“Autism: From Men and Mice With Wise Comments From Mars”

UCLA

Center for Autism Research & Treatment

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Is autism a synapse-opathy?

Autism is a dysconnection syndrome.

And how that came to be known.

Pervasive Developmental Disorders (DSM)
*Autism Spectrum Disorders (Informal)

DSM-IV (1994): Pervasive Developmental Disorders

- *Autistic Disorder
- *Asperger's Disorder
- *Pervasive Developmental Disorder NOS
- Childhood Disintegrative Disorder
- Rett's Disorder

- Group may vary widely depending on diagnostic instruments used-ADI-R &/or ADOS- & other exclusions; therefore findings may vary widely.

Common Principles of Neurology

- Brain disturbances produce a constellation of cognitive & neurologic deficits, not a single deficit
- Multi-organ involvement is the rule in non-acquired neurologic disorders- because affected genes are in every cell in the body

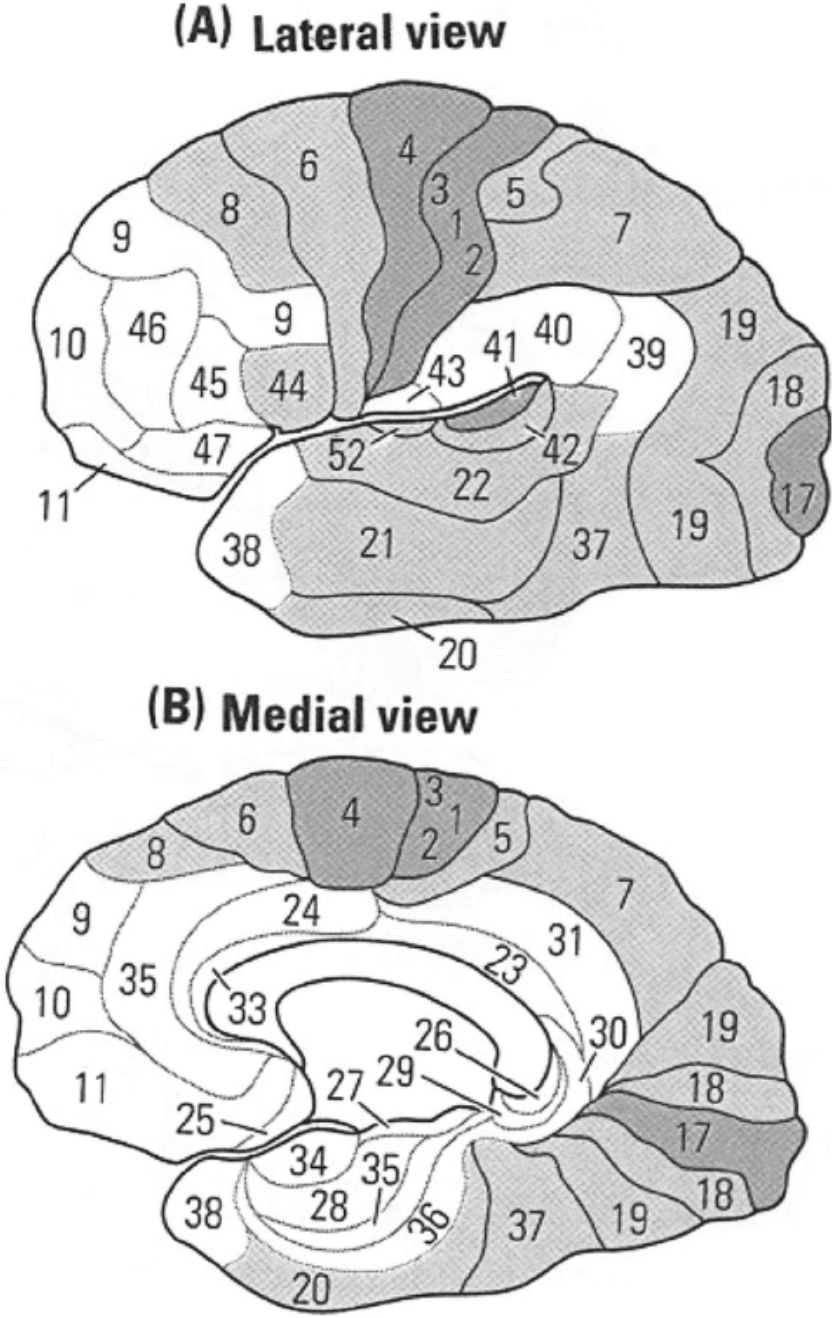
Typical Signs & Symptoms of ASD in Verbal Individuals

- Strange or odd, reflecting social impairment
- Monotone voice, little to no facial expression
- Upset by change, rituals for doing things in set ways; scripts; evolves into obsessive interests
- Obsessions w/ facts or collections; memory for detail superb
- Clumsy, awkward

Behavioral Neurology Assessment of Clinical Syndrome of Autism 1985

- Abnormalities in complex behavior
- Verbal & nonverbal language impairments
- 60% intellectual disability (aka mental retardation)
- 30% seizures
- Not deaf or blind (elementary sensory spared)
- Subtle alterations in tone & reflexes (WM spared)
- Not dysmorphic, normal growth

Interpretation: diffuse association cortex, bilateral


(A) Lateral view
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(B) Medial view
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Brodman's Map & Connectivity

- Primary sensory & motor cortex
- Unimodal association cortex
- Heteromodal association cortex
- Intra- and inter-hemispheric connections

INFORMATION PROCESSING

- Acquisition abilities
- Processing of simple information
- Processing of complex information
- Auditory & visual domains

Behavioral Neurology of Autism: First Revision 1988

- No dyslexia or visuospatial deficits- actually the opposite= no focal deficits
- Language development: capacity to repeat without ability to use words originally or comprehend
- Know names for objects but not meanings

Revision: distributed neural network disorder- underdevelopment of cortical connectivity

Disease Processes

- Infectious disease
- Vascular disease
- Tumor or mass
- Toxins
- Developmental processes

Developmental Processes

Joseph Volpe, Neonatal Neurology, 2008

- Organogenesis
- Neuronal proliferation
- Glial proliferation, migration
- Neuronal migration
- Neuronal organization
- Myelination

Neuronal Organization

Joseph Volpe, Neonatal Neurology, 2008

Neuronal organization refers to the events in brain development that result in the abilities that are most unique to humans.

Neuronal organizational events include the development of neuronal processes, dendritic arborizations, synaptogenesis, and the rich interconnections between neurons.

Neurobehavioral Approach

Neurologists' characterize all impaired AND all intact abilities to identify their common characteristics that will delineate key features of the underlying neurobiology.

This approach turned out to be particularly appropriate in autism.

Discriminant Function Analysis: Domains Without Deficits[3]

Domain	Tests Passing Tolerance	Percent Correct	Kappa[1]
Attention	Letter Cancellation; Number Cancellation	66.70	0.33
Sensory Perception	Finger Tip Writing; Luria-Nebraska Sharp/Dull Tactile Scale item	64.40	0.29
Simple Language	K-TEA Reading; K-TEA Spelling WRMT-R Attack; Controlled Oral Word Association	71.20	0.42[2]
Simple Memory	CVLT Trial 1	65.20	0.30
Visuo-Spatial	WAIS-R Block Design	56.10	0.12

[1]Kappa below .40 indicates poor agreement beyond chance
[2]Significant *Kappa* reflects superior performance by autistic subjects
[3] Based on 33 individually age, IQ, gender matched pairs of subjects

Discriminant Function Analysis[1]: Domains With Deficits

Domain	Tests Passing Tolerance	Percent Correct	Kappa
Motor	Grooved Pegboard; Trail Making A	75.80	0.52
Complex Language	K-TEA Reading Comprehension; Verbal Absurdities; Token Test	72.70	0.45
Complex Memory	Nonverbal Selective Reminding-Consistent Long Term Retrieval; WMS-R Story Recall-Delayed Recall; Rey-Osterrieth Figure-Delayed Recall	77.30	0.55
Reasoning	20 Questions; Picture Absurdities; Trail Making B	75.8	0.52

[1]Based on 33 individually matched pairs of autistic & control subjects (Neuropsychologic Functioning in Autism: Profile of a Complex Information Processing Disorder, *JINS*, 3:303-316, 1997)

The Profile of Intact & Impaired Abilities in High Functioning Autistic Individuals

Intact or Enhanced

- Attention
- Sensory Perception
- Elementary Motor
- Simple Memory
- Formal Language
- Rule-learning
- Visuospatial processing

Cognitive Weaknesses

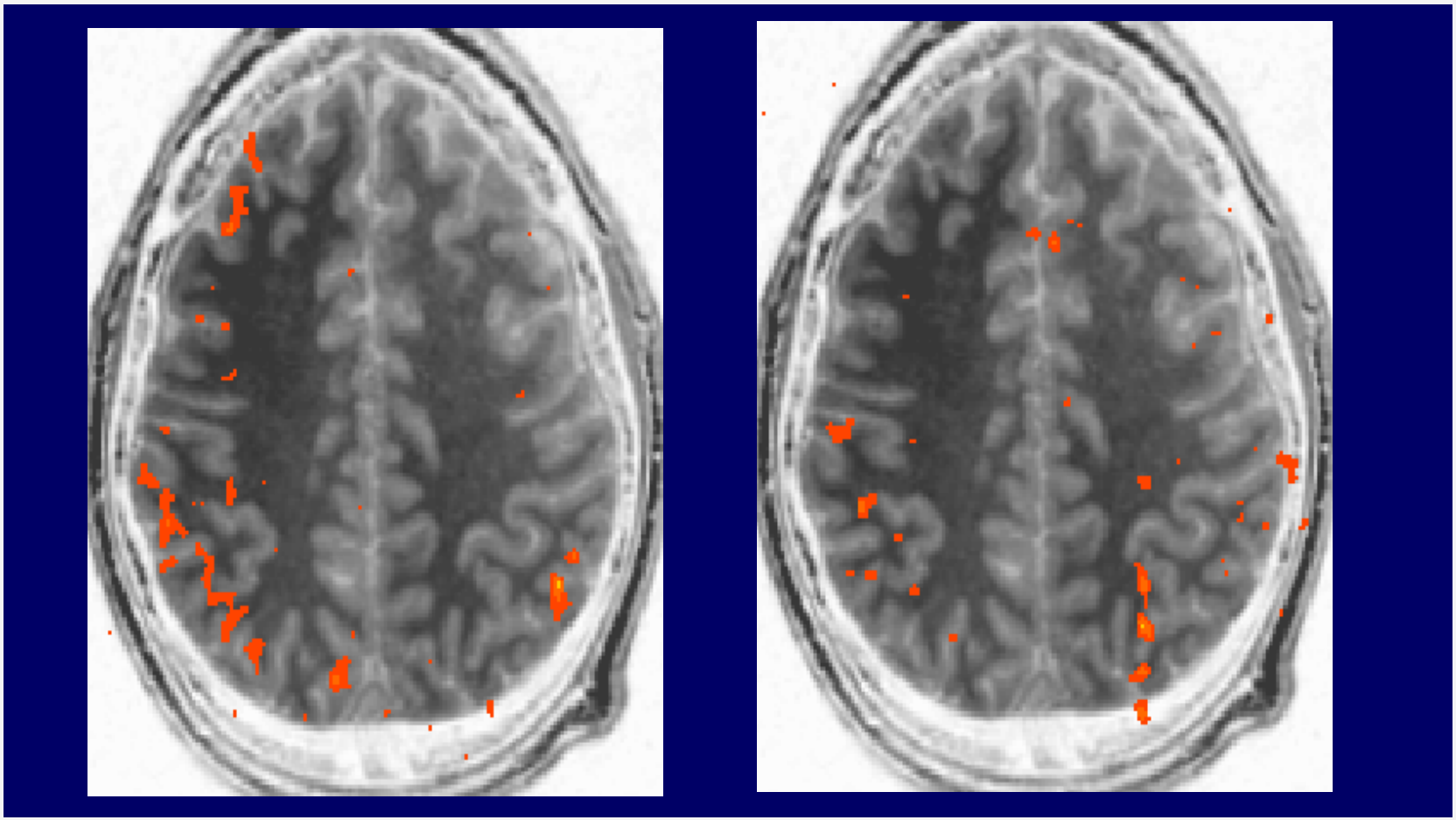
- Complex Sensory
- Complex Motor
- Complex Memory
- Complex Language
- Concept-formation
- Face Recognition

What Does The Profile Mean?

- Simpler abilities are intact or enhanced
- Information processing capacity is limited- & integrative processing & higher order cognitive abilities are disproportionately impaired

Inference: higher order brain circuitry is under developed- they are reliant on lower order circuitry particularly visual circuitry to function.

fMRI Activation During a Spatial Working Memory Task (Courtesy John Sweeney)



Healthy Group

Autism Group

Behavioral Example of Cognitive Profile: Using the Profile to Intervene

Jim was admitted for possible mania. He was agitated and had been sending money to television evangelists and became preoccupied with sin and being good, which he talked about constantly. The psychiatrists attempted daily to PERSUADE him to try lithium but he refused. His reason was that he took lithium on June 4, 1978 and he got a stomachache. He went to the clinic and a scene ensued. Staff yelled at him. No amount of REASONING worked to change his mind, until he was told and SHOWN there were now two forms of lithium - one was pink and one was blue. He took the bad blue before, but this time he would take the good pink. He immediately agreed to the medication. The deterioration in his behavior was the result of losing his job for asking a woman a question about her clothing, which was interpreted as sexual harassment. All structure was gone from his life. Socially-emotionally he was three years old. He was not reciprocal in conversation. He talked, the doctors talked.

Unique Characteristic of Within Domain Disturbances

Within each domain, there was a pattern of intact and impaired abilities. The dissociation was characteristic and was exemplified by the abstraction-EF domain. The result has a marked impact on behavior, and also on adaptive function. Along with social ineptness, the hallmark of autism in verbal individuals is their reliance on rules despite failure and generally slow processing speed.

Behavioral Example of Cognitive Profile: Rules Override Concepts

Bill is a young adult with autism who decided to take figure skating lessons. His mother drove to the rink several times a week. After a while, she decided to skate while he had his lesson. Bill performed his routine, but people learned to stay out of his way. He went where his program required him to go regardless of others. One day his mother forgot to note where Bill was and he ran her over, knocking her unconscious. The emergency team was called and she was given first aide and taken to the hospital. The next day she asked Bill why he did not come to her assistance, since he was an Eagle Scout with a first aide badge. He replied “It expired.”

Effect of dual task on memory span and tracking performance

	Digit recall		*Tracking performance*		*Mu score*
People with autism (n = 16)	*single*	*dual*	*single*	*dual*	
Mean	86.19	> 48.13	52.75	> 37.81	66.87
SD	7.55	16.77	10.47	8.22	10.74
Controls (n = 16)					
Mean	87.25	= 86.88	54.06	= 55.25	84.75
SD	4.81	7.58	14.61	7.39	11.52

Digit recall is expressed as a percentage of correct sequences.

Dual task performance deficit in autism;

(but matched performance in single task conditions)

Garcia-Villamisar & Della Sala, 2002 Cognitive Neuropsychiatry

Additional Implication of Profile: Triad to Brain-Wide

Autism is defined on the basis of abnormalities in social, communication and imaginative play, and restricted interests-repetitive behavior.

The neuropsychologic and postural findings define deficits considerably beyond this triad, suggesting a more brain-wide disturbance in information processing- befitting a disorder of neuronal organization.

Williams et al. 2006, 12: 279-298

Lessons of First Chapter

- Minshew, Goldstein & Williams: no single primary deficit but there is a multiple primary deficit pattern in which all deficits characterized by disturbances in integrative or high level processing
- Happe & colleagues: no cognitive explanation for deficits; reverted to deficit triad in theory of mind, executive dysfunction, and central coherence

But: omits sensory, motor, postural deficits

Theories or Models of Autism

- Executive Dysfunction
- Central Coherence
- Theory of Mind
- None of the above have survived
  - Information processing-connectivity model
  - Social theories
  - Dimensional approach

- A Major Omission From All Cognitive Theories

Autism: A Disorder of Affective Contact

Capacity to experience, understand & regulate emotions also fundamentally altered and not appreciated, despite frequent imaging studies of amygdala

Many verbal ASD individuals socially-emotionally as young as 12-18 months to 3-5 years of age- causes major symptms

Studies of amydala-cortical interactions, social motivation, tolerance of frustration ongoing

Social Emotional Immaturity: Also Not in Diagnosis

Dr. Temple Grandin

"For some of us with ASDs, the emotional-relatedness physical or biochemical circuitry is missing- no matter how hard we try, it's a bridge that may never be built because some of the basic building materials are missing."

"Romantic relationships have a level of social complexity that I still don't understand today and I consciously choose not to participate in them. My way of thinking and functioning does not describe everyone on the spectrum."

Convergence of Cognitive With Anatomic

Getting To A Neural Systems Perspective

From Entrenched, Focal Brain Dysfunction Models

Head Growth in Autism

Lainhart et al. Am J Med Genet 2006, 140A:2257-2274

- Group mean HC 60-70%; megalencephaly in 15%
- Onset accelerated growth 9-12 months w/ 15-20% macrocephaly by 4-5 years
- Growth decelerates and plateaus so that brain volume “normalizes” in childhood, though subset remain macrocephalic throughout life
- Important to recognize that HC>HT is not universal in autism and HC=HT and HC<HT growth trajectories also compatible with autism

Minicolumn Abnormalities in Autism: Evidence of Cortical Involvement

- First substantive abnormalities of cerebral cortex
- Radially oriented arrays of pyramidal neurons, interneurons, axons and dendrites
- Smallest radial unit of information processing; then macrocolumns and receptive fields?
- Bilateral abnormalities in areas 3, 4, 9, 17, 21, 22
- Increased #, narrower, reduced neuropil space (inhibitory neurons), neurons small

Casanova et al. Acta Neuropathol 2006; 112:287-303

Additional Evidence of Cortical Involvement

- Proton MRS study of 3-4 yr olds with autism, DD, TD: reduced choline compound concentrations and transverse relaxation, suggestion decreased cellularity or density in ASD but not DD or TD
- T2 relaxation in same children prolonged in GM but not WM in ASD but in both GM and WM in DD. Selective involvement of GM interpreted as abnormal developmental process in ASD

Friedman et al. Arch Gen Psych 2006; 63:786—794;
Petropoulous et al. Neurology 2006; 67:632-636

Additional Evidence of Cortical Involvement

- 26 males 6-17 years IQ>70 w/ autism & 26 controls
- Proton MRs revealed significantly lower levels of cortical gray matter NAA and glutamate-glutamine that were widespread in cerebral lobes and cerebellum
- Conclusion: widespread reduction in gray matter neuronal integrity and dysfunction of cortical and cerebellar glutamatergic neurons

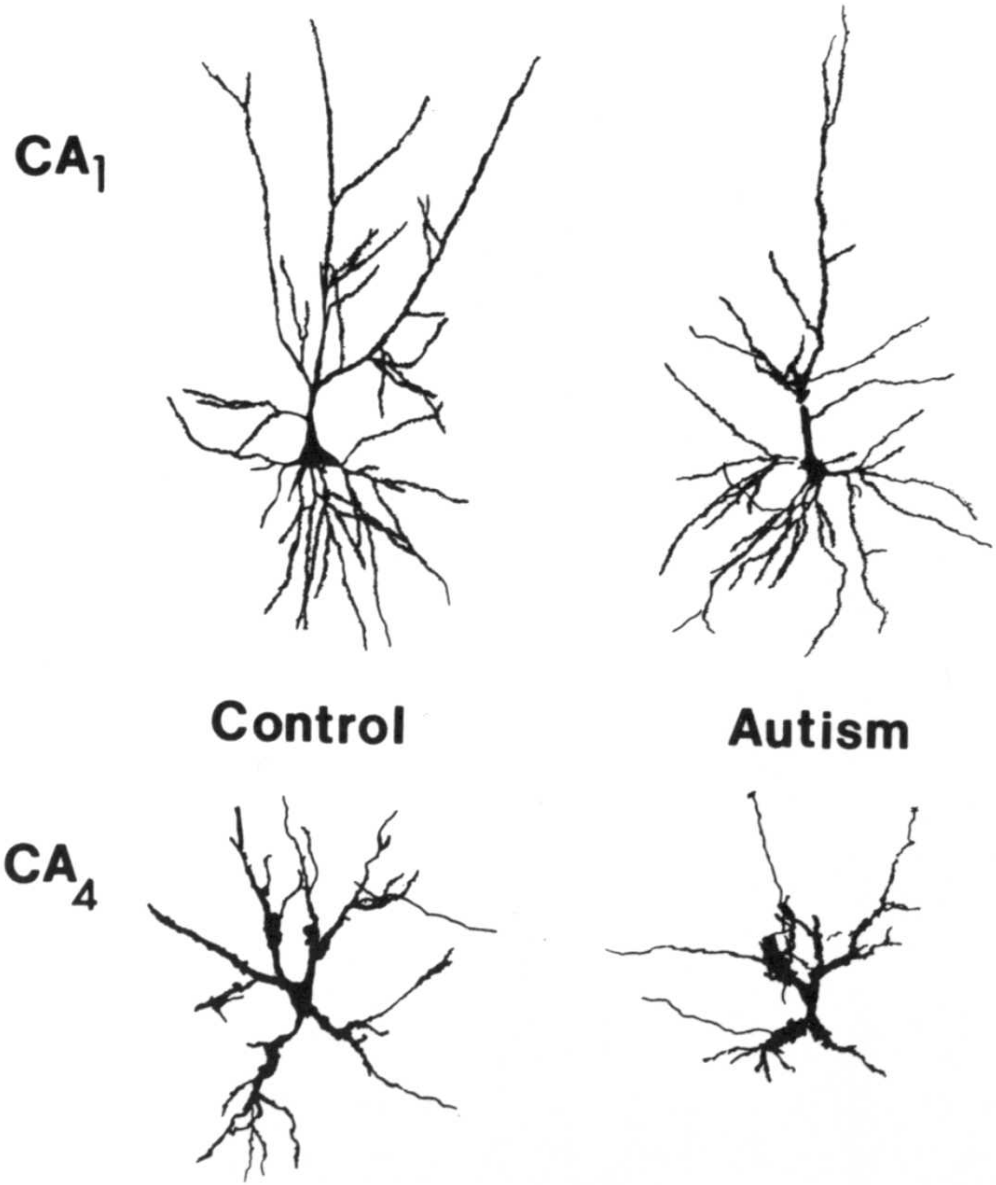
DeVito et al Biol Psychiatry 2007; 61:465-473

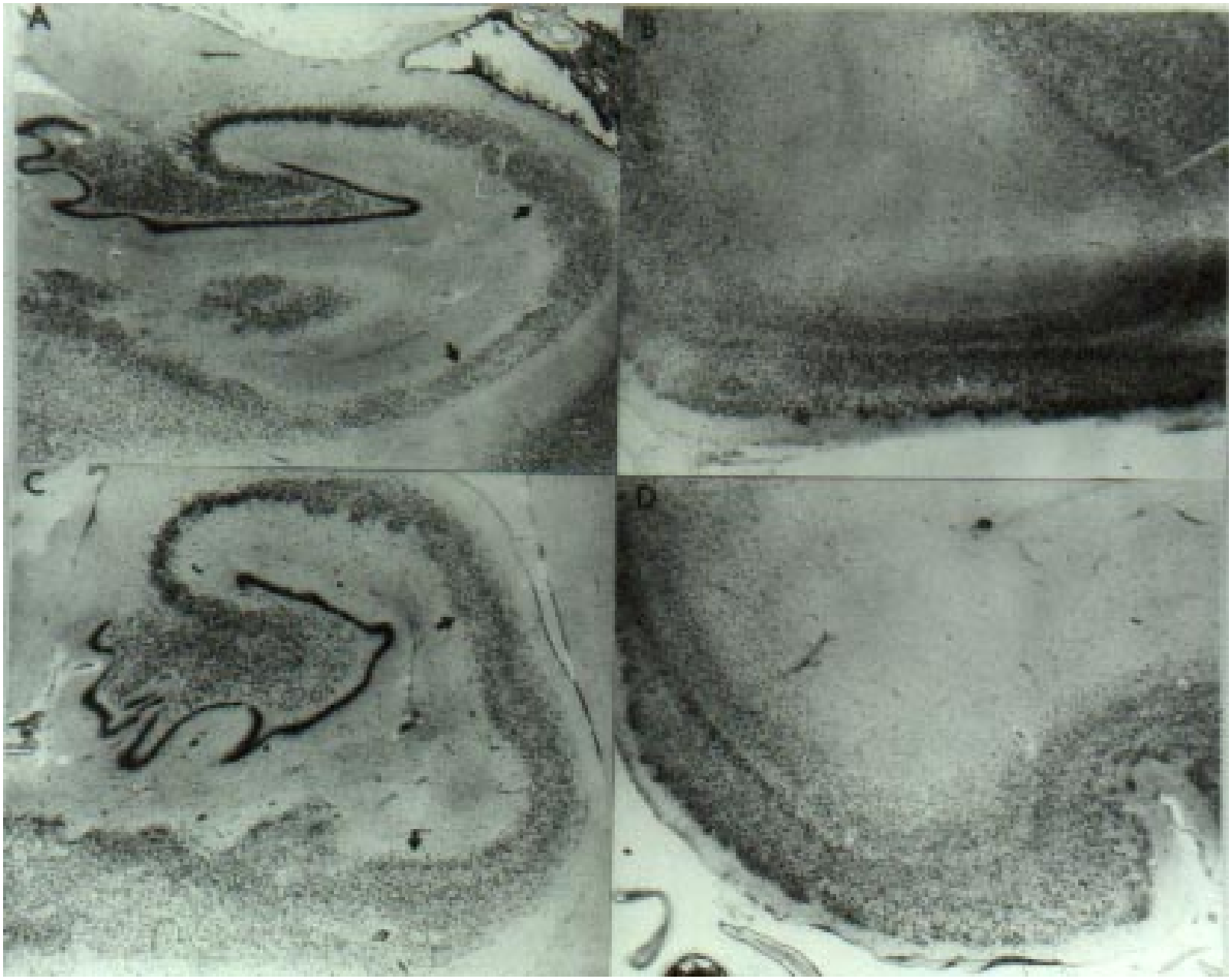
Implications of Brain Volume Studies

- Major role for white matter but without accompanying long tract signs and thus the difference between acquired and devel. disorders
- Disturbance in connectivity
- Increased white matter volume associated with dysfunction, not increased function
- Inter-hemispheric white matter e.g. corpus callosum not involved in the same process

Minshew & Williams, Arch Neurol 2007

Autism is a dysconnection syndrome.


CA1
Control
Autism
CA4


A
B
C
D

Language Profile in HFA

- Superior to age-, IQ-, gender- matched controls on word & non-word decoding, spelling, vocabulary, fluency
- Inferior to controls on comprehension of sentences, idioms, metaphors, stories

Cortical activation & synchronization during sentence comprehension in HFA subjects

Marcel Just
Vlad Cherkassky
Tim Keller
Nancy Minshew

Center for Cognitive
Brain Imaging
Carnegie Mellon

Just et al. 2004, Brain 127: 1811-1821

Sentence reading task and comprehension probe

Center for Cognitive Brain Imaging

The player was followed by the parent

Who was following?

player **parent**

Brain activation during sentence comprehension in autism

In Brain, 2004

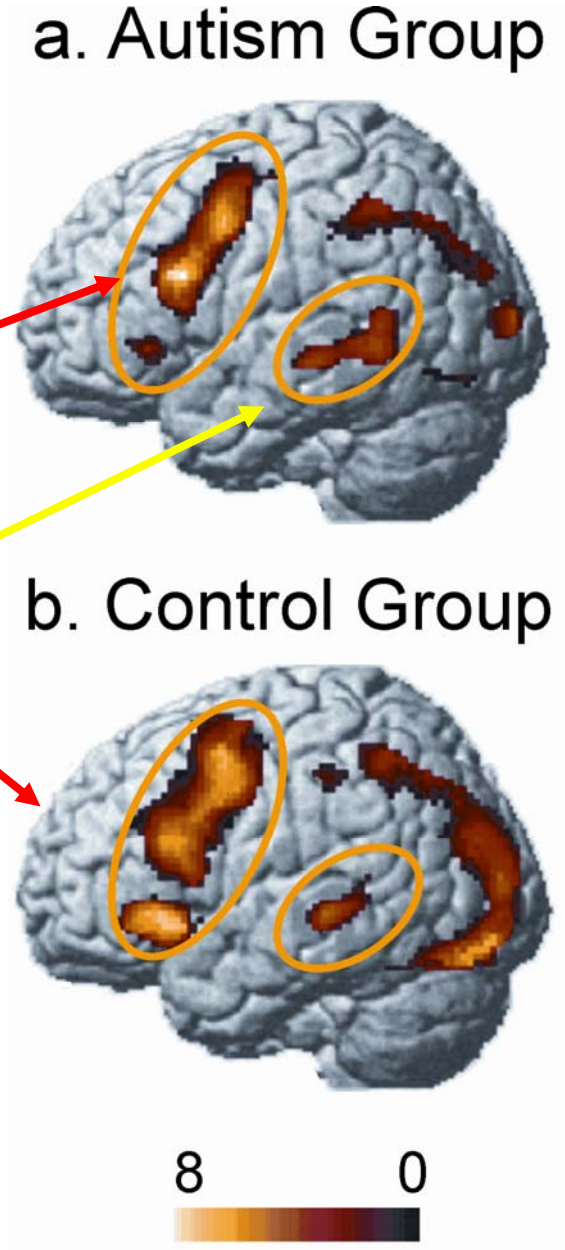
Autism group has less activation in **Broca's area**

- *(a sentence integration area)*

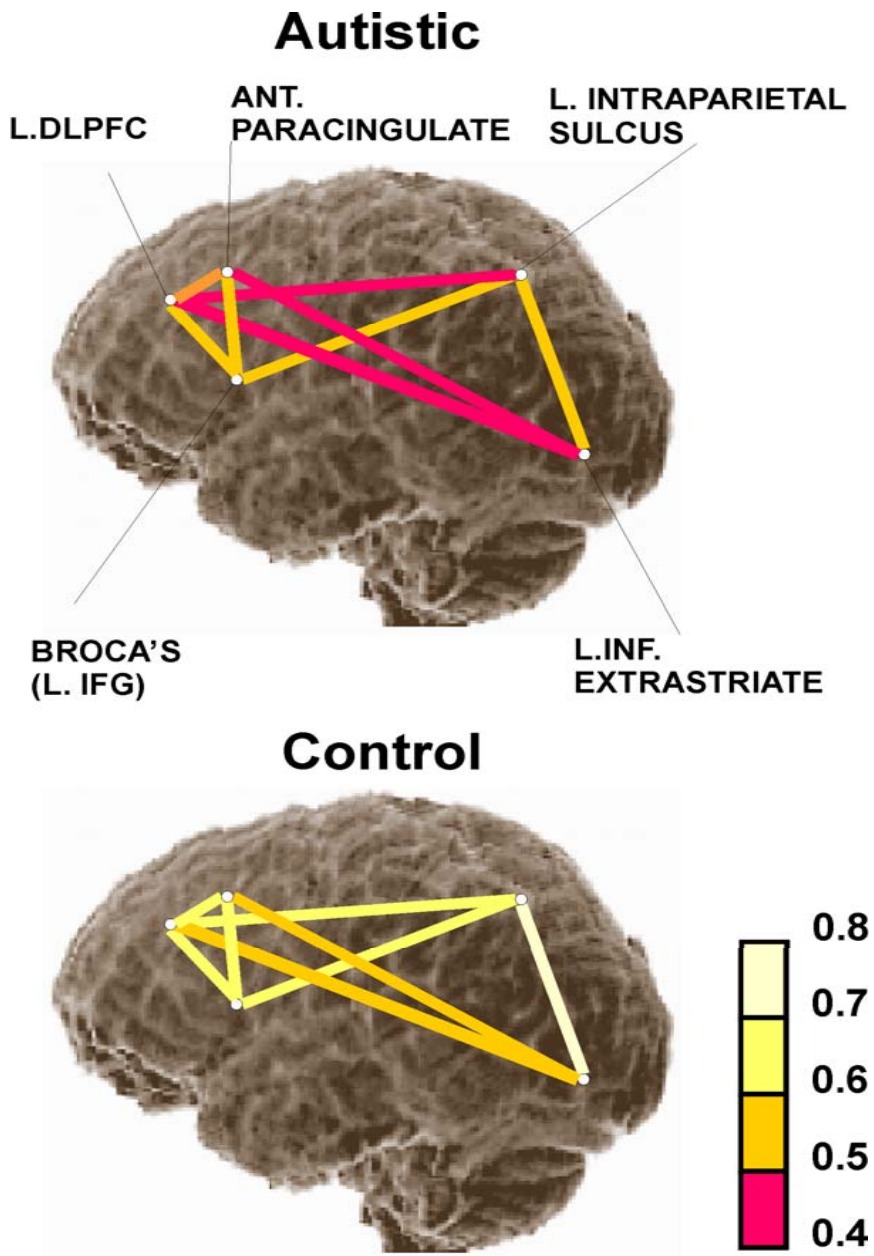
than the control group and more in **Wernicke's area**

- *(a word processing area)*

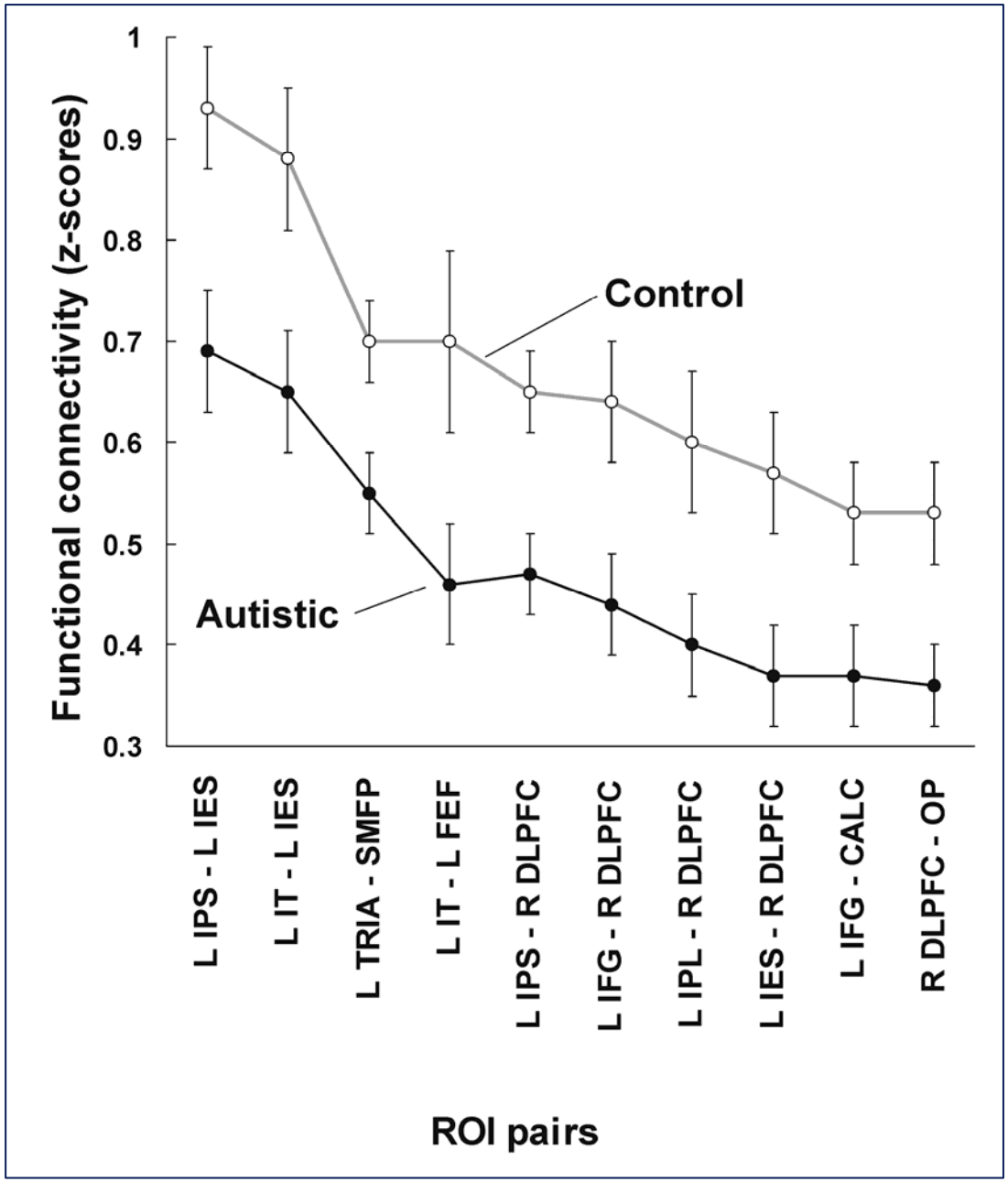
Results are consistent with poorer comprehension of complex sentences, coupled with good word reading (spelling bee champs)



Reliably lower functional connectivity for autism participants between pairs of key areas during sentence comprehension (red end of scale denotes lower connectivity)



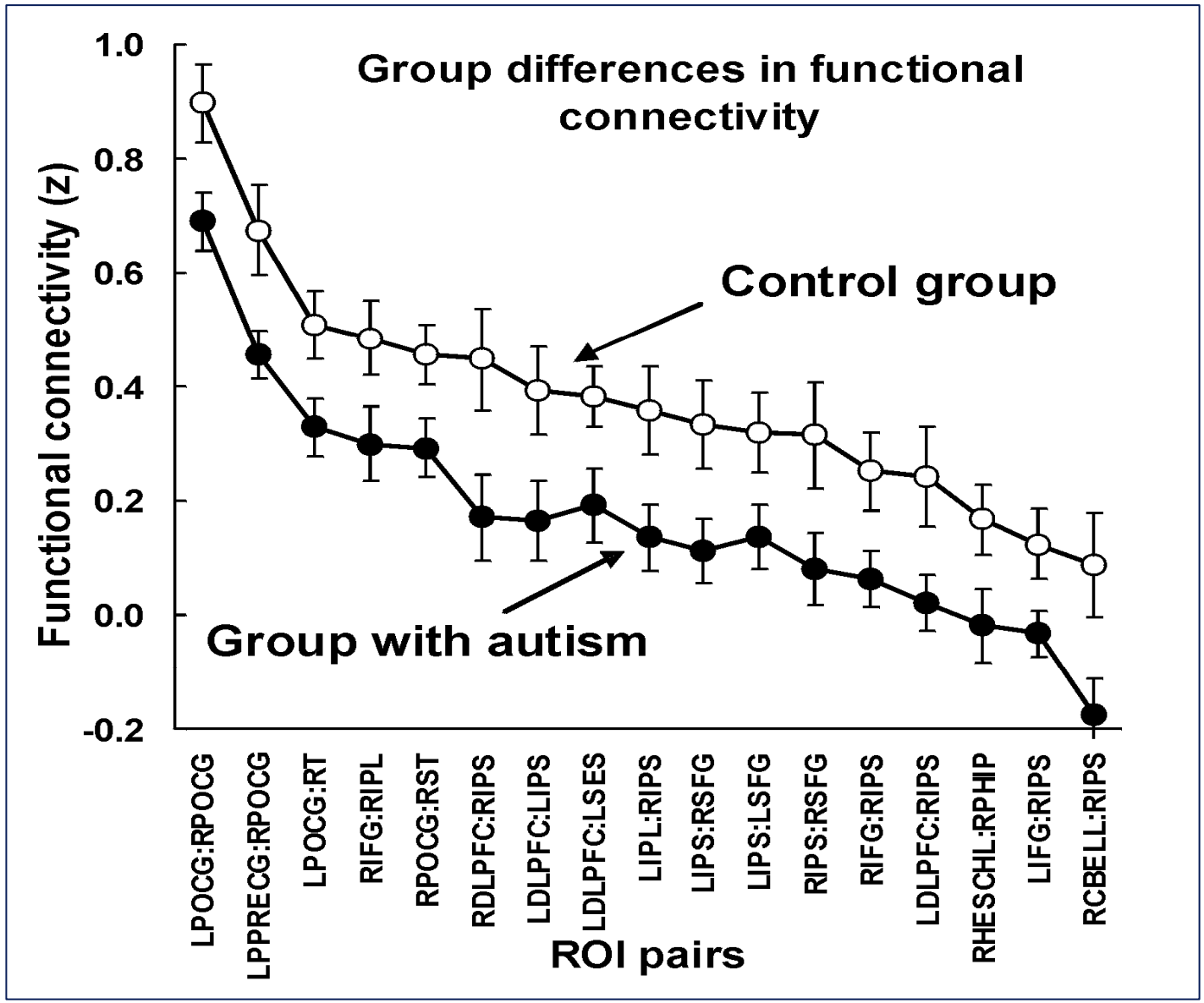
Reliable differences in functional connectivity: autism group has lower functional connectivity but same rank order



Functional Underconnectivity: fMRI of the Tower of London

Marcel Just
Nancy Minshew
Tim Keller
Vlad Cherkassky
Rajesh Kana

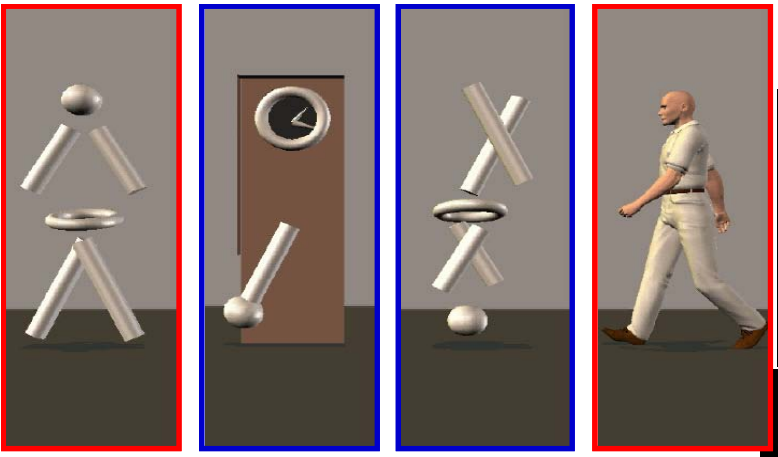
Just et al., 2006 [Epub ahead of print], Cereb Cortex

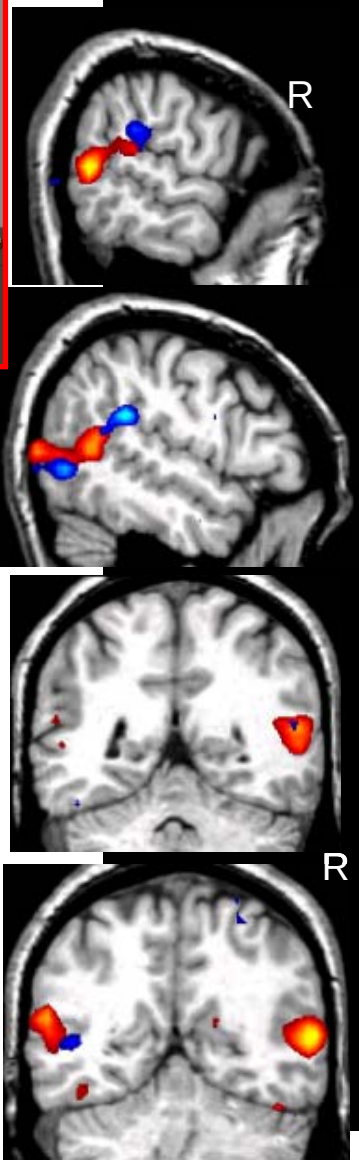

Group differences in functional connectivity
Functional connectivity (z)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Control group
Group with autism
LPOCG:RPOCG
LPPRECG:RPOCG
LPOCG:RT
RIFG:RIPL
RPOCG:RST
RDLPFC:RIPS
LDLPFC:LIPS
LDLPFC:LSES
LIPL:RIPS
LIPS:RSFG
LIPS:LSFG
RIPS:RSFG
RIFG:RIPS
LDLPFC:RIPS
RHESCHL:RPHIP
LIFG:RIPS
RCBELL:RIPS
ROI pairs

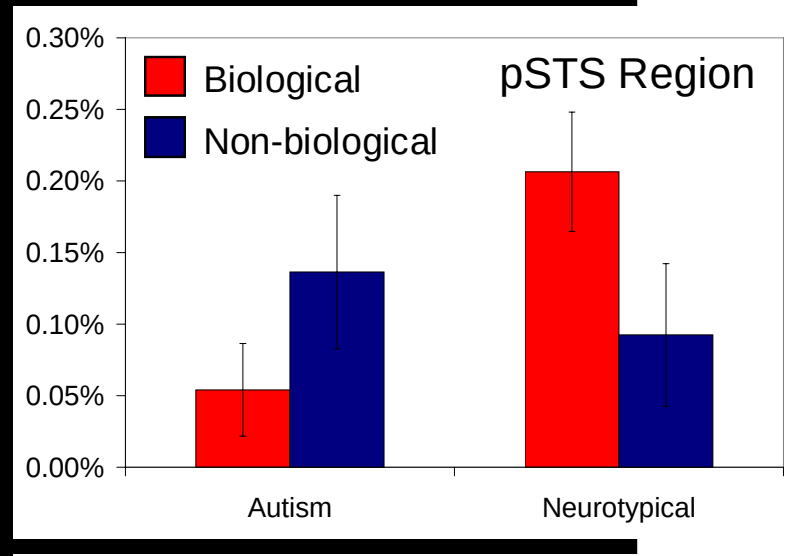
Neural Representation of Words

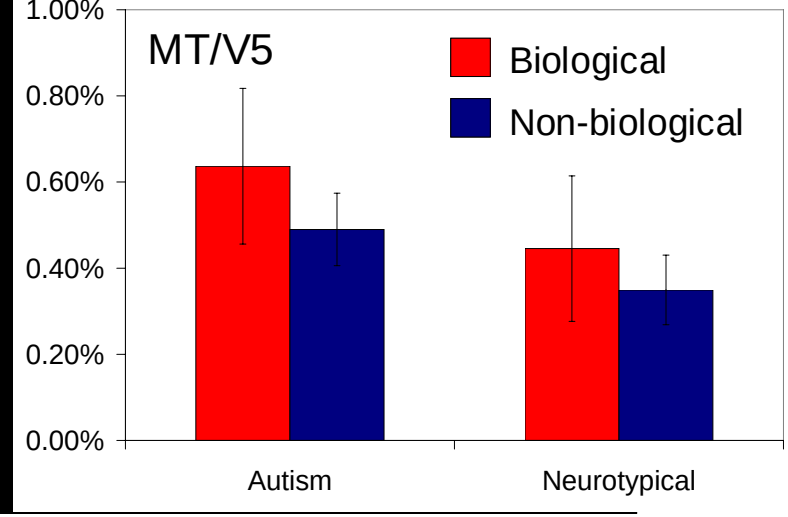
Mitchell, T. M., Shinkareva, S. V., Carlson, A., Chang, K-M., Malave, V. L., Mason, R. A., & Just, M. A. (2008). Predicting human brain activity associated with the meanings of nouns. Science, 320, 1191-1195.

Shinkareva, S. V., Mason, R. A., Malave, V. L., Wang, W., Mitchell, T. M., & Just, M. A. (2008). Using fMRI brain activation to identify cognitive states associated with perception of tools and dwellings. *PLoS ONE*, *3*, e1394.









What are the brain systems involved in representing the actions and intentions of other people?

Pelphrey et al. (2003) *Journal of Neuroscience*
Carter & Pelphrey (2007) *Social Neuroscience*

Convergence Across Systems

Clear that typical brain development results in pre-fab circuitry & systems that predispose human infant to automatically orient and prefer human contact over objects, experience emotions and perceive them in others, acquire language, make sense of the world, play with toys symbolically and with others.

“Neurotypical people have a social sense right from the time they’re born.” p. 32

“My ability to function in the world develop social relationships has been learned solely through my intellect…and use of my visualization skills. I have learned by rote how to act in different situations. Using my visualization ability, I observe myself from a distance in each situation. I call this my “little scientist in the corner”… I take note of the details that make up the situations just like a scientist observes an experiment. All that data gets put on my computer hard drive memory...

Social Interactions contd

How I "tackle social situations is very much a scientific approach, based on observation, analysis, conclusions."

She learned by reading articles and trial and error, keeping what worked and discarding what did not. She was 40 before she had enough data in her data base to improve.

Convergence of Imaging With Genetics

Neuronal Organization

Joseph Volpe, Neonatal Neurology, 2008

Is autism a synapse-opathy?

Genetic Advances

Increased rate of “de novo” copy number variations: submicroscopic deletions or duplications of DNA sequences. More common in . simplex than multiplex families. Opened door to two genetic mechanisms: inherited gene mutations and spontaneous copy number mutations- instability in replication of DNA

Potential reversal of Neurodevelopmental Disorders (in Fragile X, Rett & Angelman Syndromes) in adult mice; Proof of concept that delineating neurobiologic and genetic mechanism would lead to treatment

Genetic Advances

PTEN described in humans in association with ASD; conditional knock-out mice display enlarged brains and social behavioral deficits:

PTEN interacts with several proteins in a signaling cascade that are tied to tuberous sclerosis and neurofibromatosis. 17% of individuals with autism & macrocephaly had PTEN gene.

Genetic Advances

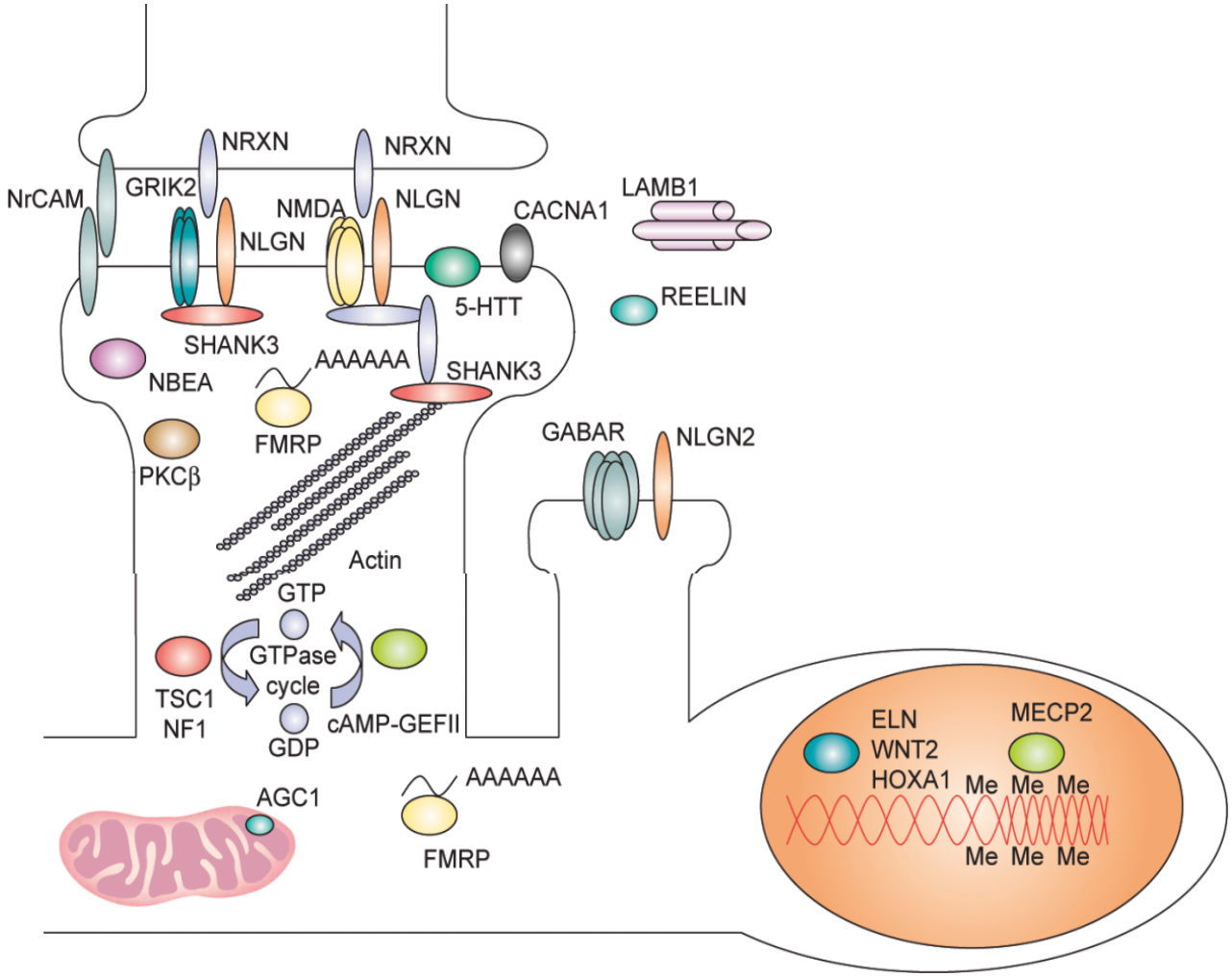
Mouse models of genes associated with autism in humans: neuroligin-3 gene mouse model:

mouse has deficits in social behaviors and an increased ability for spatial learning

Genetic Advances

Discovery of rare families with SHANK3 gene mutations added further evidence to synaptic dysfunction hypothesis.

Codes for synapse formation & maintenance. It also interacts with neuroligins and neurolexins.


NRXN
NRXN
NrCAM
GRIK2
NMDA
NLGN
NLGN
CACNA1
LAMB1
5-HTT
REELIN
SHANK3
AAAAAA
SHANK3
NBEA
FMRP
PKCβ
GABAR
NLGN2
Actin
GTP
GTPase
cycle
TSC1
NF1
cAMP-GEFII
GDP
AGC1
AAAAAA
FMRP
ELN
WNT2
HOXA1
MECP2
Me Me Me
Me Me Me

Genes and Multi-Organ Involvement and Gene Expression & Heterogeneity

- 2.27 relative risk of autism diagnosis conferred by the CC genotype MET receptor tyrosine kinase. MET signaling is involved in neocortical and cerebellar development, immune function, and gastrointestinal repair, consistent with the multi-organ symptoms reported in autism
- Anatomic expression pattern of gene overlays brain structures involved in autism- different genes will have different expression patterns

Campbell et al. PNAS 2006, 45: 16834-16839

Clarification of Onset & Genetic: Communicating Science to the Public

- Many non-traumatic child neurologic disorders present “out of the blue”.
- A recent example at CNS meeting-neuronal ceroid lipofucshinosis, uniformly fatal, not responsive to bone marrow transplant, thus a candidate for stem cell therapy.

  3 forms: neonatal, infantile, juvenile.
- DNA: day to day director of life; may come with faults with different decay rates-faulty light bulbs or time bombs present from birth

Pathophysiologic sequence of a neurodevelopmental disorder

Abnormalities in Genetic Code for Brain Development

↓

Abnormal Mechanisms of Brain Development

↓

Structural and Functional Abnormalities of Brain

↓

Cognitive & Neurologic Abnormalities

↓

Behavioral Syndrome

A Mechanism For Rapid Automatic Processing

- Non-conscious
- Not verbally mediated
- Flexible

Concept Formation Deficits: Search for More Fundamental Cognitive Mechanisms

- Motor concept learning
- Memory dependent on strategies
- Story creation or theme identification
- Face recognition
- Face affect recognition
- Strategy formation, problem solving

How the mind organizes information- thinks, Or not, in the case of autism

Cognitively the problem is with prototype formation and

automatic processes

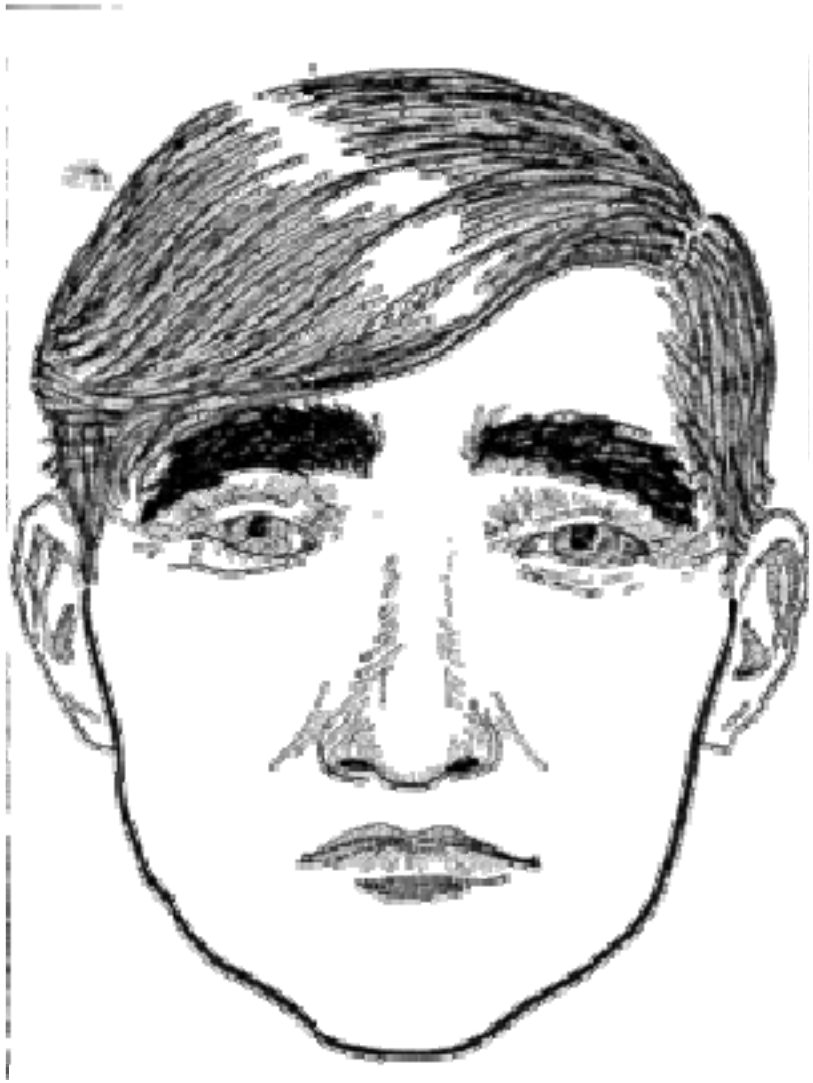
as opposed to conscious, verbally mediated reasoning.

Pitt Infant and Toddler Development Center

- Abilities that adults take for granted that normally develop in infancy and toddlerhood:
- For example:
  - ✓ Our abilities to recognize faces and emotional expressions
  - ✓ Our abilities to understand the difference between basic categories in the world– cats, dogs, lions …

Infants are born with automatic mechanisms that allow them to form Prototypical Representations of Information

Which of these is the best example of a dog?



Which of the following two faces looks more familiar to you?

1

2

Why are less typical faces so difficult?

- Require comparison to prior stored knowledge (e.g., prototypes)
- Require subtle spatial/configural processing
- Require flexible weighting of features and perhaps formation of a holistic representation
- (Note the importance of varying both age and difficulty of task)












TYPICAL

SOMEWHAT TYPICAL

ATYPICAL

Cognitive Research in 5-50 year old HFAs

- The way individuals with autism come to learn about both the world and people is different from individuals who do not have autism.
- There are core differences in the way they learn categorical information and acquire “expertise”

Gasgeb, Strauss, & Minshew. Child Dev 2006; 77: 1717-1729