of the neuron
- Structurally, in white matter pathways
- Functionally, during cognitive processing between key regions
- Across multiple large-scale brain networks

(Minshew & Williams, 2007; Uddin, Supekar, & Menon, 2013; Williams et al., 2013)

**Profile of Cognitive Strengths/Weaknesses**

(Williams, Goldstein, & Minshew, 2006; Minshew, Goldstein, & Siegel, 1997)

<table>
<thead>
<tr>
<th>Intact Abilities</th>
<th>Cognitive Weakness</th>
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<tbody>
<tr>
<td>Attention</td>
<td>Complex Sensory</td>
</tr>
<tr>
<td>Sensory Perception</td>
<td>Complex Motor</td>
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<tr>
<td>Elementary Motor</td>
<td>Complex Memory</td>
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<tr>
<td>Simple Memory</td>
<td>Complex Language</td>
</tr>
<tr>
<td>Formal Language</td>
<td>Concept formation</td>
</tr>
<tr>
<td>Rule-Learning</td>
<td>Face recognition</td>
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<tr>
<td>Visuospatial</td>
<td></td>
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<tr>
<td>Processing</td>
<td></td>
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</tbody>
</table>

**Functional Connectivity Model of ASD**

(Just et al., Brain, 2004)

- Functional underconnectivity occurs during processing of complex information
- Dynamic recruitment of neural resources as processing demands increase is compromised
Networks underlying basic abilities are intact.

These networks are relied upon to perform tasks usually performed with more highly integrative networks.

Neurocognitive Model of ASD: Complex Information Processing (CIP)

Because of neurobiological differences, ASD is dynamically realized as the person with ASD processes information.

Problems become more pronounced as the mismatch between cognitive resources and the demands of the processing task increase.

Individuals with ASD show decreasing performance as the complexity of the information to be processed or the demands of the task increase.

They show deficits at lower levels of complexity than expected relative to age and general ability level.

They accomplish tasks using lower order abilities.

What does the term “complexity” mean as used in the model?

Various types of information can be complex:

- Large amounts of information.
- Information of multiple types that must be integrated.
- Time constraints and/or multiple simultaneous processing demands.
- Stress or anxiety.

These factors affect information processing in individuals with ASD at lower levels than would be predicted by their overall cognitive level.

Cognitive abilities are not predictive of performance for individuals with ASD in the same way that they are for individuals with TD.

Results of Neural Structural and Functional Differences

Create biological constraints

Individuals with ASD are

- Not able to meet demands for integration of information
- Not able to flexibly respond to changing environmental stimuli

(Minshew, Williams, & McFadden, 2008)
How Model Applies to More Severely Affected Individuals with ASD

Hypothesize that:

- Cortical processing centers are more underconnected
- Local connections are stronger

Why language is affected in ASD

- Language learning and use is affected because it requires coordination across a number of processing centers.
- Comprehension and production must be integrated with social and/or textual context and flexibly adapted to meet those demands.

Possible reasons WHY a child with Autism Spectrum Disorder may not be able to produce spoken words

- Child may have difficulty with the perception and comprehension of human speech which may result in poor storage strength or degraded memory trace for words
- May be related to difficulty with parsing words from the speech stream
- May be related to difficulty with mapping words to objects or other environmental information

- Or, child may have difficulty with retrieving the stored representation of the word from memory and translating into a string of speech sounds (word-finding or word retrieval)
- Or, child may have difficulty with creating the motor plan required for spoken word production (dyspraxia)

- Or, child may have difficulty with producing the word due to motor problems (dysarthria or hypotonia)
- Or, child is storing conceptual knowledge but is not automatically encoding into language

New Insights into How Individuals with ASD Process Language
Language Learning in TD Infants

- Occurs through a combination of computational, cognitive, and social skills that
  - Focus the child’s attentional resources to faces, biological motion, and voices, and
  - Reduce the cognitive processing load


ASD: Problem with Automatic Processing

Behavioral, evoked response potential, and neuroimaging evidence is converging to suggest that individuals with ASD have a problem with innate implicit or automatic cognitive processing.

Carter, Williams, Lehman, & Minshew (2012a) PLOS One
Eyler et al. (2012) Brain
Jones & Klin (2013), Nature
Scott-Van Zeeland et al. (2010) Biological Psychiatry

Eye looking declines

- Eye-tracking study:
  - Children later diagnosed with ASD decline in fixation to eyes on videos of human faces from 2 to 6 mos. of age
  - Behavior being investigated as an early identifier for ASD

(Jones & Klin, 2013)

Implications of lack of automatic processing

- Effects of ASD occurring long before the behavioral signs
- Early identification essential for the most effective remediation

What are some of the automatic processes that are important for learning language?

- Preferential processing of human speech
- Statistical learning
- Automatic verbal encoding of information
- Formation of concepts/prototypes
- Changing processing in response to demands of the task or stimuli

Preferential Processing of Human Speech
Preferential Processing of Human Speech

- Behavioral studies have demonstrated that newborn infants prefer human voices over similar complex auditory stimuli (Ecklund-Flores & Turkewitz, 1996; Hutt et al., 1968).

- And prefer their mother’s voice over the voice of an unfamiliar mother (DeCasper & Fifer, 1980).

Response of Adults with ASD to Human Voices (Gervais et al., Nature Neuroscience, 2004)

An fMRI study compared responses to:

- Vocal sounds (speech + nonspeech vocal) and
- Nonspeech vocal

in male adults with autism and TD male controls.

Evidence from toddlers with ASD (Eyler et al., Brain, 2012)

- fMRI study with 1 to 4 year olds with (later diagnosed) and without autism during sleep
- 40 children with autism and 40 without
- 3 Conditions when listening to story:
  - Complex forward speech
  - Simple forward speech
  - Backward speech

Results Eyler et al., Brain (2012)

Children with ASD had:

- Abnormal left hemisphere response to speech sounds.
- Abnormal right-lateralized temporal cortex response to language.
Preschool-age Children with ASD

- Preferred to listen to non-speech vs. ‘motherese’ speech
- Preference correlated with children’s ERP brain responses to speech and severity of ASD
- And failed to demonstrate a significant brain response (mismatch negativity) to a syllable change

(Kuhl et al., Developmental Science, 2005)

Implications for intervention with children with ASD

Brain development related to language acquisition

- Guided by genetic codes for neurobiological structure, function, and timing of development
- BUT this neurofunctional development occurs interactively in response to environmental input

(Kolb & Wishaw, 1998)

For child with ASD

- Response of the brain may be affected by the underlying neurofunctional differences

(Karmiloff-Smith, 1998)

Assumptions about Intervention:

- A speech-language pathologist cannot directly change the way the brain of a child with ASD learns or processes language.
- However, a speech-language pathologist CAN change the environmental input.
- And CAN get adults to do the work that the brain of the child cannot do.

Attending to speech

- Reduce competing auditory information as much as possible → human voice needs to be obvious point of attention
  (e.g., Nguyen, 2006)
Personal FM systems and auditory trainers

- Reduce the interference of background noise and increase on-task listening behaviors in the classroom (Schafer et al., 2013; Smith et al., 1985)
- FM systems should be fit and monitored following the relevant professional guidelines (ASHA, 2002)

Learning new words

- Clearly pair language with what the words are referring to (Parish-Morris et al., 2007)

Adapting Environmental Input to Increase Language Comprehension

- Need to use with children who have extreme difficulty with decoding and attaching meaning to the spoken language they hear.
- Visual input may help them to process spoken language input.
- Use of picture symbols may help the child to understand that an object can be associated with a referent.

Specific Technique: Aided Language Stimulation

- Method by which an adult pairs a spoken word with a point to a visual representation of the word.
- Used to improve the child’s ability to comprehend the language directed to them.

Specific Technique: Aided Language Stimulation

- Visual representations are presented on boards of between 6 to 20 pictures with vocabulary related to a specific activity.

Note: May need to use fewer symbols for some children who have trouble processing multiple stimuli.

Goossens’, Crain, & Elder (1994)


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Activity specific displays may also be created using Proloquo2go
http://www.assistiveware.com/product/proloquo2go

Based on research of Dr. Ann Kaiser, Vanderbilt University

Before using this method, need to establish the child’s understanding of representation:

- Object
- Photograph
- Colored line drawing
- Black and white line drawing
- Picture symbol

Infants with Typical Development: Statistical Learning

Behavioral research with infants with TD suggests that they have an innate mechanism to detect statistical regularities and redundancies in the environment (Kirkham, 2010; Saffran, 2010).

Statistical Learning: fMRI Study
(Scott-Van Zeeland, 2010, Biological Psychiatry)

- ASD group had a lack of differential activation to the artificial language condition with the frequency & stress cues and to the condition with the frequency cues alone.

- 8-month old children with typical development are sensitive to frequency and stress cues (Aslin et al. 1998; Johnson & Jusczyk, 2001)

In normal language development, the infant brain appears to automatically use prosodic cues to identify word boundaries within a continuous speech stream (Johnson & Jusczyk, 2001)

And to compute the probability of syllable co-occurrence

Using a process that has been referred to as statistical learning (Saffran et al., 1996).
Statistical Learning (cont'd)

- The brains of individuals with ASD do not automatically process semantic information in the same way that controls do.
- Individuals with ASD may recruit more right hemisphere language areas which indicates that semantic processing is more challenging for them.

What work should the adults be doing?

- Give the child input that has clear word boundaries:
  - Single words
  - Phrases/sentences with clear prosodic cues

For example:

- Use reduced amounts of language so child does not have to have to separate the key word from the spoken language stream.
  - “Car” or “the car” vs.
  - “The car is going fast.”

EBP approaches consistent with this idea:

- Slower speaking rate (Weismer & Hesketh, 1996)
- Emphatic stress (Weismer & Hesketh, 1998)
- Melodic Intonation Therapy (Miller & Toca, 1979)
- Music Therapy (Gold et al., 2006; Whipple, 2004)

What else can you do?

- Focus on a small number of vocabulary words.
- Repeat words within a single context and across contexts.
  - Words chosen relevant to a particular child

Additional Suggestions

- Large number of examples so that the brain has a large amount of input from which to form a concept.
- Over-repetition of associations between spoken words and referents because of possible difficulty extracting this information from a limited number of exposures
Additional Thought:
Children with ASD may be learning by forming strong associations rather than extracting statistical frequencies.

Automatic Verbal Encoding of Information

Representation of Concepts
• Individuals with TD are thought represent concepts both through mental imagery and through verbal representation

(Paivio, 1990)

Automatic verbal encoding of information
• Individuals with TD use automatic verbal coding of information to reduce the cognitive processing load when managing large amounts of information.
• Allows us to share ideas with others
• Facilitates generalization of previously learned information to new contexts

(Wolford et al., 2000)

Automatic verbal encoding:
A left hemisphere language “interpreter”
• Gazzaniga proposed that the LH language regions ("the interpreter") are automatically engaged to interpret stimuli and assimilate them into comprehensible events (Wolford, Miller & Gazzaniga, 2000).

• This automatic story-telling allows for elaboration and generalization of information such that the LH creates “order from chaos”.

Automatic verbal encoding of information
• In fMRI, this encoding is demonstrated by the use of a left hemisphere network including language areas during verbal working memory tasks (Smith et al., 1998).
• Do individuals with ASD automatically encode information in a verbal form?
Individuals with autism used a right hemisphere working memory network while controls used the expected left hemisphere working memory network.

Conclusion from VWM Studies

- Both the adults and children with autism relied more on visual strategies to perform the two-letter working memory tasks.

- The TD groups primarily used linguistic strategies, indicated by the level of activation of Broca’s area.

- These studies suggest that children and adults with ASD have difficulty with the automatic verbal encoding of visually-presented information.
Even though language was unnecessary, the children with TD recruited language areas during the social judgment task. This suggested automatic encoding of their knowledge into language. However, this was not the case for the children with autism. (Carter, Williams et al. 2012, PLOS One)

These results are consistent with earlier behavioral work that proposed that the failure of individuals with ASD to recode experiences into language was an underlying cause of difficulty with recalling experiences and difficulty with generalization of knowledge. (Boucher, 1981)

Production of spoken words
- Concept
- Lexical encoding
- Syntactic construction
- Phonological code selection
- Articulatory plan
- Speech

If child is storing conceptual knowledge in a visual form and not automatically recoding into language, it may interfere with their ability to speak:
- Non or low verbal in young or lower functioning children
- Word retrieval problems in older, verbal children
- Overuse of pre-encoded “formulaic” utterances
**Prediction:**

If bridging the gap between conceptual understanding and verbal formation is a problem in ASD, then

would predict that:

interventions that help to close that gap would be effective in increasing the use of spoken language

**Translating Visual Information into Verbal Information:**

**Aided Communication**


Reminder: Representation needs to be at a level the child can easily understand to reduce the processing load

**Augmentative/Alternative Communication**

- A systematic review that included nine single subject and two group design studies found that:
  - Use of AAC resulted in gains in speech production for most of the participants with ASD

(Schlosser & Wendt, 2008)

**Speech generating devices**

A recent meta-analysis of treatment studies indicates that SGDs or voice output devices are affective in increasing the communication skills (and spoken language) in children with ASD

Ganz et al. (2012) *Journal of Autism & Developmental Disorders*

**Common components of these approaches**

- Use of visual depictions of concepts
- Associated verbal encoding provided either by a voice-output device or by the communication partner
- Therefore, visual information is translated into a verbal form
- Individual with ASD is invited to put a conceptual thought into a word form

**Potentially Important aspect >**

- Selection of visual content that includes vocabulary that the child *comprehends* but *does not use* in spontaneous spoken words
Progressing to Two-Word Combinations

- Early word combinations are based on word meanings not grammar.
- Are referred to as “semantic relations”.
- Build length of utterance by combining word meanings NOT by saying “I want ____.”

Two-Word Combinations
(Bloom, 1970; Brown, 1973; Bowerman, 1975)

- **Object (or Person) + Action**: daddy ride; car go.
- **Action + Object**: brush teeth; eat cookie.
- **Demonstrative + Object**: here cookie; there doggie; and, that hat.
- **Negation + Object**: no bubble; no want; and, cookie allgone.

- **Animal or Person + Object**: Describes a person acting on an object (“mommy juice” as mom is drinking or “daddy door” as daddy is opening the door).
- **Action + Location**: Describes an action performed in a specific location (“sit chair” as child puts stuffed dog on the chair or “put in” as child puts in a puzzle piece).
- **Object or Person + Location**: Described in a specific location (“mommy home” or “car garage”).
- **Possessor-Possession**: Describes an object owned by a person (“daddy car” as child points to car owned by dad or “mommy hair” as child brushes mom’s hair).
- **Descriptor + Object**: Early form of an adjective (“big ball” as child picks up a ball or “blue car” as child points to car in a book).
- **Recurrence**: To request another occurrence of an action or object (“more juice” or “more jump”).

Verbal children: Language Mediator

- Because information may not be automatically encoded into language, the adult may need to help the child bridge the gap.
  - E.g.: Verbalizing the steps of a procedural task
  - E.g.: Verbalizing emotional reactions
**Verbal Mediation**

- Been successfully used to promote learning of procedural sequences in older children with language-learning disabilities
- Once can verbalize steps, individual with ASD can be taught to do the mediation overtly, using “inner speech”

(Laskey, 1991)

**Additional Thoughts:**

- Individual with ASD may struggle to tell you “what's in his/her head.”
- Help them to construct a narrative version of an experience that can be shared with others rather than expecting self-construction.
- Externally create what is typically inner self-talk to regulate behavior.
- “Social stories” fit in here

(Gray, 2010, *The new social story book*)

**Creating a narrative**

- Start with what the person knows and has actual experience with
  - Personal narratives
  - Procedural discourse
- More likely to be able to encode into language because doesn’t have to create, organize, and produce the words

**Video Modeling**

See Shane et al. (2012)

- Video-modeling with videos made of the child doing the activity
- Videos of a similar activity to help child use words needed for telling about the activity (like retrieved from the Internet) Ex: Homecoming game

**Additional ideas**

- Photos of child doing an activity
- Have parent take pictures of child’s weekend or other special activities
- Use photo storage capabilities of iPad as “book” for child to share with parent rather than typical picture books

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Additional Considerations

• Ascertain pre-knowledge of semantic content or pre-teach unfamiliar semantic content so child has the words to express his knowledge/ideas

• “Scripts” may be a response to problems with linguistic coding of information

Word retrieval problems in ASD

• Problems with verbal encoding may present as word retrieval problems in children and adults with ASD who speak in connected sentences (Walenski et al., 2006)

• Consider doing an assessment for word-finding problems

• Consider incorporating treatment for word retrieval problems into the intervention plan

Cognitive Flexibility in ASD

ASD

• One of the primary diagnostic criteria is restricted, repetitive patterns of behaviors that can be manifested as an insistence on sameness or a lack of cognitive flexibility (APA, 2013)

Adaptive Functioning in Typical Development

• Abstract thinking is generally highly correlated with problem-solving ability which is predictive of better adaptive functioning.

Adaptive Functioning in ASD

• Flexibility of thought is potentially more important for adaptive functioning in the natural environment than conceptual reasoning or problem-solving (Williams et al., 2014)
Cognitive Flexibility

- In neurofunction, cognitive flexibility is manifested by a change in the pattern of processing based on input from the task or stimuli to be processed

Possible interpretations

- Individuals with ASD are more reliant on visual processing during language comprehension

- Also suggest that individuals with ASD did not vary their cognitive processing in response to differences in stimuli → used a visual imagery strategy for both the visual and verbal stimuli

Comprehension of High & Low Imagery Sentences: “Thinking in Pictures” *(Kana et al., 2006)*

- Individuals with ASD used imagery areas when processing both high and low imagery sentences

- Had difficulty efficiently changing their processing pattern when the demands of the stimuli changed

Further evidence of a lack of differential response to features of the stimuli in individuals with ASD

<table>
<thead>
<tr>
<th>Stimuli: 30 three-sentence stories</th>
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<tbody>
<tr>
<td><strong>Physical</strong></td>
</tr>
<tr>
<td>Context</td>
</tr>
<tr>
<td>Inference</td>
</tr>
<tr>
<td>Question</td>
</tr>
</tbody>
</table>
Inference sentences: Participants with autism recruited more right hemisphere regions than control participants.

(Mason, Williams et al., 2008)

During Discourse Processing:
- The control participants recruited a region involved in Theory of Mind processing only when it was invited by the content.
- The participants with autism recruited LH AND RH language areas for all three types of passages.
- The participants with autism activated the Theory of Mind area even when task did not require it.

(Mason, Williams et al., 2008)

Complex Information Processing (CIP)
- Underlying problem with differential neural response to changing task demands is consistent with CIP (Minshew & Goldstein, 2008)
- Individuals with ASD may have difficulty with meeting increasing integrative demands or responding flexibly during behavioral tasks because of difficulty with resetting neural networks needed for these tasks.

Implications for Learning
- When the processing demands of the task increase, individuals with ASD may not have additional processing resources to draw upon.
- This results in a “biological constraint” on their ability to perform more demanding tasks.

Neural Correlates in Response to Ambiguity
(Williams et al., IMFAR, 2012)
- This fMRI study involved a picture task in which participants had to make categorical decisions on typical and atypical exemplars.
- Two types of categories:
  - Semantic
  - Quantitative
- Two types of items: Ambiguous and Unambiguous

Main task of interest: Semantic

Not clear to what category the item belonged

- Sneaker or Sandal?

NO “RIGHT” ANSWER
Additional Semantic Examples:

- Lion/tiger
- Plane/helicopter

Contrasting task: Quantitative

*Could use a “rule” to answer—round up or down*

- About 3 or About 5?

Semantic Ambiguous > Unambiguous

ASD

ASD > TD

Conclusions:

- Minor differences between and within the groups when they were processing quantitative information.
- Post-testing feedback suggests that this was because they developed a decision-rule to deal with this information (i.e., rounding up or rounding down).

When dealing with semantic ambiguity, ASD group had greater activation than the TD group in right frontal areas.

Associated with greater integration and effortful processing, supporting the relative difficulty of this task for the children ASD

Suggests less automatic incorporation of information into a conceptual framework with a focus on the specific features of the stimuli

What are the implications on learning if the child’s brain processing isn’t “resetting” or differentially responding to the features of stimuli?
Implications for Learning:

- May not be able to change the way they are doing a task.
- May have difficulty switching from a visual to an auditory task or vice versa.
- Can't tell what strategy/how hard they are working by looking at their behavior.

Why warnings about change are effective

- Give warnings when activities are about to change (Flannery & Horner, 1994)
  - May not only serve to help the individual with ASD prepare behaviorally, BUT
  - My serve as notice that a change in cognitive processing needs to occur

Why explicit instructions are effective

- Give explicit directions as to what strategy the person should be using → Tell HOW to do not just WHAT to do (Schopler et al., 1995)
  - These instructions promote use of metacognitive strategies that the individual with ASD may not have employed if they only depended on the responsivity of their brain to external stimuli

Quiet time

- Giving “cooling off” or down time between cognitively demanding activities in a distraction-free area (Nguyen, 2006)
  - May give the individual with ASD time to “reset” their neural networks so they are more prepared for the upcoming activity

Implications

- Even though behavioral management strategies may be employed, the underlying cause of the observed behavioral responses are not necessarily willful choice on the part of individuals with ASD

  - Behavioral responses are driven by neurofunctional differences and the resultant cognitive processing challenges and should be understood and treated as such

Questions about specific cases?
References


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