Reframe Your Thinking

2022 ASHA CONVENTION

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Recognition of Aphasic Speech:
ASR Development and Analysis

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Presentation Overview

1. ASR for Clinical Assessment of Anomia
2. Post-Stroke Speech Transcription Challenge
3. ASR Analysis Tool: PhonoLogic Viewer
   - Download: https://psst.study/phonologic/
4. Q&A and Discussion

ASR for Clinical Assessment

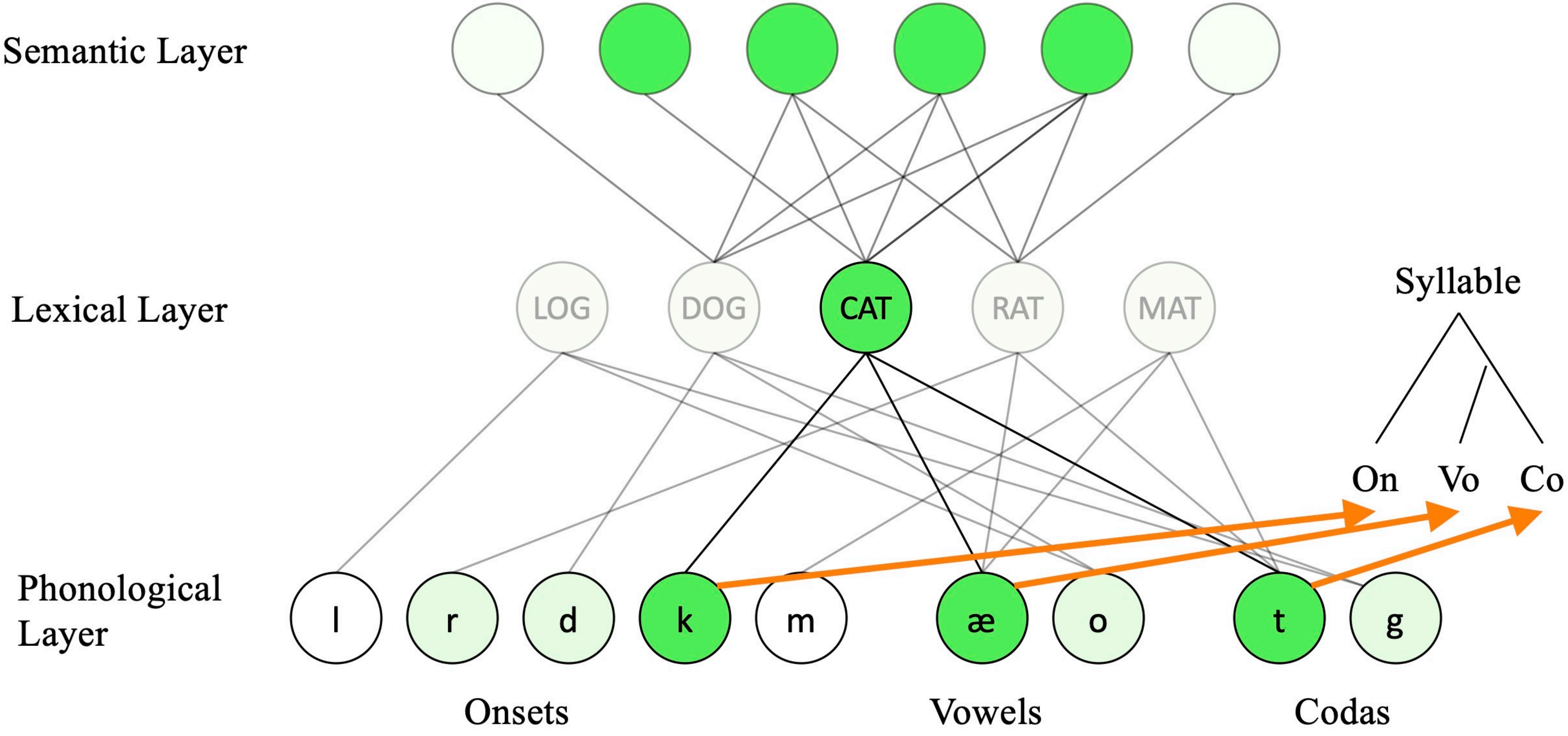
Who? people with aphasia

What? anomia

How? picture naming tests

Typical vs. Impaired Word Production

Dell's Model (Dell, 1986)

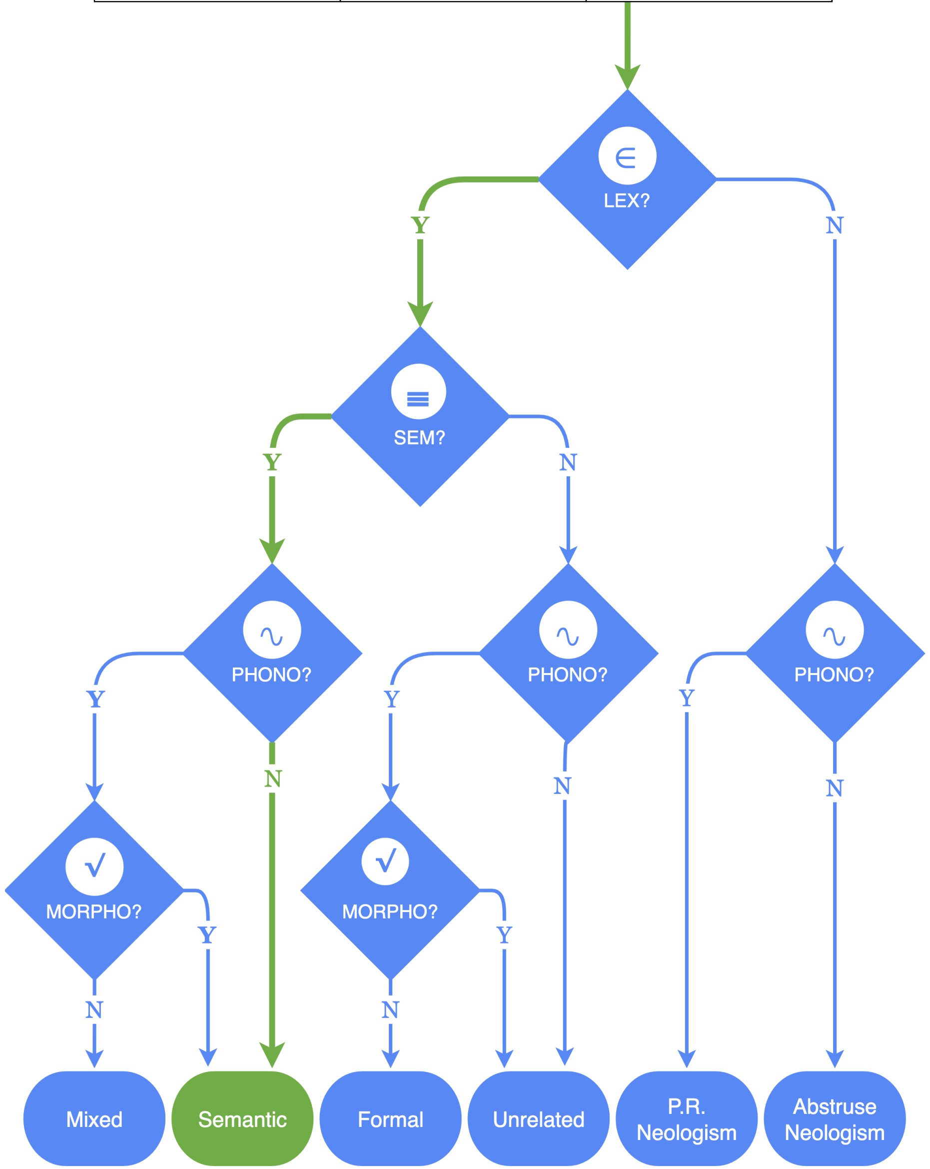


Anomia Assessment: Error Types and Analysis

	Paraphasia Type	Features			Example
		Lexical	Semantic	Phonological	
Lexical	Semantic	+	+	-	"dog" for "cat"
	Formal	+	-	+	"cot" for "cat"
	Mixed	+	+	+	"rat" for "cat"
	Unrelated	+	-	-	"mug" for "cat"
Non-Lexical	Neologism	-	n/a	+	"tat" for "cat"
	Abstruse Neologism	-	n/a	-	"vop" for "cat"

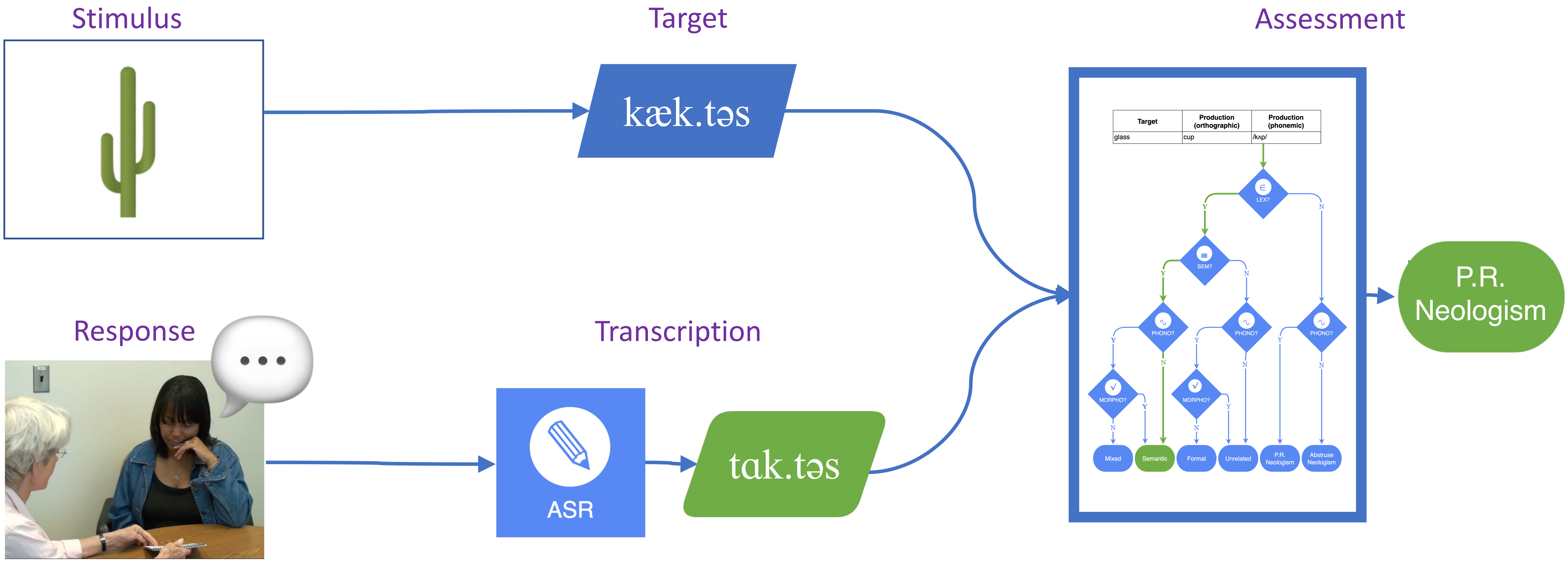
Anomia Assessment: The Value of Automation

Target	Production (orthographic)	Production (phonemic)
glass	cup	/kʌp/



Algorithmic Classification of Paraphasias aka “ParAlg” (Fergadiotis et al., 2016)

The Broader Vision:
Fully Automated Anomia Assessment



ASR: Commercial vs. Clinical

Commercial ASR:
/window/

Clinical ASR:
[bɪndoʊ]

Post-Stroke Speech Transcription (PSST) Challenge

LREC 2022
Marseille

PSST

(Gale et al., 2022)

The PSST Challenge

We provided

- A new dataset
  - Audio from English AphasiaBank (MacWhinney et al. 2011)
  - New phonemic transcripts
- A baseline phonemic ASR model
  - 26.4% phoneme error rate (PER)
  - 12.1% feature error rate (FER)

Challengers brought

- Clever new ideas
  - Several approaches to data augmentation
- An improvement on our baseline!
  - 20.0% phoneme error rate (PER)
  - 9.9% feature error rate (FER)

Gale et al. (2022) – https://aclanthology.org/2022.rapid-1.6/

PSST Speech Recognition Results

Yuan et al. (2022) →

Moëll/O’Regan. →
et al. (2022) .

Our baseline →

		Data (hours of audio)					ASR	
Model	**Arch**	**Pretrain**	**PSST**	**TIMIT**	**AphasiaBank**	**Other**	**FER**	**PER**
Y1	LARGE	60,000	2.8		33.3[U]		**9.9%**	**20.0%**
Y2	LARGE	60,000	2.8	3.9			10.3%	21.1%
Y3	LARGE	60,000	2.8		44.0[W]		10.4%	21.5%
Y4	LARGE	60,000	2.8			3.9[L]	10.6%	22.2%
Y5	LARGE	60,000	2.8				10.9%	22.3%
MO1	LARGE	960	2.8	1.1 [r]			11.3%	25.5%
MO2	LARGE	960	5.6 [p]				11.4%	25.1%
MO3	BASE	960	2.8	1.1 [r]			11.7%	26.3%
MO4	LARGE	960	5.6 [t]				11.7%	25.4%
MO5	LARGE	960	5.6 [p]	1.1 [r]			11.9%	26.0%
MO6	LARGE	960	2.8				12.0%	25.9%
MO7	BASE	960	5.6 [n]				12.0%	26.1%
PSST–A	BASE	960	2.8				12.1%	26.4%
Y6	LARGE	60,000	2.8			100[L]	12.5%	26.0%
Y7	LARGE	60,000	2.8			960[L]	16.7%	38.0%

[L] Librispeech, pseudo-labeled with G2P
[U] iteratively pseudo-labeled (unweighted)
[W] iteratively pseudo-labeled (weighted)
[p] with pitch-shifted variants
[t] with time-shifted variants
[n] with Gaussian noise augmentation
[r] RIR reverb applied

Evaluating an ASR

Word error rate (WER)

Orthographic ASR: $\frac{\#\,WORD\ ERRORS}{\#\,TARGET\ WORDS}$

Human:	a	house	🏠
ASR:	a	horse	
	✅	❌	$\frac{1}{2} = 50\%\ WER$

Phoneme Error Rate (PER)

Phonemic ASR: $\frac{\#\,PHONEME\ \ ERRORS}{\#\,TARGET\ PHONEMES}$

Human:	t	ɑ	k	t	ə	s	🌵
ASR:	d	ɑ	k	t	ə	s	
	❌	✅	✅	✅	✅	✅	$\frac{1}{6} = 17\%\ PER$

Further intuition: /taktəs/ → /daktəs / *should score better than* /taktəs/ → /oaktəs/

Phonological Features

p	=	<voiceless>	<bilabial>	<stop>
b	=	<voiced>	<bilabial>	<stop>
t	=	<voiceless>	<alveolar>	<stop>
d	=	<voiced>	<alveolar>	<stop>
k	=	<voiceless>	<velar>	<stop>
g	=	<voiced>	<velar>	<stop>

ARPAbet	IPA	consonantal	delayedrelease	continuant	sonorant	approximant	syllabic	tap	nasal	voice	spreadglottis	labial	round	labiodental	coronal	anterior	distributed	strident	lateral	dorsal
P	p	+	–	–	–	–	–	–	–	–	–	+	–	–	–	0	0	0	–	–
B	b	+	–	–	–	–	–	–	–	+	–	+	–	–	–	0	0	0	–	–
T	t	+	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–
D	d	+	–	–	–	–	–	–	–	+	–	–	–	–	+	+	–	–	–	–
K	k	+	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0	0	–	+
G	g	+	–	–	–	–	–	–	–	+	–	–	–	–	–	0	0	0	–	+

Distance between two phonemes

- Feature system: a table of distinctive features
  - Modified version of Hayes (2009)
  - 24 features x 40 phonemes
- Consider each phoneme as a set of features
- Error cost as a vector distance:

$$\text{Cost}(s, ʃ) = \left\| \overrightarrow{\text{s ʃ}} \right\| = \left\| \begin{bmatrix} +\text{cons} \\ +\text{delrel} \\ +\text{cont} \\ +\text{ant} \\ -\text{dist} \\ \ldots \\ -\text{voi} \end{bmatrix} - \begin{bmatrix} +\text{cons} \\ +\text{delrel} \\ +\text{cont} \\ -\text{ant} \\ +\text{dist} \\ \ldots \\ -\text{voi} \end{bmatrix} \right\| = \left\| \begin{matrix} 0 \\ 0 \\ 0 \\ -1 \\ 1 \\ \ldots \\ 0 \end{matrix} \right\| = 2 \text{ features apart}$$

Special considerations (don't worry too much about these)

- Values can be:
  - Present [+]
  - Absent [–] or
  - Not relevant [0]
- Diphthongs
  - Calculate as one phoneme or two?
  - Workaround, new values:
    - Absent-to-present [–+]
    - Present-to-absent [+–]

Cost	Feature Changes		
1	[–feature]	↔	[+feature]
0.75	[–feature]	↔	[+–feature]
	[–+feature]	↔	[+feature]
0.5	[–feature]	↔	[0feature]
	[–+feature]	↔	[+–feature]
	[0feature]	↔	[+feature]
0.25	[–feature]	↔	[–+feature]
	[–+feature]	↔	[0feature]
	[0feature]	↔	[+–feature]
	[+–feature]	↔	[+feature]
0	[–feature]	↔	[–feature]
	[–+feature]	↔	[–+feature]
	[0feature]	↔	[0feature]
	[+–feature]	↔	[+–feature]
	[+feature]	↔	[+feature]

Distance between two *transcripts*

- Similar to PanPhon (Mortensen, 2016)
- Find alignment with least error (Levenshtein, 1966)
- Insertions & deletions: ignore undefined features

Phoneme Error Rate (PER) ***vs.*** **Feature Error Rate (FER)**

Human:	l	æ	f			ɪ	n
ASR:	b	ɹ	ɑ	p	ɹ	ɪ	ŋ
	❌	❌	❌	❌	❌	✅	❌

$= \frac{6}{5} = 120\%$

Human:		l	æ	f		ɪ	n
ASR:	b	ɹ	ɑ	p	ɹ	ɪ	ŋ
	$\frac{22}{24}$	$\frac{4}{24}$	$\frac{2}{24}$	$\frac{3}{24}$	$\frac{23}{24}$	✅	$\frac{23}{24}$

$= \frac{58.5}{130} = 45\%$

Feature distance sounds very promising, but…

- Even when you understand the principles…
  - Unreasonable to estimate in your head
- Even when you're looking at the answer…
  - Difficult to explain why
- Cross-disciplinary: linguistics, computer science
- Cumbersome: dozens of features per phoneme, alignment

Don't fret, though…

PhonoLogic Viewer

an ASR analysis tool

Download:
https://psst.study/phonologic/

Questions?

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THANK YOU FOR ATTENDING