Who, What and Where: Word Retrieval Impairments in Aphasia

Anastasia Raymer, Ph.D., CCC-SLP
Professor, Dept of Early Childhood, Speech Pathology, & Special Education
Old Dominion University, Norfolk, Virginia

Investigator
Brain Rehabilitation Research Center
VAMC Gainesville, Florida

Perspectives to Consider in Aphasia Treatment

- WHO & I-FROM models
- What:
  - Cognitive neuropsychological influences
  - Evidence based clinical practice
- Where:
  - Neural correlates of impairments and recovery - restoration and reorganization

WHO International Classification of Functioning, Disability, & Health (2001)
http://www3.who.int/icf/

Health condition (e.g. stroke)

Body Structures/Functions Activity Participation

Contextual Factors
Environmental  Personal

Body/Structure Functions: Mental Functions

Reception of Language

Expression of Language

Word Retrieval
Morphosyntactic Operations
Phonologic Processing
Articulatory/Phonetic Processes

Activities: execution of a task
Communication
  verbal
  nonverbal

Participation: involvement in life situations

Education, Economic, Community, Social, Civic, Leisure, Religious Activities

Contextual Factors: Facilitators and Barriers

Personal:
  e.g., age, background, style, personality

Environment:
  e.g., community attitudes, architecture, transportation, climate
WHO Model
-guiding framework for all ASHA policy documents

Aphasia Treatment: WHO + A-FROM
Language Functions/Severity of Aphasia
Restorative & Reorganization treatments for language abilities
Activities/Participation
Communication in ADLs, personal interactions, education, employment, social activities
Compensatory and functional communication strategies
Environment/Personal
Facilitators/Barriers to Language Use
Modify communication environment: support systems/technology/partner training
- Impacts on our treatment choices and outcomes measured

What: Body Functions - Language
Cognitive Neuropsychological Perspective
Normal System:
Representations and Processes
Word Retrieval Impairments:
Systematic disruption of this system

Word Retrieval Mechanisms
"baked in an oven; slice for sandwiches"
Object Recognition System
Semantic System
(Bake it; Eat it; smells delicious; for sandwiches; crust, butter)
Phonological Lexemes
Articulatory processes
Gestural System
Syntactic Features: Noun/Verb
Phonological Lexemes
"bread"
Semantic Impairment
-impaired word and picture recognition
-impaired word retrieval
-impaired gesture production
-associated with transcortical sensory, global, possibly Broca’s
-semantic errors, unrelated/empty speech, no response
Gestural System
"bread"
Slicing motion
Semantic Anomia
Picture Naming Nouns 21.7% Verification Nouns 46.7%
Picture Naming Verbs 53.3% Verification Verbs 26.7%

Phonologic Access Anomia
Picture Naming Nouns 48.3% Verification Nouns 98.3%
Picture Naming Verbs 40.0% Verification Verbs 93.3%

Word Retrieval Mechanisms
Phonologic Input
Object Recognition System
Semantic System
(Bake it; Eat it; smells delicious; for sandwiches; crust, butter)
Phonological Lexemes
Articulatory processes
“bread”

Phonologic Impairment – Pure Anomia
-retained word and picture recognition
-impaired word retrieval
-associated with anomic aphasia, possibly Broca’s
circumlocution, semantic errors, phonemic errors,
no response

Optic Aphasia
WAB AQ 84.6 77.0
Aud comp 8.9 8.4
Naming 6.0 5.7
BNT 17/60 4/60
Optic Aphasia

<table>
<thead>
<tr>
<th>Task</th>
<th>Anomic</th>
<th>Optic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture Name</td>
<td>50%</td>
<td>15%*</td>
</tr>
<tr>
<td>Name to Def</td>
<td>55%</td>
<td>63%*</td>
</tr>
<tr>
<td>Aud Word/Pic Match</td>
<td>95%</td>
<td>87%</td>
</tr>
</tbody>
</table>

Word Retrieval Mechanisms

```
“Baked in an oven; slice for sandwiches”

Phonologic Input
Object Recognition System

Semantic System
(Bake it; Eat it; smells delicious; for sandwiches; crust, butter)

Phonological Lexemes

Gestural System

Syntactic Features: Noun/Verb

Articulatory processes

“baked”

Slicing motion
```

Where: Neural Correlates of Lexical Processing

Antonucci et al., 2005; Damasio et al 1993; Tranel et al. 1997; Caramazza & Hillis, 1991; Shapiro et al., 2006

Word Retrieval Impairments in Aphasia

- Disturbance at some step in complex process
  - Semantic, Access, Phonologic
- Symptoms vary across patients
- Associated with damage in many brain regions
  - Left Inf. Temp.: Nouns < Verbs
  - Left Inf. Frontal: Verbs < Nouns
  (Damasio & Tranel, 1993; Tranel et al., 1997)
- Many have impairments for both nouns and verbs (Berndt et al., 1997)

Treatment Implications

- Treatment effects may differ depending on pattern of word retrieval impairment: semantic vs phonologic
- Word retrieval training effects may differ for nouns versus verbs
- Restorative treatments: Relearning
  - Need to address semantic and/or phonologic aspects of word retrieval
- Reorganization approaches:
  - Attempt to engage alternative cognitive systems, e.g., gesture, to facilitate word retrieval

Evidence-based Clinical Practice

Clinical decision-making based on:
(Sackett et al., 2000)

- best current scientific evidence
- clinical expertise
- client values
Evidence-based Clinical Practice

- Model of clinical decision-making: Pollock & Rochon (2002); Hopper (2007)
- Evidence: lacking in many areas
- Experience: personal knowledge developed over time
- Expectations: patient’s (family’s) goals/values
- Environment: context in which rehab takes place
- Ethics: personal and professional code of conduct

Evidence: Practice Guidelines

- Recommendations based on a consensus derived from a review of the research evidence and expert opinion
- Useful evidence resources:
  - Academy of Neurologic Communication Disorders and Sciences (ANCDS) [www.ancds.org](http://www.ancds.org)
  - ASHA Compendium of Clinical Practice Guidelines and Systematic Reviews [www.asha.org/members/ebp](http://www.asha.org/members/ebp)
  - Cochrane Reviews [www.cochrane.org](http://www.cochrane.org)

WHAT can we do about word retrieval impairments?

- Posting to Div 2 Listserve:
  - “I’m searching for Internet resources for information about treatment for anomia. Any treatment suggestions from the more experienced would be appreciated.”
- Several Options (Nickels, 2002; Raymer, 2005)
  - Restorative treatments
  - Reorganization approaches
  - Compensatory strategies

Treatment of Word Retrieval Impairments

- Many studies used single participant experimental designs
  - Baseline phase/Training Phase/Maintenance
- Primary Outcome measure:
  - Picture naming – trained/untrained words
  - i.e. WHO ‘Language Functions’
- Fewer report outcomes for ‘Communication Activities/Participation’

Restorative Word Retrieval Training: Cueing Hierarchies

- Systematically present cues of increasing potency
  - (Linebaugh & Lehner, 1977; Linebaugh, 1983)
  - e.g. Semantic category cue
  - Rhyme cue
  - Initial phoneme cue
  - Repetition cue
- Patterson (2001) reviewed evidence
  - 9 studies (17 total subjects)
- Improves retrieval of trained words (nouns)
- Little generalization to untrained words
- Effects for conversational abilities untested

Semantic Cueing Treatment

- Wambaugh et al., 1999, 2001-2003

Prestimulation: Which of these is used to make juice in Florida?

Cueing hierarchy: picture presented alone
- What is this?
- Semantic cue:
  - To make juice we squeezed a ripe Florida
- Repetition cue: “orange”
Phonologic Cueing Treatment
Wambaugh et al., 1999, 2001-2003

Prestimulation: Which of these sounds like “kell”?

Cueing hierarchy: picture presented alone
What is this?
Phonologic cues:
It sounds like “kell”; It starts with /b/.
Repetition cue: “bell”

Semantic & Phonologic Cueing Treatment
Wambaugh et al

- Both treatments lead to improved naming of trained words
- Improvements occur for nouns and verbs
- Improvements occur in individuals with semantic, phonologic, and mixed anomias
- Little generalized improvement in discourse measures

Cueing Hierarchy Training:
Personalized Cues
Marshall, Freed and colleagues 2001; 2002

Contrasted word retrieval training effects when using:
- personalized cues (i.e. phrase developed by client)
- phonologic cues (i.e. provided by clinician)

Both types effective for improving picture naming
- Personalized > Phonologic
  - Personalized cues with semantic information (e.g. my whiskers need a ..razor) >
  - Personalized cues with phonologic information (e.g. sun rays ..razor)

Cueing Hierarchy Training:
Computer Application: MossTalk Words
Fink et al. (2002)
6 patients with moderate to severe phonologically-based naming impairments
Computerized phonologic cueing hierarchy training
Clinician guided versus Partial Self-guided

Results:
5/6 Improved trained picture naming
2/6 small improvements for untrained items

Cueing Hierarchy Training:
Computer Application: MossTalk Words
Ramsberger & Marie (AJSLP 2007)
4 patients with moderate to severe naming impairments
Computerized phonologic cueing hierarchy training
Compared intensive (5/wk) and less intensive (2/wk)

Results:
3/4 Improved trained picture naming
2/4 greater improvements for intensive tx
1/4 generalized to untrained picture naming

Alternative Word Retrieval Treatments:
Semantic Comprehension Training

Treatment tasks:
- Answer yes/no Qs: semantic attributes e.g. Does this have to do with a quarterback?
- Spoken word/picture matching*
- Written word/picture matching*
  - related distractors (e.g., basketball, bat, helmet)
- Category sorting (sports/clothing)
**Semantic Comprehension Training: Evidence**

Reviews by Ennis (2001); Nickels (2002)

- 7 studies (35 subjects)
- Improved naming of trained nouns 17/20 (one group study)
- Little generalization to untrained words
- No evidence of effects in conversation

Treatment effects greatest when comprehension paired with production, i.e. semantic-phonologic training

(Drew & Thompson, 1999)

Patients with semantic and phonologic word retrieval impairments respond in treatment

---

**Semantic-Phonologic Training for Verbs** (Rodriguez et al., 2006)

**Noun vs Verb Retrieval** (Raymer et al., 2007)

- Answer yes/no Qs: “pounding”
- Semantic attributes
  - e.g. Is this similar to knocking?
  - Does this have to do with a carpenter?
- Phonologic attributes
  - e.g. Does this start with /p/?
  - Does this sound like mound?
- Rehearsal phase: repeat 3 times

---

**Picture Naming Effect Sizes (d): Nouns vs Verbs**

Raymer et al. (2007)

<table>
<thead>
<tr>
<th>PT</th>
<th>ORDER</th>
<th>Effects Nouns</th>
<th>Effects Verbs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tx</td>
<td>Untx</td>
</tr>
<tr>
<td>P1 Bro</td>
<td>1N2V</td>
<td>13.2**</td>
<td>1.40</td>
</tr>
<tr>
<td>P2 Bro</td>
<td>1V2N</td>
<td>9.91**</td>
<td>.05</td>
</tr>
<tr>
<td>P3 Bro</td>
<td>1N2V</td>
<td>7.69**</td>
<td>2.92*</td>
</tr>
<tr>
<td>P4 Bro</td>
<td>1V2N</td>
<td>5.89**</td>
<td>1.93</td>
</tr>
<tr>
<td>P5 Bro</td>
<td>1N2V</td>
<td>3.41**</td>
<td>1.10</td>
</tr>
<tr>
<td>P6 Bro</td>
<td>1N2V</td>
<td>.85</td>
<td>-.16</td>
</tr>
<tr>
<td>P7 Wern</td>
<td>1V2N</td>
<td>1.39</td>
<td>-1.33</td>
</tr>
<tr>
<td>P8 Anom</td>
<td>1V2N</td>
<td>.98</td>
<td>.67</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>5.42</td>
<td>.82</td>
</tr>
</tbody>
</table>

Responders: 5/8 1/8 5/8 0/8

No group diff: t=.36
Pre-treatment predictors  **p<.01

<table>
<thead>
<tr>
<th>Test</th>
<th>Verb Tx</th>
<th>Noun Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAB Aph Quotient</td>
<td>.31</td>
<td>.42</td>
</tr>
<tr>
<td>WAB Naming</td>
<td>.87**</td>
<td>.91**</td>
</tr>
<tr>
<td>WAB Repetition</td>
<td>.26</td>
<td>.36</td>
</tr>
<tr>
<td>WAB Aud Comp</td>
<td>.34</td>
<td>.38</td>
</tr>
<tr>
<td>ANT</td>
<td>.83*</td>
<td>.86**</td>
</tr>
<tr>
<td>Picture Name Nouns</td>
<td>.79*</td>
<td>.91**</td>
</tr>
<tr>
<td>Picture Name Verbs</td>
<td>-.12</td>
<td>-.04</td>
</tr>
<tr>
<td>Verification Nouns</td>
<td>.07</td>
<td>-.05</td>
</tr>
<tr>
<td>Verification Verbs</td>
<td>.23</td>
<td>.16</td>
</tr>
</tbody>
</table>

Relationship to Changes on Secondary Outcome Measures  **p<.01

<table>
<thead>
<tr>
<th>Test</th>
<th>Verb Tx</th>
<th>Noun Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAB</td>
<td>.05</td>
<td>-.33</td>
</tr>
<tr>
<td>BNT</td>
<td>-.05</td>
<td>.27</td>
</tr>
<tr>
<td>ANT</td>
<td>.23</td>
<td>-.13</td>
</tr>
<tr>
<td>FOQ</td>
<td>-.14</td>
<td>.60</td>
</tr>
<tr>
<td>CETI</td>
<td>.94**</td>
<td>-.60</td>
</tr>
<tr>
<td>ASHA-FACS Basic</td>
<td>.04</td>
<td>-.41</td>
</tr>
<tr>
<td>ASHA-FACS Social</td>
<td>.21</td>
<td>.66</td>
</tr>
<tr>
<td>% Nouns</td>
<td>.02</td>
<td>-.87*</td>
</tr>
<tr>
<td>% Verbs</td>
<td>-.14</td>
<td>.14</td>
</tr>
</tbody>
</table>

3 Nonresponders

- Severity of word retrieval impairment influential
- 3 severe naming impairments
- 1 Broca’s: severe apraxia of speech/nonfluency
- Nature of impairment partly important
- 2/3 severe semantic impairment

By the way…. 
- Time post stroke: not influential
- 2/3 earliest post stroke in the sample

Computerized Semantic Comprehension Training: MossTalk Words

Raymer et al. (2006)
- 2 patients with severe semantic anomia aphasia
- 3 with phonologic access anomia
- 10 sessions training: Word/picture matching modules (written and spoken word/picture matching tasks)

Results:
- Improved comprehension for trained and untrained words in 1/2 when trained 1-2 times/wk
- Improved picture naming for trained words
- 5/5 when trained 3-4 times/wk
- 2/5 when trained 1-2 times/wk

Contextual Priming

Martin et al., 2004, 2006

**Semantically related context**

Match spoken name to picture – then repeat name several times

**Phonologically related context**

- Premise: thru massed repetition priming, leads to spreading of activation to semantically and phonologically related words
- Initially during training - may lead to interference in naming across related items
- Over time – see improve naming of trained items
- Best effect in patients with preserved semantic abilities
**Semantic-Phonologic Treatments Summary**

- Large effects for trained words
- Less potent generalized training effects to untrained words
- Despite neural differences, no apparent differences between nouns and verbs

**Other Methods for Improving Generalization in Word Retrieval Training**

**Semantic Feature Analysis Training**

- **Group**
  - Use
  - Action
- **Target Picture**
  - Properties
  - Location
  - Association

**Semantic Feature Analysis Training**

- Boyle & Coelho, 1995  n=1  Bro
- Boyle, 1997  n=2  anom/Wern
- Coelho et al, 2000  n=1  fluent
- Lowell et al, 1995  n=3  2 cond/1 anom
- Boyle, 2004  n=2  Wern.

**Semantic Feature Analysis Training**

- Trained picture naming  8/9 improved
- Untrained picture naming  8/9 improved
- Connected speech  3/4 improved
  - (5 not reported)

*All studies trained noun retrieval

**Training within Semantic Categories**

Spencer et al. (2000)

- Single participant design (n=1)
- Trained with rhyme cues across 3 semantic categories:
  - animals
  - household items
  - tools

- Improvements in picture naming for trained words
- Generalization to untrained pictures within category
- Eventually…generalization to untrained category
**Surprise: Training with Atypical Exemplars**

Kiran & Thompson (2003)  
4 individuals with fluent aphasia and word retrieval deficits  
single participant design  
Semantic training within categories (birds, vegetables)  
Contrasted training targets: typical vs atypical examples  
typical (n=8): robin, carrot  
atypical (n=8): ostrich, artichoke  

Results:  
Typicals trained: little generalization to untrained  
Atypicals trained: greater generalization to untrained!  

Replicated by Waters et al. 2006; Kiran 2007

---

**Amount Matters: Train for Many Sessions**

Some studies report generalized improvement in picture naming for untrained words  
McNeil et al 1998  
Richards et al 2002  
Spencer et al 2000  

Common element?  
Many, many training sessions

---

**Intensity of Treatment**

Hinckley & Craig (1998)  
Retrospective group analyses of aphasia treatment  
No therapy  
Intensive speech therapy (23 hrs/wk for 6 wks)  
Non-intensive therapy (2-3 hrs/wk for 6 wks)  
Outcome: Boston Naming Test scores  

Result: Effects sizes  
Intensive therapy: very large effect sizes  
Non-intensive therapy: no effect to small effect  
No therapy: small effect  

Problem: Amount and intensity confounded

---

**Computerized Semantic Comprehension Training: MossTalk Words**

Raymer et al. (2006)  
Improved picture naming for trained words  
5/5 when trained 3-4 times/wk  
2/5 when trained 1-2 times/wk

---

** Cueing Hierarchy Training: Computer Application: MossTalk Words**

Ramsberger & Marie (2007)  
compared 5 times/wk vs 2 times/wk  
all received overall same amount of tx  

Results:  
3/4 Improved trained picture naming  
2/4 greater improvements for intensive tx  
1/4 generalized to untrained picture naming

---

**WHAT:**  
Reorganization Approaches to Word Retrieval Treatment
Use of Gesture to Facilitate Communication

- Reorganization approach to treatment to facilitate improvement of language abilities
- Compensatory strategy to circumvent blocks in communication
- Problem to consider: Limb Apraxia, as it may impede the use of gesture for compensatory communication

Gestures to Facilitate Communication

- Not a new idea
- AmerInd
  - Skelly, 1974; 1975
  - Rao & Horner, 1978
- Recent research has examined active factors to enhance treatment effects

Reorganization Approaches: Verbal + Gestural Treatment

- Pair pantomime + word to facilitate word retrieval
- Rehearse pantomime: pounding the nail - manipulate limb if necessary
- Rehearse spoken word production: pound
- Pair pantomime and spoken word production

Raymer 2001 reviewed 9 studies n=16 participants
Rose et al 2002 n=1

Improvements
- Naming (nouns) 14/17
- Gestures 15/15

Who didn't improve? Severe apraxia of speech

Prior research focused on noun retrieval
- Neural networks for gesture tend to be more tightly linked to verbs than nouns (Druks, 2001)
- Are verbal+gestural treatment effects greater for verbs than nouns?

Contrasting Verbal+Gestural Training Effects for Nouns versus Verbs

Raymer et al. (2006)
- 9 individuals with aphasia and word retrieval impairments for nouns and verbs
- Single participant crossover design (order counterbalanced across participants)
- Verbal+Gestural Training 10 sessions
- Outcomes:
  - Picture naming, Gesture production: trained and untrained nouns and verbs
  - Videotaped Conversations
### Picture Naming Effect Sizes (d) Raymer et al. (2006)

<table>
<thead>
<tr>
<th>Order</th>
<th>Nouns</th>
<th>Verbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained</td>
<td>Untrained</td>
<td>Trained</td>
</tr>
<tr>
<td>P1 fl</td>
<td>V-N</td>
<td>.32</td>
</tr>
<tr>
<td>P5 nonfl</td>
<td>V-N</td>
<td>.50</td>
</tr>
<tr>
<td>P9 fl</td>
<td>V-N</td>
<td>1.92</td>
</tr>
<tr>
<td>P2 nonfl</td>
<td>N-V</td>
<td>15.97*</td>
</tr>
<tr>
<td>P6 nonfl</td>
<td>V-N</td>
<td>10.18*</td>
</tr>
<tr>
<td>P7 nonfl</td>
<td>N-V</td>
<td>4.3*</td>
</tr>
<tr>
<td>P3 nonfl</td>
<td>V-N</td>
<td>6.88*</td>
</tr>
<tr>
<td>P4 nonfl</td>
<td>N-V</td>
<td>2.71*</td>
</tr>
<tr>
<td>P8 fl</td>
<td>N-V</td>
<td>.20</td>
</tr>
<tr>
<td>Mean</td>
<td>4.80</td>
<td>.39</td>
</tr>
<tr>
<td>Responders</td>
<td>5/9</td>
<td>6/9</td>
</tr>
</tbody>
</table>

Nouns vs Verbs: t=.09, p=.93

### Gesture Effects sizes (d) Raymer et al. (2006)

<table>
<thead>
<tr>
<th>Order</th>
<th>Nouns</th>
<th>Verbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained</td>
<td>Untrained</td>
<td>Trained</td>
</tr>
<tr>
<td>P1 fl</td>
<td>V-N</td>
<td>19.38*</td>
</tr>
<tr>
<td>P4 nonfl</td>
<td>V-N</td>
<td>19.67*</td>
</tr>
<tr>
<td>P6 nonfl</td>
<td>V-N</td>
<td>10.16*</td>
</tr>
<tr>
<td>P7 nonfl</td>
<td>N-V</td>
<td>16.49*</td>
</tr>
<tr>
<td>P3 nonfl</td>
<td>V-N</td>
<td>13.60*</td>
</tr>
<tr>
<td>P5 nonfl</td>
<td>V-N</td>
<td>23.44*</td>
</tr>
<tr>
<td>P9 fl</td>
<td>V-N</td>
<td>6.11*</td>
</tr>
<tr>
<td>P2 nonfl</td>
<td>N-V</td>
<td>4.00*</td>
</tr>
<tr>
<td>P8 fl</td>
<td>N-V</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td>12.54</td>
<td>1.74</td>
</tr>
</tbody>
</table>

Nouns vs Verb: trained: t=.06, p=.96; untrained: t=1.87, p=.10

### Naming: Nonresponders vs Responders Raymer et al. (2006)

<table>
<thead>
<tr>
<th>Impairment</th>
<th>Noun Retrieval</th>
<th>Verb Retrieval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sem Phon</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Respond</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nonrespond</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Treatment effects**

- Phonologic impairment > Semantic impairment
- Within semantics: Mild > Severe

- No improvement:
  - Fluent aphasia/ severe semantic impairment

### Influence of Limb Apraxia Raymer et al. (2006)

- No significant correlation between treatment outcomes and limb apraxia
- All participants improved gesture production, regardless of apraxia severity

### Significant Correlations Raymer et al. (2006)

- Effect sizes for Untrained Verb Gestures & Total Gesture Use (r=.76, p=.02)
- Effect sizes for Untrained Noun Gestures & Total Gesture Use (r=.94, p=.00)
- If participant generalized gesture use in constrained picture naming task, also saw increased gesture use in conversations
**Verbal+Gestural Treatment Summary**

Large word retrieval effects trained words  
Large gesture production effects for trained and some untrained words  
Gesture changes in conversation in some participants  
Despite neural differences, no apparent differences between nouns and verbs

**Problem: Pantomime treatment confounds symbol & movement**

Hanlon et al., 1990  
Nonsymbolic limb movements may enhance word retrieval  
- nonfluent named better when producing distal flexing movements of right hand

Rose & Douglas, 2001  
Iconic gestures > visualization, pointing or cued articulation gesture (pointing to mouth)  
- only in patients with phonologic retrieval impairments

**Think about MIT**

- In addition to intonation during training, the clinician taps with the patient’s left hand.
- Is tapping playing an important role in MIT effects?
- Boucher et al. 2001  
- Tones vs. rhythmic hand tapping effects during sentence repetition training  
- Hand tapping was as effective as intonation alone during training  
Is simply movement of the limb sufficient to incite word retrieval changes, without an actual pantomime?

**Intentional Treatment for Word Retrieval**

Richards, Crosson et al., 2002; Crosson et al., 2007  
Premise:  
Left hemisphere mesial frontal regions (pre-SMA) critical during initiating of language  
If damaged or disconnected from left frontal language regions, disrupts ability to initiate language production  
If move left limb in a complex action, can activate right pre-SMA regions.  
If use left limb movements during word retrieval, perhaps right pre-SMA might facilitate initiation of production – intentional treatment

**Intentional Treatment for Word Retrieval**

Richards et al. 2002: 8 patients with nonfluent aphasia  
7 of 8 improved picture naming for trained words  
Some improvements for untrained words

**Intentional Treatment for Word Retrieval**

Crosson et al. (2007)  
34 patients with mod-profound word retrieval impairments  
10 sessions: 5x/wk  
Results:  

<table>
<thead>
<tr>
<th>Group</th>
<th>% improvement picture naming trained</th>
<th>% improvement picture naming untrained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mod-severe</td>
<td>20.23%</td>
<td>15.86%</td>
</tr>
<tr>
<td>Profound</td>
<td>9.50%</td>
<td>2.73%</td>
</tr>
</tbody>
</table>

Conclusion: Complex limb movement, not necessarily pantomime, may be sufficient to incite training effects
To summarize....

- Aphasic word retrieval can be facilitated through use of
  - Gestural pantomimes – verbal+gestural treatment
  - Nonsymbolic left limb movements – intentional treatment

- Advantage of pantomimes: compensatory communication
- Advantage of nonsymbolic movements: can be used for any conversational topic

- Need to be aware of limb apraxia as it may disrupt ability to use gesture as a compensatory strategy

---

**Restoration versus Reorganization?**

**Lessons from Constraint-Induced Language Therapy**

---

**Constraint Induced Language Therapy (CILT)**
(Pulvermuller et al., 2001)

Barrier activity with dyad of patients
Verbal games

Forced use of verbal responses: no compensatory communication strategies

Intensive treatment schedule: 3 hr/day for 2 wks

Results: Forced language group > traditional tx group in auditory comp and naming

Are the results due to forced language use or intensive treatment schedule?

---

**Forced Language Use?**
CILT versus PACE: Intensive
Maher et al. 2006

CILT: N = 4
PACE: N=5

TX: 4 days/week, 3 hours/day, 2 weeks = 24 total TX hours

- WAB improved: 3/4 CILT, 1/5 PACE
- BNT improved: 3/4 CILT, 0/5 PACE
- ANT improved: 2/4 CILT, 1/5 PACE

*Intensity also plays a role

---

**ASHA Sponsored First Systematic Review:**
Constraint Induced Language Therapy (CILT) for Aphasia
Cherney, Patterson, Raymer et al., 2008

- Public policy or reimbursement issues
- Importance to clients consumers
Framing the clinical question

- Two principles of CILT are intertwined
  - Constraint
  - Intensive/Massed practice

- PICO (Population-Intervention-Comparison-Outcome)
  - **P** = stroke-induced chronic aphasia,
    stroke-induced acute aphasia
  - **I** = CILT and intensive aphasia treatment
  - **C** = contrasting treatment or no treatment
  - **O** = measures of language impairment,
    communication activity/participation (WHO ICF)

5 CILT Questions

- For stroke-induced chronic aphasia, what is the influence of CILT on...
  - measures of language impairment?
  - measures of communication activity/participation?

- For stroke-induced acute aphasia, what is the influence of CILT on...
  - measures of language impairment?
  - measures of communication activity/participation?

- For stroke-induced chronic aphasia, what treatment outcomes are maintained following CILT?

5 Intensity Questions

- For stroke-induced chronic aphasia, what is the influence of treatment intensity on...
  - measures of language impairment?
  - measures of communication activity/participation?

- For stroke-induced acute aphasia, what is the influence of treatment intensity on...
  - measures of language impairment?
  - measures of communication activity/participation?

- For stroke-induced chronic aphasia, what treatment outcomes are maintained following intensive language treatment?

Search Parameters

- Inclusion:
  - Peer-reviewed English literature from 1990 to 2006
  - Adults with stroke-induced aphasia
  - Direct comparison of CILT with other treatment/no treatment; direct comparison of treatment intensities

  • Extensive Literature Search of several databases

Identified 10 Studies

<table>
<thead>
<tr>
<th>CILT</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maher et al., 2006</td>
<td>Basso &amp; Caporal, 2001</td>
</tr>
<tr>
<td>Meinzer et al., 2004</td>
<td>Denes et al., 1996</td>
</tr>
<tr>
<td>Meinzer et al., 2005</td>
<td>Hinckley &amp; Craig, 1998</td>
</tr>
<tr>
<td>Pulvermuller et al., 2001</td>
<td>Hinckley &amp; Carr, 2005</td>
</tr>
<tr>
<td>Pulvermuller et al., 2005</td>
<td>Pulvermuller et al., 2001</td>
</tr>
<tr>
<td>Pulvermuller et al., 2005</td>
<td>Raymer et al., 2006</td>
</tr>
</tbody>
</table>

Evaluating the Evidence - Methodological Quality

ASHA Levels of Evidence Scheme (Mullen, 2007)
Similar to PEDRO scale (Maher et al., 2003)

<table>
<thead>
<tr>
<th>9 dimensions</th>
<th>Highest quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Design</td>
<td>Controlled trial</td>
</tr>
<tr>
<td>Blinding</td>
<td>Assessors blinded</td>
</tr>
<tr>
<td>Sampling</td>
<td>Random sample adequately described</td>
</tr>
<tr>
<td>Group Comparability/Participants described</td>
<td>Groups comparable at baseline or Participants well described</td>
</tr>
<tr>
<td>Treatment Fidelity</td>
<td>Evidence provided</td>
</tr>
<tr>
<td>Outcomes</td>
<td>Valid &amp; reliable outcome measure</td>
</tr>
<tr>
<td>Significance</td>
<td>p value reported/calculable</td>
</tr>
<tr>
<td>Precision</td>
<td>Effect size &amp; confidence interval reported/calculable</td>
</tr>
<tr>
<td>Intention to Treat</td>
<td>Analyzed by intention to treat</td>
</tr>
</tbody>
</table>
# highest quality indicators across 10 studies of the EBSR

- Design: Controlled trial: 5
- Assessor blinded: 2
- Random sample well-described: 1
- Comparable groups: 10
- Participants well-described: 2
- Treatment fidelity: 9
- Valid outcomes: 10
- Significance calculable: 7
- Precision calculable: 3/5

## Quality Scores & Effect Sizes (d) CILT Studies

### Impairment Outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Score</th>
<th>Outcome measure</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maher et al., 2006</td>
<td>6/9</td>
<td>WAB AQ</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BNT</td>
<td>-.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANT</td>
<td>-.14</td>
</tr>
<tr>
<td>Meinaer et al., 2004</td>
<td>4/8</td>
<td>AAT TT</td>
<td>.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AAT Profile</td>
<td>.34</td>
</tr>
<tr>
<td>Meinaer et al., 2005</td>
<td>5/9</td>
<td>AAT Profile</td>
<td>1.63</td>
</tr>
<tr>
<td>Pulvermuller et al., 2001</td>
<td>6/9</td>
<td>AAT Profile</td>
<td>2.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TT</td>
<td>.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Naming</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comprehension</td>
<td>1.12</td>
</tr>
<tr>
<td>Pulvermuller et al., 2005</td>
<td>3/8</td>
<td>AAT Token Test</td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repetition</td>
<td>.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Naming</td>
<td>.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comprehension</td>
<td>.46</td>
</tr>
</tbody>
</table>

### Activity/Participation Outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Score</th>
<th>Outcome measure</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahar et al., 2006</td>
<td>6/9</td>
<td>story retelling</td>
<td>-.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td># wds</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td># utterances</td>
<td>-.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td># sentences</td>
<td>-.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mean length utt.</td>
<td>.33</td>
</tr>
<tr>
<td>Meinaer et al., 2005</td>
<td>5/9</td>
<td>Comm Effect. Index</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comm Activity Log</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quantity Pt.</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quantity Fam.</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comp. Pt.</td>
<td>.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comp. Fam.</td>
<td>1.1</td>
</tr>
<tr>
<td>Pulvermuller et al., 2001</td>
<td>6/9</td>
<td>Comm Activity Log</td>
<td>3.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patient.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Family</td>
<td>2.64</td>
</tr>
</tbody>
</table>

### Intensity studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Score</th>
<th>Outcome measure</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinckley &amp; Carr, 2005</td>
<td>7/9</td>
<td>PALPA Oral Naming</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Written Naming</td>
<td>1.48</td>
</tr>
<tr>
<td>Pulvermuller et al., 2001</td>
<td>6/9</td>
<td>AAT Profile</td>
<td>2.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TT</td>
<td>.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Naming</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comprehension</td>
<td>1.12</td>
</tr>
<tr>
<td>Raymer et al., 2006</td>
<td>5/8</td>
<td>Picture Naming</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>11.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plc Name Maint</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comp Maint</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>2.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>2.14</td>
</tr>
</tbody>
</table>

## Quality Scores & Effect Sizes (d) Intensity studies Activity/Participation Outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Score</th>
<th>Outcome measure</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinckley &amp; Craig, 1998</td>
<td>4/8</td>
<td>Content Units</td>
<td>.53</td>
</tr>
<tr>
<td>Hinckley &amp; Carr, 2005</td>
<td>7/9</td>
<td>Catalogue order</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oral (Quiet)</td>
<td>-.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oral (Concurrent)</td>
<td>-.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Written (Quiet)</td>
<td>-.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Written (Concurrent)</td>
<td>-.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CADL</td>
<td>-.15</td>
</tr>
<tr>
<td>Pulvermuller et al., 2001</td>
<td>6/9</td>
<td>Comm Activity Log</td>
<td>3.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patient.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Family</td>
<td>2.64</td>
</tr>
</tbody>
</table>

## Findings - CILT

- 5 studies with 90 participants
- Language impairment measures: CILT resulted in positive changes
- Communication activity/participation measures: mixed results; some large positive favoring CILT; some large positive favoring comparison treatment
- Data available only for chronic aphasia. No data speak to the effects of CILT in acute aphasia.
- Maintenance of CILT effects: reported to lead to positive changes; no effect sizes calculable.
Findings - Treatment Intensity

- 6 studies with 68 participants
- Language impairment measures: Increased treatment intensity was associated with positive changes in both chronic and acute aphasia.
- Activity/Participation measures: Equivocal results, favoring neither more intensive nor less intensive treatment for persons with chronic aphasia.
- Maintenance of treatment: little data; also equivocal, favoring more intense treatment for one outcome measure and less intense for the other.

CILT and Treatment Intensity

- Observations suggest that there can be complex interactions among intensity of treatment schedule, type of treatment, and type of outcome measure.
- Forced verbal is important influence
- Intensity also is important factor

Here’s Some Evidence....

Several effective methods available for treatment of word retrieval impairments

Effects are mostly training specific unless provided in intensive or extended schedules

How can we extend our treatment effects given limited treatment resources? 
- computers 
- groups 
- caregiver training

Where:
Neural Correlates of Word Retrieval Treatment

Structural Variables – Aphasia Recovery

- Critical cortical regions for naming recovery
  - Hillis et al 2006
  - perfusion- and diffusion-weighted imaging to assess dysfunctional brain regions at stroke onset
  - 3-5 days later, evaluated which re-perfused brain regions associated with increased naming abilities
  - left posterior middle temporal/fusiform gyrus,
  - Wernicke’s area – left superior temporal 
  - Broca’s area – left inferior frontal

Structural Variables – Aphasia Recovery

- Poor recovery of word retrieval associated with:
  - larger lesions (>60 cm³)
  - extensive lesions affecting left superior temporal and inferior parietal regions
  - less severe but persistent problems associated with insula & putamen lesions
  - not clear whether pts involved in treatment

- Knopman et al., 1984

Considerable spontaneous recovery of naming functions in patient with inferior temporal lesion (area 37)

- Raymer et al 2000
Naming Recovery

Poor Recovery
-Better recovery

-Pertains to noun recovery
-Little information about recovery of verbs

Structural Predictors of Word Retrieval Treatment Response

Despite fact that word retrieval treatment very common for aphasia, limited evidence of neural correlates of response to word retrieval treatment

Intentional treatment for word retrieval in aphasia -poorer treatment success in pts with lesions in:
- Wernicke's area
- left supramarginal gyrus
- anterior and posterior periventricular white matter
- left insula

Cato et al. 2006

Word Retrieval Impairments in Aphasia

Common across aphasia syndromes Goodglass et al., 2000

Noun Retrieval Impairments
-often greater than for verbs in fluent aphasias
-associated with left inferior temporal lesions

Verb Retrieval Impairments
-often greater than nouns in nonfluent aphasias
-associated with left inferior frontal lesions

Noun & Verb Retrieval Impairments common in many individuals
Damasio et al., 1993; Hills et al., 2002; Miceli et al., 1984; Tranel et al., 1997; Zingesser & Berndt, 1990

Neural Correlates of Successful Treatment of Word Retrieval Impairments

Raymer 2002

14 participants in word retrieval treatment studies:
word retrieval impairments/no severe apraxia of speech i.e. able to repeat words

Treatments: Restitutive semantic-phonologic
Substitutive Verbal + Gestural

13 received noun retrieval training
11 received verb retrieval training
3 only noun, 1 only verb
-order counterbalanced

Mapped CT/MRI scans of 10 participants (Damasio et al., 1989)
Reports from 4 others

Neural differences for noun & verbs may translate to differences in word retrieval treatment response

Response to Noun Treatment

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Lesion localization in Left Hemi</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 signif</td>
<td>white inf front-post</td>
</tr>
<tr>
<td>Wre fl</td>
<td>nonfl frontal-post XX</td>
</tr>
<tr>
<td>Js fl</td>
<td>nonfl frontal-post XX XX</td>
</tr>
<tr>
<td>Mq fl</td>
<td>nonfl frontal-post XX XX X</td>
</tr>
<tr>
<td>Ac fl</td>
<td>nonfl frontal-post XX XX X</td>
</tr>
<tr>
<td>Drs fl</td>
<td>nonfl frontal-post XX XX</td>
</tr>
<tr>
<td>2 mild</td>
<td>post frontal-post XX XX</td>
</tr>
<tr>
<td>Ji fl</td>
<td>post frontal-post XX X</td>
</tr>
<tr>
<td>5 no resp</td>
<td>post XX XX</td>
</tr>
<tr>
<td>Rc fl</td>
<td>post XX XX</td>
</tr>
<tr>
<td>Bj fl</td>
<td>post XX XX</td>
</tr>
<tr>
<td>Rs fl</td>
<td>post XX XX</td>
</tr>
<tr>
<td>Dr fl</td>
<td>post XX XX</td>
</tr>
<tr>
<td>Ep fl</td>
<td>post frontal-post XX XX</td>
</tr>
</tbody>
</table>
Response to Verb Treatment

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Lesion localization in Left Hemi</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 signifi.</td>
<td>white</td>
</tr>
<tr>
<td>Wre</td>
<td>nonfl. fronto-post</td>
</tr>
<tr>
<td>Wra</td>
<td>nonfl. fronto-post</td>
</tr>
<tr>
<td>Js</td>
<td>nonfl. fronto-post</td>
</tr>
<tr>
<td>Mq</td>
<td>nonfl. fronto-post</td>
</tr>
<tr>
<td>Ac</td>
<td>nonfl. fronto-post</td>
</tr>
<tr>
<td>1 mild</td>
<td>post X</td>
</tr>
<tr>
<td>5 no resp</td>
<td>fl. post XX XX XX</td>
</tr>
<tr>
<td>Rs</td>
<td>fl. post XX XX XX</td>
</tr>
<tr>
<td>Ji</td>
<td>fl. post X</td>
</tr>
<tr>
<td>Sd</td>
<td>nonfl. fronto-post</td>
</tr>
<tr>
<td>Ep</td>
<td>nonfl. fronto-post</td>
</tr>
</tbody>
</table>

Neural Correlates of Successful Word Retrieval Treatment
Parkinson et al. (2006)

15 participants in word retrieval treatment studies: retrievable CT (n=7) or MRI (n=8) scans
- Noun Tx n=6 Verb Tx n=4
- Verbal+Ges n=7 n=8
- Total n=13 n=12
- Lesion Ratings of 29 cortical and subcortical regions on 6 point scale (Naeser et al., 1989)
  - 2 raters (r=.887)

Partial Correlations between Naming Improvements (d) and Cortical Lesion extent controlling for Basal Ganglia lesion
Parkinson et al. (2006)

- Anterior lesion x Noun improvement .858 <.0005
- Posterior lesion x Noun improvement .373 .232
- Anterior lesion x Verb improvement .821 .002
- Posterior lesion x Verb improvement -.256 .448
- The larger the anterior lesion, the greater improvement associated with treatment - for both nouns and verbs

Partial Correlations between Naming Improvements (d) and Basal Ganglia Lesion extent controlling for Frontal lesion
Parkinson et al. (2006)

- Anterior lesion x Noun improvement .749 .005
- Posterior lesion x Noun improvement .249 .434
- Anterior lesion x Verb improvement .785 .004
- Posterior lesion x Verb improvement -.159 .641
- The smaller the anterior basal ganglia lesion, the better the response to word retrieval treatment ---for both nouns and verbs

Interpretations: “Noisy Output”
Parkinson et al. 2006

- Smaller anterior lesions generate noisy, imperfect output
- Larger anterior lesions eliminate ‘noisy’ activity and competition with other regions for recovery of function
- Basal ganglia allow suppression of ‘noisy’ activity of the cortical regions

Why no differences: Neural Networks of Nouns vs Verbs

Functional Neuroimaging Studies

Nonoverlapping networks
(e.g., Kable et al., 2002; Shapiro et al, 2005)
- Left Inferior Frontal – verb mediation
- Left/Bilateral Ventral Temporal – noun mediation

Overlapping networks
(e.g., Soros et al., 2003; Tyler et al., 2001)
So... What are the neural regions mediating word retrieval recovery?

• Studies of word retrieval recovery and treatment suggest important role of left perilesional cortex (e.g., Fernandez et al., 2004; Leger et al., 2002; Thulborn, Carpenter & Just, 1999; Cornelissen et al., 2003)

• Other patients show contralesional changes (e.g., Peck et al. 2004; Crosson et al., 2005)

• And still others show bilateral changes (e.g., Crosson et al., 2005; Pulvermuller et al., 2005; Winhuisen et al., 2005)

S115 Structural Scan: Left frontal-subcortical lesion

S105 Structural Scan: Left temporal-parietal

fMRI Pre- & Post- Noun Retrieval Treatment
Moore et al., 2004

P115 – 81 years old, 5 years post stroke, right hemiplegia, nonfluent aphasia semantic+phonologic treatment Phase 1: nouns

P105: 49 yr old woman, 3 years post stroke verbal+gestural treatment Phase 2: nouns

S115: Picture naming accuracy for trained nouns and untrained nouns following semantic-phonologic training

P105 Naming and Gesture Production for trained and untrained Nouns: Verbal+Gestural Treatment

fMRI Procedures

Scanner. 1.5 T GE Signa; Dome-Shaped Quadrature RF Head Coil

Functional Images. 2-Interleave Spiral Scan, Gradient Echo Pulse Sequence, TE=40 ms

Structural Images. Spoiled GRASS Sequence

Task. Overt naming of viewed line drawings of objects used in treatment study

Analyses. Hemodynamic responses during naming deconvolved from baseline resting state of activation
Summary of Neural Findings

Greater improvements in word retrieval training for nouns and verbs when preserve left posterior cortex
left basal ganglia

Word retrieval training improvements mediated by:
Patient with left frontal lesion (large effect size) left frontal bilateral posterior cortex
Patient with left posterior lesion (smaller effect size) left frontal right posterior

What determines neural reorganization in left perilesional vs right hemisphere?

- Smaller left hemisphere lesions allow for perilesional mediation
- Larger left hemisphere lesions require more right hemisphere mediation Crosson et al (2008)

- Neural mediation may change over time
  - Acute - little activation of perilesional or right
  - Subacute – more right hemisphere mediation
  - Chronic – more left perilesional mediation Saur et al 2006

- Better treatment response seen when perilesional left hemisphere regions engaged compared to right homologous regions Heiss & Thiel 2006
WHO, What, and Where

- Good deal of evidence
- Still more to learn
- Use clinical judgment, patient values to make best decision for each patient

References:

References:

Acknowledgements....
NIH P50 Clinical Research Center with University of Florida

Collaborators at the Brain Rehabilitation Research Center, VAMC Gainesville, FL

Leslie Gonzalez Rothi
Lynn Maher
Steve Nadeau
Lee Blonder
Tim Keterson
Amy Rodriguez
Flo Singleton
Renee Fuller
Lori Altman

Kenneth Heilman
Bruce Crosson
Jay Rosenbek
Diane Kendall
Sam Wu
Anna Moore
Maribel Ciampitti
Bruce Parkinson
Christina del Toro


References:


