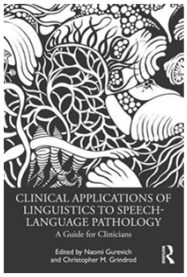
Disclosures

- Financial Disclosures:
  - *Clinical Applications of Linguistics to Speech-Language Pathology: A Guide for Clinicians* (Routledge, 2023)
- Nonfinancial Disclosures:
  - I like coffee
  - I designed ISHA's logo



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Prioritizing treatment targets by their functional importance to speech intelligibility

Naomi Gurevich, PhD, CCC-SLP, CSD, PFW
Heejin Kim, PhD, Linguistics, UIUC

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Outcomes

- At the end of this session, participants will be able to
  1. list and define phonological factors with functional importance to intelligibility.
  2. compare various word contexts in terms of their importance to speech intelligibility.
  3. formulate prioritized treatment goals for intelligibility intervention that select consonants in English based on their functional importance to intelligibility.

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Abstract

Articulatory accuracy is relevant to intelligibility, but are all speech sounds equally important? The answer is no, there is a functional hierarchy: Some sounds, in some word positions, play a bigger role in speech intelligibility than do others. This role relates to specific properties of speech sounds that involve phonology (language-specific rules and sound inventories) in addition to phonetics (the place and manner of articulation of sounds). These specific phonological properties include *contrast* (referring to phonemes, where a difference in sounds leads to a difference in meaning), *positional context* (with respect to word location and surrounding speech sounds), *frequency* (how often a phoneme occurs in speech), and *functional load* (the number of words that depend on a given phoneme to be distinguished from each other). When taken all together, these properties help identify which speech sounds are most relevant to intelligibility. This, in turn, helps identify priority treatment targets.

In this talk we outline the hierarchy of *functional importance to intelligibility* (FITI) and explain how phonological properties of speech sounds influence speech intelligibility. We then showcase a novel clinical resource that helps prioritize treatment targets for adults with dysarthria.

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Gurevich, N. and Kim, H. (2023). **The phonetics and phonology of intelligibility: The functional importance to intelligibility of speech sounds.** In Gurevich N. and Grindrod, C. (Eds.) *Clinical Applications of Linguistics to Speech-Language Pathology: A Guide for Clinicians.* Routledge. doi:10.4324/9781003045519-8

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Intelligibility

- A measure of how much of a person's speech can be understood by a listener
  - Speech = acoustic signal
- Comprehensibility
  - In CSD: a holistic measure of overall communicative effectiveness (Gurevich & Scamihorn, 2017; Yorkston et al., 1996)
  - In language acquisition field: a measure of how easy accented speech is to understand (Isaacs & Trofimovich, 2012; Munro & Derwing, 1999)

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Dysarthria

- Neurological motor speech disorder (MSD)
- Etiologies
  - Congenital (e.g., cerebral palsy)
  - Acquired (e.g., Parkinson's, multiple sclerosis, traumatic brain injury, stroke)
  - Iatrogenic (e.g., side effect of certain narcotics)
- Types (depending on place of lesion)
  - Spastic, flaccid, mixed, ataxic, hypokinetic, hyperkinetic

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Dysarthria: Speech production components

- Five components necessary for normal speech production
  - Respiration
  - Phonation
  - Resonance
  - Articulation
  - Prosody
- A key functional deficit
  - Reduced intelligibility

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Dysarthria: Reduced intelligibility

- A functional deficit that can be addressed in skilled SLP therapy
  - To improve ability to communicate wants/needs
  - To increase participation in social activities, ADLs
  - To improve quality of life
  - To return to PLOF
- Requires measuring
  - To provide baseline, assess progress
  - For purposes of reimbursement

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Dysarthria: Measuring intelligibility

- Inherently subjective
  - Measured by listener's ability to hear/interpret
  - The evaluation of a function that depends on the evaluator
  - Affected by **context**, **situation**, **topic**
  - Affected by **familiarity** with speaker

(Gurevich & Scamihorn, 2017)

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Measuring intelligibility

- Best practice: objective measures
  - To determine % intelligible speech (e.g., 50% intelligible)
  - Or to determine severity rating (e.g., mod impaired)

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Measuring intelligibility

- Informal assessment
  - Estimating % or severity based on
    - Spontaneous speech
    - Non-standardized word and phrase lists
    - Reading a passage

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Measuring intelligibility

- Use of formal measures by SLPs
  - Literature & anecdotal data suggest minimal use
    - Expensive, rarely available, not enough time to use
    - Informal assessments are preferred
  - Agreement that measuring intelligibility is clinically relevant, but
  - Formal tools are rarely used & not meeting needs of clinicians

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Measuring intelligibility

- Purpose
  - Investigate trends of Dx intelligibility of adults with dysarthria
  - Confirm findings regarding reliance on non-standardized assessments
  - Determine possible reasons for trends

(Gurevich & Scamihorn, 2017)

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Study results and conclusion

- Results:
  - Support previous findings that clinicians are **not using formal assessments** to evaluate intelligibility
    - Lack of access (d/t cost, lack of familiarity)
    - Perceived as less useful, efficient, simple compared to informal methods
      - Clinicians still using physical exams (that don't involve speech) to rate intelligibility
- Need:
  - Education on methods of assessments
  - Cost-effective, useful, efficient and simple to use tools to objectively assess intelligibility

(Gurevich & Scamihorn, 2017)

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The Phonology of Intelligibility

- We set out to build a new tool
  - Need better stimuli
  - Need to better represent speech

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The Phonology of Intelligibility

- Acquired dysarthria
- Adult speakers
  - Mastered the full phonemic inventory and internalized the phonological rules
  - Tx goals not analogous to pediatric speech-sound Tx
  - Beyond *which* sounds are difficult; consider *where* those sounds are difficult
    - And how disruptive to verbal communication

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The Phonology of Intelligibility

- Consonants
  - Critical to word-level intelligibility in speech perception (Fogerty et al., 2012; Toro et al., 2008) & language acquisition (Hochmann et al., 2011)

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The Phonology of Intelligibility

- Perceiving and decoding acoustic signals
- Acoustic clarity
  - Role varies depending on linguistic properties

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The Phonology of Intelligibility

- The key phonological factors with *functional importance to intelligibility* (FITI)
  1. Contrast
  2. Context
  3. Frequency
  4. Functional load

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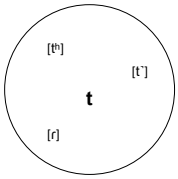
(1) Phonological Contrast

- Define basic terms:
  - **Phonemes**: sounds that are **contrastive** in a language
  - **Allophones**: positional variations of phonemes (**not contrastive**)
  - Compare production of /t/
    - top **t**ɑp
    - pet pɛ**t**
    - still stɪl
    - atom ærəm



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(1) Phonological Contrast

- The perception of sounds depends on phonological contrast (Boomershine et al., 2008; Noguchi & Kam, 2018; Trubetzkoy, 1939)
- Acoustic distinction between contrastive sounds (phonemes) is perceived better than between non-contrastive sounds (allophones)
  - As early as 6months old babies stop attending to differences that are not meaningful in their language (Kuhl et al., 1992)

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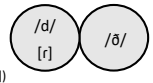
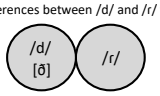
(1) Phonological Contrast

- English and Spanish (Boomershine et al., 2008)
  - In **English**:
    - /ð/ and /d/ are phonemes (they are contrastive: 'den' vs. 'then')
    - [ɾ] is an intervocalic allophone of /d/ ('Adam' [æɾəm]; 'kiddo' [ˈkɪɾo])
    - ➢ Speakers are more sensitive to the difference between /ð/ and /d/ than /d/ and [ɾ]
  - In **Spanish**:
    - /ɾ/ and /d/ are phonemes
    - [ð] is an allophone of /d/
    - ➢ Speakers are more sensitive to the differences between /d/ and /ɾ/ than /d/ and [ð]





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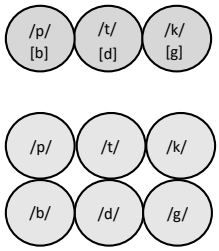
(1) Phonological Contrast

- **Korean** and **English**
  - Korean does not have voicing contrasts for plosives. [b, d, g] are allophones of /p, t, k/ between voiced segments (e.g., V_V)
  - Korean learners of English have difficulties producing and perceiving voiced stops



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(1) Phonological Contrast & Intelligibility

- Role of contrast in FITI
  - Hierarchy: Contrastive sounds are more FITI
- Reduced ability to produce sufficient acoustic cues for phonemic distinctions ⇨ significant consequences for intelligibility

✪ Materials used to elicit speech for clinical purposes must include all phonemes in a language

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(2) Positional Context

- What positions?
  - In syllable (onset, coda) or in a word (word-initial, -medial, -final)
  - The surrounding sounds (pre-, post-, or inter-vocalic; pre-, post-, or inter-consonantal)
  - Stress status (stressed, unstressed)
- The perception of sounds fluctuates based on phonological context (Trubetzkoy, 1939)

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(2) Positional Context

- **Syllables**: Distinctions between phonemes are more perceptible in syllable onsets & pre-V contexts and less perceptible in codas & pre-C (e.g., Gurevich, 2004; Jun, 2011)
  - Second language acquisition studies report better performance of non-native consonants in onset position than in codas (Cheng & Zhang, 2015)

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(2) Positional Context

- **Word positions**: Word-initial positions are more important than word-final
  - Cross-linguistic: devoicing and deletion are more common word-finally (Gurevich 2004 & 2011)
  - Foreign-accented speech: word-initial errors interfere with intelligibility more (Gurevich & Kim, 2023a)
  - Language development: most consonants are acquired word-initially first (e.g., Bleile, 2015) & children discriminate contrasts better word-initially (Cilibrasi et al., 2015)
  - Dysarthric speech: errors are influenced by word positions (Antolík & Fougeron, 2013; Kim & Gurevich, 2021)
    - E.g., in CP-associated dysarthric speech (American English) fewer production errors in word-initial positions for stops, liquids, and nasals (Kim & Gurevich, 2021)

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(2) Positional Context

- **Prosody**: Stressed positions are indisputably more prominent than unstressed ones (Gurevich & Kim, 2023a)
  - Sounds in stressed syllables are more strongly articulated (referred to as prosodic strengthening)
  - Language development: children repeat stressed syllables more accurately than unstressed ones (& discriminate contrast better in stressed syllables)

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(2) Positional Context & Intelligibility

- Role of context in FITI
  - Hierarchy: Certain positions (pre-vocalic, word-initial, stressed) are more FITI
- Reduced ability to produce sufficient acoustic cues for phonemic distinctions (contrast) in certain contexts ⇨ consequences for intelligibility

✪ Materials used to elicit speech for clinical purposes must include phonemes in all allowable positional contexts in that language

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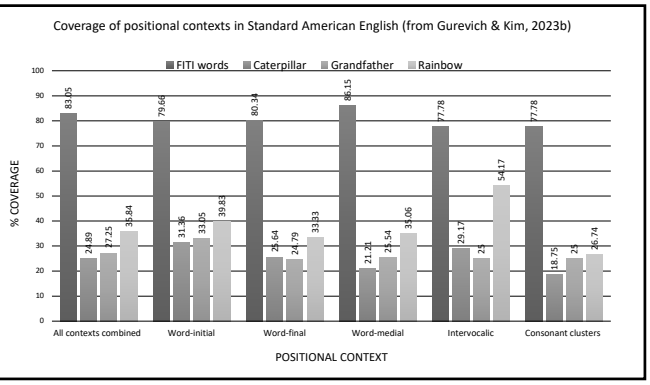

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(3) Frequency

- Frequency of phonemes
- How often they occur in speech
  - More frequent phonemes in a language are less dependent on acoustic clarity to be decoded by listeners (Gurevich, 2004; Moates et al., 2006)
- Word-level frequency
  - More common/frequent words in a language are more easily recognized from lesser signals (Kingston, 2008)
  - Perceived as less accented in foreign-accented speech (Levi et al., 2007)

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(3) Frequency

- The most frequent common words in a language are least dependent on acoustic signal: Function words
  - They are predictable from grammar and hence don't depend on clarity of signal to be decoded (e.g., Gurevich, 2004)

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(3) Frequency & Intelligibility

- Role of frequency in FITI
  - Hierarchy: Frequent phonemes in content words are more FITI
- Reduced ability to produce sufficient acoustic cues for phonemic distinctions (contrast) of more frequent sounds (in content words) ⇨ consequences for intelligibility

✪ Materials used to elicit speech for clinical purposes should have a hierarchy of phonemes by frequency in content words only, excluding function words

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(4) Functional Load

- The number of words that depend on a phoneme to be distinguished from each other (e.g., p/t/k vs. ʃ/ʒ)
- The acoustic clarity of a phoneme with a higher functional load may be more important for decoding speech (e.g., Gurevich, 2004)
- Paradox with frequency:
  - Opposing forces of functional load and frequency: While a higher functional load suggests that an opposition is more integral to comprehension, the frequency of the phonemes involved may make them less dependent on acoustic signals.

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(4) Functional Load & Intelligibility

- Role of functional load in FITI
  - Hierarchy: Higher functional load is more FITI
- Reduced ability to produce sufficient acoustic cues for phonemic distinctions (contrast) of phonemes with higher functional load ⇨ consequences for intelligibility

✪ Materials used to elicit speech for clinical purposes should include and prioritize high functional load elements and downgrade, or omit, low functional load ones

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Using FITI Properties in Speech Materials

- Creating new stimuli with FITI for clinical use (Gurevich & Kim, 2023b)
  - 308 unique words from corpus of 5000 most frequent words in American English (but only out of 4706 content words)
  - Includes every phoneme in English (phonological **contrast**)
  - In every allowable phonological **context** in English
  - **Frequency** and **functional load** represented
    - Frequency in speech is represented by phonemic balance
    - Lowest functional load contexts omitted
    - Function words excluded

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The FITI Table: A Clinical Tool

Scan QR code or use the URL below to request a copy through ResearchGate

https://www.researchgate.net/publication/369890370_FITI_Table_Appendix_of_Gurevich_Kim_Chapter_2023

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The FITI Table: A Clinical Tool

	Tier 1			Tier 2	Tier 3			
	#_V	V_V	C_V	#_C	V_C	V_#	C_C	C_#
/r/	really	around	problem		service	appear		
/t/	teacher	return	student	treatment	treatment	about	control	result
/n/	never	enough	technology	*	only	begin	concerned	return
/s/	system	decide	consider	student	suggest	produce (v)	understand	perhaps
/l/	little	believe	include		also	control	girlfriend	girl
/k/	country	become	discuss	question	actually	attack	include	think
/p/	people	appear	important	problem	perhaps	escape	explain	help
/d/	different	today	condition	driver	address	provide	hardly	understand
/m/	mister	remain	information	music	company	become	firmly	perform
/f/	family	affect	performance	future	reflect	enough	confront	golf
/b/	business	about	baseball	brother	subject (n)	describe	embrace	absorb
/ŋ/	shoulder	machine	insurance	shrimp	freshman	push	*	harsh
/v/	very	development	involve	viewer	movement	receive	involved	involve
/g/	government	begin	forget	global	agree	fatigue	congressional	*
/w/	woman	away	question					
/z/	zodiac	result	exactly	*	business	disease	transmit	sometimes
/ð/	general	majority	enjoy	*	judgment	engage	largely	charge
/h/		whisper			single	along		
/j/	usually	Crayola	community					
/ʧ/	challenge	achieve	exchange	*	approached	approach	researched	lunch
/h/	happen	behavior	perhaps					
/θ/	theory	authority	enthusiasm		athletic	both	birthday	month
/ð/	therefore	within	northern	threaten	breathes	breathe	*	*
/ɔ/		decision	version	*		garage		

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The FITI Table

- Assessment
  - Identify treatment targets most likely to affect intelligibility
  - Create a prioritized list for intervention
- Treatment
  - Not in itself a treatment activity
  - Once a treatment target is identified, find additional tokens to work on it
    - E.g., if word-initial pre-vocalic /r/ ('really'), a highly FITI target, is a problem, find additional word-initial /r/ words (in English all word-initial /r/ words will be pre-vocalic) to practice

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The FITI Table: Organization

- **Rows**
  - All the phonemes in order of their frequency in common ***content*** words
    - /r/ is most frequent
    - /ʒ/ and /ð/ are least
  - FITIness: **contrast**, **frequency** (higher frequency, higher FITI), **functional load**

/r/
/t/
/n/
/s/
/l/
/k/
/p/
/d/
/m/
/f/
/b/
/ŋ/
/v/
/g/
/w/
/z/
/ʤ/
/ŋ/
/j/
/ʧ/
/h/
/θ/
/ð/
/ʒ/

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The FITI Table: Organization

- **Columns**
  - Ranked in three tiers from most prominent (tier 1) to least (tier 3)
  - FITIness: positional **context** (ranked by FITI)

Tier 1			Tier 2	Tier 3			
#_V	V_V	C_V	#_C	V_C	V_#	C_C	C_#

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The FITI Table: Organization

- **Gray Cells**
  - Empty gray cells: disallowed contexts in the language (in this case, English)
  - Starred gray cells: allowed, but rare
  - These are low FITI
  - FITIness: **functional load** (& frequency)

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The FITI Table: Use

- Relative FITI of elements is ranked
  - The higher the row, the higher the FITI
  - Tiers 1, 2, 3 are in order of FITI
    - Within tiers, columns are also organized in order of importance
  - Ranking of rows generally more consequential to intelligibility than information in columns
    - Hence, any Tier 3 /t/ (row 2) expected to have higher FITI than Tier 1 /g/ (row 14)

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The FITI Table: Use

- Expect individual differences/needs
  - A client's needs may lead to higher FITI for elements rendered less important by the phonology
    - E.g., high usage of foreign borrowings or names; high use of uncommon words
  - Focus on more complex elements (even if lower FITI) to practice strategies
    - E.g., inter-consonantal context to practice hyper-articulation or slower rate

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The FITI Table: Use

- Use this hierarchy to prioritize initial treatment goals
  - Client has difficulty with /d͡ʒ/, /θ/, and /ʃ/
    - Order by FITI: /ʃ/ first, then /d͡ʒ/, followed by /θ/
  - Client has difficulties with /n/ in prevocalic & in word-final positions
    - Order by FITI: work on prevocalic first (Tier 1)

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Adapting Resource to Other Languages

- Need a list of phonemes ranked in order of frequency in common words
  - Taken from common content words (not function words)
  - These will be ranked in rows
- Tier organization is based on universal (cross-linguistic) properties
  - Can use existing columns
- The gray cells are language-specific
  - Identify disallowed contexts
- Add word tokens with the target phonemes in each context
  - Starred gray cells for allowable but infrequent contexts

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Summary

- Fundamental hierarchy supported by external evidence from cross-linguistic studies in phonetics & phonology, language acquisition, and language disorders
- Stimuli to assess intelligibility in all FITI contexts:
  - Gurevich, N. and Kim, H. (2023b). Development of novel speech stimuli with phonetic coverage and phonemic balance. *Perspectives of the ASHA Special Interest Groups*. https://doi.org/10.1044/2023_PERSP-22-00180

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