Using big data to understand theories of rehabilitation

SWATHI KIRAN & CARRIE DES ROCHES

SPEECH LANGUAGE AND HEARING SCIENCES

BOSTON UNIVERSITY

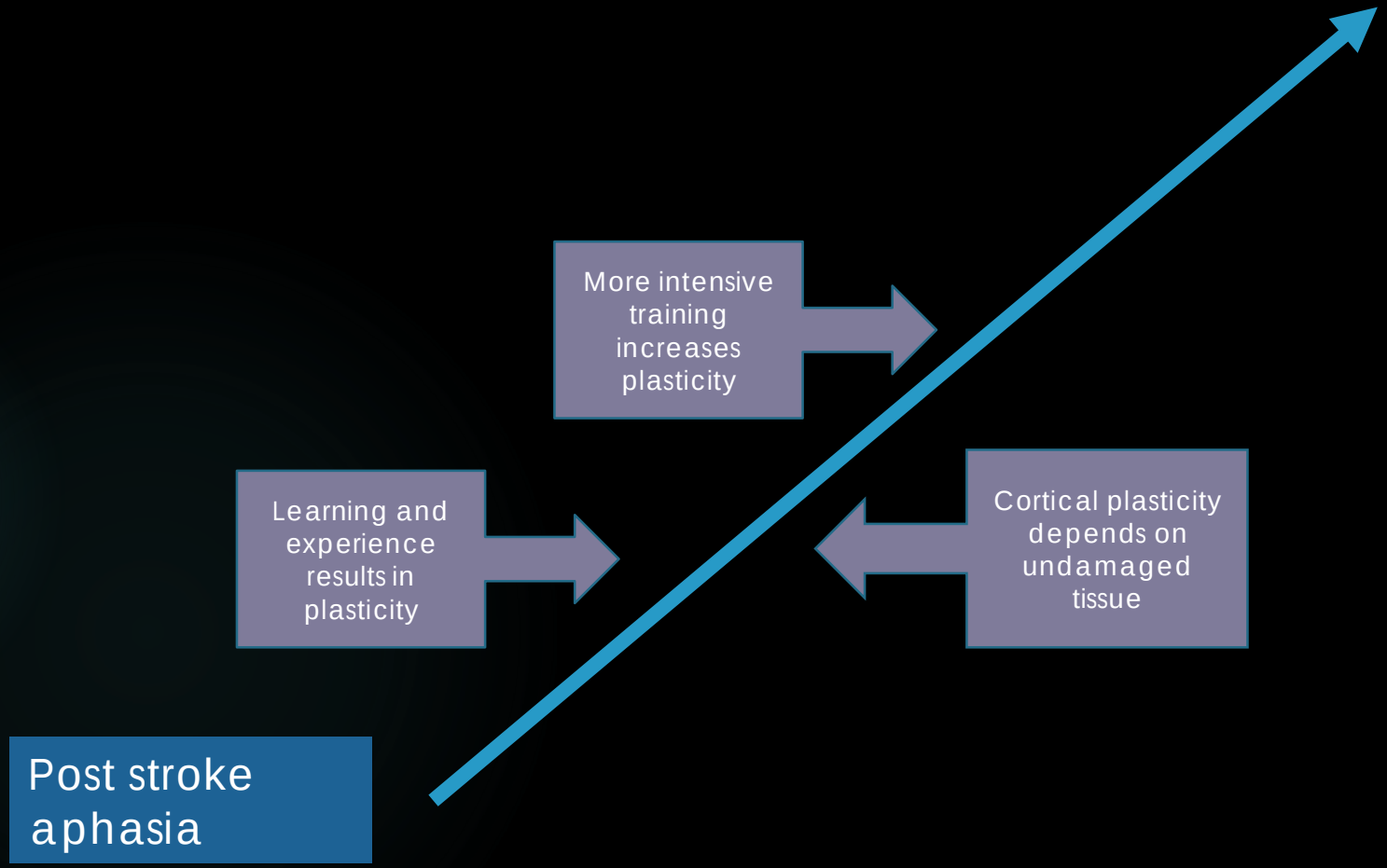
Disclosure

Has significant financial Interest

- Scientific Advisor for Constant Therapy
- Ownership stock in Constant Therapy

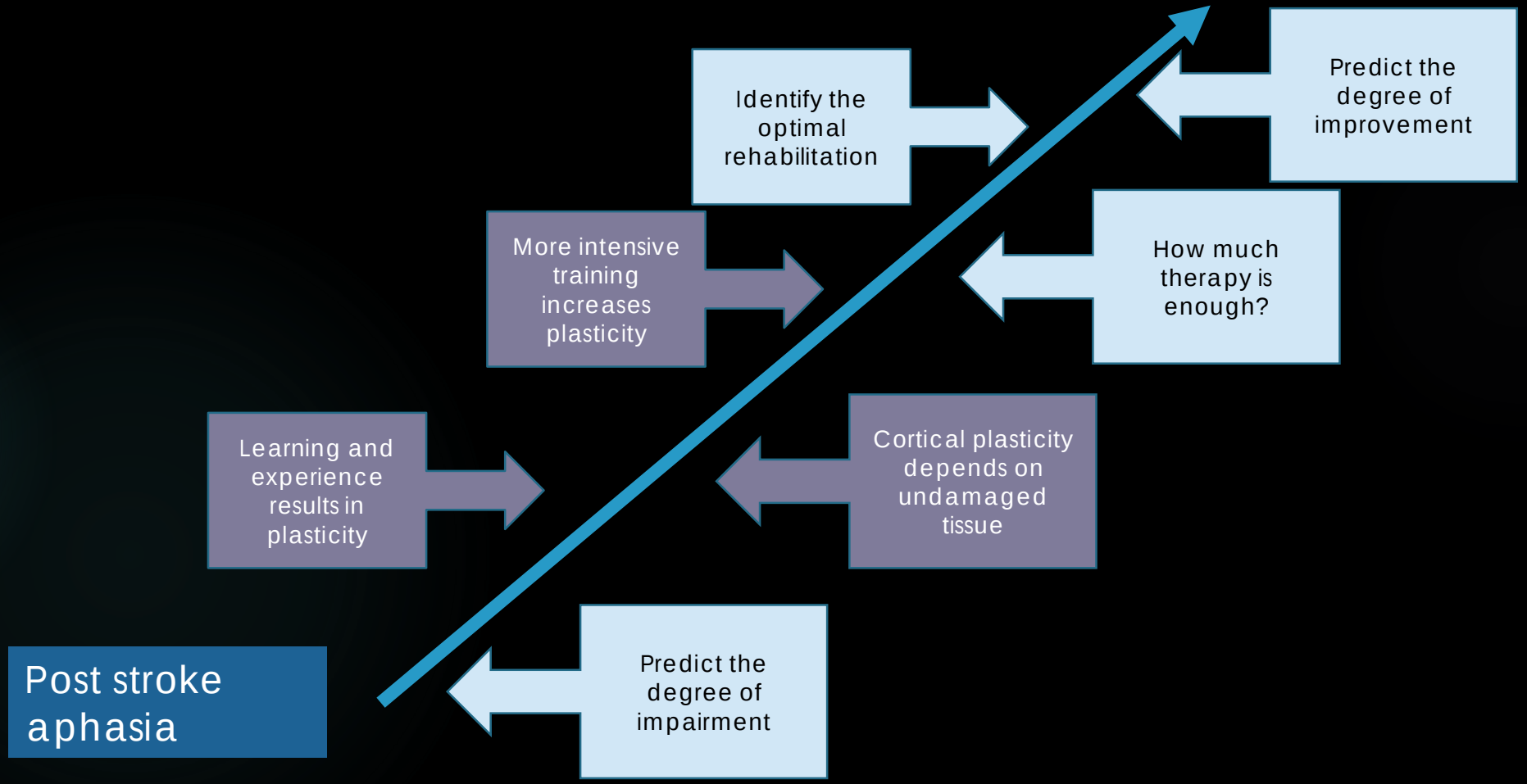
Achieve functional communication independence

Post stroke aphasia



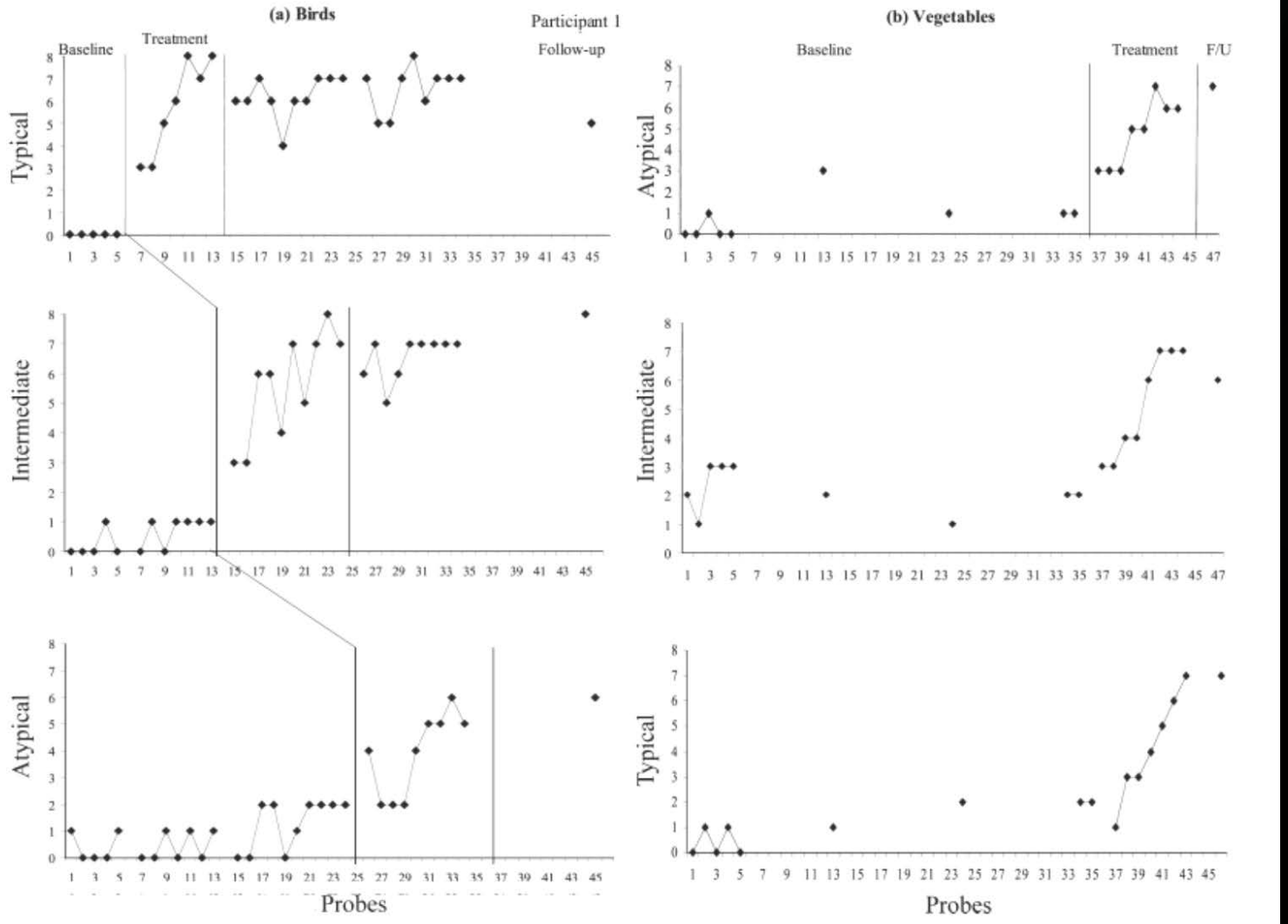
Kleim, 2011; Kleim & Jones, 2008

Achieve functional communication independence



- Age
- Lesion location
- Lesion size/volume
- Months post stroke
- Education
- Severity of impairment
- Duration of treatment
- Type of treatment

Figure 1. (a) Naming accuracy on typical, intermediate, and atypical items for the category *birds* and (b) naming accuracy on atypical, intermediate, and typical items for the category *vegetables* across baseline, treatment, and follow-up phases for Participant 1.



Kiran & Thompson, 2003, JSLHR

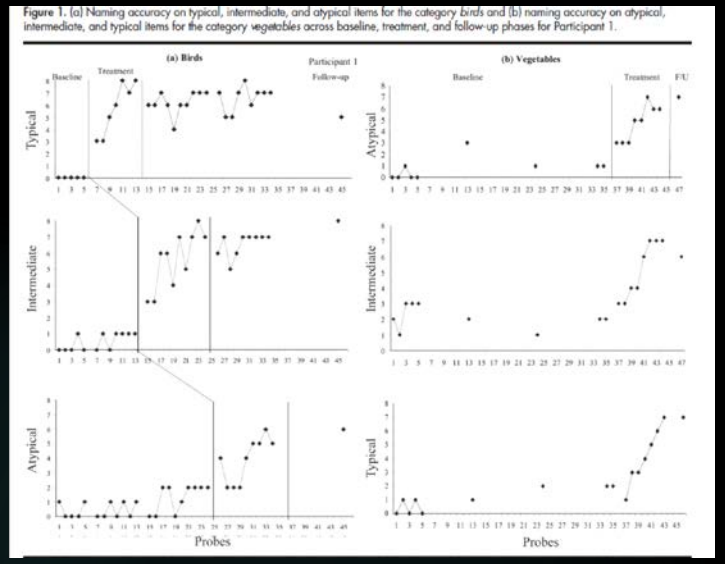
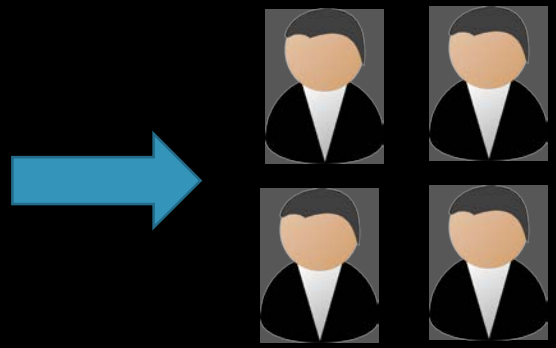
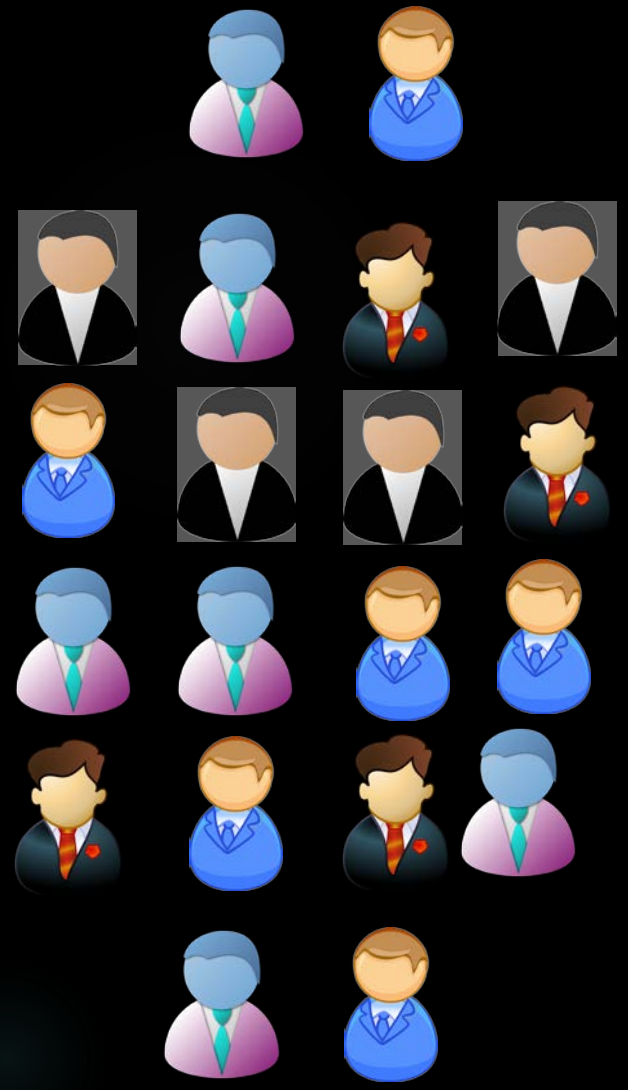


Figure 1. (a) Naming accuracy on typical, intermediate, and atypical items for the category *birds* and (b) naming accuracy on atypical, intermediate, and typical items for the category *vegetables* across baseline, treatment, and follow-up phases for Participant 1.

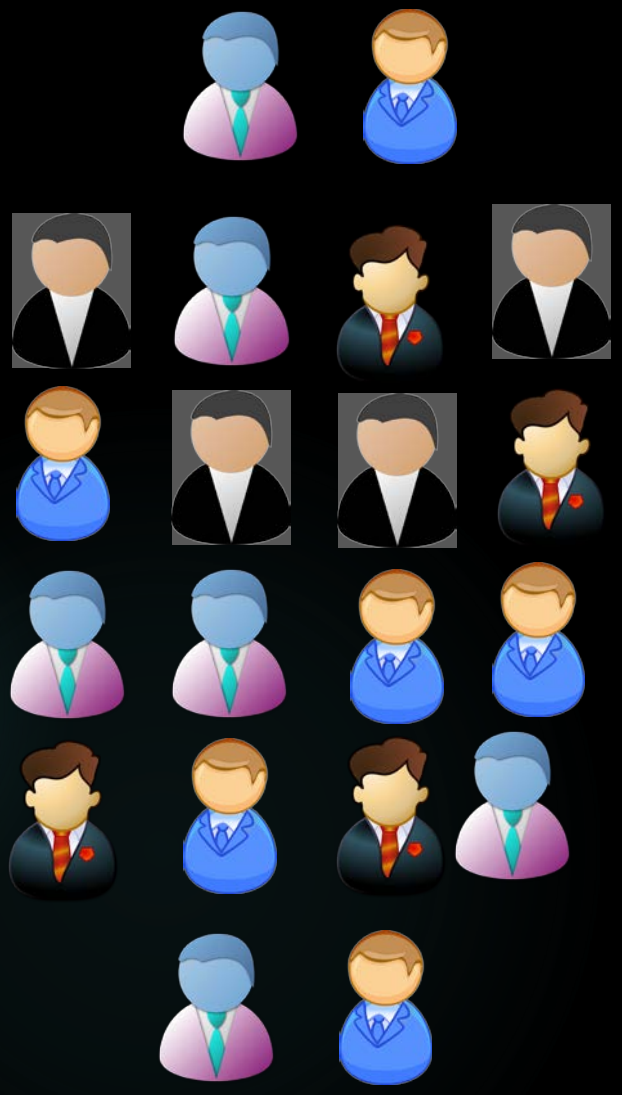
Individual patient analysis



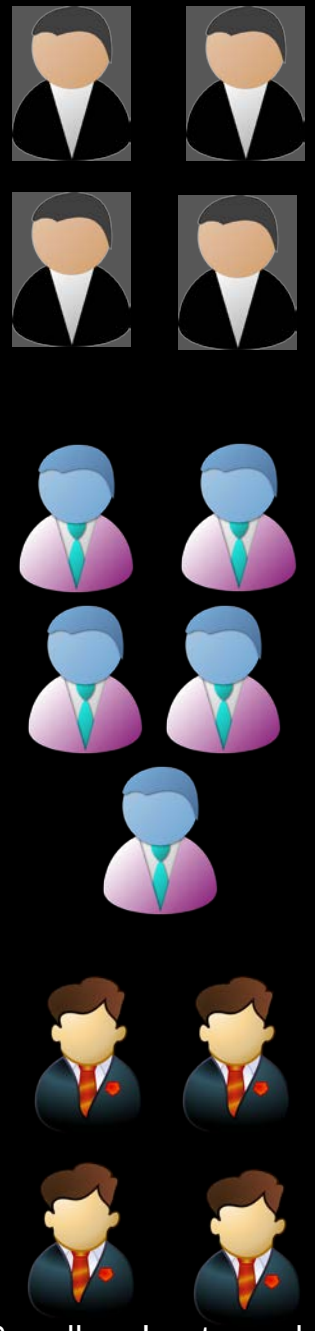
Small cohort analysis



Population analysis



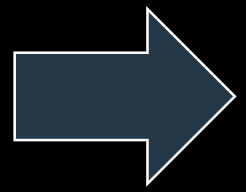
Population analysis



Small cohort analysis

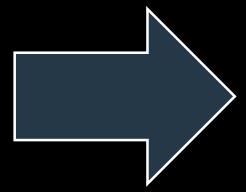
Individual patient analysis

- Age
- Lesion location
- Lesion size/volume
- Months post stroke
- Education
- Severity of impairment
- Duration of treatment
- Type of treatment



Therapy Outcomes

- Age
- Lesion location
- Lesion size/volume
- Months post stroke
- Education
- **Severity of impairment**
- Duration of treatment
- Type of treatment



Therapy Outcomes

What do we know about severity?

Initial aphasia severity associated with poorer outcomes; patients with milder aphasia show greater recovery (Laska et al., 2001; Pederson et al., 2004; Plowman et al., 2011)

Initial severity has a negative effect on outcome of stroke rehabilitation (van Bragt, 2014)

Using technology to improve treatment delivery

- Recent studies have examined the efficacy of rehabilitation techniques, such as videoconferencing, for individuals with hearing, stuttering and motor speech issues (Georgeadis et al., 2004; Hill et al., 2006).

- Other studies have provided aphasia therapy over the internet to individual patients (*Goral et al., 2010;* 2011).

- Virtual Therapy programs: Sentactics (Thompson, Choy, Cole & Holland, 2010); ORLA-VT; (Cole, Cherney et al).

- Computerized rehabilitation programs:
  - Multicue (Doesborgh, van de Sandt-Koenderman, 2004).
  - MossTalk (Fink et al, 2002).
  - Other computerized methods (Palmer et al., 2012; Rambserger & Marie, 2007).
  - Software platforms such as Constant Therapy (Des Roches et al., 2015).

Using technology to improve treatment delivery

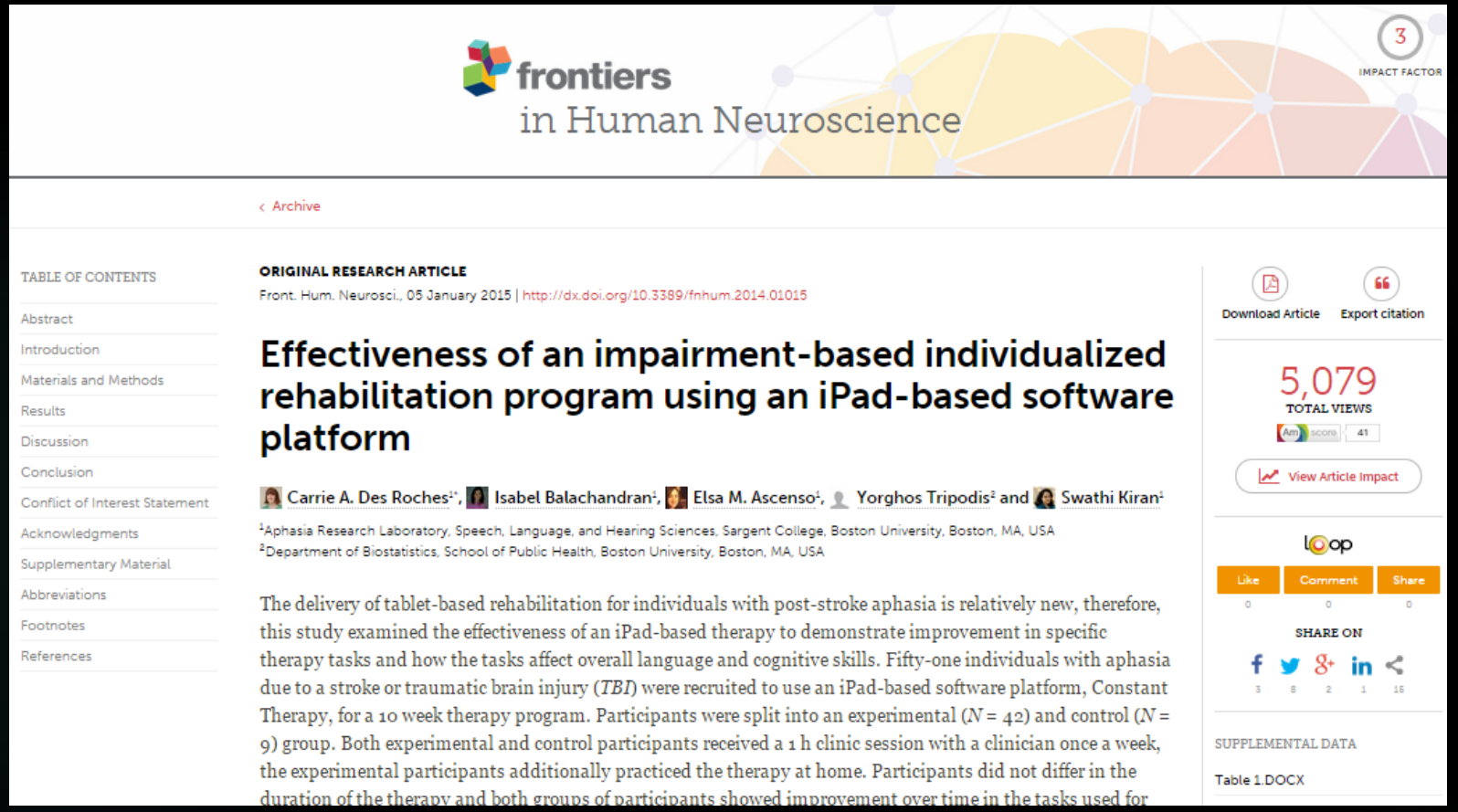
- Recent studies have examined the efficacy of rehabilitation techniques, such as videoconferencing, for individuals with hearing, stuttering and motor speech issues (Georgeadis et al., 2004; Hill et al., 2006).

- Other studies have provided aphasia therapy over the internet to individual patients (*Goral et al., 2010;* 2011).

- Virtual Therapy programs: Sentactics (Thompson, Choy, Cole & Holland, 2010); ORLA-VT; (Cole, Cherney et al).

- Computerized rehabilitation programs:
  - Multicue (Doesborgh, van de Sandt-Koenderman, 2004).
  - MossTalk (Fink et al, 2002).
  - Other computerized methods (Palmer et al., 2012; Rambserger & Marie, 2007).
  - Software platforms such as Constant Therapy (Des Roches et al., 2015).

Study #1



frontiers in Human Neuroscience

3 IMPACT FACTOR

‹ Archive

TABLE OF CONTENTS

Abstract
Introduction
Materials and Methods
Results
Discussion
Conclusion
Conflict of Interest Statement
Acknowledgments
Supplementary Material
Abbreviations
Footnotes
References

ORIGINAL RESEARCH ARTICLE

Front. Hum. Neurosci., 05 January 2015 | http://dx.doi.org/10.3389/fnhum.2014.01015

Effectiveness of an impairment-based individualized rehabilitation program using an iPad-based software platform

Carrie A. Des Roches[1]*, Isabel Balachandran[1], Elsa M. Ascenso[1], Yorghos Tripodis[2] and Swathi Kiran[1]

[1]Aphasia Research Laboratory, Speech, Language, and Hearing Sciences, Sargent College, Boston University, Boston, MA, USA
[2]Department of Biostatistics, School of Public Health, Boston University, Boston, MA, USA

The delivery of tablet-based rehabilitation for individuals with post-stroke aphasia is relatively new, therefore, this study examined the effectiveness of an iPad-based therapy to demonstrate improvement in specific therapy tasks and how the tasks affect overall language and cognitive skills. Fifty-one individuals with aphasia due to a stroke or traumatic brain injury (*TBI*) were recruited to use an iPad-based software platform, Constant Therapy, for a 10 week therapy program. Participants were split into an experimental ($N = 42$) and control ($N = 9$) group. Both experimental and control participants received a 1 h clinic session with a clinician once a week, the experimental participants additionally practiced the therapy at home. Participants did not differ in the duration of the therapy and both groups of participants showed improvement over time in the tasks used for

Download Article
Export citation

5,079
TOTAL VIEWS
Alm score 41

View Article Impact

loop
Like Comment Share
0 0 0

SHARE ON
3 8 2 1 15

SUPPLEMENTAL DATA
Table 1.DOCX

- 51 patients with stroke or TBI
- 42 experimental patients and 9 control patients
- Both groups matched for WAB AQ, CLQT composite severity and age
- Both groups practiced Constant Therapy on their ipads.

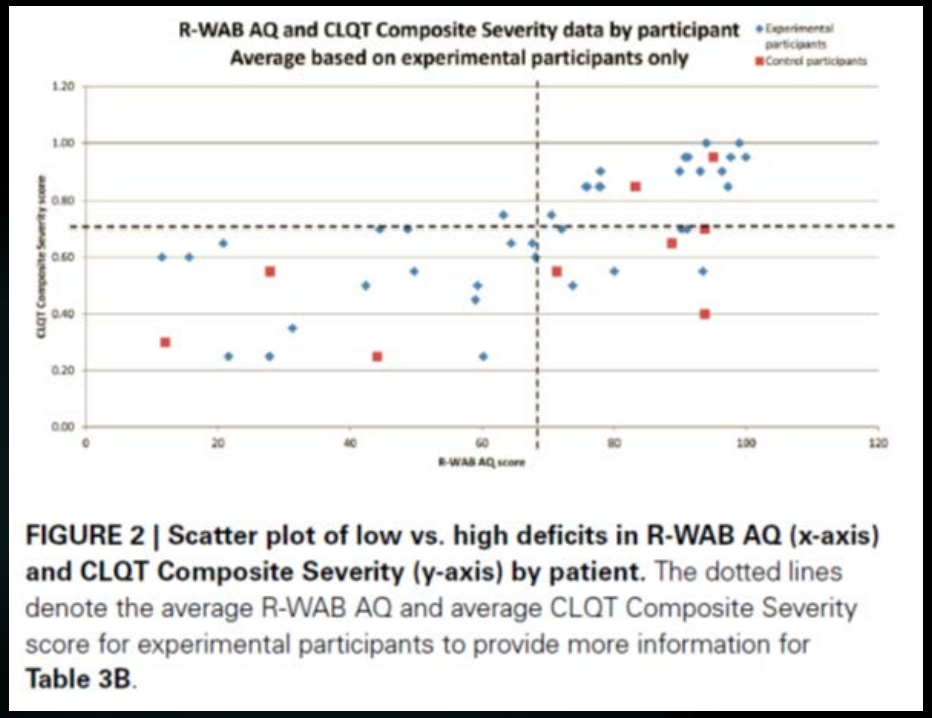
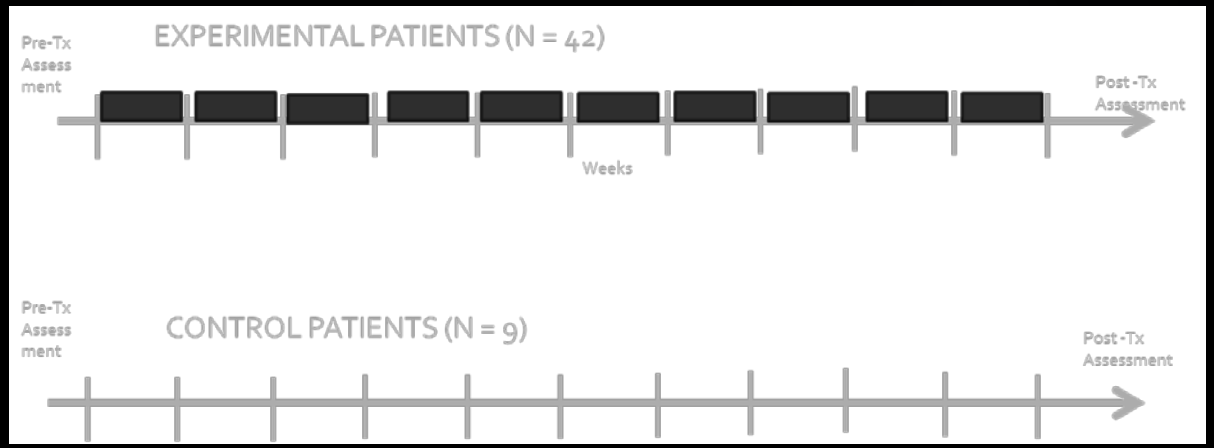


FIGURE 2 | Scatter plot of low vs. high deficits in R-WAB AQ (x-axis) and CLQT Composite Severity (y-axis) by patient. The dotted lines denote the average R-WAB AQ and average CLQT Composite Severity score for experimental participants to provide more information for **Table 3B**.

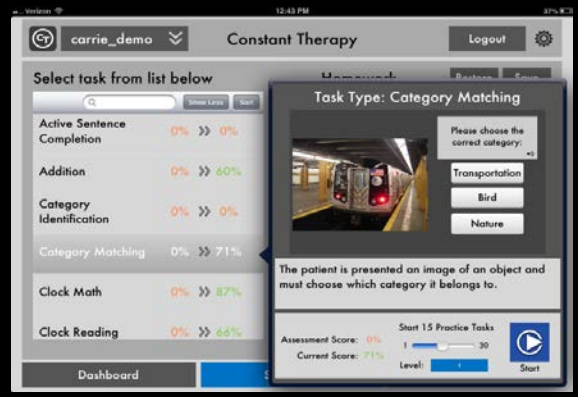


Des Roches et al., 2015, Frontiers in Human Neuroscience

Assess baseline performance

- Language and cognitive skills

Assign individualized set of tasks



Task assigned if accuracy less than 80% on first session

Des Roches et al., 2015

Assess baseline performance

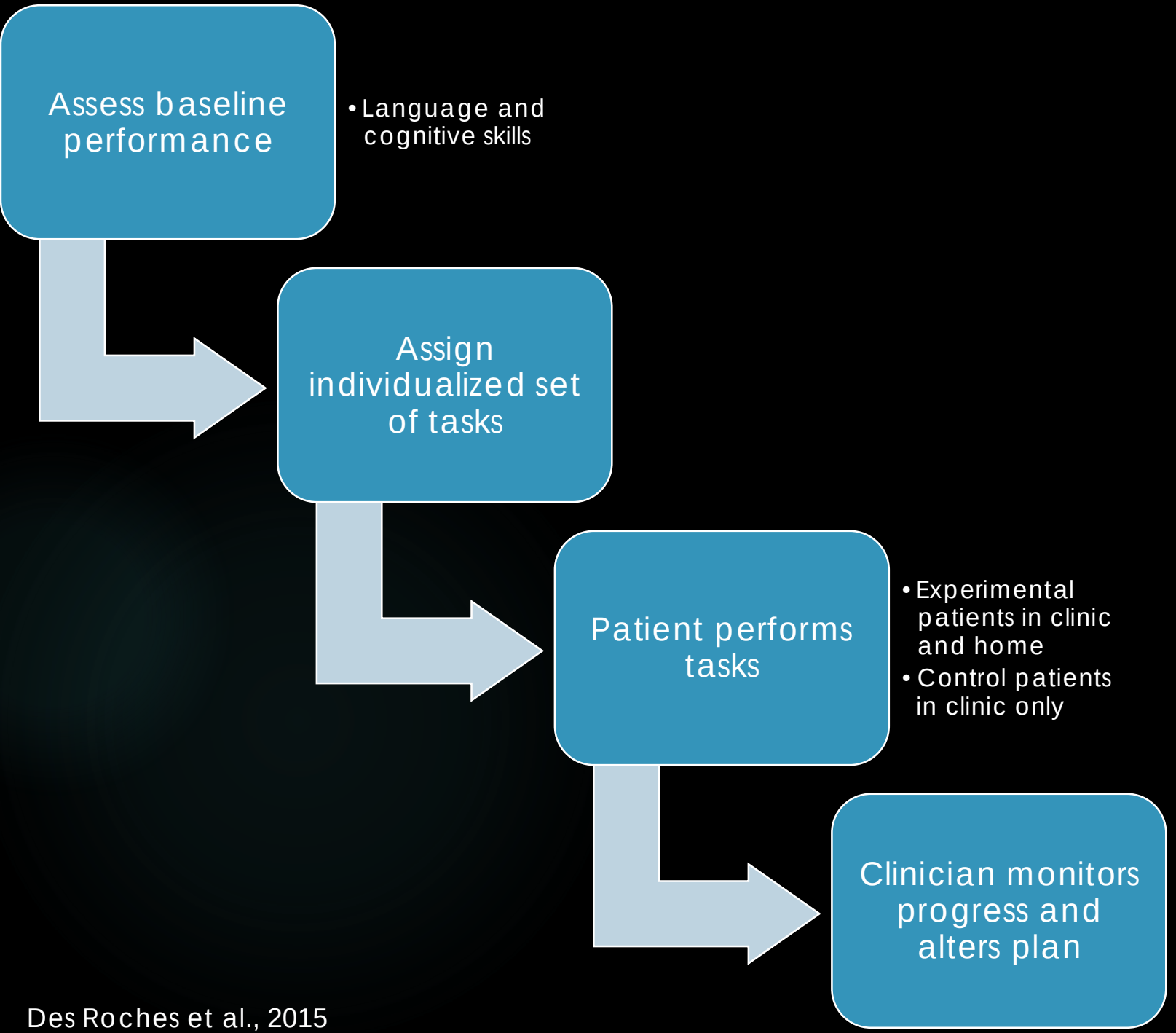
- Language and cognitive skills

Assign individualized set of tasks

Patient performs tasks

Experimental patients in clinic and home
Control patients in clinic only

Des Roches et al., 2015



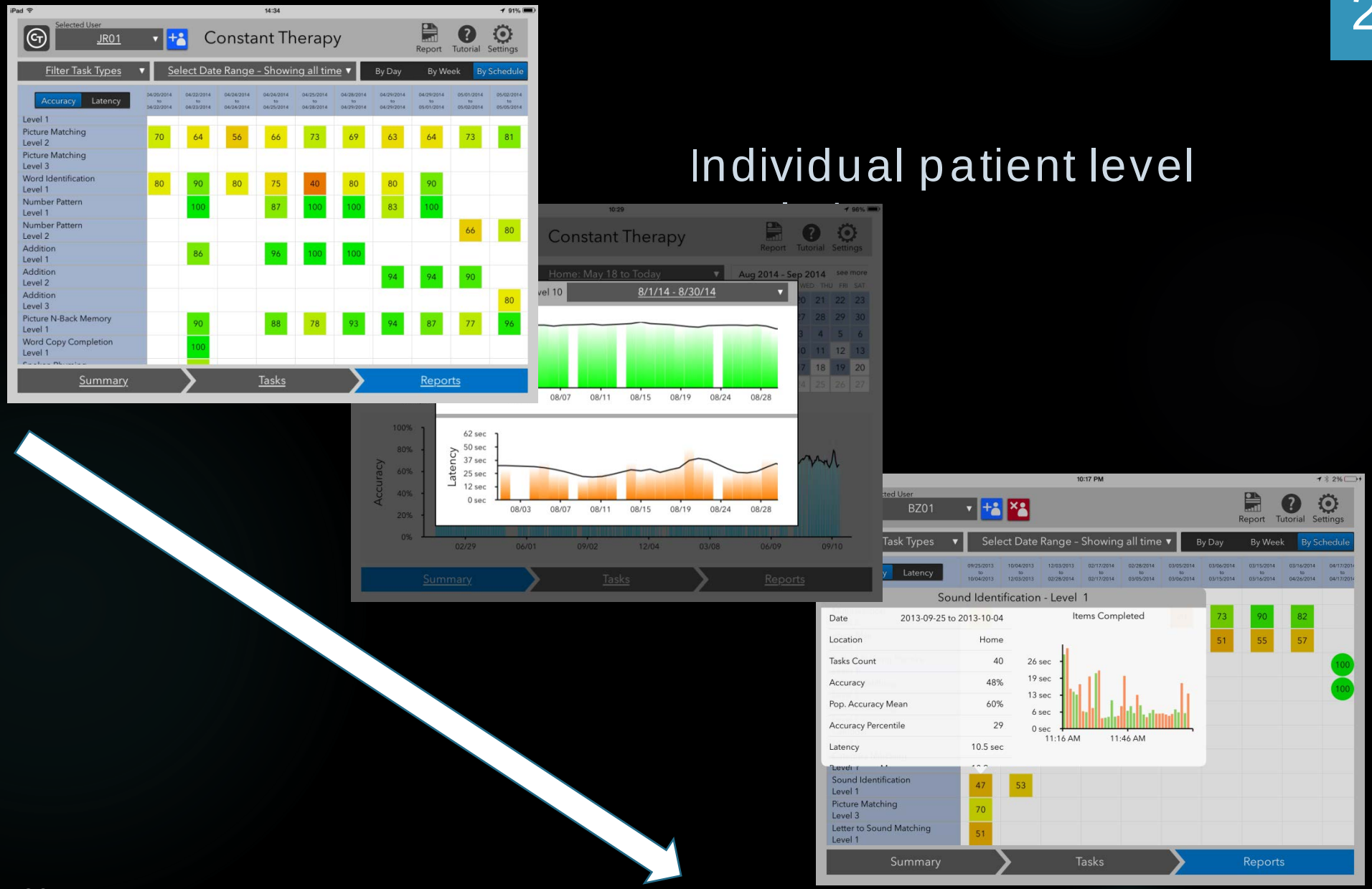
Des Roches et al., 2015

Weekly clinic sessions

- Keep the task or modify the task
- If the participant achieved 95% or higher accuracy two times in succession,
  - The clinician would either progress the next level of difficulty or different task.
- If a participant was not improving on a task over time,
  - Either a lower level of that task was assigned in addition to or in replacement of the original task,
  - A different task examining the same skill,
  - No change.

Des Roches et al., 2015

Individual patient level



Des Roches et al., 2015

		Accuracy		Latency
Domain	Task	DF	Conditional Improvement	
Naming	Category Matching	1018		
	Feature Matching	388		
	Naming Picture	392		
	Rhyming	1043		
	Sound Identification	849		
	Syllable Identification	393		
Reading	Category Identification	721		
	Letter to Sound Matching	593		
	Sound to Letter Matching	690		
	Reading Passage	771		
	Long Reading Comprehension	130		
	Word Identification	647		
Writing	Word Copy	361		
	Word Copy Completion			
	Word Spelling	503		
	Word Spelling Completion	348		
	Picture Spelling	313		
	Picture Spelling Completion			
Sentence Planning	Active Sentence Completion			
	Passive Sentence Completion			
Auditory Memory	Voice Mail	138		
	Sound Matching	403		
Visuospatial Memory	Picture Matching	728		
	Word Matching	631		

overall, experimental participants show beneficial and significant change

overall, experimental participants show non-beneficial but significant change

Des Roches et al., 2015

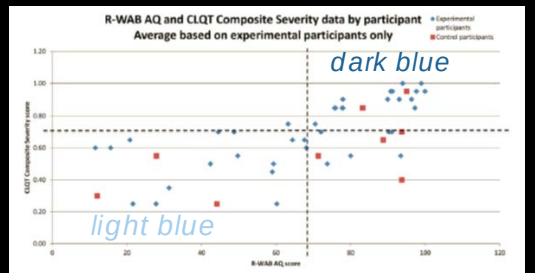


FIGURE 2 | Scatter plot of low vs. high deficits in R-WAB AQ (x-axis) and CLQT Composite Severity (y-axis) by patient. The dotted lines denote the average R-WAB AQ and average CLQT Composite Severity score for experimental participants to provide more information for **Table 3B**.

		Accuracy				Latency
Domain	**Task**	DF	Conditional Improvement	Effect of R-WAB AQ	Effect of CLQT Composite Severity	
Naming	Category Matching	1018				
	Feature Matching	388				
	Naming Picture	392				
	Rhyming	1043				
	Sound Identification	849				
	Syllable Identification	393				
Reading	Category Identification	721				
	Letter to Sound Matching	593				
	Sound to Letter Matching	690				
	Reading Passage	771				
	Long Reading Comprehension	130				
	Word Identification	647				
Writing	Word Copy	361				
	Word Copy Completion					
	Word Spelling	503				
	Word Spelling Completion	348				
	Picture Spelling	313				
	Picture Spelling Completion					
Sentence Planning	Active Sentence Completion					
	Passive Sentence Completion					
Auditory Memory	Voice Mail	138				
	Sound Matching	403			*	
Visuospatial Memory	Picture Matching	728				
	Word Matching	631				

light blue : participants with a lower score than average show more improvement in the task

participants with a lower than average WAB AQ score show more improvement in accuracy,

Participants with a higher than average CLQT score show more improvement in accuracy

dark blue: participants with a higher score than average show more improvement in the task

Des Roches et al., 2015

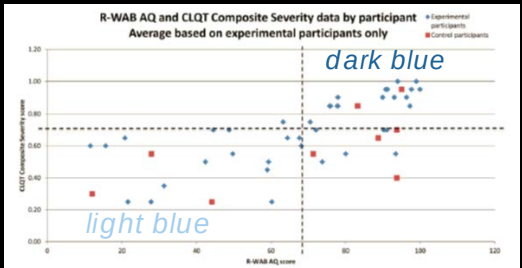


FIGURE 2 | Scatter plot of low vs. high deficits in R-WAB AQ (x-axis) and CLQT Composite Severity (y-axis) by patient. The dotted lines denote the average R-WAB AQ and average CLQT Composite Severity score for experimental participants to provide more information for **Table 3B**.

		Accuracy				Latency			
Domain	**Task**	DF	Conditional Improvement	Effect of R-WAB AQ	Effect of CLQT Composite Severity	DF	Conditional Improvement	Effect of R-WAB AQ	Effect of CLQT Composite Severity
Naming	Category Matching	1018				1019			
	Feature Matching	388				393			
	Naming Picture	392				433			
	Rhyming	1043				1044			
	Sound Identification	849				849			
	Syllable Identification	393				393			
Reading	Category Identification	721				722			
	Letter to Sound Matching	593				597			
	Sound to Letter Matching	690				691			
	Reading Passage	771				771			
	Long Reading Comprehension	130				131			
	Word Identification	647				647			
Writing	Word Copy	361				361			
	Word Copy Completion								
	Word Spelling	503				504			
	Word Spelling Completion	348				349			
	Picture Spelling	313				313			
	Picture Spelling Completion								
Sentence Planning	Active Sentence Completion								
	Passive Sentence Completion								
Auditory Memory	Voice Mail	138				138			
	Sound Matching	403			*	404			
Visuospatial Memory	Picture Matching	728				728			
	Word Matching	631				631			

Des Roches et al., 2015

Subtest	Experimental Group (N= 41)	Control Group (N = 9)
WAB-LQ	2.13 (t = -2.05, p <.05)	1.42 (ns)
WAB-CQ	2.15 (t = -2.16, p <.05)	1.32 (ns)
WAB-AQ	3.18 (t = -2.89, p <.01)	0.65 (ns)
CLQT-composite severity	5.26 (t = -3.10, p < .01)	4.44 % (ns)
CLQT-Attention	10.9 % (t = -1.93, p <.05)	7.6% (ns)
CLQT-Memory	1.55% (ns)	1.14% (ns)
CLQT-Executive Function	5.06% (t = -2.74, p < .01)	1.66% (ns)
CLQT- Language	1.42% (ns)	1.65% (ns)
CLQT- Visuospatial skills	6.89 (t = -3.45, p < .001)	2.96% (ns)

Experimental patients show more significant changes on standardized tests than control patients.

Patients with lower initial scores showed more improvements on the standardized tests than patients with higher initial scores.

Des Roches et al., 2015

What can we understand about severity?

The more severely language-impaired participants tended to benefit from the simpler tasks (e.g., category matching) that were assigned.

The less severely language-impaired participants benefit from more difficult tasks and those that combined language and cognitive skills.

Patients with lower initial scores showed more improvements than patients with higher initial scores.

Possible to better tailor treatment based on starting level severity of impairment across a group of patients.

Not only can examine quantitative measures that we are used to looking such as accuracy and latency.

We can even begin to look at more qualitative metrics such as scaffolds.

Quantify the way patients interact with therapy.

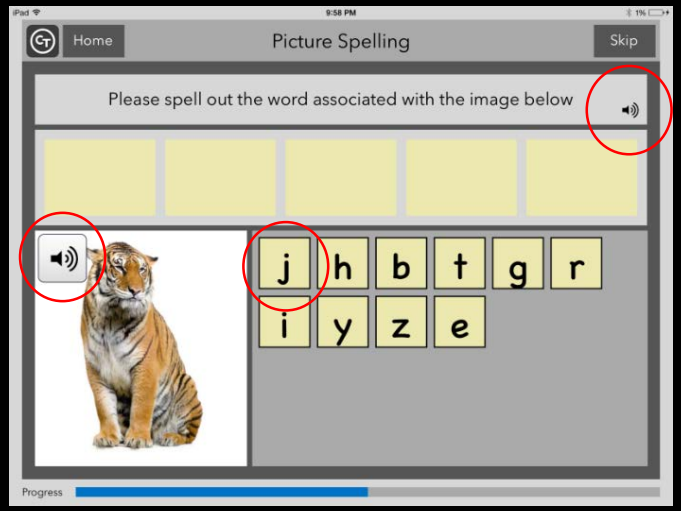
Follow up- Study #2

- Examined individual differences in the way patients used cues to solve the tasks.
- 51 individuals with aphasia,
- 10 week therapy program using the Constant Therapy software platform,
- Participants could self-administer hints (available in 28 of the 37 tasks).

Des Roches et al., in preparation

Hint use and accuracy

- Examined individual differences in the way patients used cues to solve the tasks.
- 51 individuals with aphasia,
- 10 week therapy program using the Constant Therapy software platform,
- Participants could self-administer hints (available in 28 of the 37 tasks).



Des Roches et al., in preparation

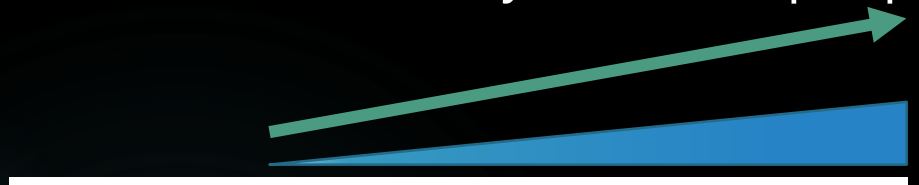
What is the relationship between accuracy and hint use?

- First, a simple regression of the count of all hints self-administered within a session and average accuracy within the session for all participants
  - Hint use had a significant negative predictive relationship with accuracy.
- K-means cluster analysis for sample participants.

Des Roches et al., in preparation

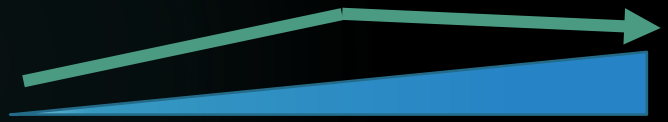
What is the relationship between accuracy and hint use?

- First, a simple regression of the count of all hints self-administered within a session and average accuracy within the session for all participants
  - Hint use had a significant negative predictive relationship with accuracy.
- K-means cluster analysis for sample participants.

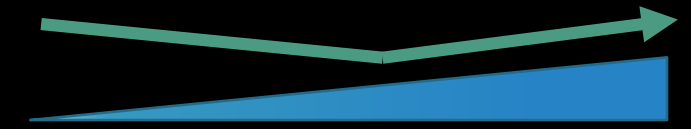


Participant 12	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Average Accuracy	92%	92%	97%	100%	100%
Average Hint Use	<1	9	19	28	44
Number of Cases	275	11	5	7	2

Participant 18	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Average Accuracy	87%	80%	76%	71%	67%
Average Hint Use	<1	16	27	42	57
Number of Cases	319	125	64	17	3



Participant 34	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Average Accuracy	80%	79%	92%	89%	88%
Average Hint Use	1	11	26	38	58
Number of Cases	82	26	4	4	3

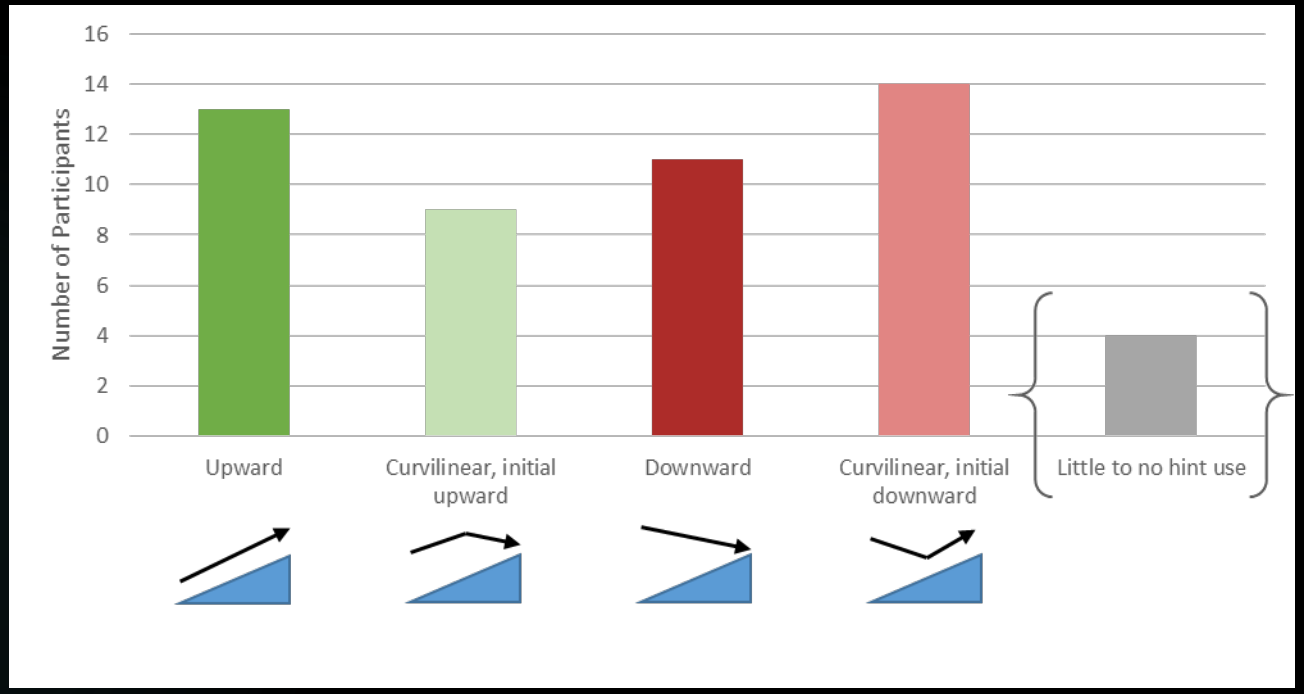


Participant 2	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Average Accuracy	74%	68%	65%	74%	77%
Average Hint Use	<1	8	16	28	39
Number of Cases	255	144	30	10	5

Des Roches et al., in preparation

What is the relationship between accuracy and hint use?

Patients form five subgroups in terms of whether increased hint use is associated with increased accuracy.

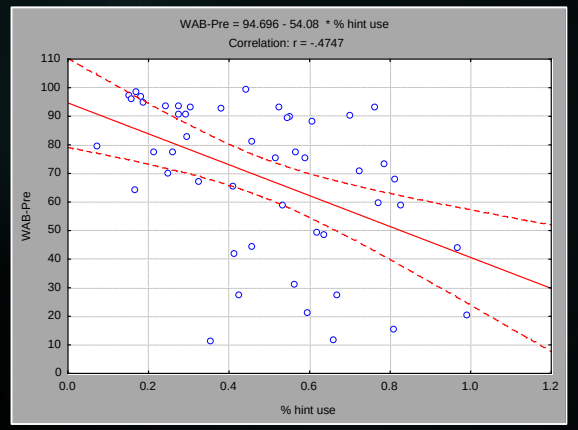


Des Roches et al., in preparation

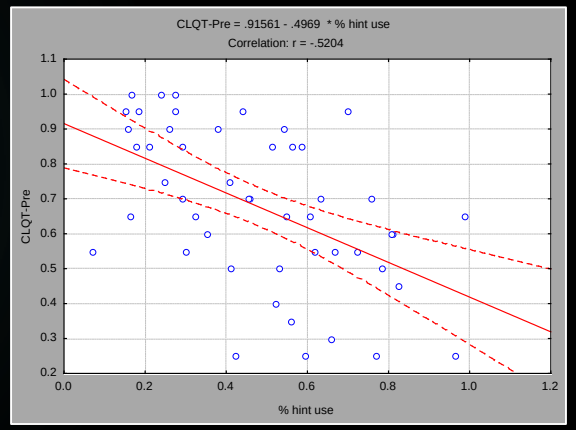
Are participants' severity profiles related to frequency of self-administered hint use?

- Pearson correlation of frequency of hint use with all standardized test scores and demographic information,
- All severity measures negatively correlated with frequency of hint use,
- The more severe the participant, the more frequently they used hints.

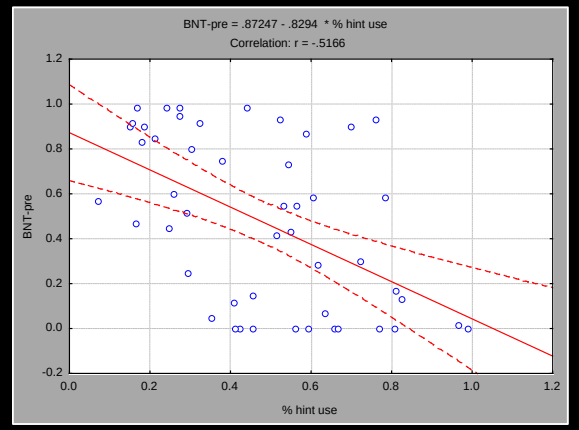
WAB & Hint use



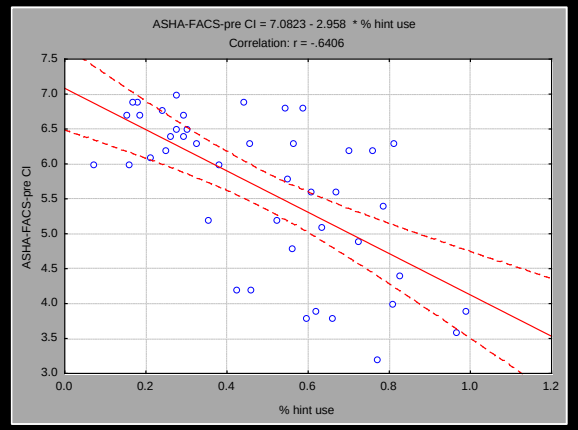
CLQT & Hint use



BNT & Hint use



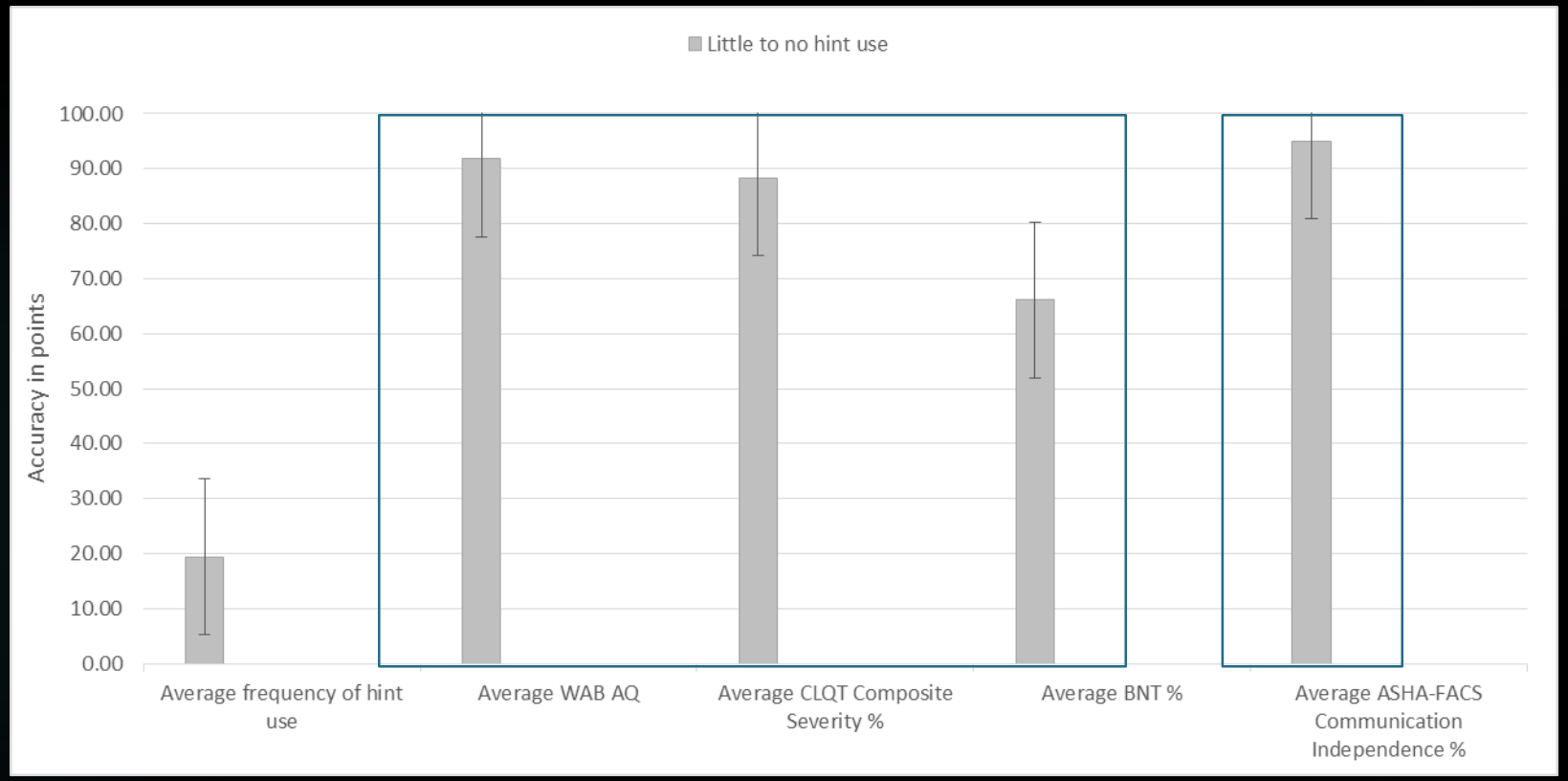
ASHA FACS CI & Hint use



Des Roches et al., in preparation

- Combining severity and frequency of hint use
- Overall accuracy on task ranged between 75%-85%

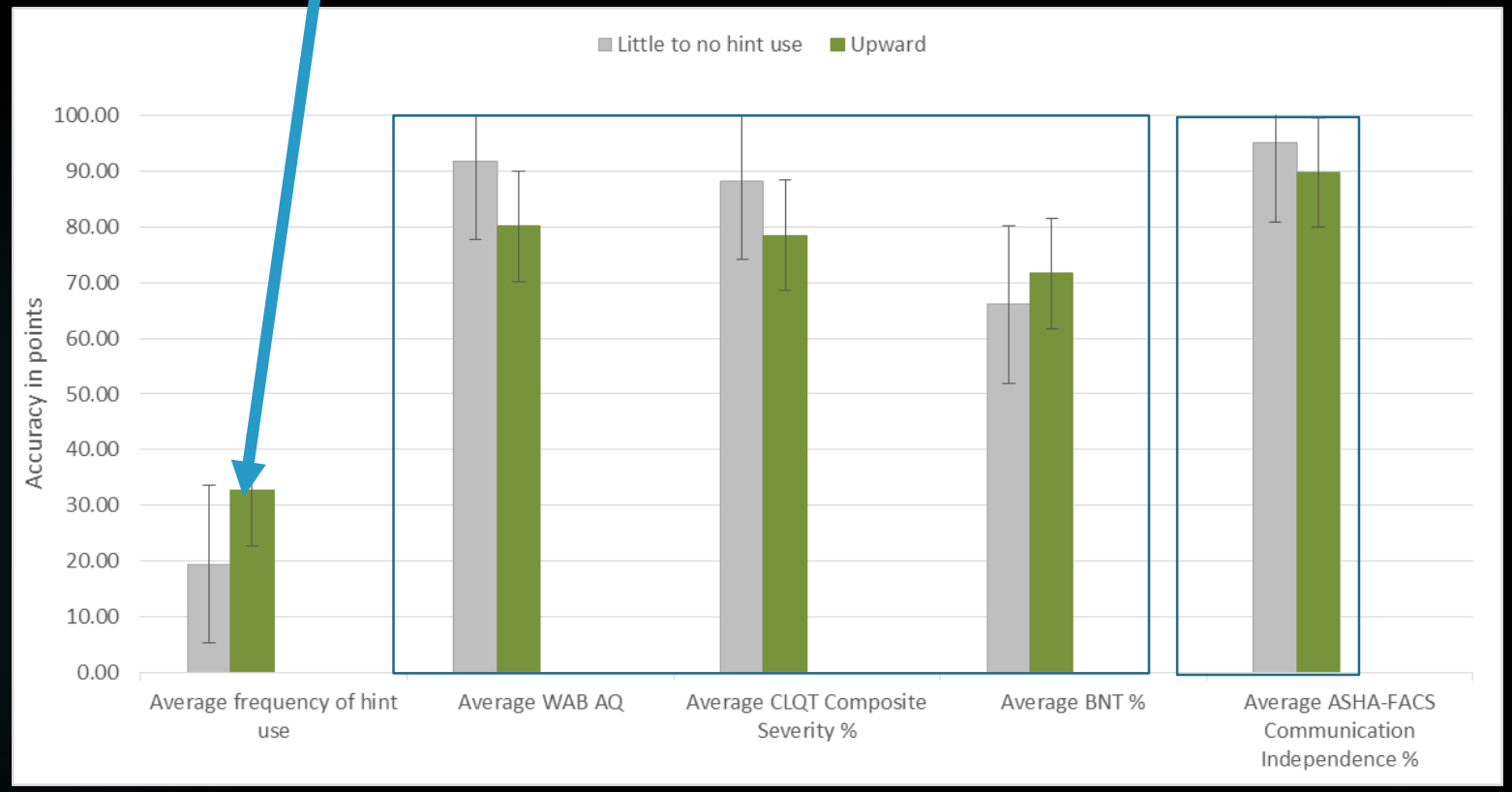
These participants used hints infrequently and had the highest scores on most of the standardized measures.



Des Roches et al., in preparation

- Combining severity and frequency of hint use

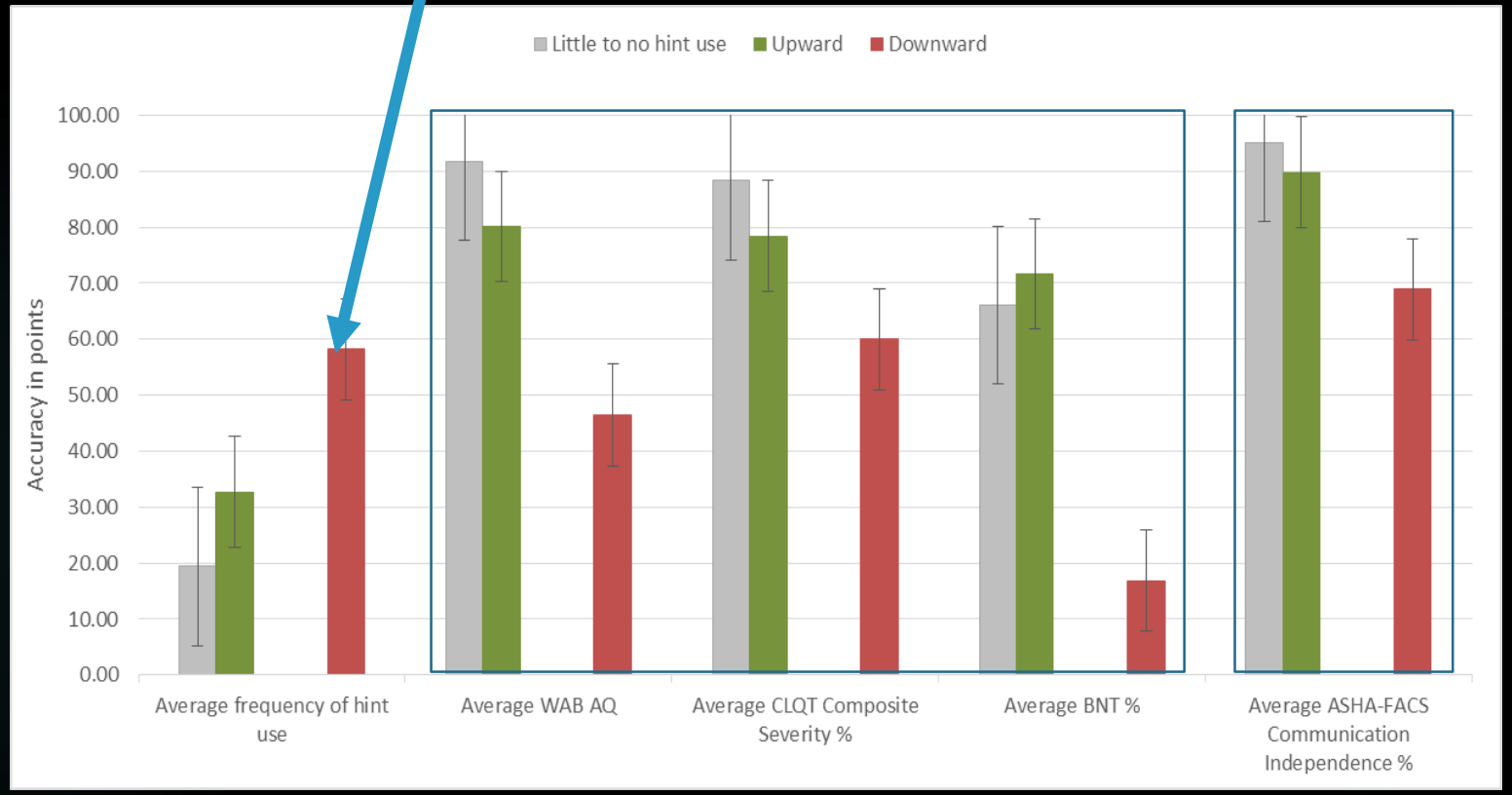
Low but beneficial hint use



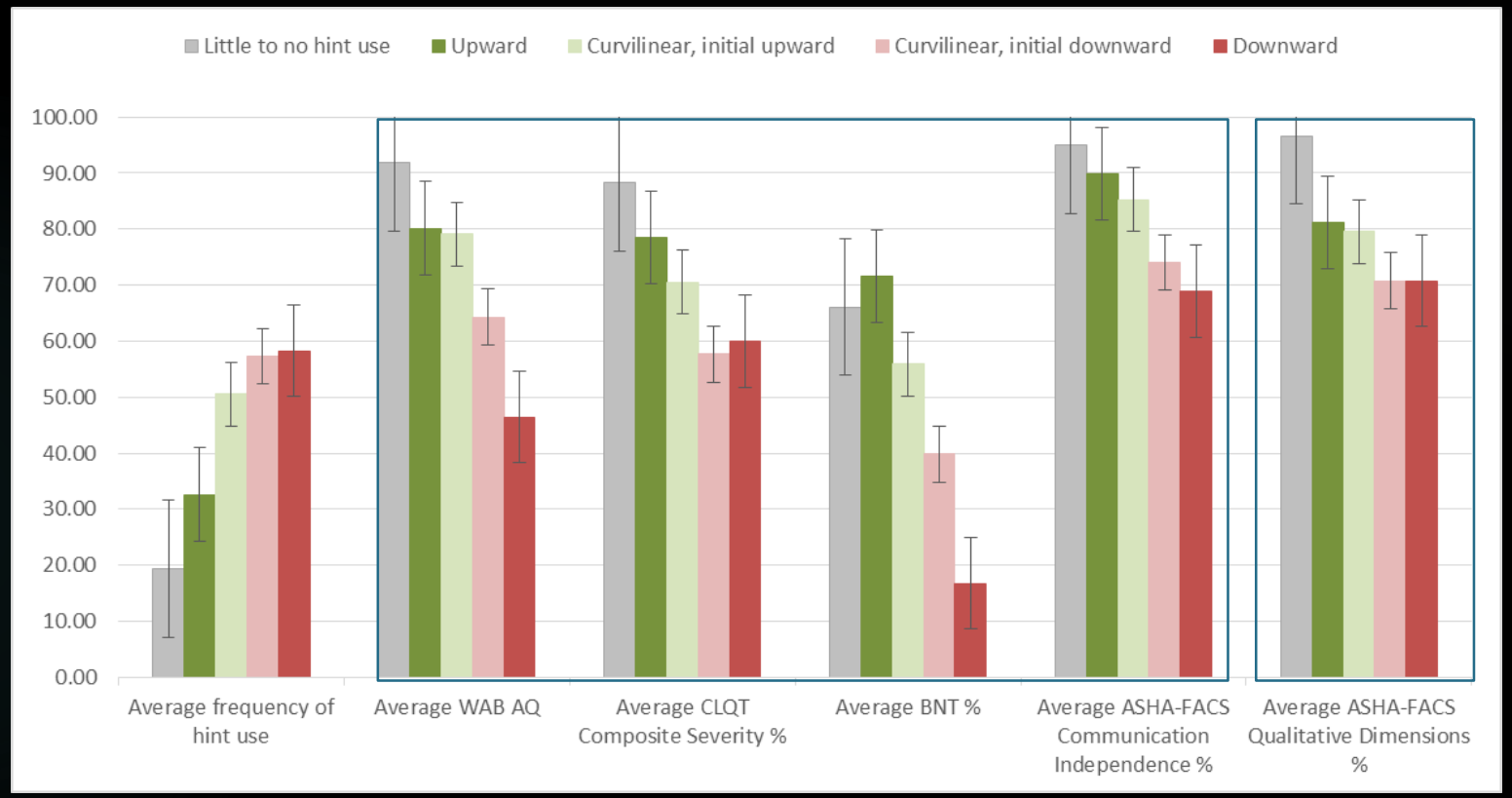
Des Roches et al., in preparation

- Combining severity and frequency of hint use

High but non-beneficial hint use



Des Roches et al., in preparation



Des Roches et al., in preparation

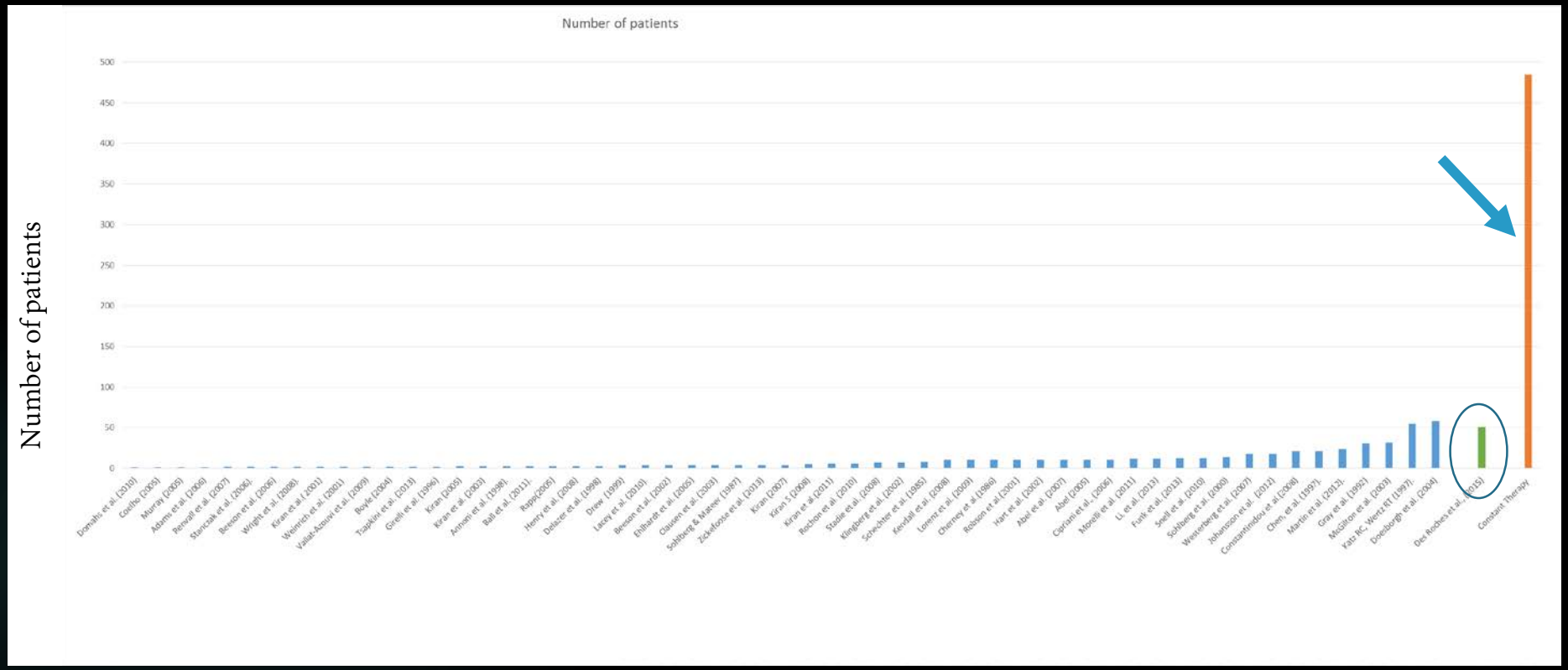
What does this tell us about severity?

The more severe patients (based on the standardized tests) also used hints more frequently, but this higher hint use was not beneficial.

The less severe patients (based on the standardized tests) used hints less frequently, but this hint use was beneficial for them.

Has implications for the way self-administered hints or clinician-generated cues may help or hinder patients during rehabilitation.

How can big data inform clinical decision making?



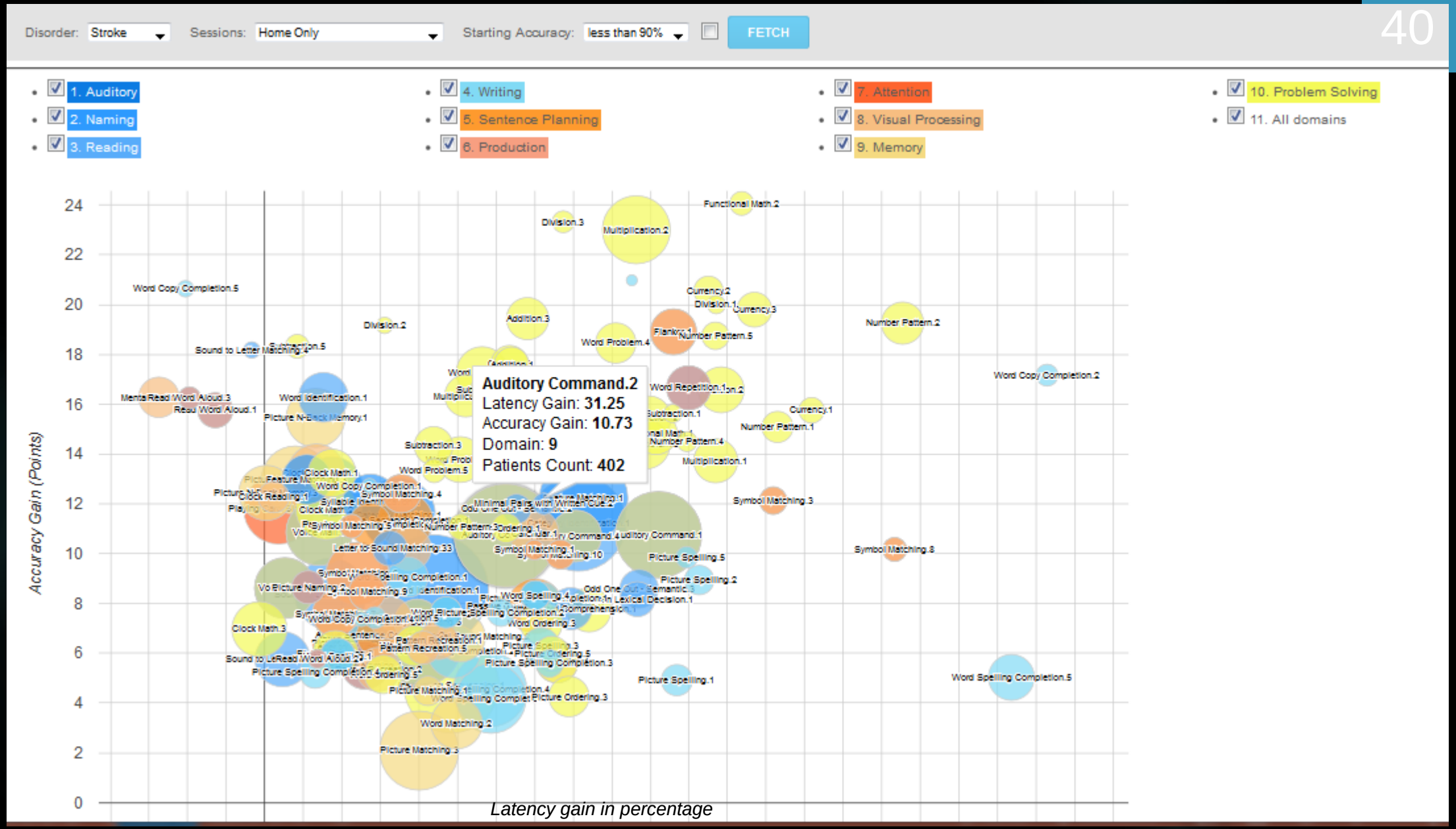
Case –studies, SSED

Large data sets

** Scientific Advisor and Ownership stock for Constant Therapy

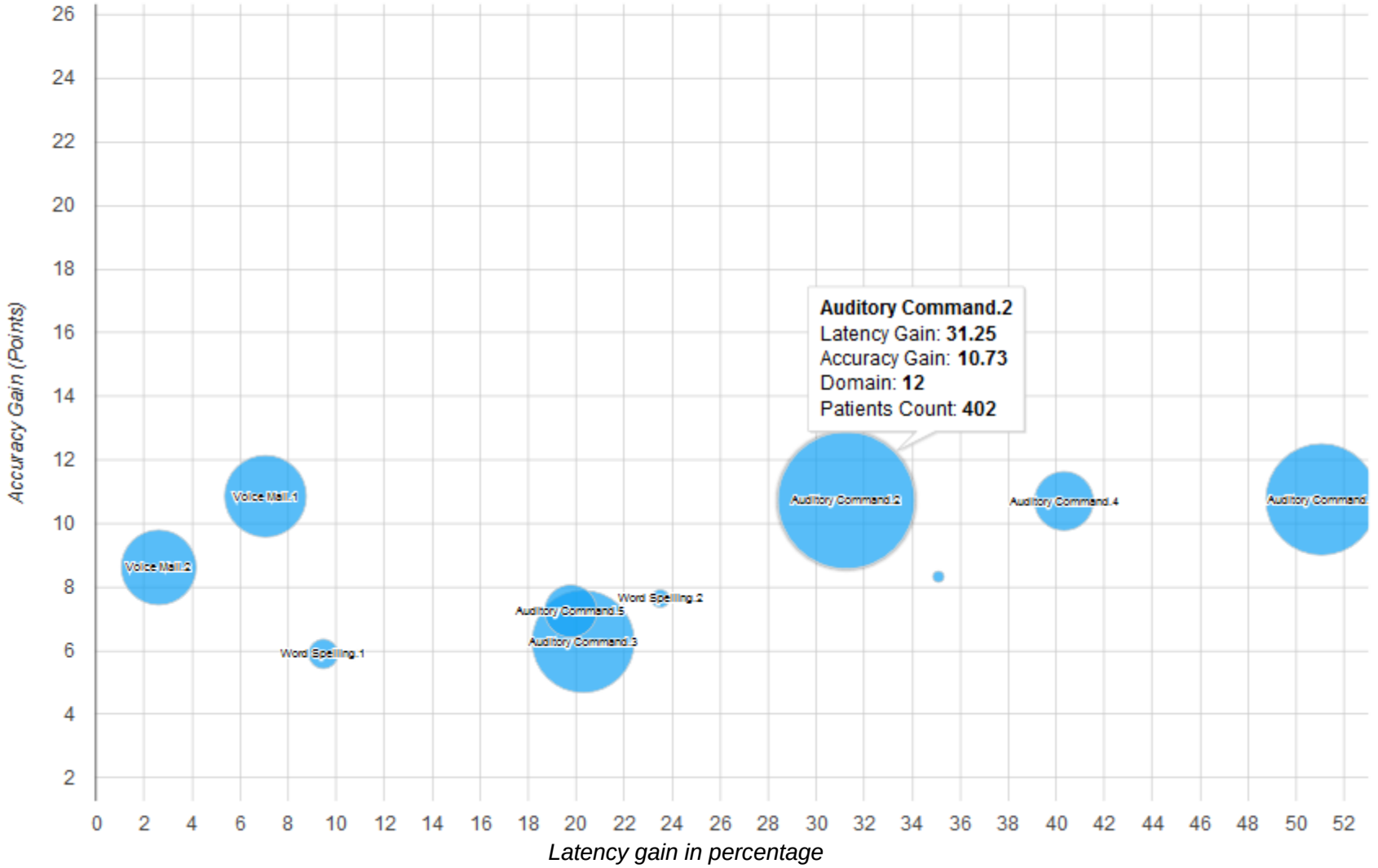
Approach for CT data

- Patients download the app and sign up for an account.
- Based on an initial baseline assessment, a given task is assigned as long as its performance is between 40% and 90% accuracy and average latency.
- For the analysis, for given task type and level :
  - Compared post-tx performance (Average of the last 10 items for each patient) – pre-treatment performance (average of the first 10 items for each patient).
  - Drop the first three items of a given task.
- Paired t-test (two tailed) per task; Only consider $p < .05$ as statistically significant changes.
- Same analysis for accuracy and latency.

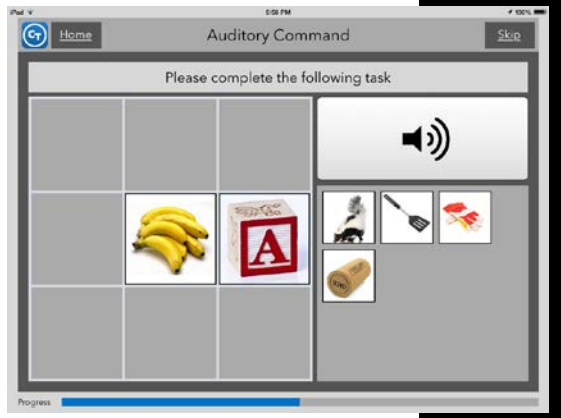

Disorder: Stroke
Sessions: Home Only
Starting Accuracy: less than 90%
FETCH
1. Auditory
2. Naming
3. Reading
4. Writing
5. Sentence Planning
6. Production
7. Attention
8. Visual Processing
9. Memory
10. Problem Solving
11. All domains
Auditory Command.2
Latency Gain: 31.25
Accuracy Gain: 10.73
Domain: 9
Patients Count: 402
Accuracy Gain (Points)
Latency gain in percentage

Disorder: Stroke Sessions: Home Only Starting Accuracy: less than 90% FETCH

- 1. Auditory
- 2. Naming
- 3. Reading
- 4. Writing
- 5. Sentence Planning
- 6. Production
- 7. Attention
- 8. Visual Processing
- 9. Memory
- 10. Problem Solving
- 11. All domains

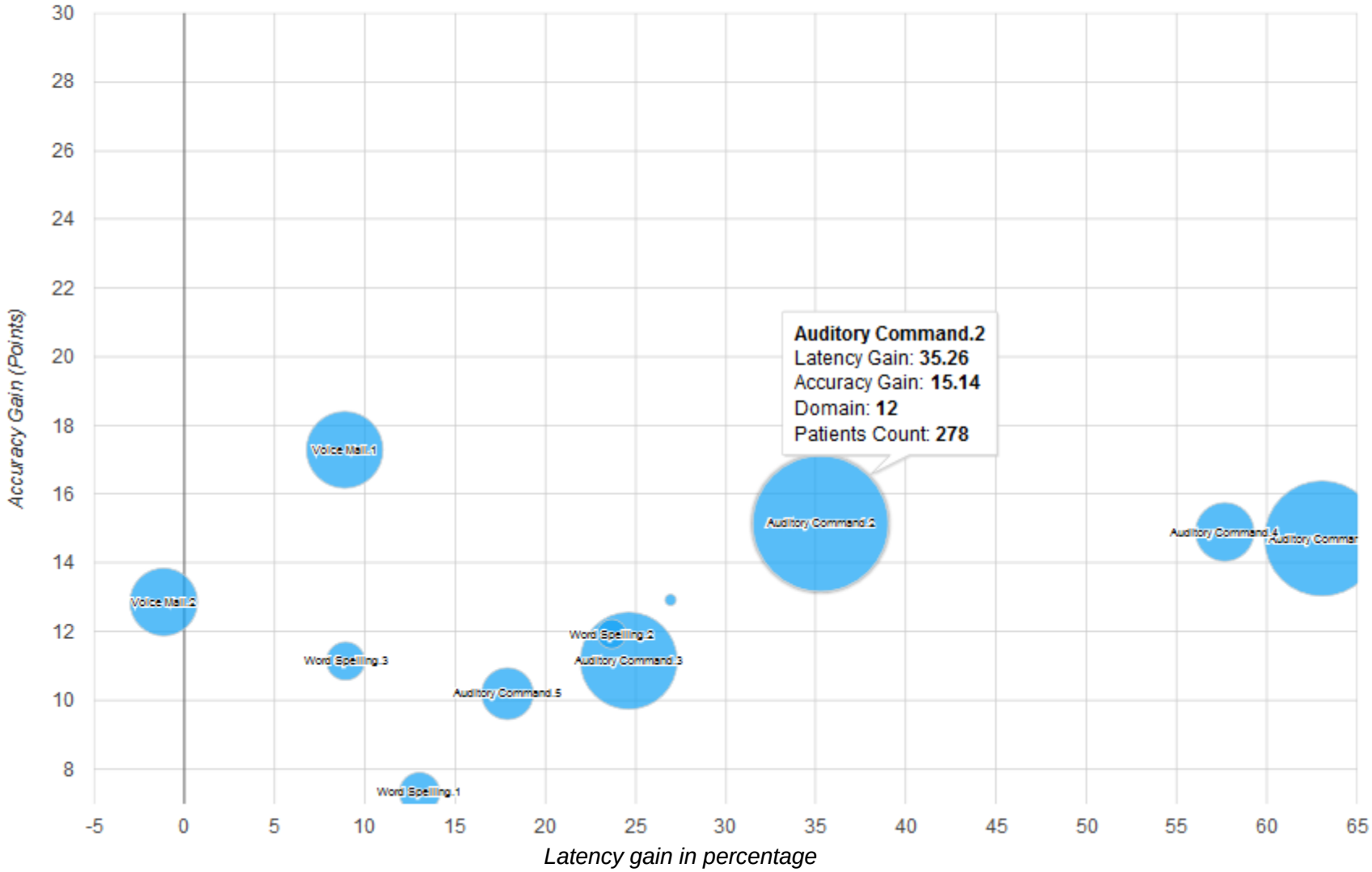


Less than 90% accuracy

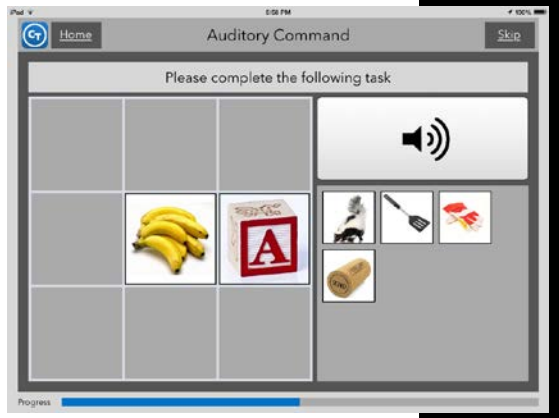


Disorder: Stroke Sessions: Home Only Starting Accuracy: less than 80% FETCH

- 1. Auditory
- 2. Naming
- 3. Reading
- 4. Writing
- 5. Sentence Planning
- 6. Production
- 7. Attention
- 8. Visual Processing
- 9. Memory
- 10. Problem Solving
- 11. All domains

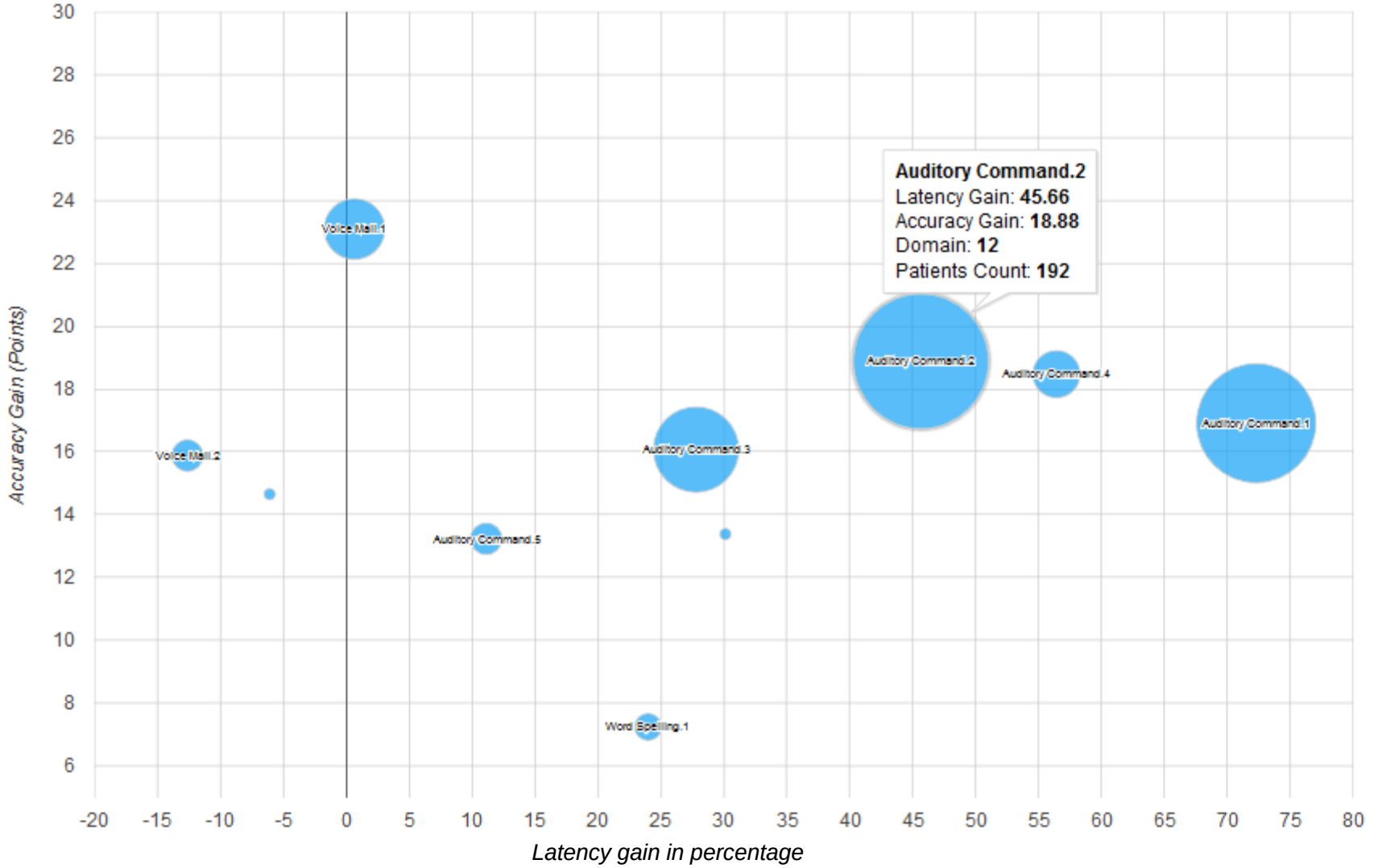


Less than 80% accuracy

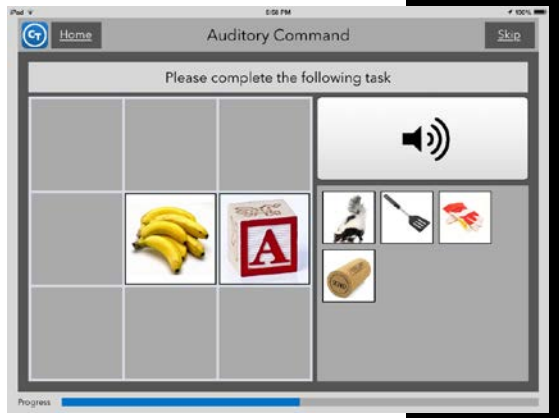


Disorder: Stroke | Sessions: Home Only | Starting Accuracy: less than 70% | FETCH

- 1. Auditory
- 2. Naming
- 3. Reading
- 4. Writing
- 5. Sentence Planning
- 6. Production
- 7. Attention
- 8. Visual Processing
- 9. Memory
- 10. Problem Solving
- 11. All domains

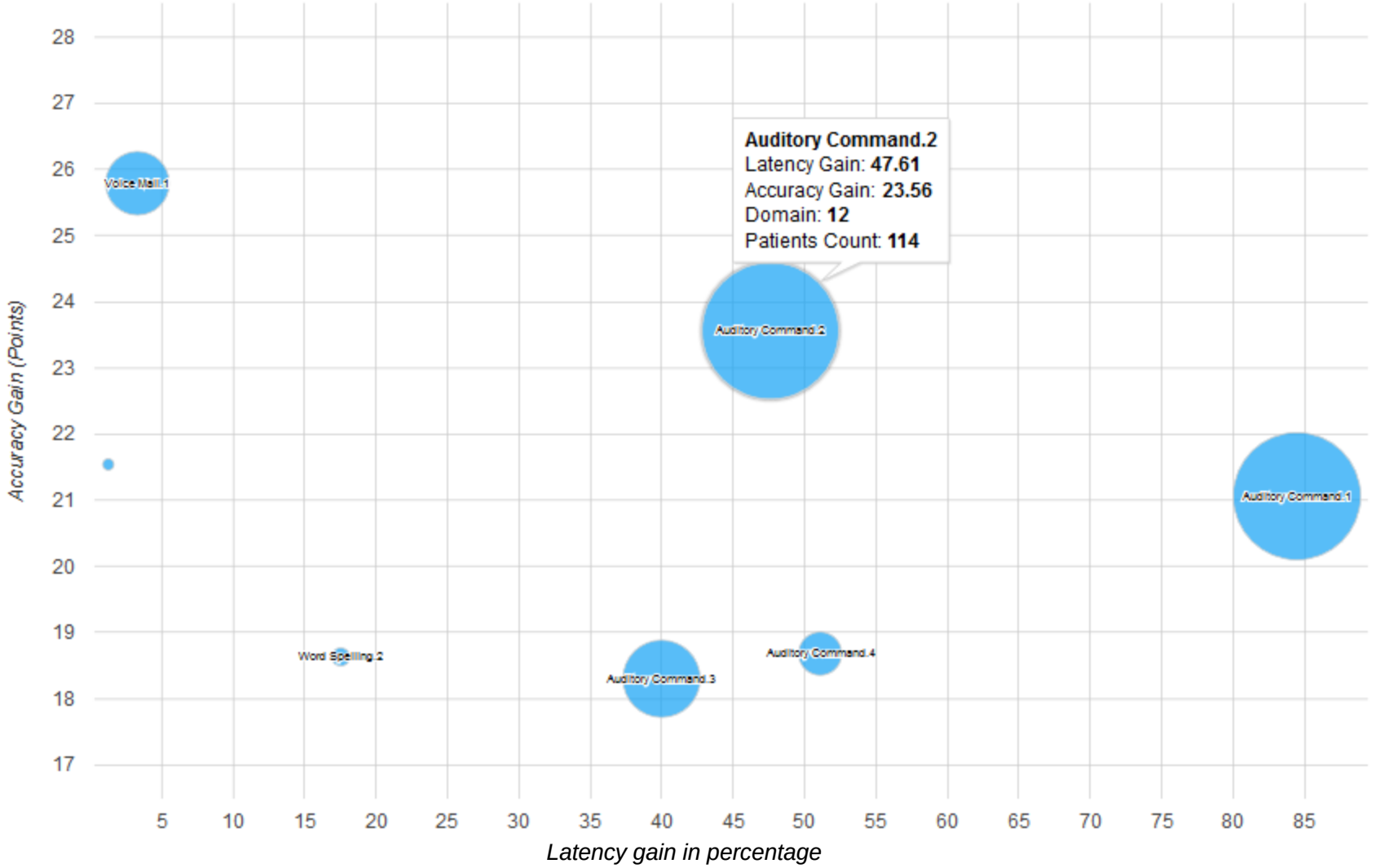


Less than 70% accuracy

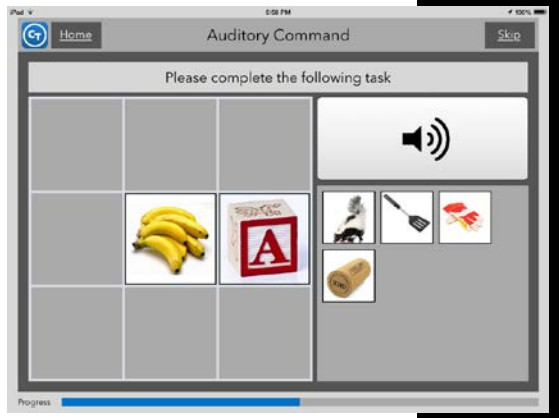


Disorder: Stroke | Sessions: Home Only | Starting Accuracy: less than 60% | FETCH

- 1. Auditory
- 2. Naming
- 3. Reading
- 4. Writing
- 5. Sentence Planning
- 6. Production
- 7. Attention
- 8. Visual Processing
- 9. Memory
- 10. Problem Solving
- 11. All domains

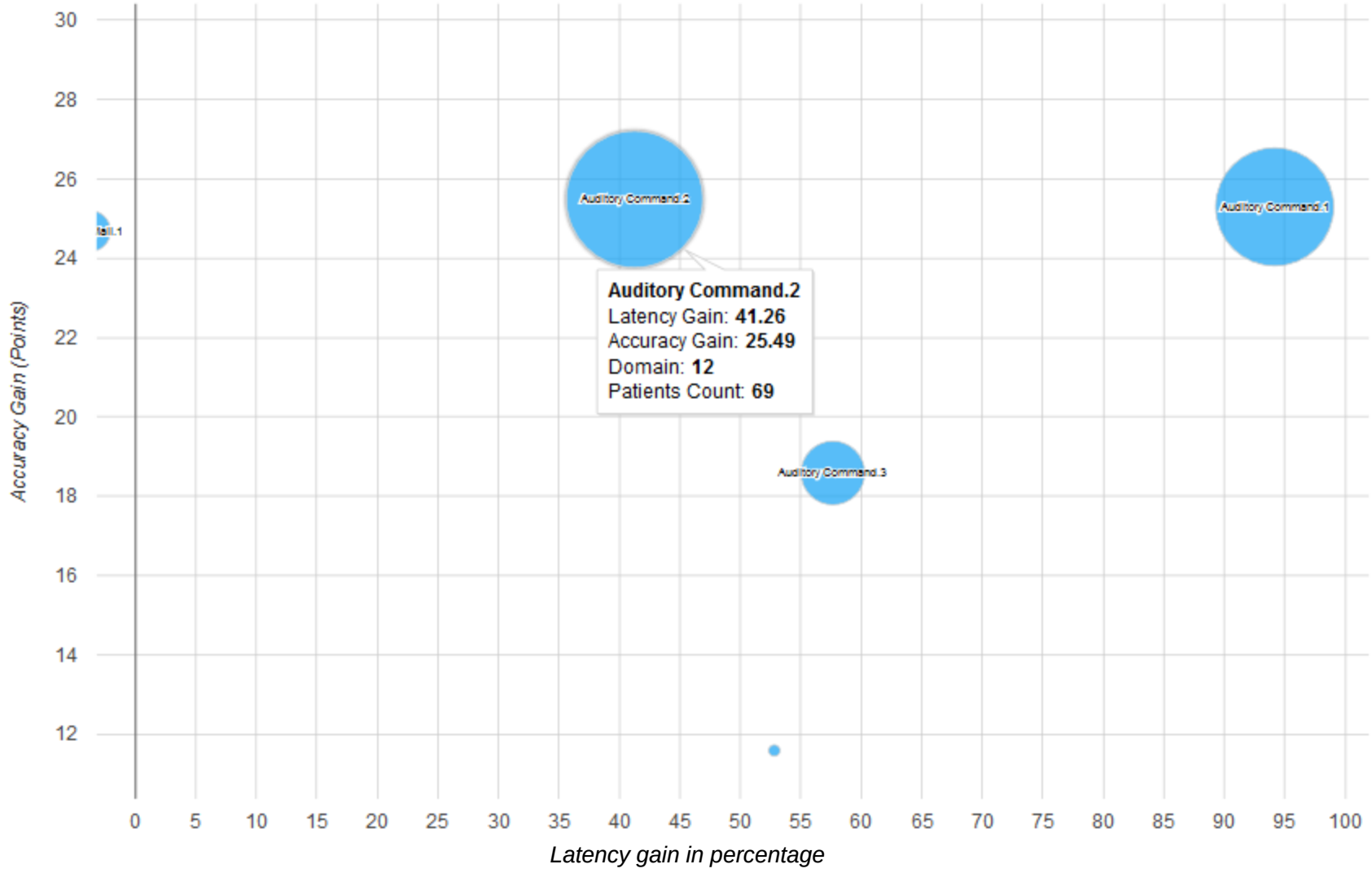


Less than 60% accuracy

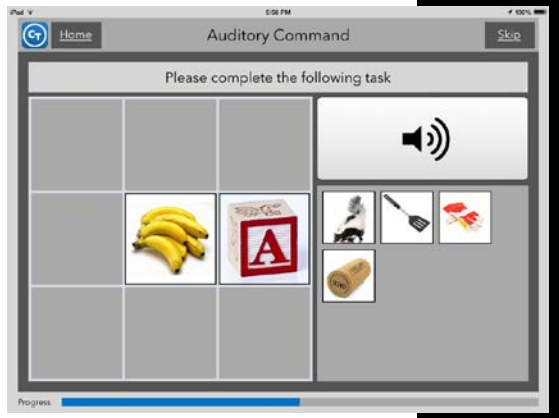


Disorder: Stroke Sessions: Home Only Starting Accuracy: less than 50% FETCH

- 1. Auditory
- 2. Naming
- 3. Reading
- 4. Writing
- 5. Sentence Planning
- 6. Production
- 7. Attention
- 8. Visual Processing
- 9. Memory
- 10. Problem Solving
- 11. All domains

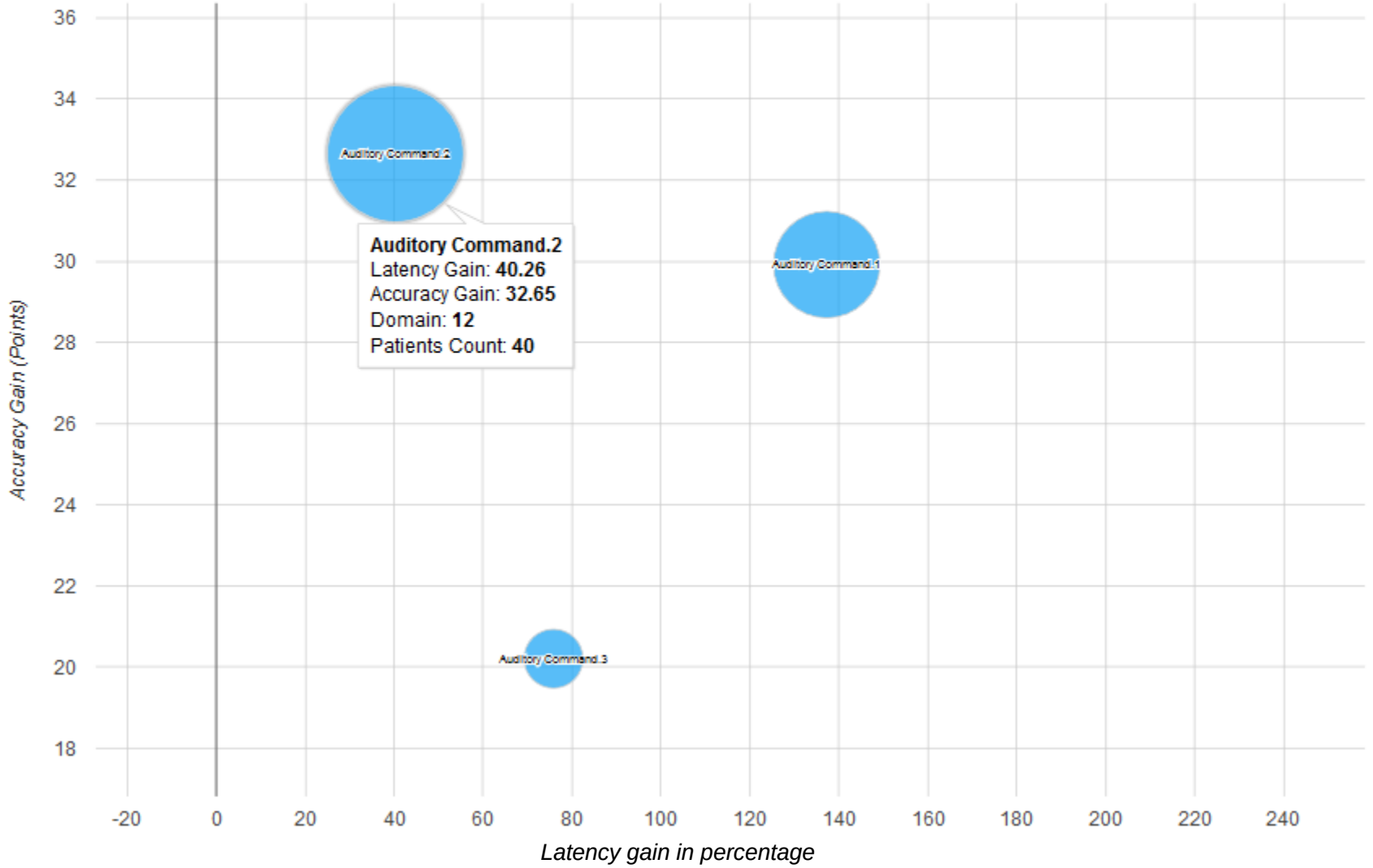


Less than 50% accuracy

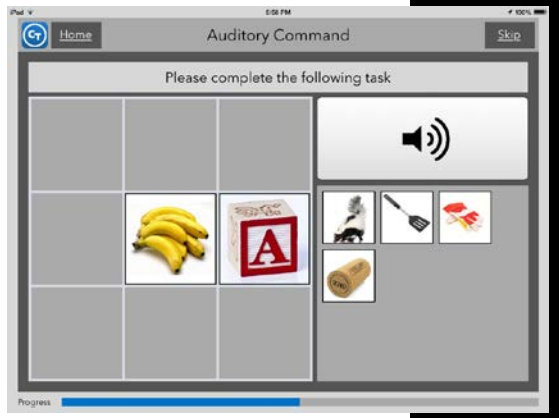


Disorder: Stroke Sessions: Home Only Starting Accuracy: less than 40% FETCH

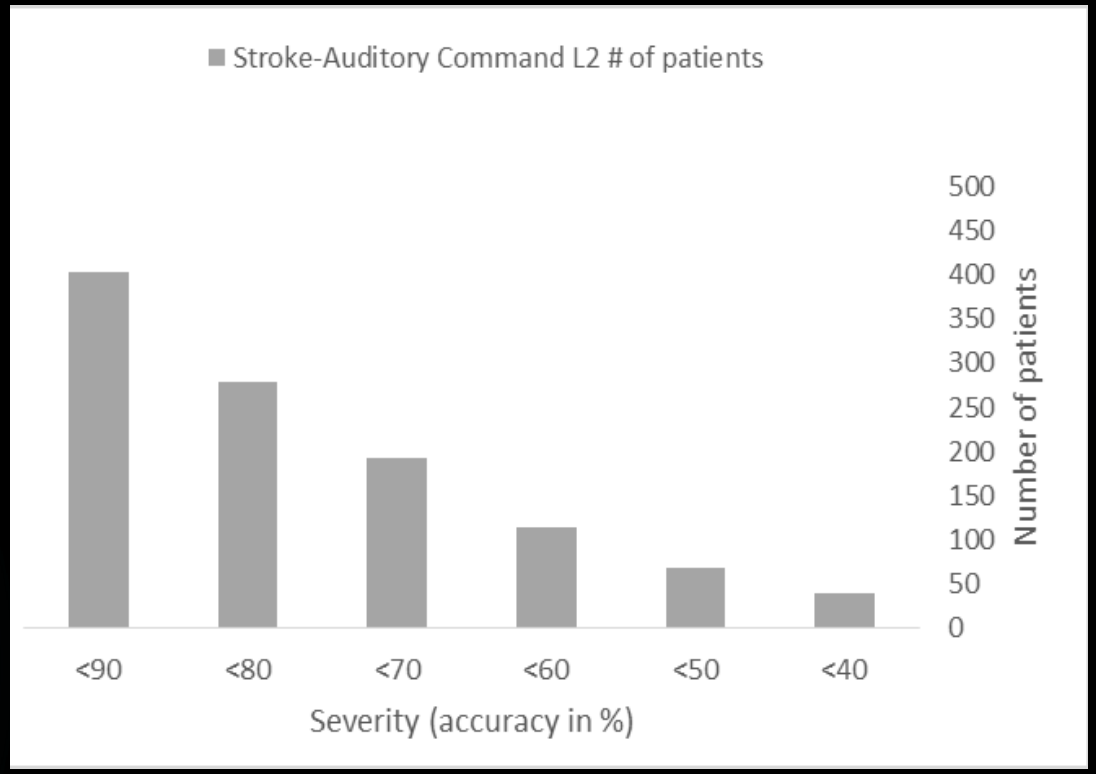
- 1. Auditory
- 2. Naming
- 3. Reading
- 4. Writing
- 5. Sentence Planning
- 6. Production
- 7. Attention
- 8. Visual Processing
- 9. Memory
- 10. Problem Solving
- 11. All domains

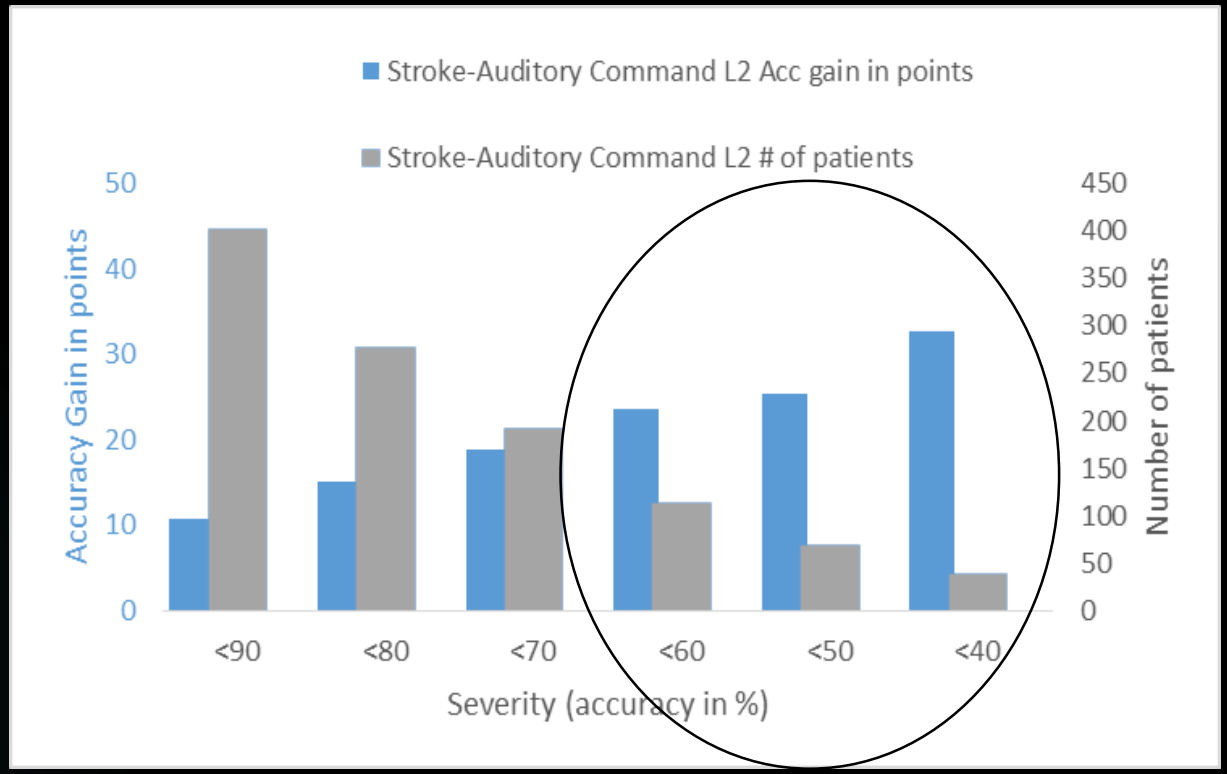


Less than 40% accuracy

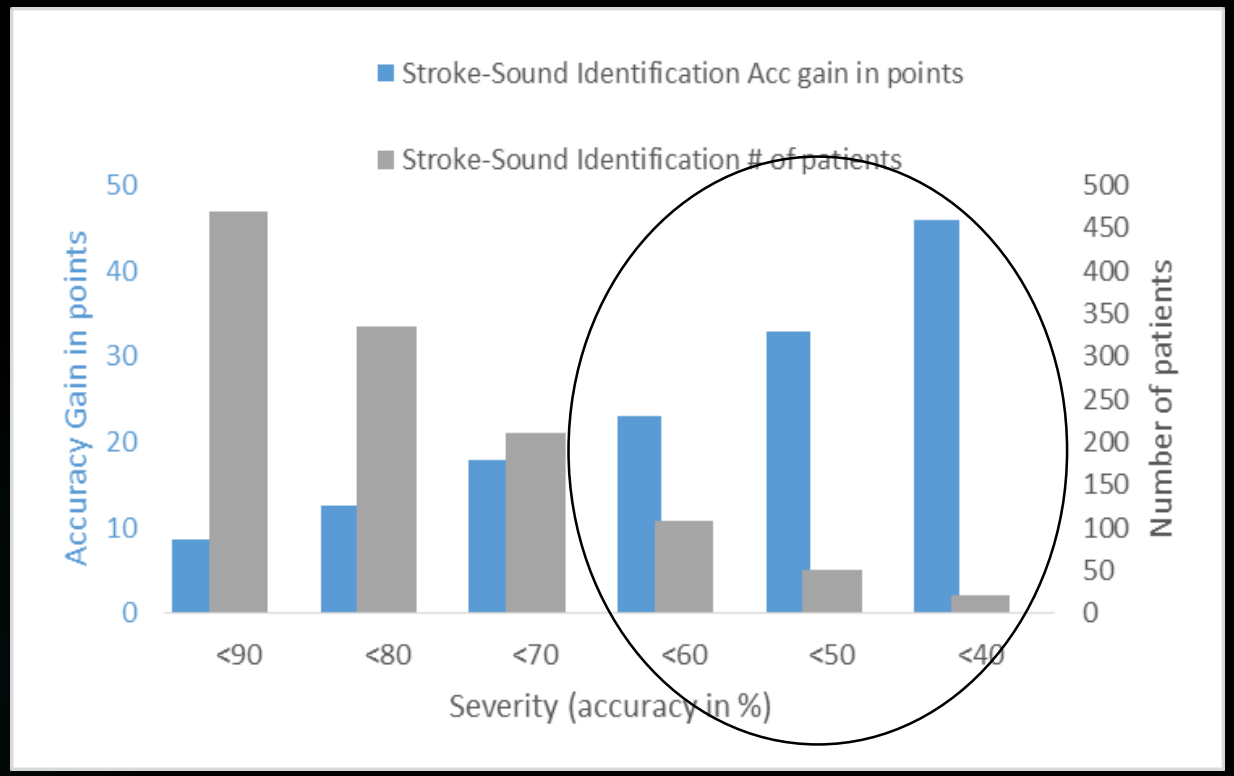


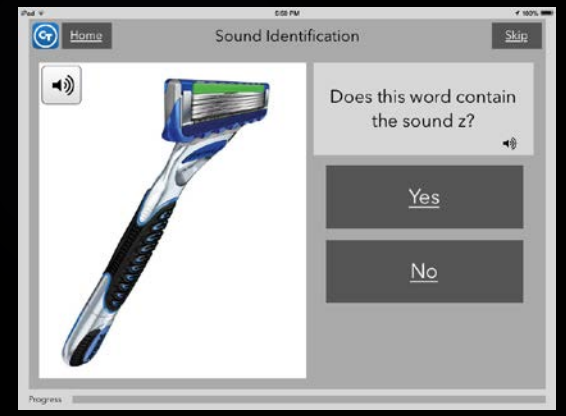
What does this tell us about severity?

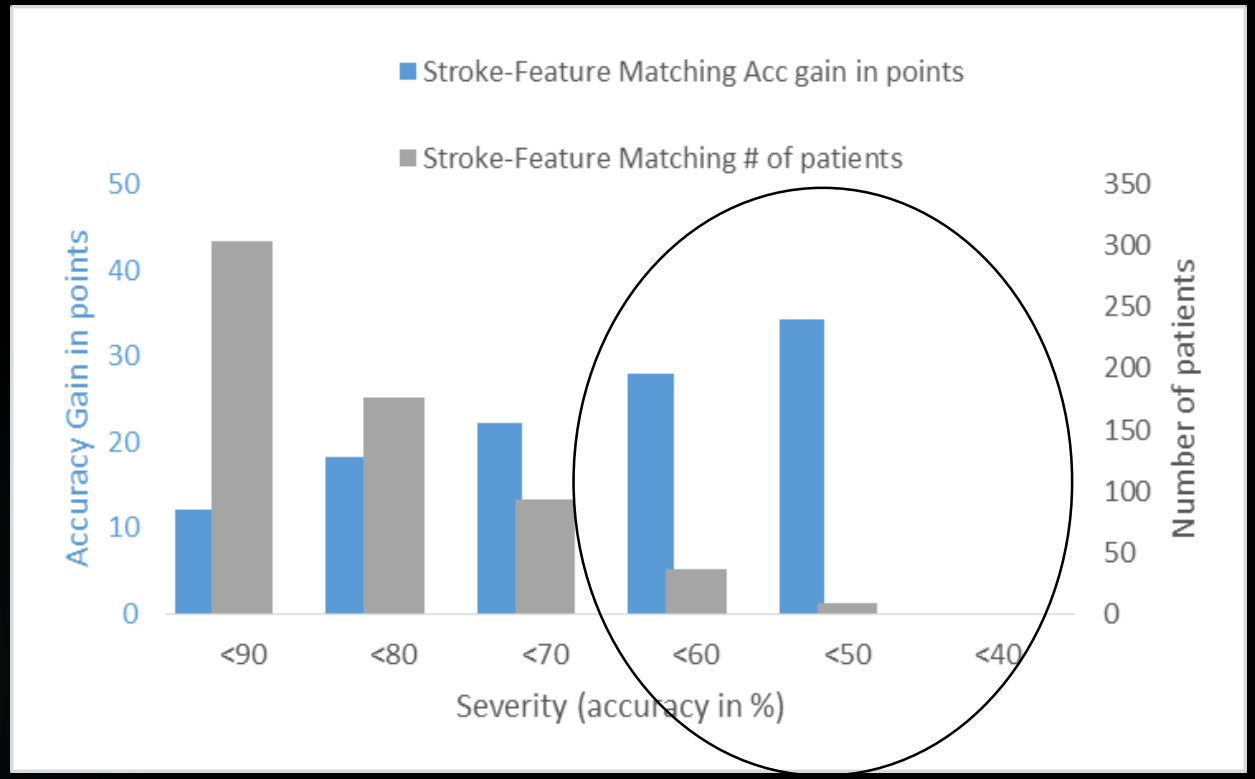



Stroke-Auditory Command L2 Acc gain in points
Stroke-Auditory Command L2 # of patients
Accuracy Gain in points
Number of patients
0
10
20
30
40
50
0
50
100
150
200
250
300
350
400
450
<90
<80
<70
<60
<50
<40
Severity (accuracy in %)

Home
Auditory Command
Skip
Please complete the following task


Stroke-Sound Identification Acc gain in points
Stroke-Sound Identification # of patients
Accuracy Gain in points
Number of patients
0
10
20
30
40
50
0
50
100
150
200
250
300
350
400
450
500
<90
<80
<70
<60
<50
<40
Severity (accuracy in %)


Home
Sound Identification
Skip
Does this word contain the sound z?
Yes
No


Stroke-Feature Matching Acc gain in points
Stroke-Feature Matching # of patients
Accuracy Gain in points
Number of patients
50
40
30
20
10
0
350
300
250
200
150
100
50
0
<90
<80
<70
<60
<50
<40
Severity (accuracy in %)

Home
Feature Matching
Skip
has a head
Yes
No

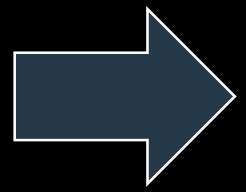
What does this tell us about severity?

Worse starting performance does not indicate poorer outcomes.

Moderate-severely impaired patients can make strong gains in treatment.

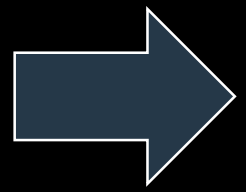
Implications for providing therapy services for the more severe-impaired patients.

- Age
- Lesion location
- Lesion size/volume
- Months post stroke
- Education
- Severity of impairment
- Duration of treatment
- Type of treatment



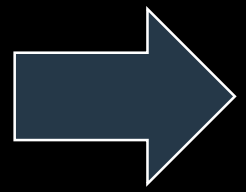
Therapy Outcomes

- Age
- Lesion location
- Lesion size/volume
- Months post stroke
- Education
- Severity of impairment
- Duration of treatment
- Type of treatment

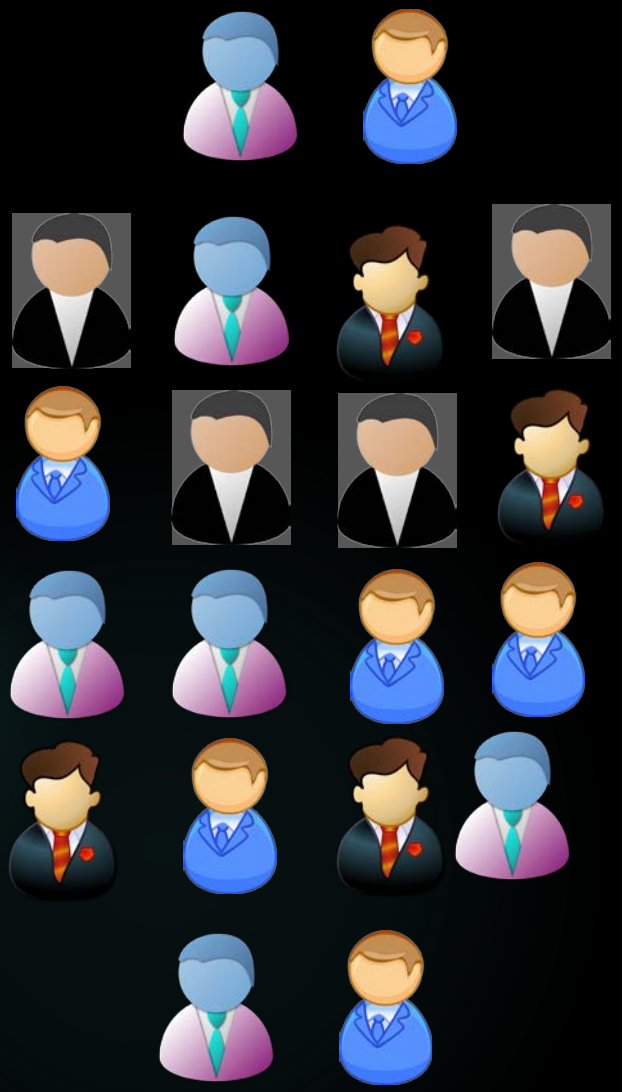


Therapy Outcomes

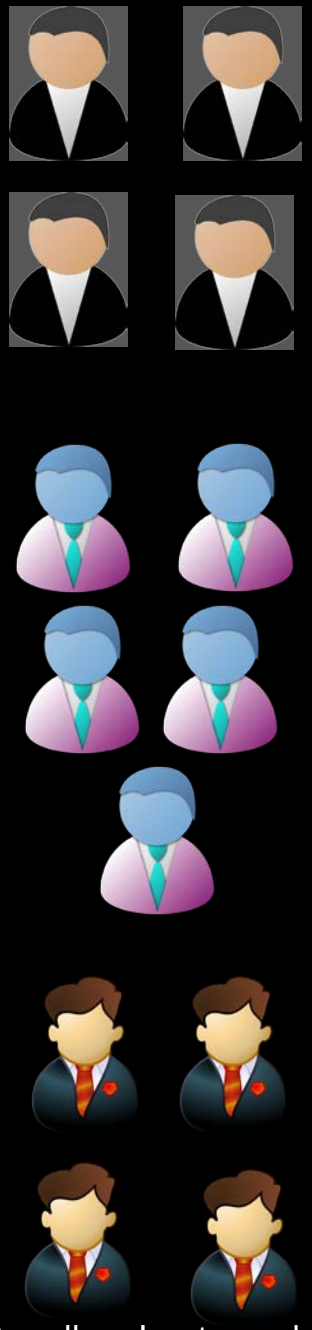
- Age
- Lesion location
- Lesion size/volume
- Months post stroke
- Education
- Severity of impairment
- Duration of treatment
- Type of treatment



Therapy Outcomes



Population analysis



Small cohort analysis

Individual patient analysis

Future Direction

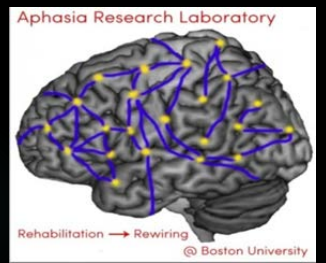
- We are really only at the beginning of accessing big data.
- Lot more work needs to be done.
- But we have the tools to examine and understand the factors that contribute to rehabilitation outcomes.
- Future work examine different types of control conditions.
- Relationship between symptomatology and treatment gains.

Thank you

- Research papers were funded by the Coulter Foundation for Translational Research.
- Thanks to Elsa Ascenso, Isabel Balachandran, Stephanie Keffer, Sahil Luthra, and Anna Kasdan for their contributions to the project and for their assistance in data collection.
- Everyone in the APHASIA LAB
- Mahendra Advani – Constant Therapy

BOSTON UNIVERSITY

WALLACE H. COULTER Foundation



Individualized treatment assignment and analysis

Language Tasks	Naming						Reading						Writing						Sentence Planning	
ID	Category Matching	Feature Matching	Naming Picture	Rhyming	Sound Identification	Syllable Identification	Category Identification	Letter to Sound Matching	Sound to Letter Matching	Reading Passage	Long Reading Comprehension	Word Identification	Word Copy	Word Copy Completion	Word Spelling	Word Spelling Completion	Picture Spelling	Picture Spelling Completion	Active Sentence Completion	Passive Sentence Completion
23		*										*	*		*					
24								*				*								
25								*												
27	*			*				*	*	*			*							
28																				

slope coefficient values found to be beneficial

Assigned as tx for patient

Assessed only once for patient

Des Roches et al., 2015, Frontiers in Human Neuroscience