Transdisciplinary Assessment and Treatment of Language-based Learning Disabilities: The Theoretical Importance of Sensory Processing
Neurons - How the Brain Works

- How many neurons in the brain?
  - ~ 100 Billion
- How many connections exist in the neural networks formed in the brain?
  - ~ 100 Trillion
- How many “connections” from one neuron?
  - ~ 40,000
- The brain is specifically designed for learning and behaviors. It is ready and willing to create neural networks.
- Learning to drive?
- Driving to Ft. Lauderdale…..
STG (bilateral)  acoustic-phonetic speech codes

pIFG/dPM (left)  articulatory-based speech codes

Area Spt (left)  auditory-motor interface

STG (bilateral)  acoustic-phonetic speech codes

pMTG (left)  sound-meaning interface

STS phoneme representations

Hickok & Poeppel (2000), Trends in Cognitive Sciences
Hickok & Poeppel (2004), Cognition
UNIQUE AND OVERLAPPING NETWORKS
SENTENCE/SYNTACTIC, SEMANTIC, PHONOLOGICAL

VIGNEAU et al., 2006
How does the brain develop these distributed networks of sensory and cognitive abilities?
UNIVERSAL SPEECH PERCEPTION: 0-6 MONTHS

**SENSORY LEARNING**

- Infants discriminate phonetic contrasts of all languages
- Infants produce vowel-like sounds
- Infants produce non-speech sounds
- Infants discriminate phonetic contrasts of all languages

**STATISTICAL LEARNING** (distributional frequencies)

- Language-specific perception for vowels

**UNIVERSAL SPEECH PRODUCTION: 0-6 MONTHS**

(Kuhl, 2004)
UNIVERSAL SPEECH PERCEPTION: 6-12 MONTHS

Sensory Learning

Language-specific speech perception

LANGUAGE-SPECIFIC PERCEPTION FOR VOWELS

PERCEPTION

PRODUCTION

6  7  8  9  10  11  12  TIME (MONTHS)

DETECTION OF TYPICAL STRESS PATTERNS IN WORDS

STATISTICAL LEARNING (DISTRIBUTIONAL FREQUENCIES)

CANONICAL BABBLING

STATISTICAL LEARNING (TRANSITIONAL PROBABILITIES)

LANGUAGE SPECIFIC SPEECH PRODUCTION

RECOGNITION OF LANGUAGE-SPECIFIC SOUND PRODUCTION

INCREASE IN NATIVE-LANGUAGE CONSONANT PERCEPTION

DECLINE IN FOREIGN-LANGUAGE CONSONANT PERCEPTION

FIRST WORDS PRODUCTION

Sensory-Motor Learning

Language Specific Speech Production

(Kuhl, 2004)
Multisensory = any senses?

- To promote language development, does it matter what sensory systems or how the sensory systems are engaged/experienced?
Sensory Systems & Speech Perception

(Kuhl et al., 2003)
Sensory Systems & Language

- Why did live / invivo experience with a parent improve 2\textsuperscript{nd} language discrimination when TV and Headphone experience didn’t?
- What sensory systems are engaged by live experience and NOT by recorded experiences?
- What do you do when you teach a baby a new word and he/she has trouble saying all the word’s sounds, e.g. “ba” versus ball?
Early Language Development

- Brain is tuned to parents’ language
- What systems do newborn’s integrate for speech?
  - Oral-facial movements – visual
  - Speech sounds – phonology
  - Speech/babble – oral motor tactile kinesthetic
  - Social-emotional – (non verbal tones & gestures) – pragmatics
- Newborns speech perception is affected by multisensory experiences during language development.
Is an adult’s well-developed speech perception affected by multisensory experiences?

http://www.youtube.com/watch?v=eQoYKuNcCpU&feature=fvwrel

Spell pseudo words
How does the brain develop these distributed networks of sensory and cognitive abilities?

Sensory and motor systems that fire together wire together to form functional neural networks in a typically developing brain.

Which sensory systems are firing during development of speech perception?
Overview of Sensory Processing and Quality of Life

- **Context**
  - Social Participation
  - Learning/School Success
  - Regulated Interactions
  - Self Confidence & Self Esteem

- **Environment**
  - Abstract Qualities
  - Functional Outcomes
  - Integration Sensation, Attention, Emotion
  - Higher Level Processes
  - Basic Processes
  - Physiology & Regulation
  - Sensation

- **Tasks**
  - Ideation
  - Reciprocal Interactions
  - Emotional Control
  - Body Awareness
  - Discrimination
  - Planning & Sequencing
  - Feeding Nutrition
  - Oral, Fine & Gross Motor
  - Postural & Ocular Abilities
  - Attention
  - Filtering
  - Modulation
  - Olfactory
  - Gustatory
  - Auditory
  - Visual
  - Vestibular

- **Relationships and Engagement**
  - Goals

**Arousal Regulation** (Miller, 2011)
Typical **LANGUAGE** Networks

- **SPEECH PRODUCTION AREA**
- **AUDITORY PROCESSING AREA**
- **VISUAL-LANGUAGE ASSOCIATION AREA**
- **VISUAL / VERBAL AREA**

**LEFT HEMISPHERE**
Typical **READING** Areas

LEFT HEMISPHERE

**WORD ANALYSIS**

**WORD ANALYSIS**

**AUTOMATIC (SIGHT WORD)**
“CHANGES IN SYNAPSES?”

At what chronological age do neurons lose the ability to make new connections (synapses) or networks?

Can neural networks make new connections even after documented brain injury?
Following a stroke, can partially damaged brain areas be re-activated by neurorehabilitation?

YES! New activity and improved behaviors occur in some patients.

(Chang, et al. 2006)
Principles Of Neural Plasticity

- Neurons that fire together - wire together
  - Multiple, salient sensorimotor inputs that wire together can strengthen neural networks

- Optimal arousal and attention

- Consistent input/learning experiences

- Learning experiences drive neural plasticity:
  1. SALIENCE – specificity of instruction/experience
  2. FREQUENCY - hour(s) per day
  3. INTENSITY - days per week
     - practice, practice, practice

(Heilman and Alexander, 2003; Kleim and Jones, 2008)
Variability in Neural Plasticity?

- Why don’t neural networks all form the same for each person’s brain?
- Why do some brains work “differently” than others?
Visual, auditory & oral sensory systems – Are they integrated well in dyslexia?

Articulation Accessing scores of subjs in sample 2

Montgomery, 1981
WHAT DYSLEXIA IS NOT

DYSLEXIA...

 .. is NOT A VISUAL PROBLEM
 .. is NOT A LACK OF INTELLIGENCE
 .. is NOT DUE TO LACK OF EFFORT
 .. is NOT A DEVELOPMENTAL LAG
 .. is NOT UNCOMMON: 5–17.5 % OF POPULATION
 .. is NOT RESPONSIVE TO STANDARD READING INSTRUCTION
DYS = trouble  LEXIA = words

Dyslexia is...

- Neurologic in origin – genetic
- Lifelong – but environment may alter course
- Reading comprehension > word reading skills

Dyslexia may include accompanying challenges

- ADHD 50-70%
- Behavioral problems
- Sensory motor difficulty

= More challenging to remediate
THE PICTURE OF DYSLEXIA
(ALL STRENGTHS DO NOT OCCUR FOR EVERYONE)
(Alexander & Conway, 2007)

STRENGTHS

LEADERSHIP SKILLS

THINKING “OUT OF THE BOX”

CHURCHILL

JFK

TED TURNER

POLITICAL & MILITARY

BUSINESS

THOMAS EDISON

SCIENTISTS & INVENTORS
THE PICTURE OF DYSLEXIA

(ALL STRENGTHS DO NOT OCCUR FOR EVERYONE)

(Alexander & Conway, 2006)

STRENGTHS

CREATIVITY

WRITERS

ARTISTS

MUSICIANS

ACTORS/DIRECTORS

H.C. ANDERSEN  
Da VINCI  
MOZART  
SPEILBERG / FORD
THE PICTURE OF DYSLEXIA
(ALL STRENGTHS DO NOT OCCUR FOR EVERYONE)
(Alexander & Conway, 2006)

STRENGTHS

VISUOSPATIAL / MOTOR SKILLS

SURGEONS

ATHLETES

NEUROSURGERY  MUHAMMAD ALI  NOLAN RYAN
THE PICTURE OF DYSLEXIA

(ALL SYMPTOMS DO NOT OCCUR WITH EVERYONE)

(Alexander & Conway, 2006)

ORAL LANGUAGE

CHALLENGES

LISTENING

Phonological Awareness

Auditory Memory
(word sequences, phone numbers, remembering directions)

Foreign Language

SPEAKING

Word Finding

Multi-syllable Words

Sequencing Ideas

Foreign Language

Alexander & Conway, 2006
THE PICTURE OF DYSLEXIA
(ALL SYMPTOMS DO NOT OCCUR WITH EVERYONE)
(Alexander & Conway, 2006)

WRITTEN LANGUAGE CHALLENGES

READING
- Mechanics
  - Speed
- Comprehension

SPELLING & WRITING
- Mechanics
- Expressing Ideas
  - Speed
THE PICTURE OF DYSLEXIA
(ALL SYMPTOMS DO NOT OCCUR WITH EVERYONE)
(Alexander & Conway, 2006)

ACCOMPANYING SENSORIMOTOR CHALLENGES

- Messy Eating
- Oral Motor
- Writing/knots
- Fingers
- Lose Place
- Eyes
- Words Swim
- Tired
- Spatial Awareness
- Left/Right
- Up/Down

(ALL SYMPTOMS DO NOT OCCUR WITH EVERYONE)
(Alexander & Conway, 2006)
ACCOMPANYING CHALLENGES (BEHAVIORAL) (ALEXANDER & CONWAY, 2006)

THE PICTURE OF DYSLEXIA
(ALL SYMPTOMS DO NOT OCCUR WITH EVERYONE)

Brain / Behavior Disorders

- Anxiety
- OCD
- Oppositional Behavior
- Depression
- Parents with similar challenges

Attention & Executive Function
Dyslexia – really, what is it?
If Phonology Is So Important, Then When Does It Begin Developing?

At what age do children begin to learn the sounds of their native language?
Developmental Building Blocks for Language

PHONOLOGY

PRAGMATICS

SEMANTICS

SYNTAX

READING

WRITING

SPELLING

METALINGUISTICS

PRAGMATICs

(FUNCTION)

(SEMANTICS)

(SYNTAX

(FORM))

(WRITING

(SPELLING)

(READING))

(PHONOLOGY

(FORM))

1 MONTH

9 MONTHS

18 MONTHS

5 YEARS

9 YEARS
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Typical READING Areas

LEFT HEMISPHERE

WORD ANALYSIS

AUTOMATIC (SIGHT WORD)
Neuronal migration goes awry in developmental dyslexia?
NEURONAL MIGRATION

*transmembrane adhesion molecules and receptors

*downstream targets: change cytoskeletal processes & neuron motility

(Galaburda, et al., 2006)
Neuronal Ectopia

(Ramus, 2004)
What effects on brain function might ectopias have?

Functional MRI (fMRI)
- same machine as clinical MRI
- additional measure of blood oxygenation levels in brain
- shows brain’s active areas when doing some behavior/task
BRAIN ACTIVITY DURING READING

“SIGNATURE” DYSLEXIC BRAIN

Simos, et al 2002
TREATMENT CHANGES the BRAIN’S ACTIVITY

Decreased activity in right hemisphere

Treatment = Increased activity in left hemisphere

(Simos, et al., 2002)
Biology

Behavior

Cognition

(RAMUS, 2004)
PHONOLOGY (PERCEPTION & PRODUCTION)

EXECUTIVE FUNCTION / INTENTION

WORKING MEMORY
HOLD / MANIPULATE

PHONEMIC REPRESENTATION

PROSODIC (WORD LEVEL)

ORAL MOTOR
SOMATOSENSORY
ACOUSTIC
VISUAL

ATTENTION / AROUSAL

(Alexander, 2006)
READING
(PERCEPTION/PRODUCTION)

EXECUTIVE FUNCTION / INTENTION

WORKING MEMORY

HOLD / MANIPULATE

ATTENTION / AROUSAL

ORTHOGRAPHIC REPRESENTATION
ARTICULATORY REPRESENTATION
PHONOLOGIC REPRESENTATION
PROSODIC REPRESENTATION
MORPHOSYNTACTIC REPRESENTATION

SEMANTIC/LEXICAL REPRESENTATION
PHONICS RULES
SYNTACTIC REPRESENTATION

(Alexander, 2006)
Theory


“The inability to associate the position of their articulators with speech sounds may impair the development of phonological awareness and the ability to convert graphemes to phonemes. Unawareness of their articulators may be related to programming or feedback deficits.”
Interdisciplinary Team for Assessment & Treatment

Disciplines:

- Neuropsychology
- Psychiatry
- Nursing/Nurse Practitioner
- Clinical Psychology
- Occupational Therapy
- Speech-Language Pathology
- Education
Multidisciplinary vs Interdisciplinary

- Multidisciplinary – more than one discipline individually evaluates and treats
  - Each discipline retains its methodologies and assumptions, without change or development from other disciplines
  - Cooperation may be mutual and cumulative, but is not interactive

- Interdisciplinary – several disciplines evaluate and treat together
  - Each discipline is trained in some tenets of the other disciplines
  - Shared theoretical models that integrate perspectives from several disciplines
  - Blends the practices and assumptions of each discipline involved
Case Study

- High school student
- History of dyslexia since elementary school
- Parent is a school teacher
- Years of school-based academic intervention and specialized tutoring at franchised centers...
- Starting athlete with scholarship potential, but he has body function and academic deficits in...
Case Study - Assessment Findings

Deficits in:
- **Attention**
  - ADHD-Inattentive
- **Language**
  - Phonological
  - Reading
  - Writing
  - Spelling
  - Written comprehension
  - Expression

- **Sensory Processing Disorder**
  - Visual vigilance
  - Visual tracking
  - Vestibular
  - Visual perceptual
  - “Low Registration” on Sensory Profile
  - Poor balance with eyes closed
  - Poor supine flexion
Case Study: Interdisciplinary Treatments

Psychology:
- Individual therapy
- Therapy with mother

Speech-Language:
- Phonological Awareness (LiPS Program®)
- Mental Imagery (Visualizing & Verbalizing®)
- Written Composition (Visual-Kinesthetic Sentence Structure)

OT w/ SI focus:
- Sensory modulation & processing - esp. vestibular
- Oculomotor skills
- Joint stability
- Visual perceptual skills
- Balance
- Movement perception
- Sequencing
**Case Study:**
**Interdisciplinary Treatment of Dyslexia**

**Treatment Schedule:**
- Daily
- 4-6 hours treatment per day
  - ~1 hour of OT-SI
  - ~3-5 hours language
- 5 days per week
- ~12 weeks

**Treatment Hours:**
- Phonological/Cognitive: ~150 (neurodevelopmental LiPS®)
- Semantic/Memory (V/V®): ~50
- Syntax/Cognitive (VKSS): ~50
- Physical Medicine (OT-SI): ~45.
Sensory Processing Disorder (SPD)

- “...difficulty taking in and interpreting sensory information so that an appropriate response can be generated.” (Bialer & Miller, 2011, pg 20)
Treatment of SPD

- “So, to be able to design and implement helpful treatment activities for kids with sensory challenges, it is important on a behavioral level to have some understanding about how sensory input either supports or challenges a child.” (Bialer & Miller, 2011, pg.20)
Body Functions:
Visual-Motor Integration (VMI)

IQ = 101

Pre and Post scores for Visual-Motor Integration and Motor Coordination.
Body Functions:
Test of Visual Processing Skills-3

Scaled score

Visual Discrimination: Pre 14, Post 13
Visual Memory: Pre 13, Post 12
Spatial Relationships: Pre 11, Post 10
Form Constancy: Pre 15, Post 14
Sequential Memory: Pre 10, Post 9
Figure Ground: Pre 8, Post 7
Visual Closure: Pre 9, Post 8

IQ=101
Body Functions:
Comprehensive Test of Phonological Processing (CTOPP)

IQ = 101

Standard score
Phonological Awareness | Alternate Phonological Awareness
Improved Body Functions

- **Sensory Processing** – “Low registration” was improved with OT-SI, medication and arousal strategies for use at home and school.

- **Processing/ Modulation of Vestibular Information** - R & L LE balance without vision = 4 and 7 secs, improved to 21 and 18 secs; impaired supine flexion improved to 90 seconds while counting (without holding shoulders); depressed post rotary nystagmus was improved

- **Oculomotor Skills** - losing his place during reading and poor visual endurance (blinked excessively during visual tasks/testing), both visual tracking and endurance were improved and excessive blinking was markedly decreased

- **Visual Perception** - TVPS=83 SS (below average) to TVPS=110 (high average)

- **Graphomotor Skills** - VMI Motor Coordination = 75 SS improved to 89

- **Oral Motor Skills** - trouble with his oral-motor “feeling” was improved
Academic Functions:
WECHSLER INDIVIDUAL ACHIEVEMENT TEST (WIAT-II)

- Pseudoword Decoding
- Word Reading
- Reading Comprehension
- Written Expression

Standard score

Pre  Post
Conclusions and Future Directions

Participant01 Demonstrated:

- Improved Body Functions,
- Improved Academic Functions
- Improved School Performance
  - passed high school proficiency tests (including written exam)
  - earned a standard high school diploma
- Follow-up report: He has completed his first year of college
Future Directions:

- More “Single-Subject Research Design” and RCT studies need to be published to document the specific impact of OT-SI treatment on body functions and academic functions for children with LD’s.

- OT is an essential part of an interdisciplinary assessment and treatment for children and young adults with LD’s, but more empirical data is needed.
Future Perspectives: Interdisciplinary Treatment

Complimentary Interventions (adapted from Doreit & Miller, 2011)

- Language
- Sensory processing/integration
- Interpersonal relationships
- Social engagement
- Auditory processing
- Cognitive behavioral strategies
- Regulating mood/affect
- Executive functioning
- Academic performance
- Parent & client education/training
Thank You

Questions & Comments

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Human Sensory Systems

- Visual
- Gustatory
- Olfactory
- Auditory
- Tactile

Also:
- Vestibular – movement of the head in relation to gravity
- Proprioception – pressure in the muscles and joints
- Interoception – awareness of body organs, hunger, thirst...
Reading Pseudo words

Front

Pre-Treatment

Post-Treatment