

State of the Art in CAS Diagnostic Marker Research

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Thesis

Conclusive behavioral markers of Childhood Apraxia of Speech will be both theoretically and clinically informative if developed within integrative genomic, neurodevelopmental, and speech processes frameworks in the cognitive neurosciences and pediatric speech sciences.

Topics

Diagnostic Marker Research In CAS

- ❑ Premises
- ❑ An Integrative Framework
- ❑ Some Recent Findings
- ❑ Conclusions

Some Classification Terms

Adjective

Behavioral

Clinical

Core

Diagnostic

Research

Noun

Characteristic(s)

Feature(s)

Marker(s)

Phenotype(s)

Sign(s)

- ❑ Optional adjective with any noun
- ❑ Inconsistent literature definitions and use of the 10 terms
- ❑ This paper:

‘Diagnostic Marker’: Positive status on a criterion
number of ‘signs’

Premise 1

There Is Currently No Conclusive, Lifespan Assessment Protocol for Classification of CAS

“It is the policy of ASHA that the diagnosis and treatment of CAS are the proper purview of certified speech-language pathologists. . . It is the certified speech-language pathologist who is responsible for making the primary diagnosis of CAS. . .” (ASHA, 2007a; p.2)

- ❑ **‘Conclusive’** diagnostic markers in clinical speech pathology require positive and negative likelihood ratios of > 10 and $< .10$, respectively (i.e., $>90\%$ sensitivity/specificity) (Dollaghan, 2007)
- ❑ **‘Lifespan’** measures of CAS require diagnostic accuracy and psychometric stability for individuals with active, persistent, and partially to perhaps near fully normalized CAS
- ❑ **‘Assessment Protocols for Classification of CAS’** require information in many domains supplementary to direct speech assessment (e.g., family genetic history, speech history, treatment history, motor speech examination)
- ❑ **Over-diagnosis of CAS** continues worldwide, with published and informal estimates of approximately 50% - 95% in clinical and research contexts

Premise 2

There Are Currently No Programmatic Diagnostic Marker Findings in CAS to Review

Research Goals in CAS

- ❑ Identify one or more **conclusive diagnostic markers** to discriminate CAS from Speech Delay, CAS from the dysarthrias, and CAS from a putative motor speech disorder we term Motor Speech Disorder-Not Otherwise Specified
- ❑ Identify **genomic origins**
- ❑ Identify **neuroanatomical and neurophysiological** substrates
- ❑ Identify one or more **neurobiological marker(s)** of active, persistent, and normalized CAS
- ❑ Identify **preventive** and optimal **treatment** approaches

Premise 2

There Are Currently No Programmatic Diagnostic Marker Findings in CAS to Review

Challenges in Programmatic Diagnostic Marker Research in CAS

- ❑ Identify a 'gold standard' to validate speech classification status
- ❑ Select and organize candidate signs
- ❑ Operationalize methods for data acquisition, data reduction, and data analyses
- ❑ Standardize criteria for a positive marker using a reference database that allows for both chronological and mental age standardization
- ❑ Computerize as many of the data acquisition, data reduction, and data analyses methods as possible
- ❑ Administer protocol to a large number of sociodemographically diverse speakers who have CAS in idiopathic, neurogenetic, neurological, and complex neurodevelopmental contexts
- ❑ Obtain evidenced-based statistics required for a conclusive diagnostic marker that discriminates CAS from all other speech sound disorders

Premise 2

There Are Currently No Programmatic Diagnostic Marker Findings in CAS to Review

Current Sources for Diagnostic Markers of CAS

☐ Checklists

- Adaptations of signs and marker criteria from the adult AOS literature
- Signs and marker criteria in CAS dating from approximately the 1950s

☐ Reports and Conference Sessions

- 2002 CASANA Conference Report
- Technical sessions at Nijmegen, Motor Speech, ASHA, other conferences
- 2007 ASHA Technical Report

☐ Diagnostic accuracy findings

- Several reports of the diagnostic accuracy of specific signs of CAS
- Several reviews of the diagnostic accuracy of CAS tests

Toward Lifespan Biomarkers for CAS^a

nature events directory

Biomarkers for Brain Disorders: Challenges and Opportunities

3rd - 5th February 2013

Organization: [Wellcome Trust](#)

Type: Conference

Venue: [Moller Centre, Churchill College, Cambridge, UK](#)

Location: [Cambridge, United Kingdom](#)

Website: [Biomarkers for Brain Disorders: Challenges and Opportunities](#)

Area: Life Sciences

Specialty: Neuroscience

Subject: Neuroscience

^aMorgan, A.T., Masterton, R., Pigdon, L., Connelly, A., & Liégeois, F.J. (2013). Functional magnetic resonance imaging of chronic dysarthric speech after childhood brain injury: reliance on a left-hemisphere compensatory network. *Brain*, 136, 646-657.

Toward Lifespan Biomarkers for CAS

The New York Times

Science

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS

ENVIRONMENT SPACE

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Obama Seeking to Boost Study of Human Brain

By JOHN MARKOFF
Published: February 17, 2013

The Obama administration is planning a decade-long scientific effort to examine the workings of the human brain and build a comprehensive map of its activity, seeking to do for the brain what the Human Genome Project did for genetics.

[Enlarge This Image](#)



Danny Moloshok/Reuters

Francis S. Collins, the director of the National Institutes of Health, one of the federal agencies involved in the project.

The project, which the administration has been looking to unveil as early as March, will include federal agencies, private foundations and teams of neuroscientists and nanoscientists in a concerted effort to advance the knowledge of the brain's billions of neurons and gain greater insights into perception, actions and, ultimately, consciousness.

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Premise 3

CAS is a Sensorimotor, Multiple Domain Disorder

‘Sensorimotor’ Disorder

□ Sensorimotor Research

- Findings in sensory and motor research support **integrated sensorimotor pathways** for speech processes
- Continued research and clinical classification of CAS as a ‘**motor speech disorder**’ likely due to hysteresis in paradigm shifts

‘Multiple Domain’ Disorder

□ *FOXP2*-CAS studies

- **Bilateral, widespread *FOXP2* expression**, including gene regulation in pathways for vision, audition, speech, language, and many other domains (e.g., Horng et al., 2009)
- **Cognitive, auditory-perceptual, language, oral motor, affective deficits; dysmorphologies; dysarthrias** (e.g., Rice et al., 2011; Tomblin et al., 2009; Zeesman, 2006)

Premise 3

CAS is a Sensorimotor, Multiple Domain Disorder

‘Multiple Domain’ Disorder

□ CAS in Idiopathic Contexts

Reports of participants suspected to have CAS support **deficits in auditory-perceptual and other processes** yielding underspecified representations (see reviews in ASHA, 2007b; Froud & Khamis-Dakwar, 2012)

□ CAS in Neurogenetic, Neurological, and Complex Neurodevelopmental Contexts

Findings from direct assessment and developmental histories of participants suspected to have CAS indicate **persistent significant deficits in encoding and memory** (Shriberg, 2010; Shriberg et al., 2012)

Premise 4

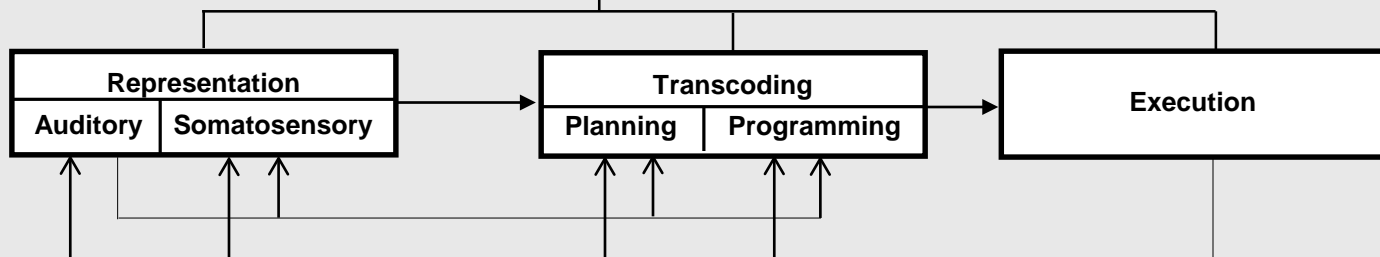
Diagnostic Signs of CAS Should Be Integrated With Their Underlying Genomic, Neurodevelopmental, and Speech Processes Substrates

I. Etiological Processes
(Distal Causes)

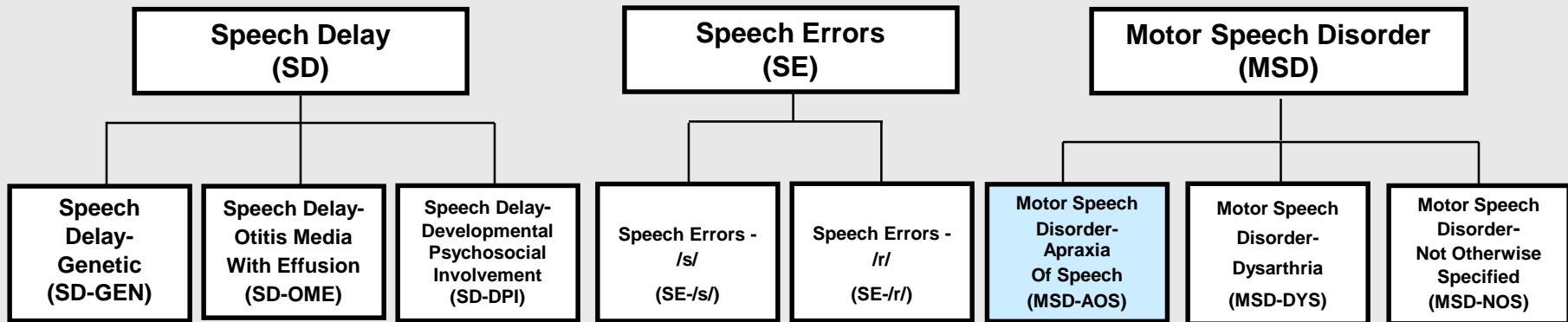
Genomic and Environmental Risk and Protective Factors

II. Speech Processes
(Proximal Causes)

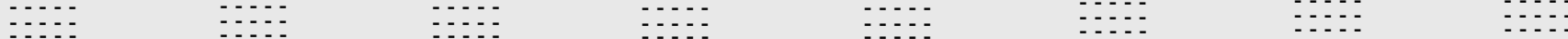
Neurodevelopmental Substrates



III. Clinical Typology
(Behavioral Phenotype)



IV. Diagnostic Markers
(Criterial Signs of Phenotype)



Premise 4

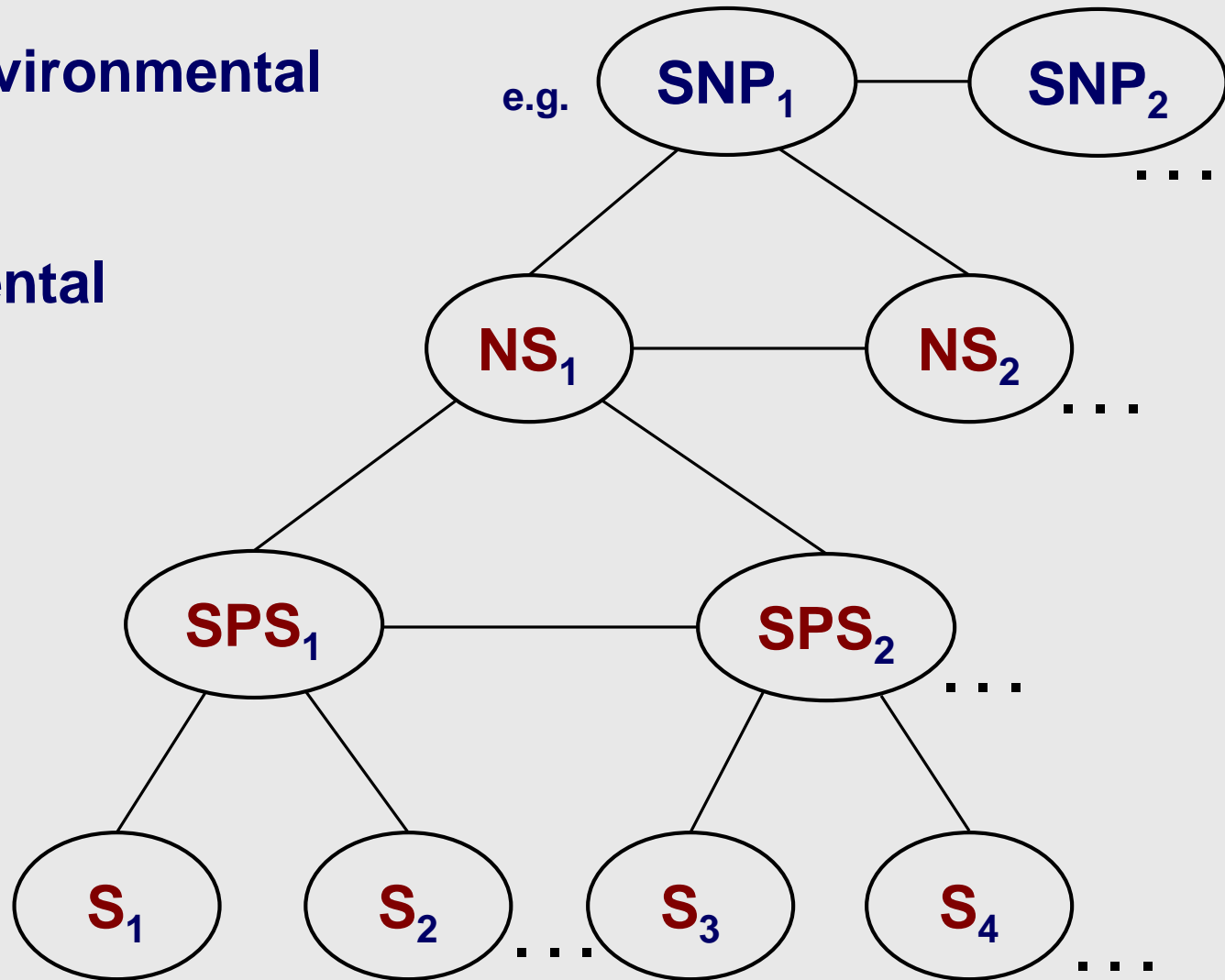
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Genomic and Environmental Substrates

Neurodevelopmental Substrates

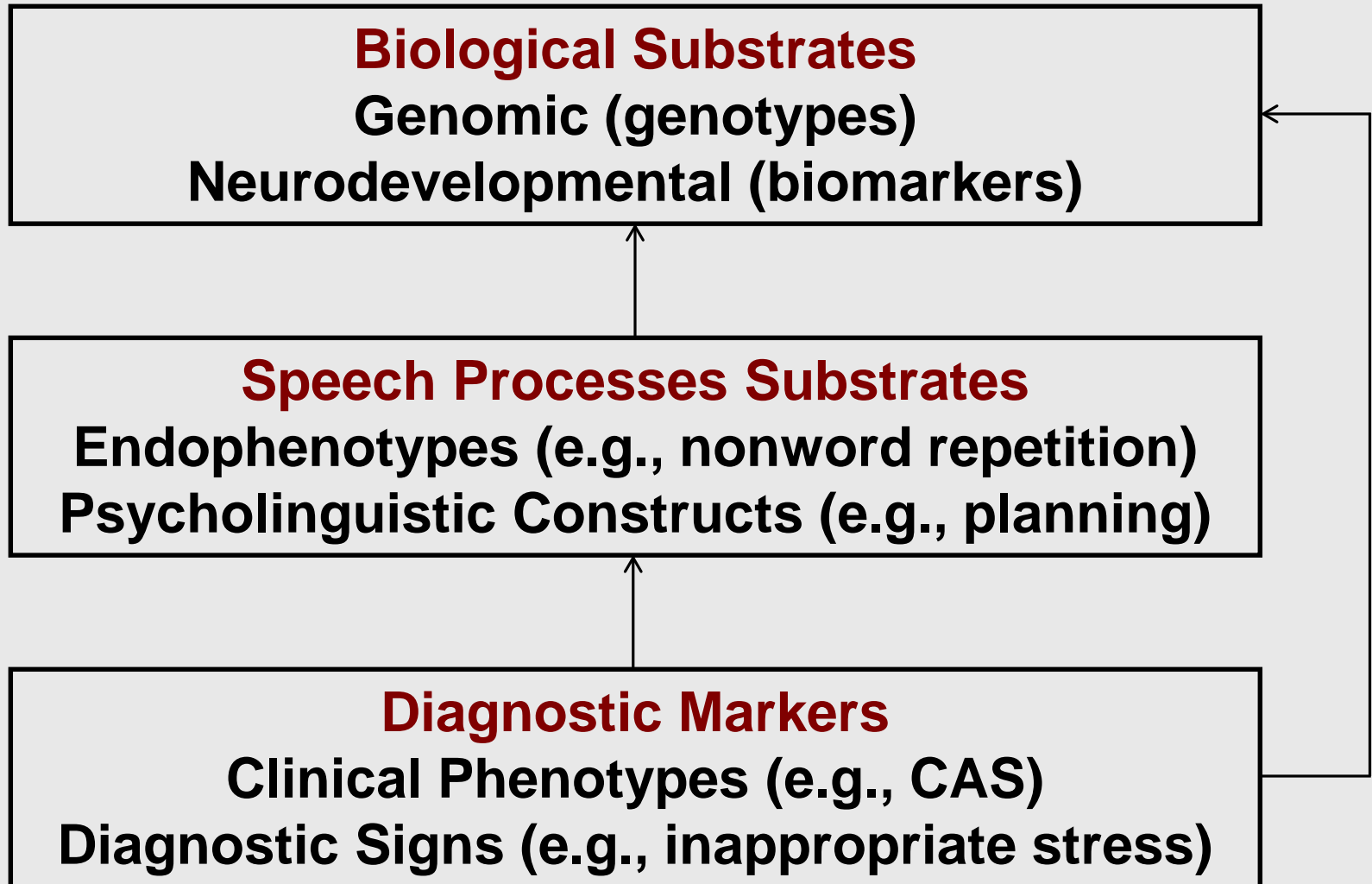
Speech Processes Substrates

CAS Signs Comprising Behavioral Marker



Premise 4

Diagnostic Signs of CAS Should Be Integrated With Their Underlying Genomic, Neurodevelopmental, and Speech Processes Substrates



Topics

Diagnostic Marker Research In CAS

- Premises
- **An Integrative Framework**
- Some Recent Findings
- Conclusions

An Integrative Framework for Diagnostic Marker Research in CAS

Goal: To Integrate CAS Signs with Explanatory Substrates

□ Dual Stream Framework

- Hickok, Poeppel, & colleagues (see References); others
- Present focus on the **ventral and dorsal substrates of speech processes** in CAS

□ Speech Processes Framework

- Incorporates common **elements from many frameworks** (Guenther, Hickok, Maassen, Levelt, Nijland, Poeppel, Terband, van de Merwe, Ziegler, others) (see References)
- Generic, emergent, and wholly **underspecified** framework

□ Diagnostic Marker of CAS

- Shriberg, Strand, Jakielski, & Lohmeier (2013)
- Currently a four-sign marker to **discriminate CAS from Speech Delay**
- Programmatic goals are to modify the marker as needed to **discriminate CAS from the dysarthrias and from MSD-NOS**

Premise 4

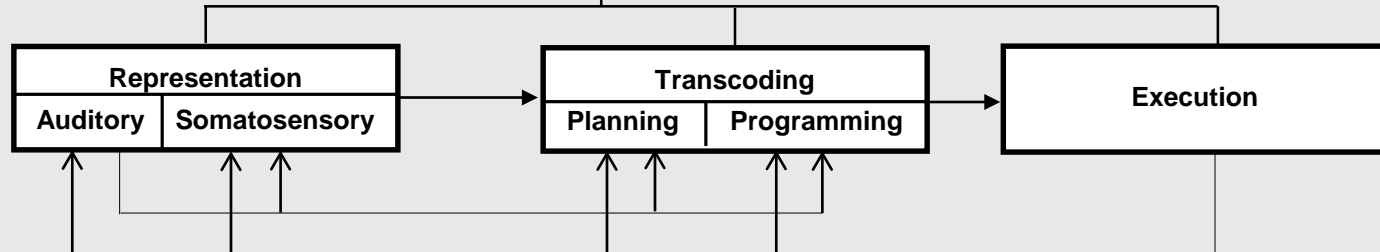
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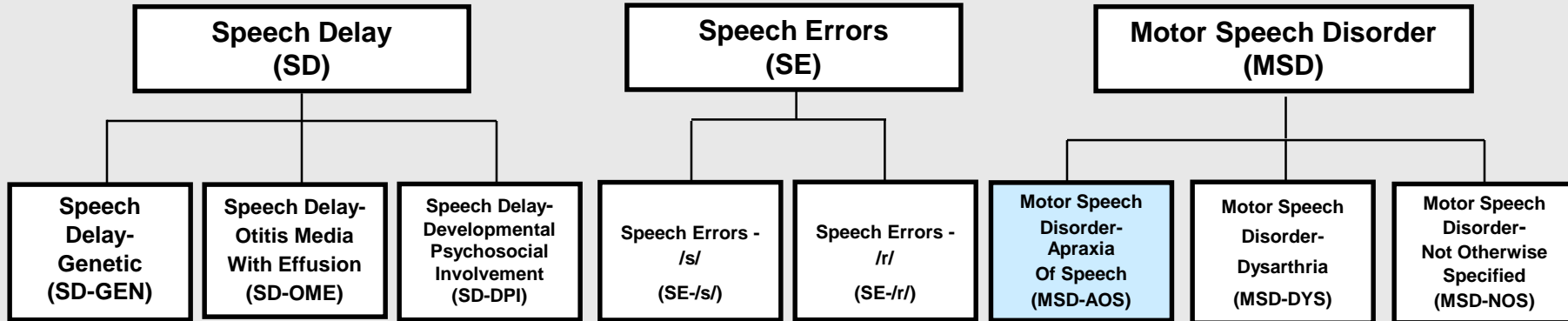
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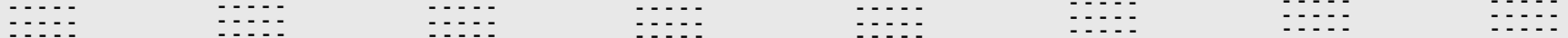
Neurodevelopmental Substrates



*III. Clinical Typology
(Behavioral Phenotype)*



*IV. Diagnostic Markers
(Critical Signs of Phenotype)*



Premise 4

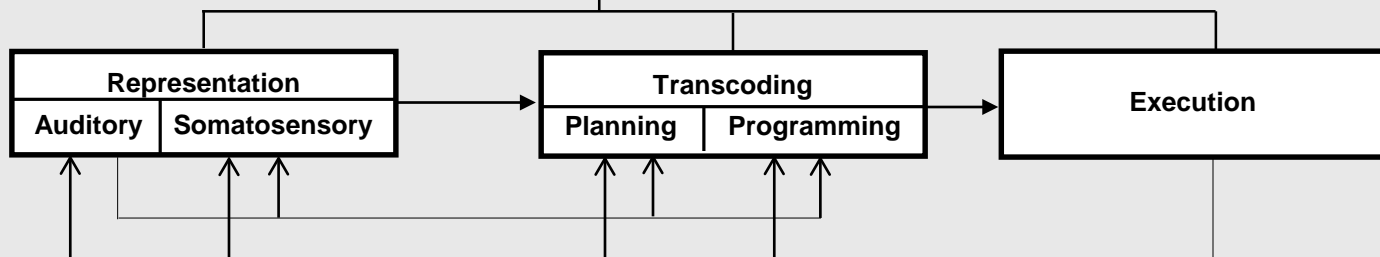
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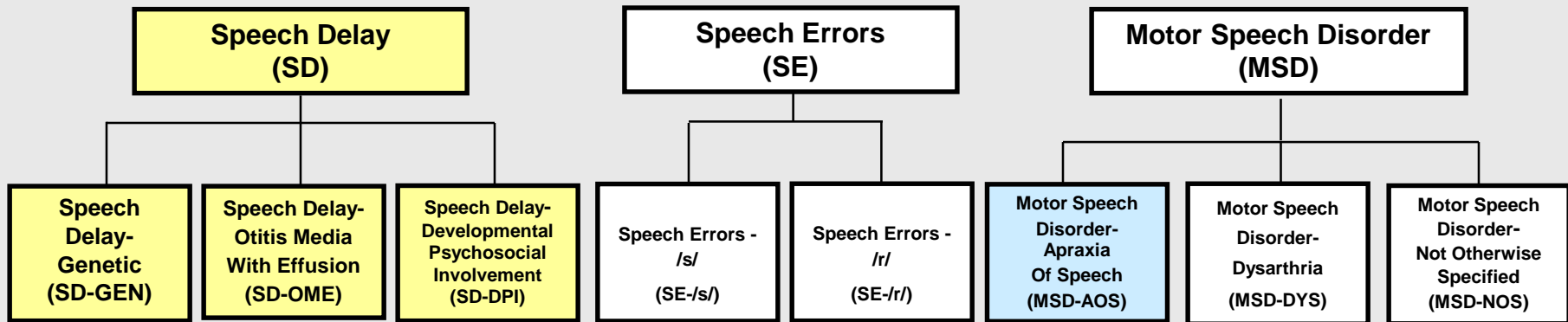
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II. Speech Processes
(Proximal Causes)

Neurodevelopmental Substrates



III. Clinical Typology
(Behavioral Phenotype)



IV. Diagnostic Markers
(Criterial Signs of Phenotype)

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Premise 4

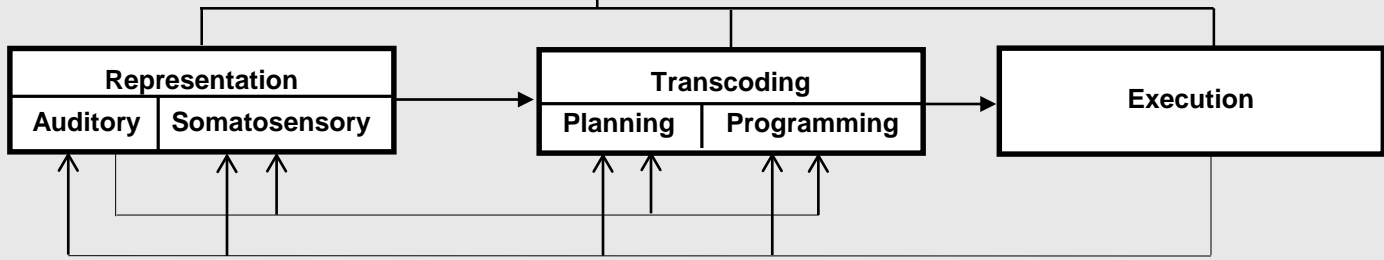
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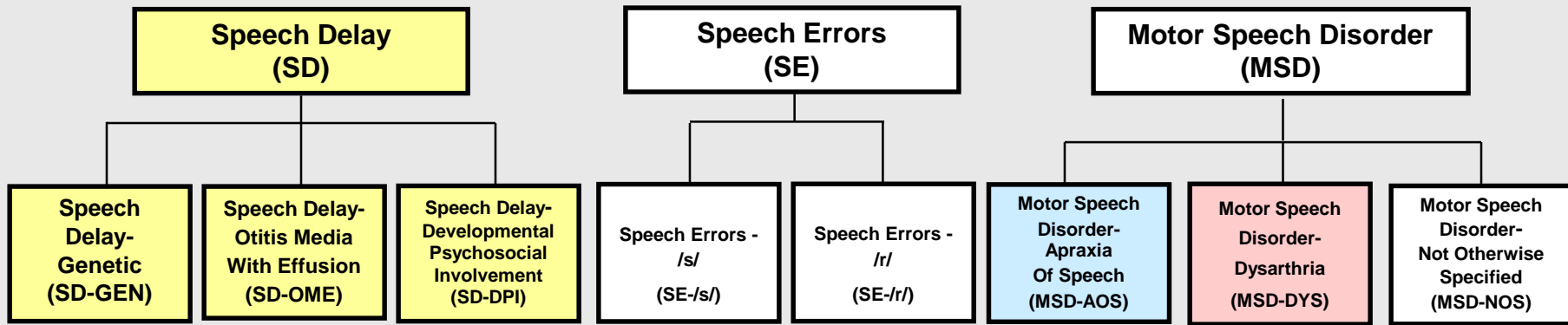
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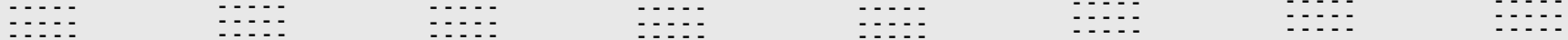
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IV. Diagnostic Markers
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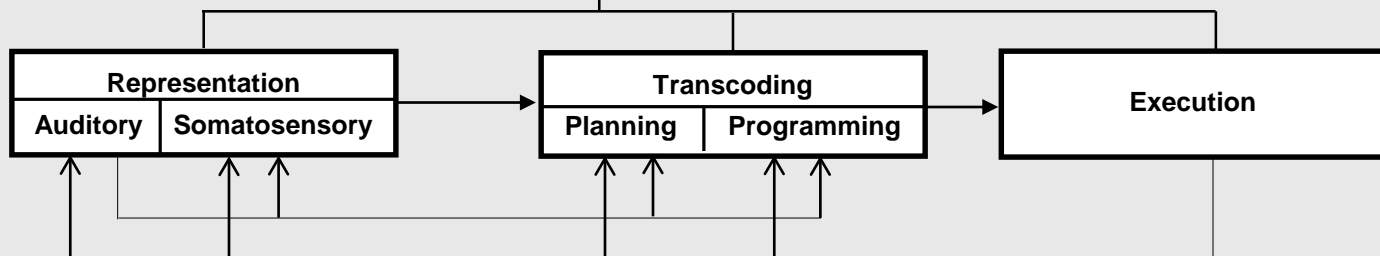
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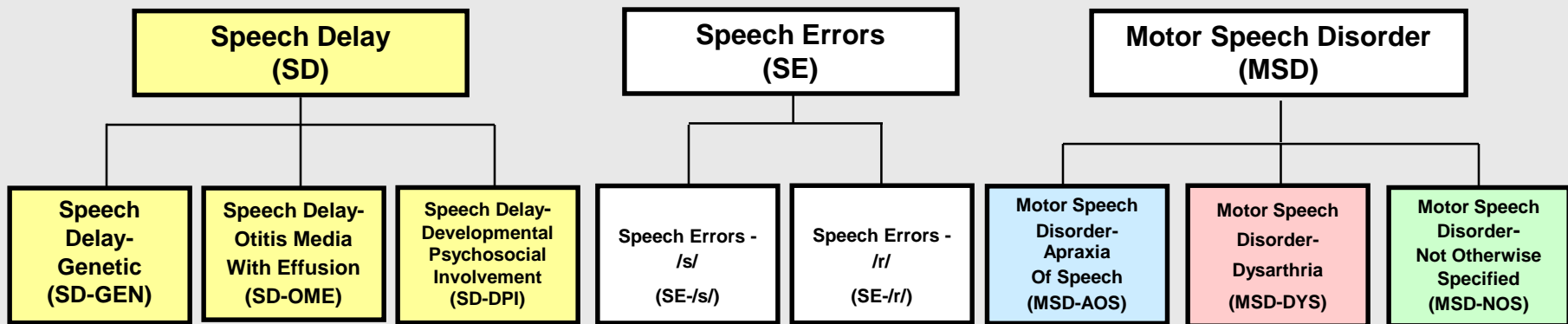
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II. Speech Processes
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Neurodevelopmental Substrates



III. Clinical Typology
(Behavioral Phenotype)



IV. Diagnostic Markers
(Criterial Signs of Phenotype)

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An Integrative Framework for Diagnostic Marker Research in CAS

Some Contrastive Neurodevelopmental Concepts in the Dual Stream Framework

Ventral Stream

Earlier Ontogeny

Auditory

Perception

Phonemic

Semantic, Syntactic

Instantiated

Dorsal Stream

Later Ontogeny

Somatosensory

Production

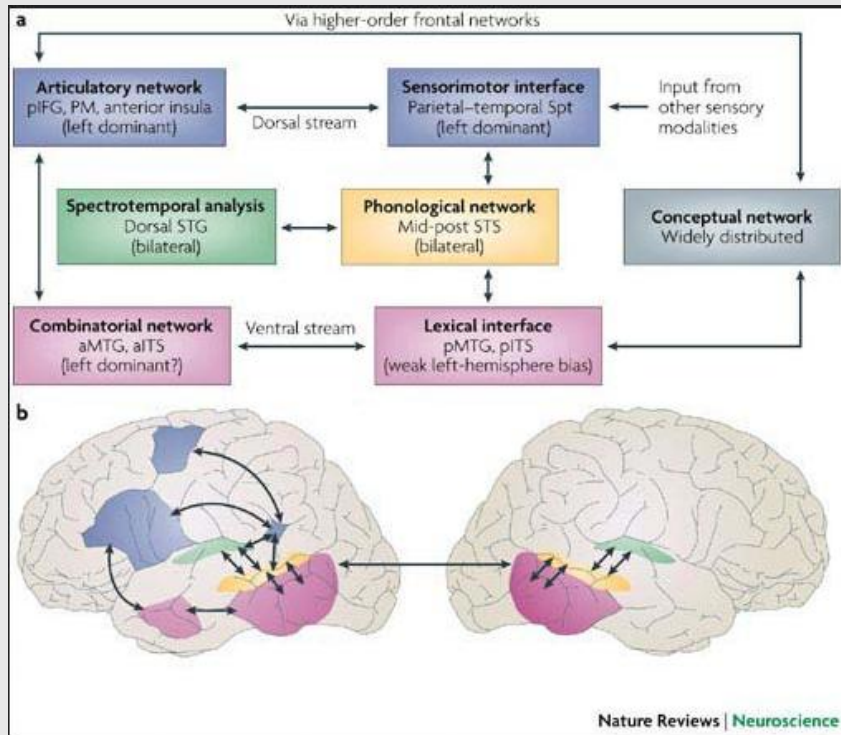
Phonetic

Articulatory

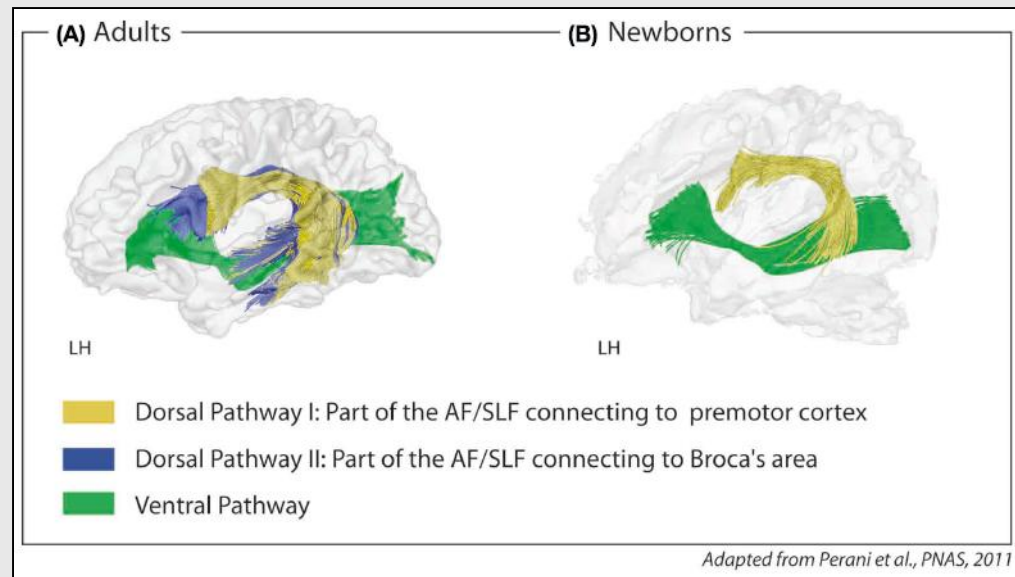
Novel

An Integrative Framework for Diagnostic Marker Research in CAS

Dual Stream Framework



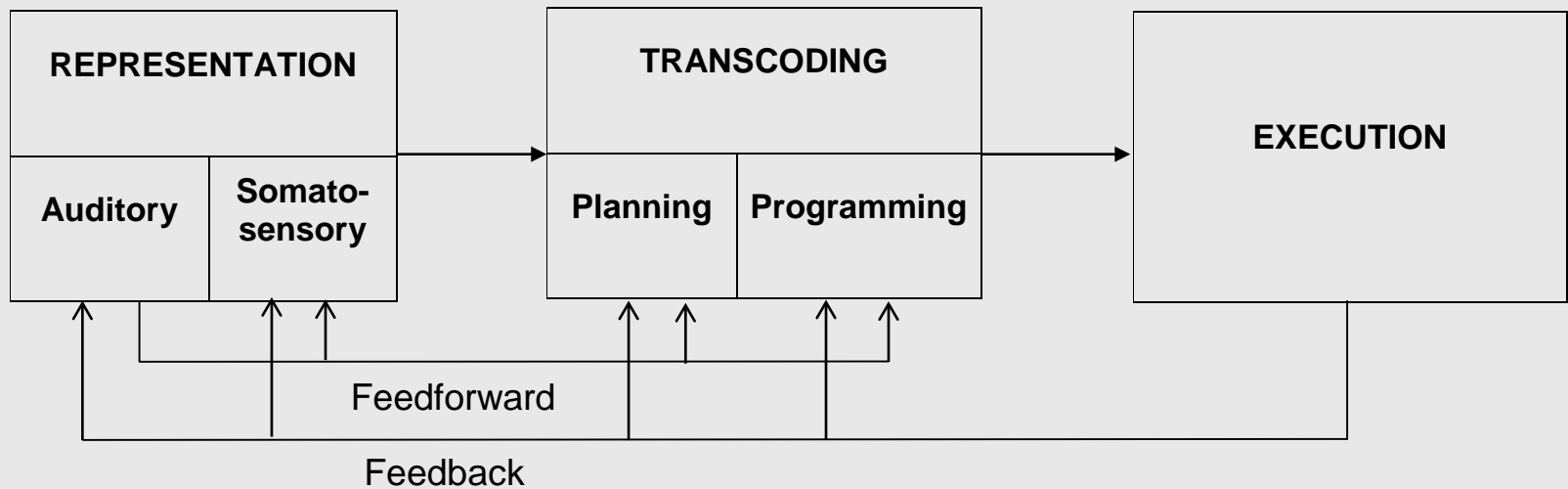
Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience*, 8, 393-402.



Friederici, A. D. (2012). Language development and the ontogeny of the dorsal pathway. *Frontiers in Evolutionary Neuroscience*, 4, 1-7. Adapted from Perani, D., Saccuman, M. C., Scifo, P., Anwander, A., Spada, D., Baldoli, C., Poloniato, A., Lohmann, G. & Friederici, A. D. (2011). Neural language networks at birth. *Proceedings of the National Academy of Sciences*, 108, 16056-16061.

An Integrative Framework for Diagnostic Marker Research in CAS

**A Speech Processes Framework
(Generic, Emergent, *Underspecified)**



An Integrative Framework for Diagnostic Marker Research in CAS

A Four-Sign Diagnostic Marker to Discriminate CAS from Speech Delay^a

	Word 1	Word 2	etc.
Prosodic Signs			
Inappropriate Pauses	— ↓ —	↓ —	...
Slow Articulatory Rate	<—>	—	...
Inappropriate Stress	↕↕↔	—	...
Segmental Sign			
Inaccurate Transcoding	— + —	—	...

^aMetric, methods, and findings for each sign in next section.

An Integrative Framework for Diagnostic Marker Research in CAS^a

Speculative Integration of a Diagnostic Marker of CAS with the Dual Stream and Speech Processes Frameworks

Dual Stream Framework		Speech Processes Framework	Four-Sign CAS Marker			
Ventral	Dorsal		Rate	Pauses	Stress	Transcoding
X		Representation	X	X	X	X
X		Planning	X	X	X	X
X	X	Programming	X	X	X	
X	X	Feedforward	X	X	X	
	X	Execution	X			
X	X	Feedback	X			

^a Speculative associations between the Dual Stream and Speech Processes frameworks based primarily on proposals, findings and discussion in Hickok, Poeppel, and colleagues (see References)

Some Proposed Associations Between Frameworks and Signs

Speculative Integration of the Dual Stream and Speech Processes Frameworks

Dual Stream Framework		Speech Processes Framework
Ventral	Dorsal	
X		Representation
X		Planning
X	X	Programming
X	X	Feedforward
	X	Execution
X	X	Feedback

- ❑ Pathways in the **ventral** stream underlie speech **Representation** and **Planning** processes
- ❑ Pathways in both **ventral** and **dorsal** streams underlie speech **Programming**, **Feedforward**, and **Feedback** processes
- ❑ Pathways in the **dorsal** stream underlie speech **Execution** processes

Some Proposed Associations Between Frameworks and Signs

Speech Processes Framework	Four-Sign CAS Marker			
	Rate	Pauses	Stress	Transcoding
Representation	X	X	X	X
Planning	X	X	X	X
Programming	X	X	X	
Feedforward	X	X	X	
Execution	X			
Feedback	X			

- ❑ **Slow Articulatory Rate** is speculated to reflect deficits in **any/all six** speech processes (ventral/dorsal)
- ❑ **Inappropriate Pauses and Inappropriate Stress** are speculated to reflect deficits in **Representation, Planning, Programming, and/or Feedforward** processes (ventral/dorsal)
- ❑ **Inaccurate Transcoding** is speculated to reflect deficits in **Representation and/or Planning** processes (ventral)

An Integrative Framework for Diagnostic Marker Research in CAS

Deconstruct CAS Phenotypes to Test Genotype, Neural Phenotype, and Speech Processes Hypotheses

Genomic Substrates	Neurodevelopmental Substrates		Speech Processes Substrates	Behavioral Phenotype			
Systems Biology	Dual Stream Framework		Speech Processes Framework	Four-Sign CAS Marker			
	Ventral	Dorsal		Rate	Pauses	Stress	Transcoding
	X		Representation	X	X	X	X
	X		Planning	X	X	X	X
	X	X	Programming	X	X	X	
	X	X	Feedforward	X	X	X	
		X	Execution	X			
	X	X	Feedback	X			

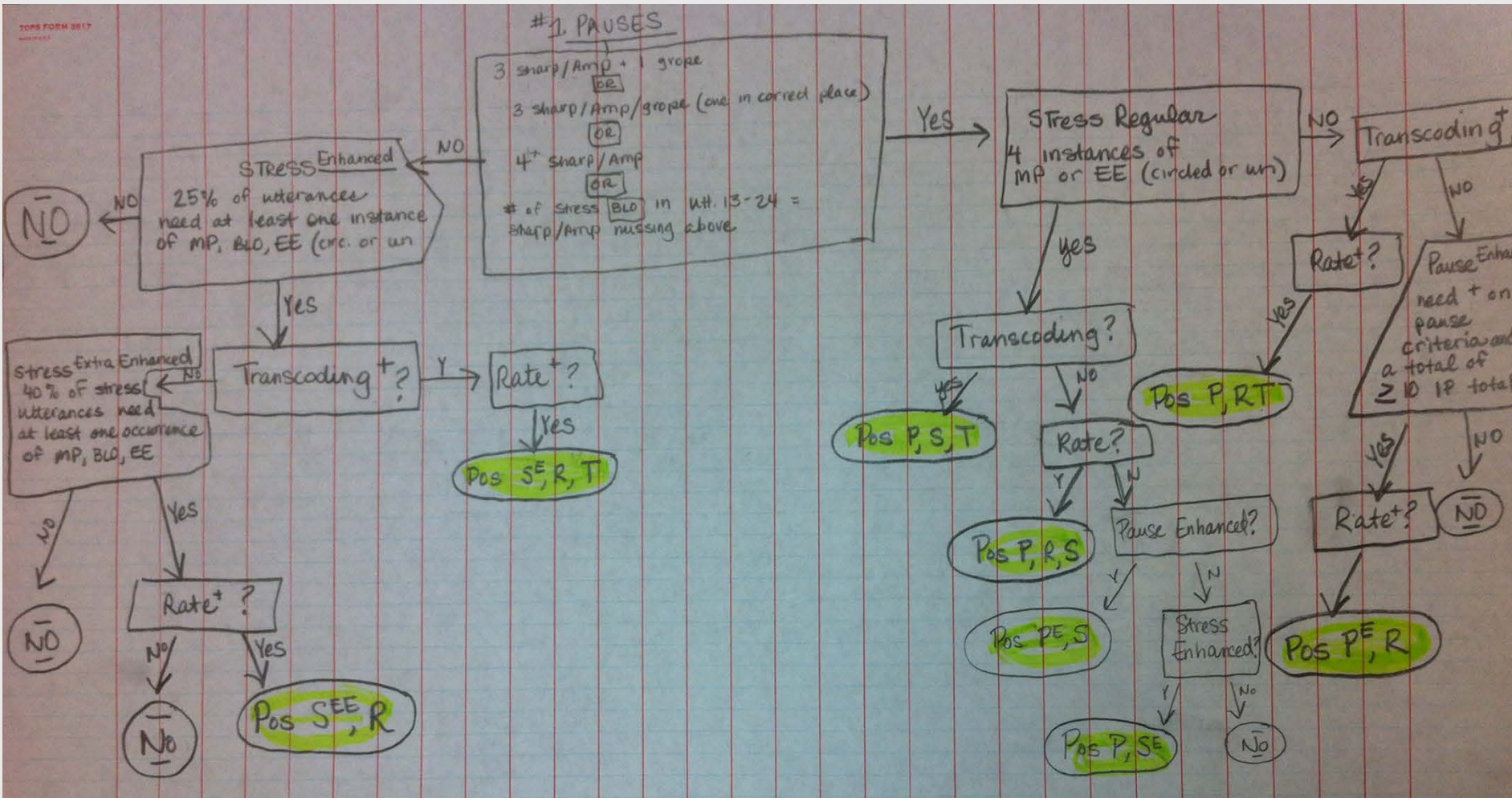
Topics

Diagnostic Marker Research In CAS

- ❑ Premises
- ❑ An Integrative Framework
- ❑ Some Recent Findings**
- ❑ Conclusions

Some Recent Findings

'Old School' Algorithm Development^a



Some Recent Findings

Prior Promising Diagnostic Signs of CAS^a

Linguistic Domains	Precision	Stability
Segmental		
Vowels/Diphthongs	Reduced Vowel Space Reduced Vowel Substitution Coefficients Increased Distorted Vowel Substitutions Less Precise Diphthongs	Less Stable F1 Less Stable Vowel Duration
Consonants	Increased % of /j/ Deletions in Clusters Reduced SRT Transcoding Scores	Less Stable Sibilant Centroids
Suprasegmental		
Phrasing	Increased % of Pauses Increased % of Inappropriate Pauses	
Rate	Slower Speaking Rate Slower Articulation Rate	
Resonance Quality	Lowered F2: High Vowels (Nasopharyngeal)	Less Stable F2: High Vowels (Nasopharyngeal)

^a**Bolded signs use acoustic methods**

Some Recent Findings

Participants ($n=500$) in a Four-Sign CAS Marker Study

Group	<i>n</i>	Age (yrs)			% Males	Percentage of Consonants Correct (PCC)	
		<i>M</i>	SD	Range		<i>M</i>	SD
Speech Delay (SD)							
Clinic Cohort	89	4.3	1.3	3 – 9	73.0	72.4	12.9
Research Cohort	22	5.5	0.6	5 – 7	72.7	81.8	7.3
Research Cohort	84	3.9	0.7	3 – 5	71.4	69.6	9.8
Research Cohort	29	4.5	0.9	3 – 7	48.3	68.8	11.4
Total	224	4.3	1.1	3 – 9	69.2	71.8	11.7
Childhood Apraxia of Speech (CAS)							
Suspected CAS	50	7.7	3.2	3 – 15	78.0	75.4	13.3
Idiopathic CAS	20	8.7	4.3	4 – 19	50.0	71.5	13.2
Neurogenetic CAS	13	15.8	11.4	8 – 50	46.2	78.7	10.6
Total	83	9.3	6.1	3 – 50	66.3	74.5	13.5
Apraxia of Speech (AOS)							
Research Cohort	10	62.0	11.0	50 – 82	80.0	93.9	4.0
Research Cohort	12	68.1	12.0	45 – 84	41.7	92.1	6.4
Total	22	65.3	11.7	45 – 84	59.1	92.9	5.4
Complex Neuro-developmental Disorders (CND)							
Fragile X Syndrome	30	16.1	3.1	11 – 22	100.0	93.1	3.2
Down Syndrome	29	14.4	2.0	10 – 18	69.0	81.1	7.4
Down Syndrome	17	12.9	2.8	8 – 18	29.4	75.3	9.1
Down Syndrome	4	15.8	3.1	13 – 20	100.0	73.5	13.1
Galactosemia	31	8.8	2.9	5 – 16	64.5	84.3	13.2
22q11.2 Deletion Syndrome	18	10.1	3.2	7 – 18	61.1	81.4	13.6
Autism Spectrum Disorder	42	6.0	1.2	4 – 8	78.6	92.0	5.9
Total	171	11.0	4.5	4 – 22	71.9	85.7	10.9

Some Recent Findings

Madison Speech Assessment Protocol (MSAP)^a

Four age-based, 25-task protocols:

Preschool, school-aged, adolescent, adult

Each protocol includes 15 speech tasks

- Articulation Task
- Challenging Word Tasks (2)
- Challenging Phrase Task
- Consonants Task
- Conversational Sample
- DDK Task
- Phonation Task
- Nonword Repetition Tasks (2)
- Stress Tasks (2)
- Vowel Tasks (3)

^aReference data on 150 typical speakers (Potter et al., 2012)

Some Recent Findings

A “Gold Standard”: Pediatric Adaptation of Mayo Clinic System^a

Classification of a speaker as positive for CAS (CAS+) required **at least 4** of the following 10 signs in **at least 3** of the MSAP speech tasks:

- ❑ Vowel distortions
- ❑ Difficulty achieving initial articulatory configurations or transitional movement gestures
- ❑ Equal stress; lexical or phrasal stress errors
- ❑ Distorted substitutions
- ❑ Syllable or word segregation
- ❑ Groping
- ❑ Intrusive schwa
- ❑ Voicing errors
- ❑ Slow speech rate and/or slow DDK rates
- ❑ Increased difficulty with multisyllabic words

^aShriberg, L. D., Potter, N. L., & Strand, E. A. (2011)

Some Recent Findings

Data Reduction

PEPPER Environment

Perceptual

Narrow phonetic transcription

Prosody-Voice Screening Profile

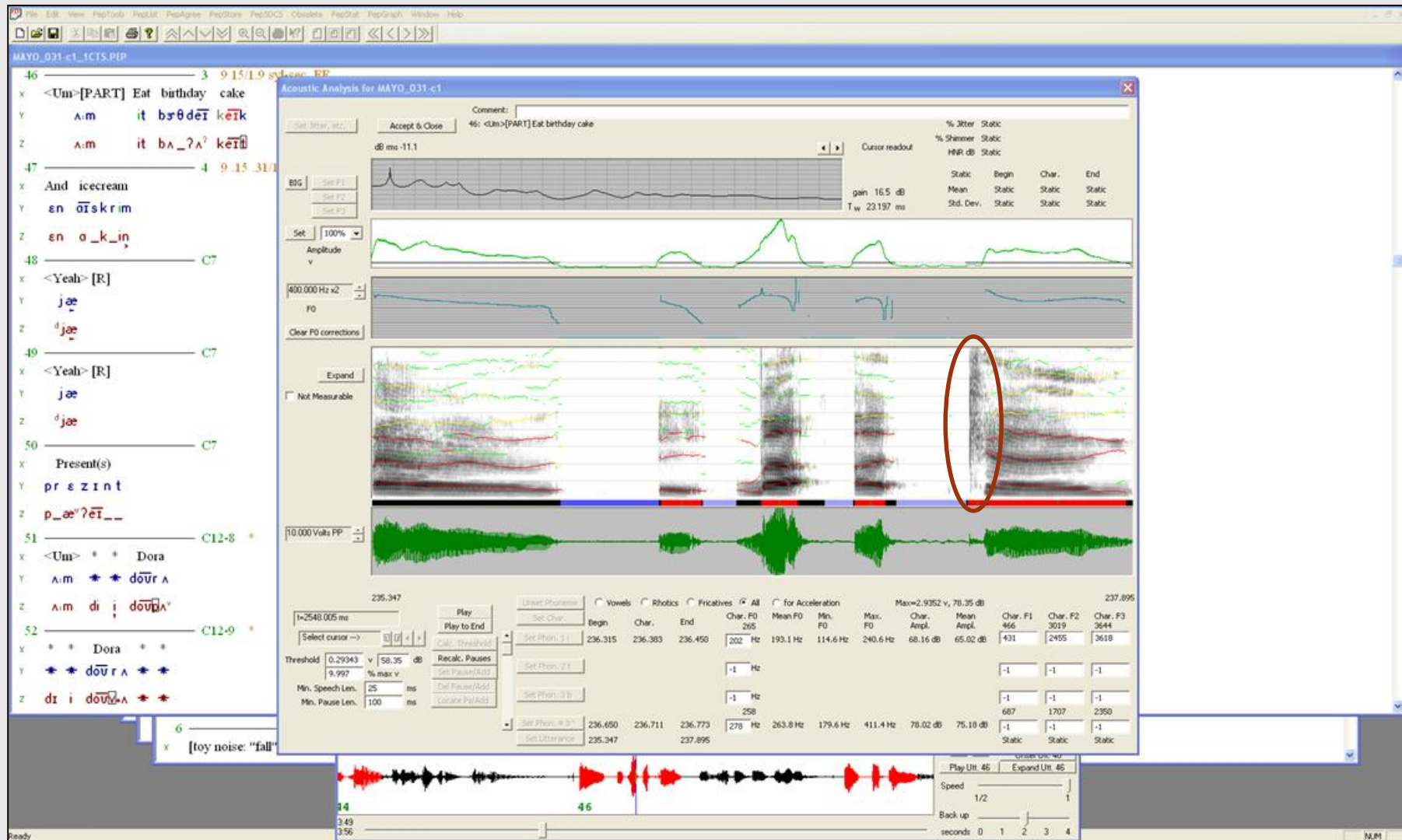
Acoustic

TF32-Active X

Automated; high throughput

Some Recent Findings

Acoustic Data Reduction



Some Recent Findings

A Four-Sign Diagnostic Marker to Discriminate CAS from Speech Delay

Classification Criterion for CAS:

Positive finding on at least three of the four signs of CAS

Sign	Finding
Inappropriate Pauses	+
Slow Articulatory Rate	+
Inappropriate Stress	+
Inaccurate Transcoding	+

Any 3 or all 4 = CAS

Some Recent Findings

Three of the Four Diagnostic Signs Are Obtained from a Conversational Sample

Inappropriate Pauses^a

- ❑ 12 utterances eligible for coding
- ❑ Coding scheme includes a subcode typology
- ❑ Perceptual and acoustic methods
- ❑ Appropriate Pauses =
$$\frac{\text{Appropriate Pauses}}{\text{Appropriate} + \text{Inappropriate Pauses}} \times 100$$

Slow Articulatory Rate^a

- ❑ Same 12 utterances as above
- ❑ Coding scheme includes an utterance length typology
- ❑ Perceptual and acoustic methods
- ❑ Rate = Syllables per second, with pause time removed

^a**Standardized (z-scores) by age and gender; positive sign = >1 standard deviation in deficit direction**

Some Recent Findings

Inappropriate Stress^a

- ❑ 24 utterances eligible for coding
- ❑ Coding scheme includes a stress code typology
- ❑ Perceptual (currently) methods

- ❑ Appropriate Stress =
$$\frac{\text{Utterances with Appropriate Stress}}{\text{All Utterances}} \times 100$$

^aDetermined using algorithm criteria for the stress codes

Some Recent Findings

The Fourth Diagnostic Sign is Obtained from the Syllable Repetition Task (SRT)^a

Sign: Inaccurate Transcoding

- | | |
|-----------|--------------|
| 1. bada | 10. dabama |
| 2. dama | 11. madaba |
| 3. bama | 12. nabada |
| 4. mada | 13. banada |
| 5. naba | 14. manaba |
| 6. daba | 15. bamadana |
| 7. nada | 16. danabama |
| 8. maba | 17. manabada |
| 9. bamana | 18. nadamaba |

^a Lohmeier & Shriberg (2011); Shriberg & Lohmeier (2008); Shriberg et al. (2009; 2012)

Some Recent Findings

Transcoding^a

Examples of Inaccurate Transcoding

<u>SRT Item</u>	<u>Homorganic Nasal</u>	<u>Heterorganic Nasal</u>	<u>Non-Nasal</u>
bada	ba <u>nda</u>	ba <u>m</u> da	
mada			ma <u>r</u> da
nabada			na <u>b</u> ay <u>d</u> a

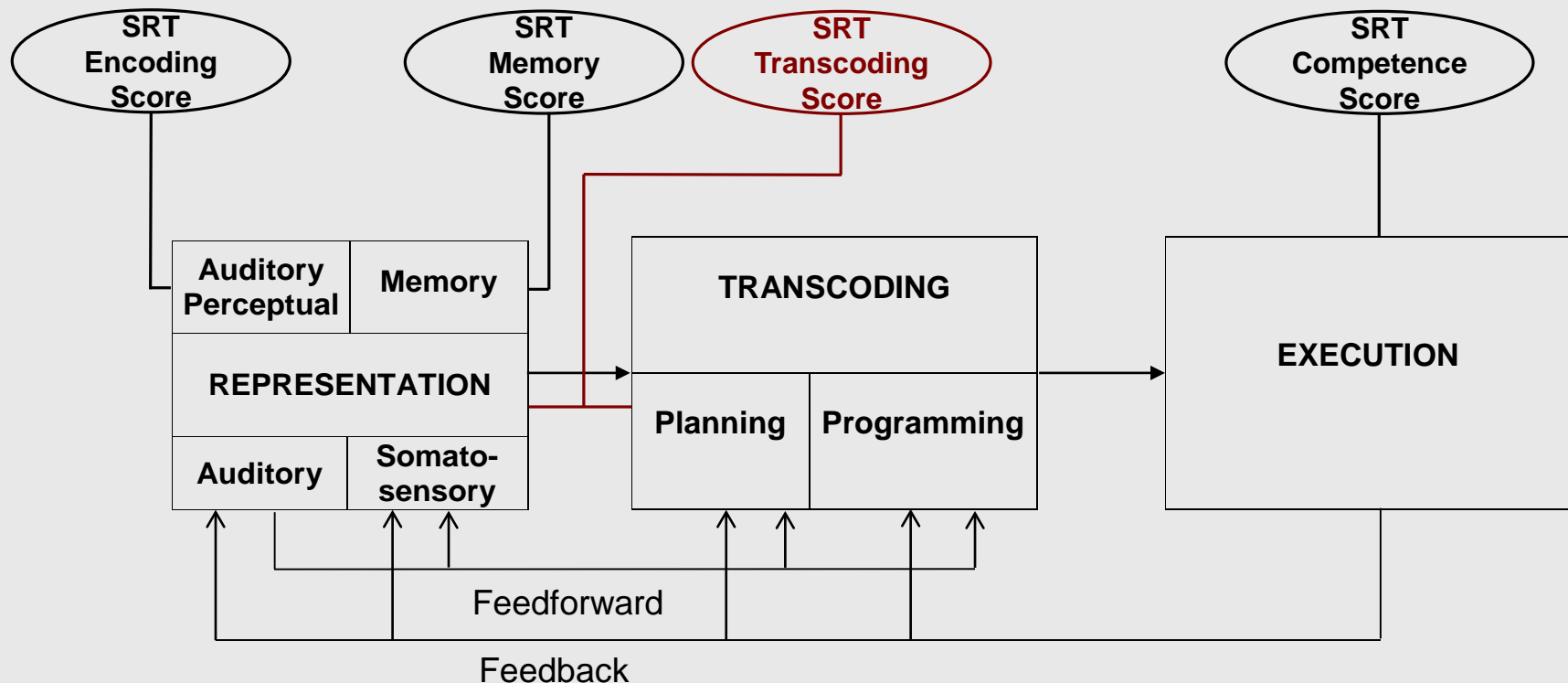
$$\text{Transcoding Percentage} = 1 - \frac{\text{No. of Additions}}{\text{No. of Eligible Stop Consonants}} \times 100$$

Inaccurate Transcoding = < 80%

^aA preceding nasal consonant was the most common addition (92% of all additions) in participants with CAS; Shriberg, Strand, Jakielski, & Lohmeier (2013)

An Integrative Framework for Diagnostic Marker Research in CAS

**A Speech Processes Framework
(Generic, Emergent, *Underspecified)**



Some Recent Findings

Diagnostic Agreement Findings (CAS or Not [Presently] CAS) Between the Madison Marker and the Mayo Clinic Marker^a

Group	Diagnostic Agreement	
	<i>n</i>	%
CAS and AOS		
Suspected CAS	29	69.0
Idiopathic CAS	19	89.5
Neurogenetic CAS	9	100.0
Research Cohort AOS	12	91.7
Total	69	82.6
Complex Neurodevelopmental Disorders		
Down Syndrome	13	30.8
Galactosemia	26	88.5
22q11.2 Deletion Syndrome	18	72.2
Fragile X Syndrome	27	96.3
Total	84	78.6
Overall Total	153	80.4

^aA total of 8 cohorts were eligible for percentage of agreement calculations

Some Recent Findings

A “Gold Standard”: Pediatric Adaptation of Mayo Clinic System^a

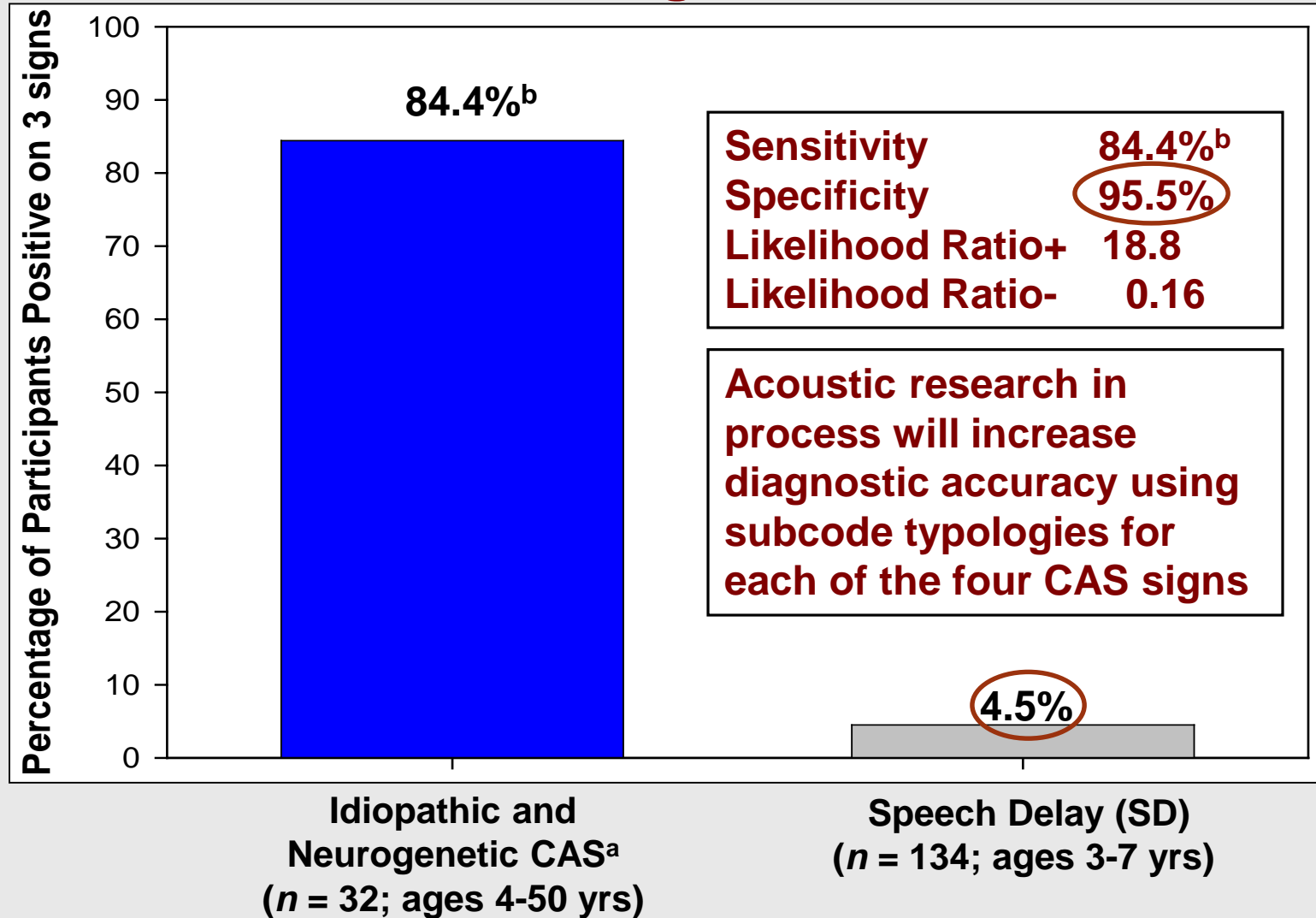
Classification of a speaker as positive for CAS (CAS+) required **at least 4** of the following 10 signs in **at least 3** of the MSAP speech tasks:

- ❑ Vowel distortions
- ❑ Difficulty achieving initial articulatory configurations or transitionary movement gestures
- ❑ **Equal stress; lexical or phrasal stress errors**
- ❑ Distorted substitutions
- ❑ **Syllable or word segregation**
- ❑ Groping
- ❑ Intrusive schwa
- ❑ Voicing errors
- ❑ **Slow speech rate and/or slow DDK rates**
- ❑ Increased difficulty with multisyllabic words*

^aShriberg, L. D., Potter, N. L., & Strand, E. A. (2011)

Results

Diagnostic Accuracy Findings for a Standardized Four-Sign Marker of CAS^a



^aVetted positive for CAS by Mayo marker and/or clinical referral information, speech histories, or treatment histories ^bIncreased to 86.7% in alternative calculation

An Integrative Framework for Diagnostic Marker Research in CAS

Deconstruct CAS Phenotypes to Test Genotype, Neural Phenotype, and Speech Processes Hypotheses

Genomic Substrates	Neurodevelopmental Substrates		Speech Processes Substrates	Behavioral Phenotype			
Systems Biology	Dual Stream Framework		Speech Processes Framework	Four-Sign CAS Marker			
	Ventral	Dorsal		Rate	Pauses	Stress	Transcoding
	X		Representation	X	X	X	X
	X		Planning	X	X	X	X
	X	X	Programming	X	X	X	
	X	X	Feedforward	X	X	X	
		X	Execution	X			
	X	X	Feedback	X			

Premise 4

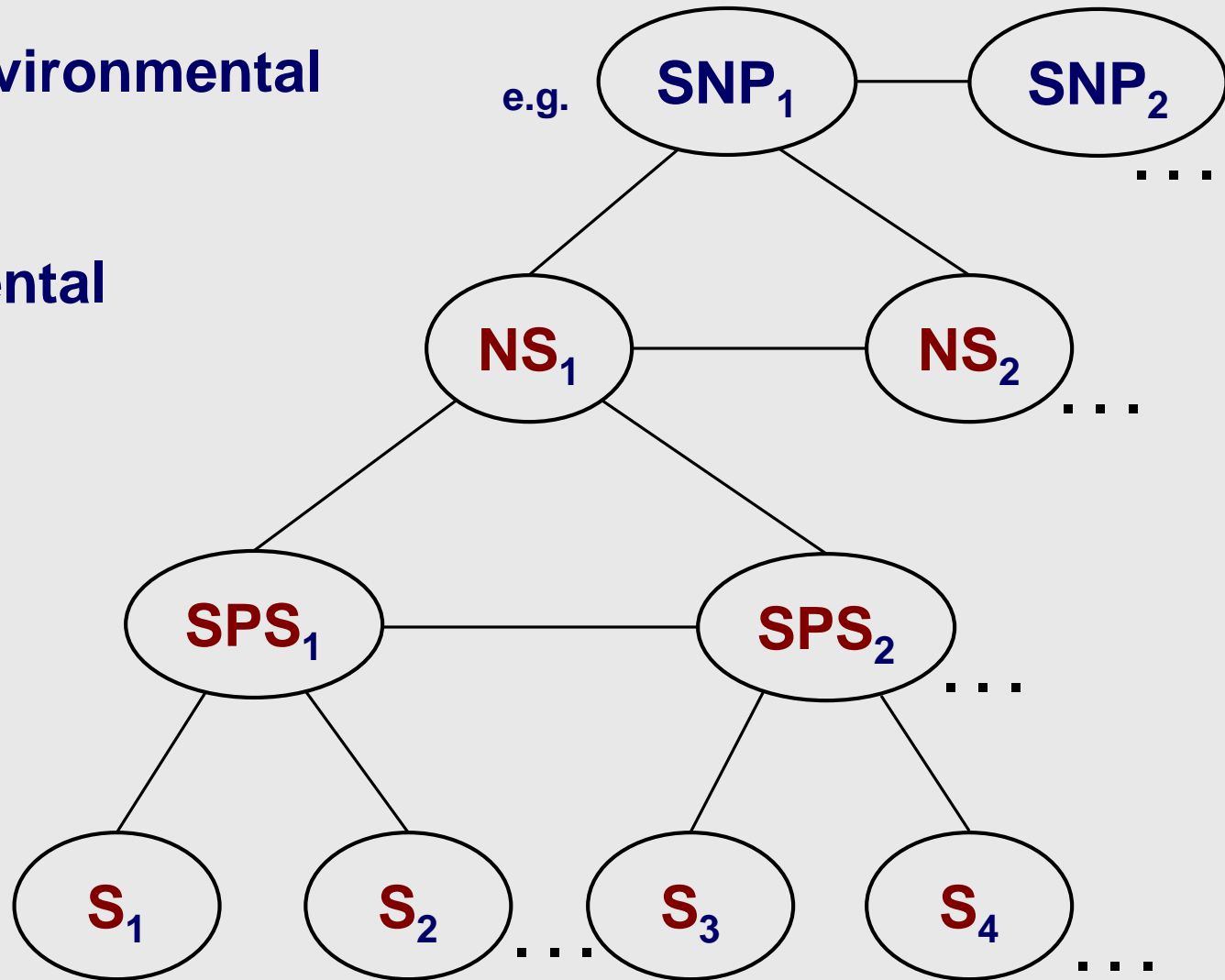
Diagnostic Signs of CAS Should Be Integrated With Their Underlying Genomic, Neurodevelopmental, and Speech Processing Substrates

Genomic and Environmental Substrates

Neurodevelopmental Substrates

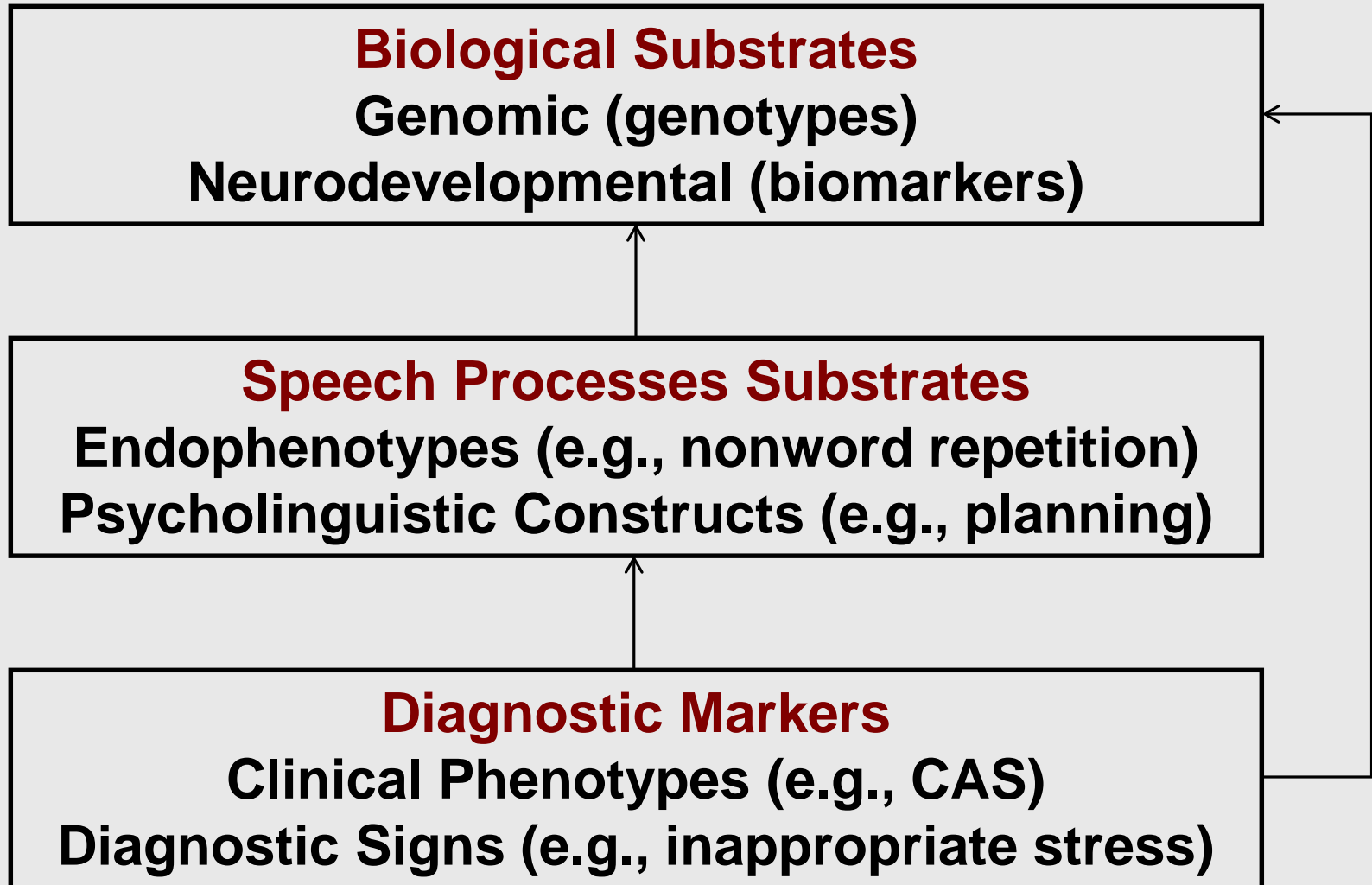
Speech Processes Substrates

CAS Signs Comprising Behavioral Marker



Premise 4

Diagnostic Signs of CAS Should Be Integrated With Their Underlying Genomic, Neurodevelopmental, and Speech Processes Substrates



Premise 4

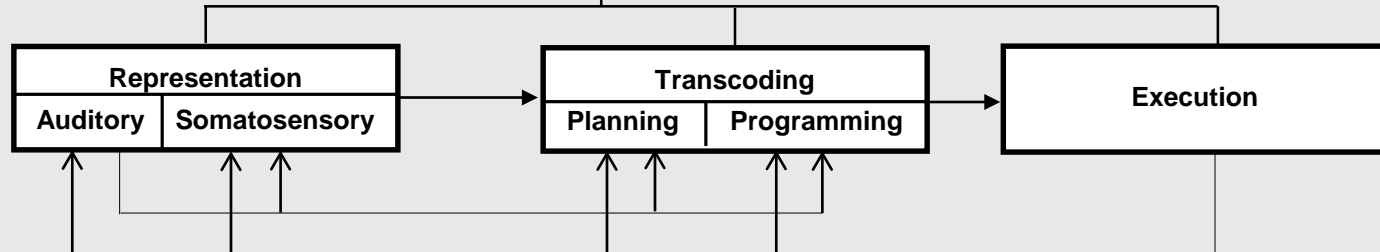
Diagnostic Signs of CAS Should Be Integrated With Their Underlying Genomic, Neurodevelopmental, and Speech Processing Substrates

I. Etiological Processes
(Distal Causes)

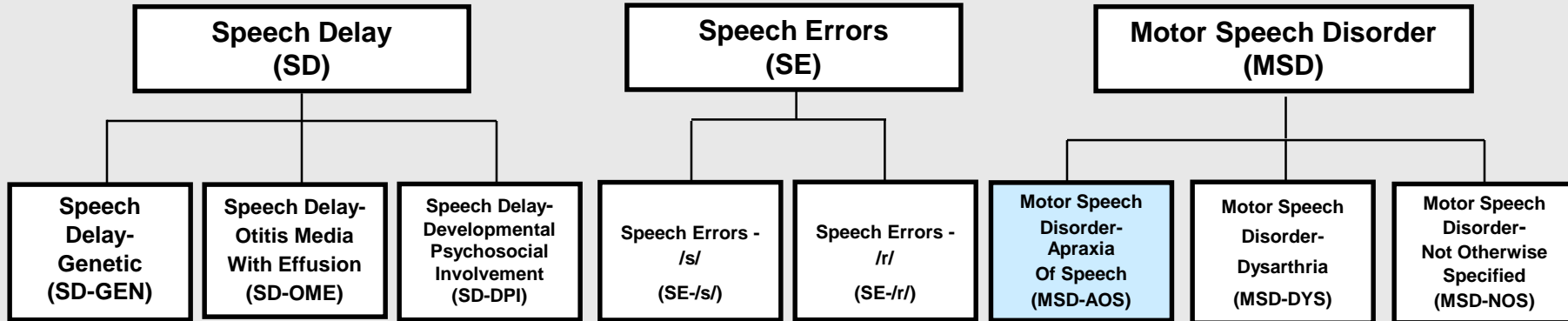
Genomic and Environmental Risk and Protective Factors

II. Speech Processes
(Proximal Causes)

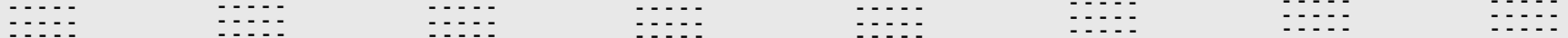
Neurodevelopmental Substrates



III. Clinical Typology
(Behavioral Phenotype)

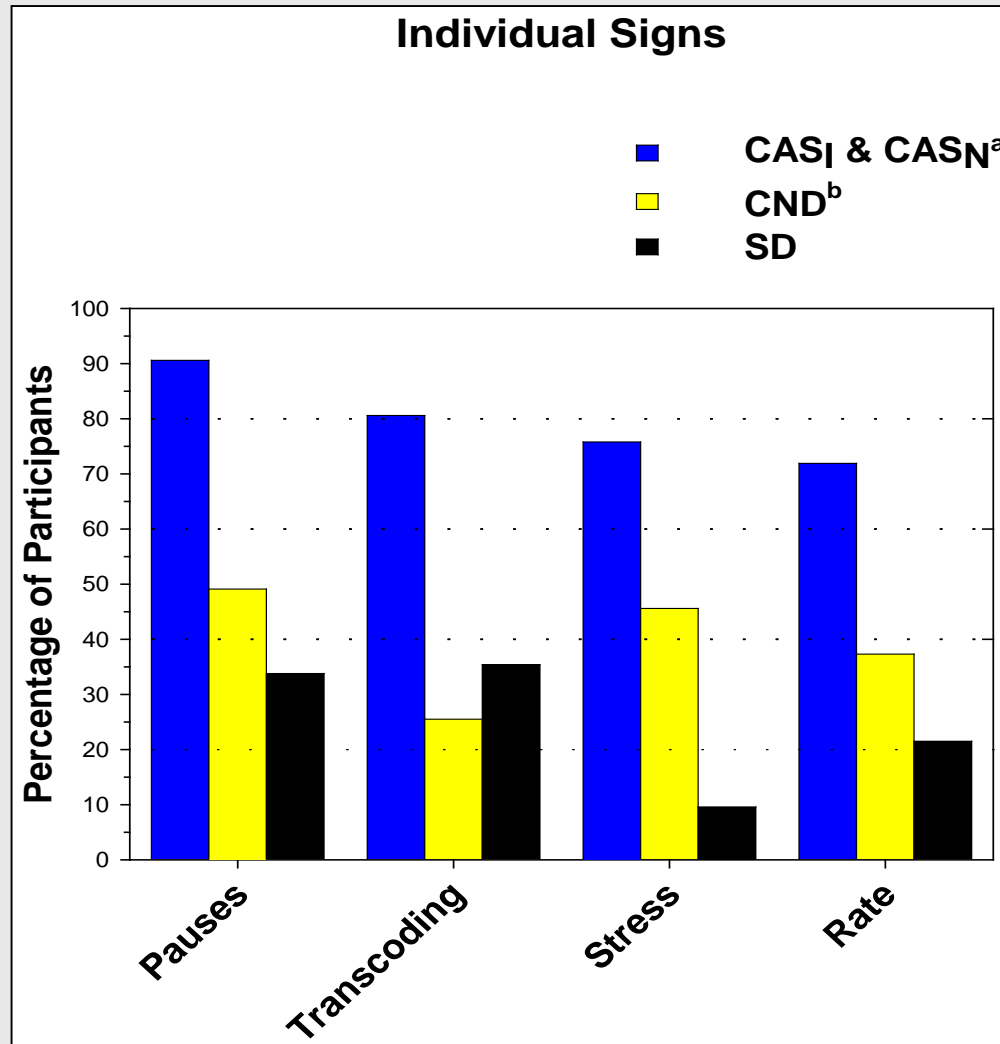


IV. Diagnostic Markers
(Critical Signs of Phenotype)



Results

Diagnostic Findings for the Four Individual Signs of CAS

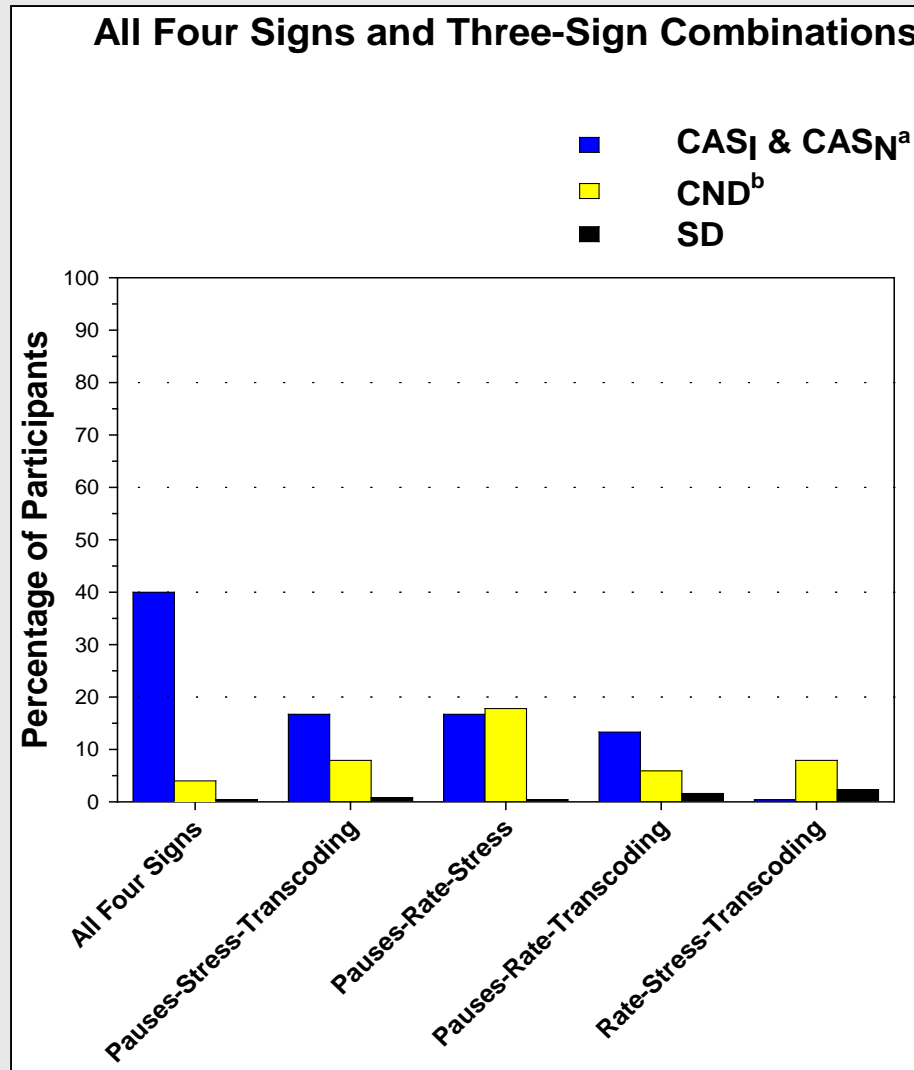


^aSame participants as in prior slide, denominators adjusted for eligibility

^bUnspecified for CAS

Results

Diagnostic Findings for the Four Three-Sign Markers of CAS



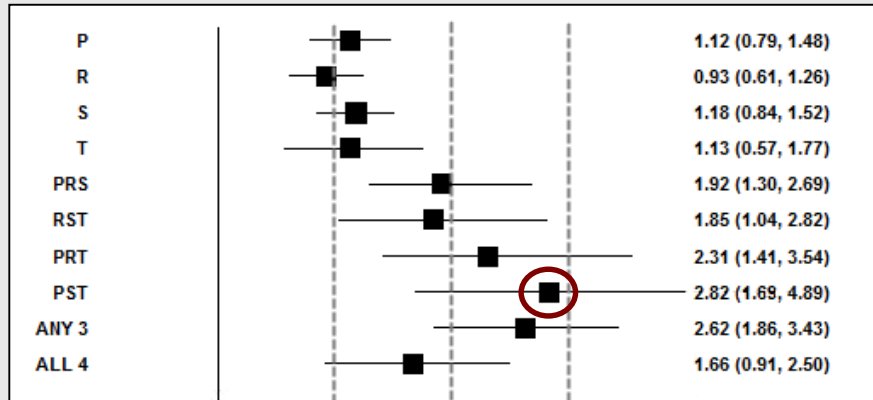
^aSame participants as in prior slide, denominators adjusted for eligibility

^bUnspecified for CAS

Results

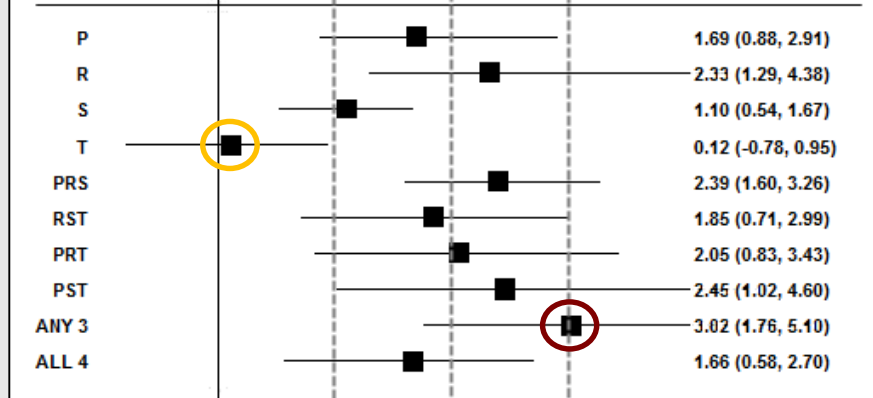
Forest Plots of Effect Sizes (Cohen's d)

CAS_I & CAS_N
vs.
Speech Delay

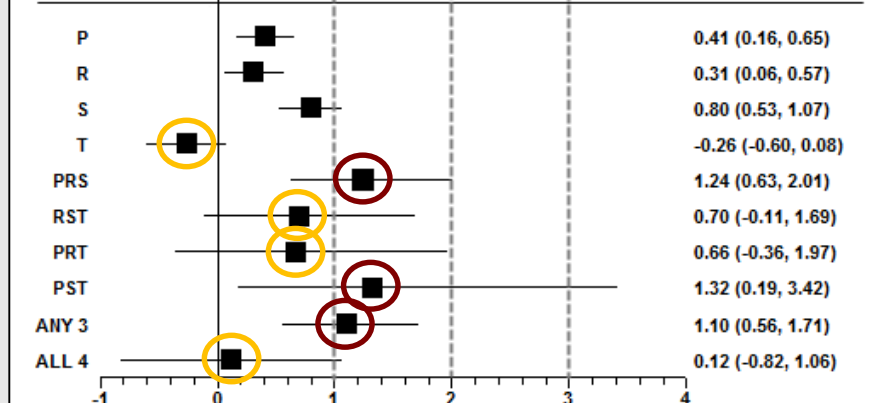


P - Inappropriate Pauses
R - Slow Articulatory Rate
S - Inappropriate Stress
T - Inaccurate Transcoding

AOS
vs.
Speech Delay



Complex
Neuro-
developmental
Disorders
vs.
Speech Delay



Topics

Diagnostic Marker Research In CAS

- ❑ Premises
- ❑ An Integrative Framework
- ❑ Some Recent Findings
- ❑ **Conclusions**

Some Conclusions for Theory, Assessment, and Treatment

Theory

1. CAS is a **sensorimotor, multiple domain disorder** with disruptions in **speech processes** due to neurodevelopmental deficits in **ventral and dorsal pathways**.
2. **Individual differences in the pattern of speech signs** that comprise the diagnostic marker and descriptive profiles of speakers with CAS may contribute information to identify **causative substrates in genomic, neurodevelopmental, and speech processes domains**.

Assessment

3. Speaker heterogeneities and methodological constraints limit the ability of speech sound production tasks to identify conclusive **segmental markers of CAS**.

Some Conclusions for Theory, Assessment, and Treatment

4. Speech production performance in response to **nonword repetition tasks**, however, may provide lifespan signs of **auditory-perception, memory, and speech processes** deficits in speakers with CAS.
5. Behavioral markers of CAS, particularly in an older speaker, are **not conclusive** without case history support for **late speech onset, effortful speech, and significant delay in normalization**.

Treatment

6. A contemporary perspective of CAS as a **sensorimotor disorder with deficits in multiple domains** has significant implications for **treatment targeting**.

Thesis

Conclusive behavioral markers of Childhood Apraxia of Speech will be both theoretically and clinically informative if developed within integrative genomic, neurodevelopmental, and speech processes frameworks in the cognitive neurosciences and pediatric speech sciences.

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