Speech in Noise Testing
An expanded and integrated view

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SPEAKER DISCLOSURE

Relevant Financial Relationships: Employee of WS Audiology

Relevant Non-financial Relationships: None

AGENDA

- Realistic communication model
  - Objective vs subjective intelligibility assessment
  - Working memory limits speech in noise comprehension
  - Role of cognitive factors , e.g. listening effort
  - Psychological factors to stay in noise – noise acceptance, including the TNT
- Repeat-Recall Test (RRT) and Quick-RRT
- Clinical use for the Quick RRT

REALISTIC COMMUNICATION

Listener activities

We listen to understand

Clinicians' task

Need to understand how much they **understand** and how much they **think** they **understand**

OBJECTIVE VS **SUBJECTIVE** INTELLIGIBILITY TESTS

Objective tests

(actual understanding)

- Listeners repeat sentences/ words they hear or understand
- Takes some time
- All clinical speech tests we use (NU-6, HINT, QuickSin) – single nonsense words to meaningful sentences
- Somewhat predictable from audibility (may have cognitive component)

Subjective tests

(“think” understanding)

- Listeners estimate how much they think they heard or understand
- Takes less time (in principle)
- HINT and QuickSin have been adapted to yield subjective SRT50 – sentences
- Typically, we expect subjective to be similar to objective (for words and sentences).

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SCORING THE **QUICKSIN** AS A **SUBJECTIVE** INTELLIGIBILITY TEST (OU & WETMORE 2020)

List 1		Score
1. A white silk jacket goes with any shoes.	S/N 25	_____
2. The child crawled into the dense grass.	S/N 20	_____
3. Footprints showed the path he took up the beach.	S/N 15	_____
4. A vent near the edge brought in fresh air.	S/N 10	_____
5. It is a band of steel three inches wide.	S/N 5	_____
6. The weight of the package was seen on the high scale.	S/N 0	_____
27.5 - TOTAL =_____ SNR Loss	**TOTAL**	_____

OBJECTIVE TEST

Repeat the sentence and score the number of correct words. Add up total score.

SUBJECTIVE TEST

Estimate how much of the sentence is understood using a number from 0 to 5 with 0 means nothing and 5 every word of the sentence. Add up total score.

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WHY IS IT **IMPORTANT** TO KNOW WHAT LISTENER **THINKS S/HE UNDERSTANDS**?

Perception can be affected by emotions, cognition in addition to acoustics

Perception can affect decisions (such as HA satisfaction and purchase)

Subjective intelligibility

Objective intelligibility

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PROBLEMS WITH SUBJECTIVE INTELLIGIBILITY NOT BEING THE SAME AS OBJECTIVE INTELLIGIBILITY

- Subjective = objective – reasonable expectations, expected outcome from intervention (S = O)
- Over-estimator – thinks s/he hears better than s/he actually does – denies problem, less willing to accept help (S > O)
- Under-estimator – thinks s/he has more problems than the hearing loss or speech test results suggest – critical of hearing (or intervention), difficult to please, lower satisfaction (O > S)

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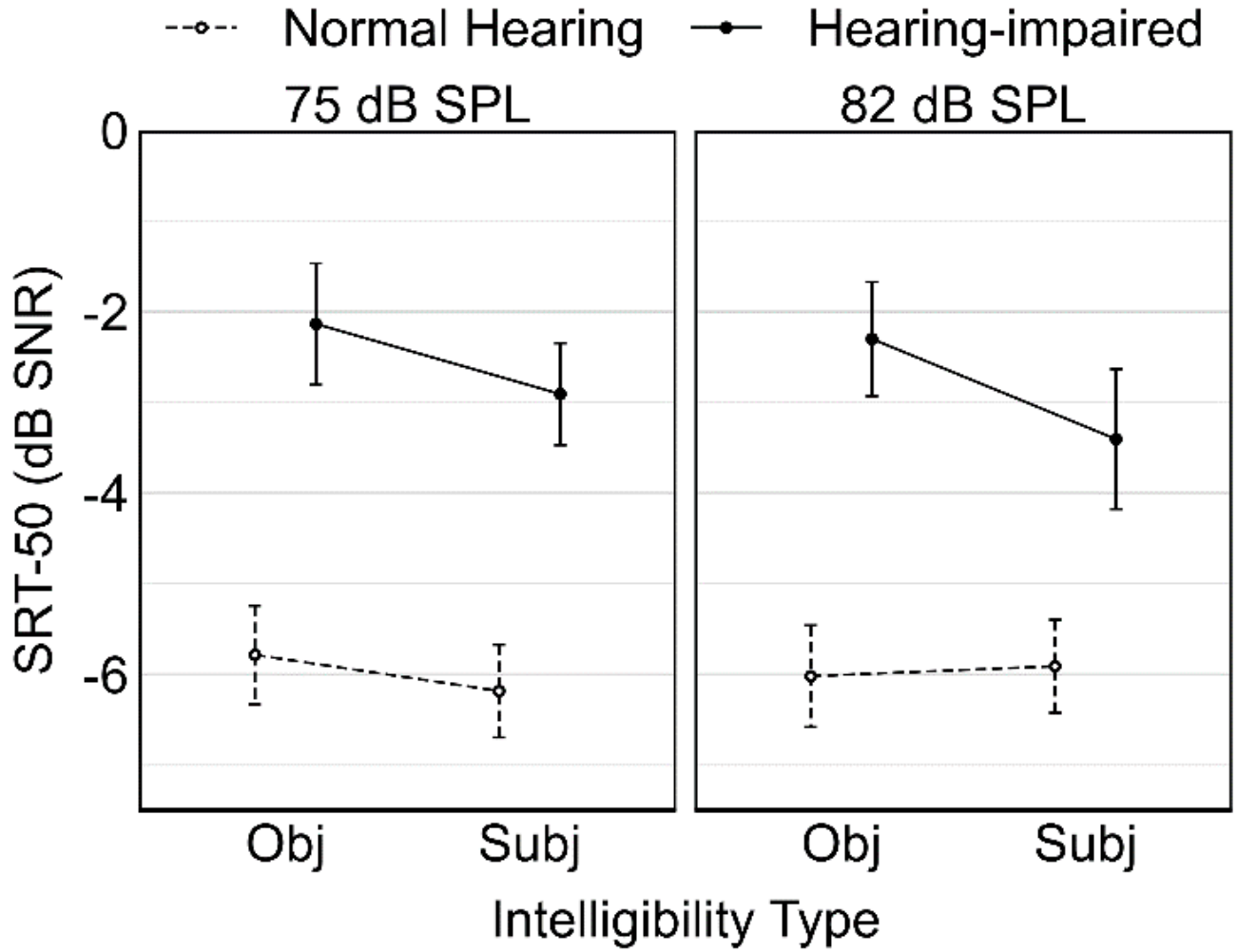
SUBJECTIVE-OBJECTIVE INTELLIGIBILITY DIFFERENCE (SRT50) BETWEEN NORMAL-HEARING AND HEARING-IMPAIRED (**UNAIDED MODE**)



For Normal-Hearing listeners, average subjective SRT_{50} is same as objective SRT_{50} around -6 dB

For Hearing-Impaired listeners, average subjective SRT_{50} is better (or lower) than objective SRT_{50} by 1 – 1.5 dB (average around -2.5 to -3.0 dB)

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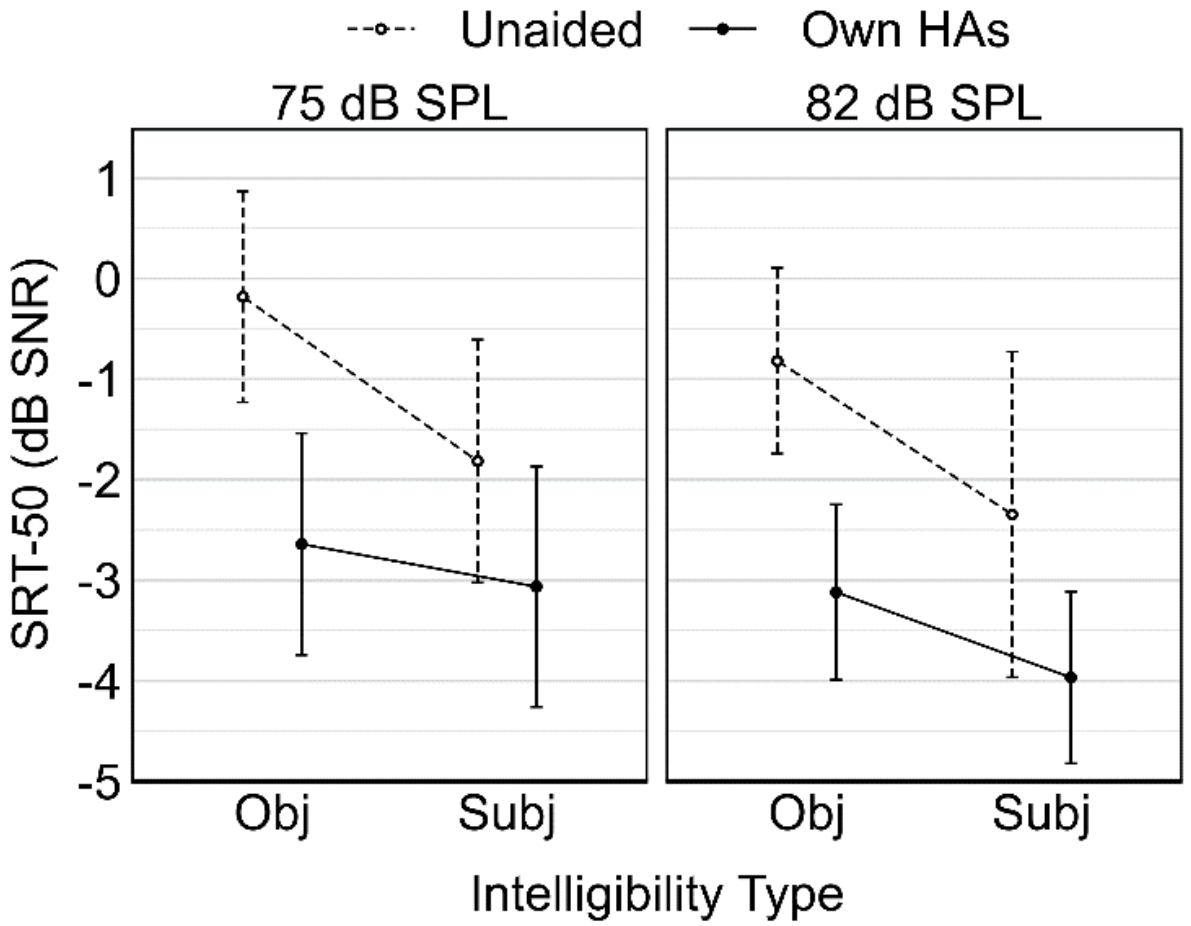
SUBJECTIVE-OBJECTIVE INTELLIGIBILITY DIFFERENCE (SRT50) BETWEEN **UNAIDED AND AIDED** MODES IN HEARING- IMPAIRED



For the Hearing-Impaired listeners,

- Unaided – subjective SRT > objective SRT about 1.5 dB
- Aided – subjective SRT = objective SRT (+/-0.5-1, not significant); SRT about -3 to -4 dB

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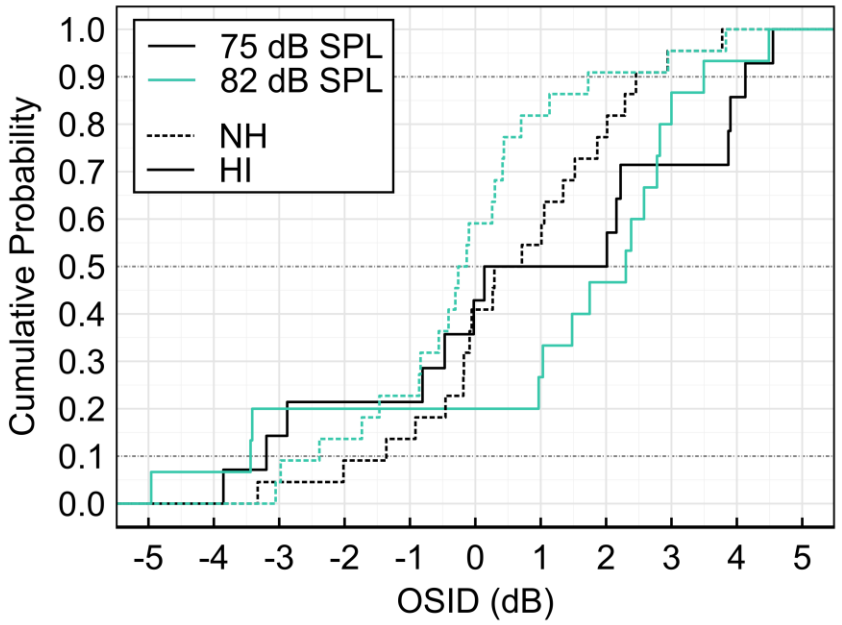
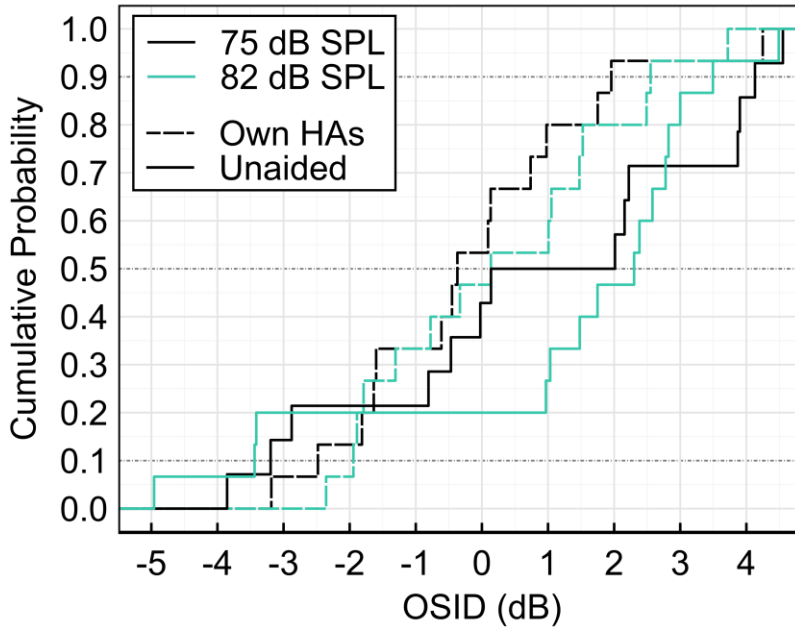
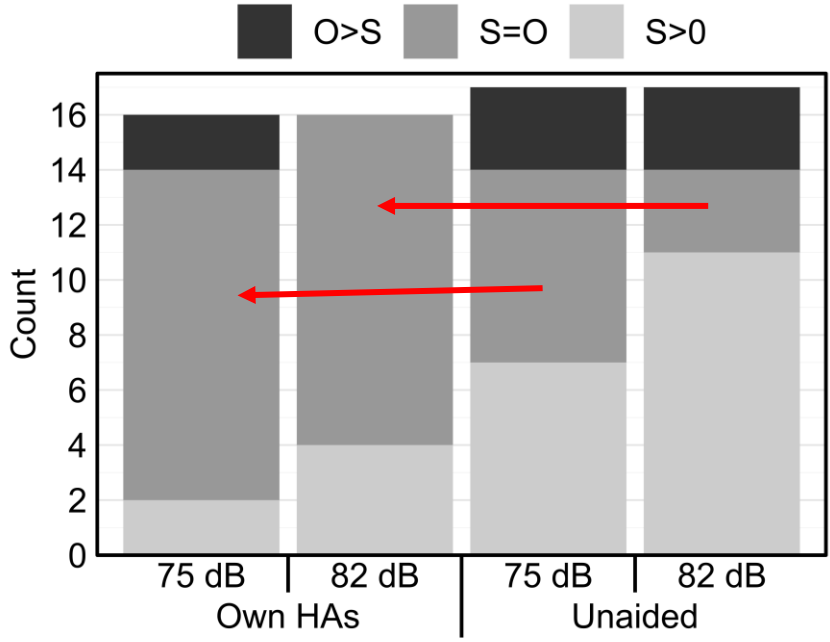
OUR **RECENT STUDY** ON SUBJECTIVE VS OBJECTIVE INTELLIGIBILITY SHOWS

- We used related sentences created from our TNT test passages
- Normal hearing listeners showed similar performance between subjective and objective tests
- Hearing impaired listeners showed better subjective performance than objective performance in unaided mode (almost half, based on criterion from NH)
- Hearing impaired listeners showed less difference between subjective performance and objective performance in aided mode (similar to normal hearing)

INCIDENCE OF OVER- & UNDER-ESTIMATOR IN HI LISTENER RE:NH LISTENER







IMPLICATIONS AND **CHALLENGES**

- Implications
  - Unaided - HI perceives less difficulty than reality (S>O)
  - Aided – HI's subjective intelligibility closer to NH
    - HAs restore some level of "normal" perception of intelligibility or reality
    - HI perceives less benefit than reality (benefit = aided – unaided performance)
- Challenges
  - Convincing HI listeners to try amplification when they perceive less difficulty than they really have and to show them more benefit than they perceive - ***demonstration***
  - Include subjective evaluation – ***as a supplement to objective measure***

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REALISTIC COMMUNICATION

Listener activities

We listen to understand

Clinicians' task

Need to understand how much they **understand** and how much they **think** they **understand**

Need to understand size of **working memory**

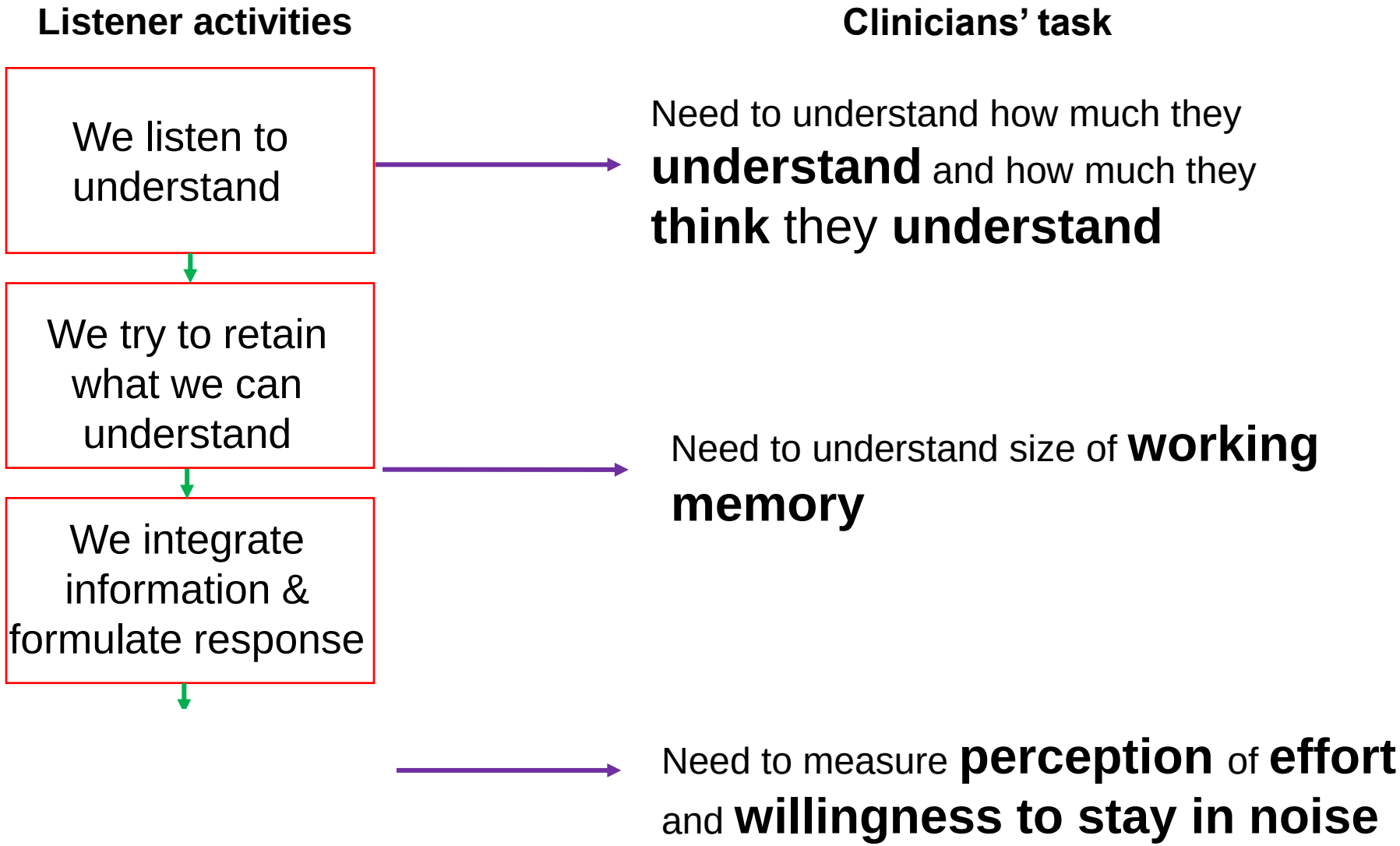
WHAT IS **WORKING MEMORY?**

- Memory that **TEMPORARILY STORES** information for **SUBSEQUENT PROCESSING**
- Examples
  - Following instructions
  - Map directions
- Can be **verbal or nonverbal** (may or may not be same size)
- Age effect, not same as cognitive impairment
- Please visit www.orca-us.info for “**RRT 1: Rationale and Development”** to hear a distinction between dementia, MCI and working memory

PEOPLE WITH BETTER vs POORER WORKING MEMORY

- Better working memory
  - **Better** speech in noise, lower listening effort, more willing to spend more time in noise
- Poorer working memory
  - Greater need for noise management strategies
  - Greater need to preserve signal naturalness (use of slow compression, low delay etc)

REALISTIC COMMUNICATION



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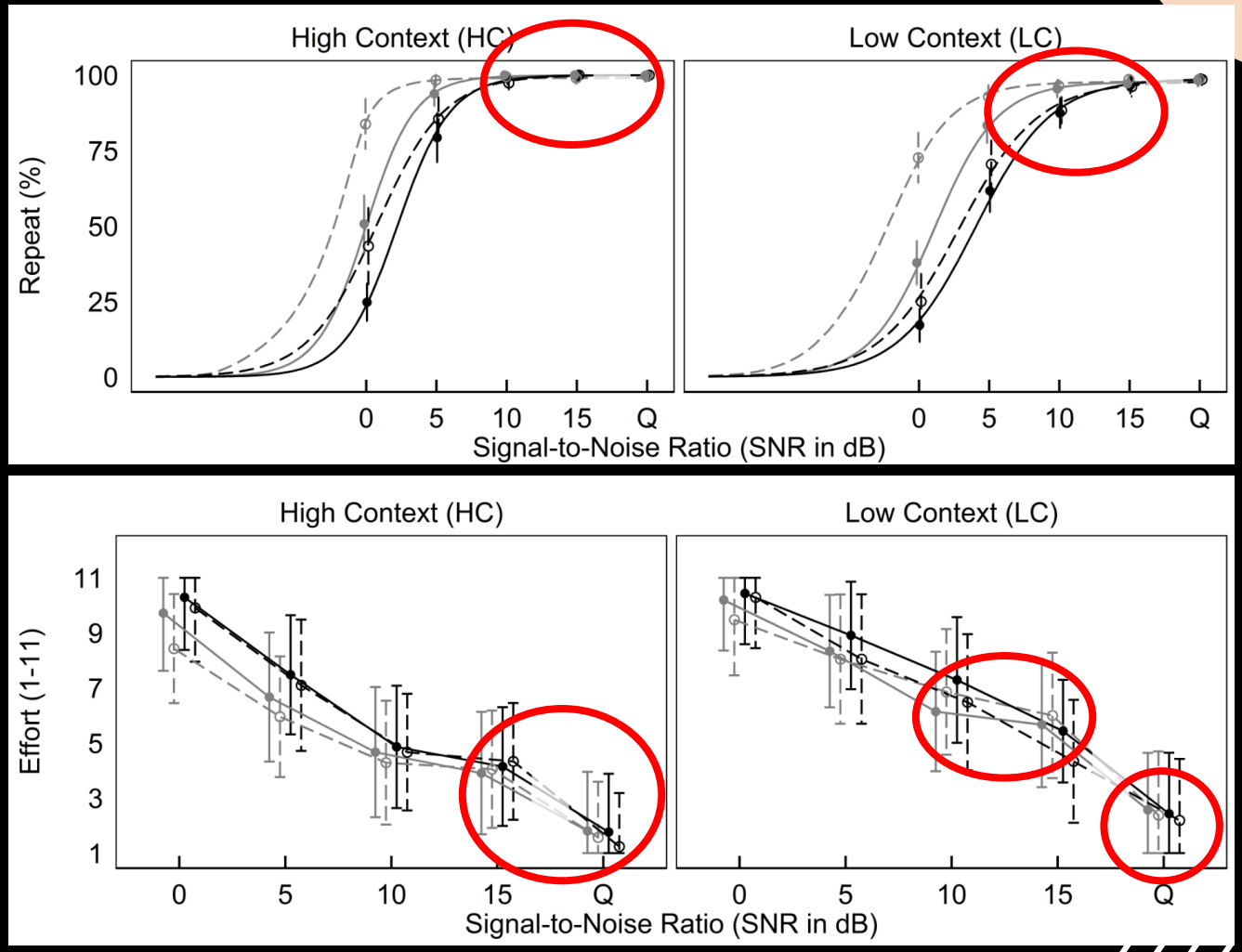
WHAT IS **LISTENING EFFORT**?

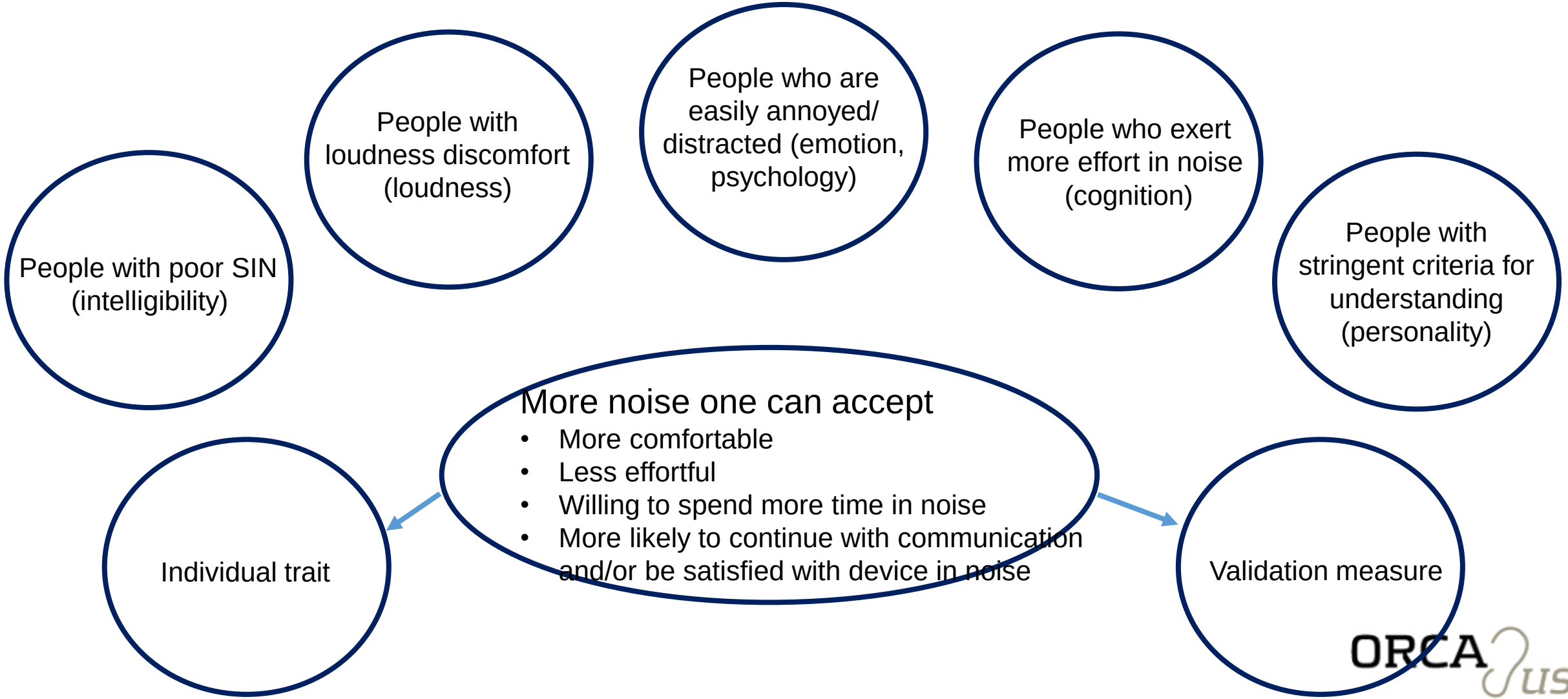
- "…*the deliberate allocation of mental resources to overcome the obstacle in goal pursuit when carrying out a listening task*…" (Pichora-Fuller et al, 2016)
- Means to measure
  - Physiological
    - Heart Rate Variability
    - Pupillometry
    - EEG (alpha)
  - Behavioral
    - Dual task
    - Rating

LISTENING EFFORT CAN BE ***BIASED*** BY PERFORMANCE; BUT NOT ALWAYS



A subjective task;
As a cross check on performance;
May be especially sensitive when performances are similar

WHY NOISE ACCEPTANCE MEASURE (WHILE MAINTAINING SPEECH UNDERSTANDING) MAY BE BETTER AT ESTIMATING COMMUNICATION?

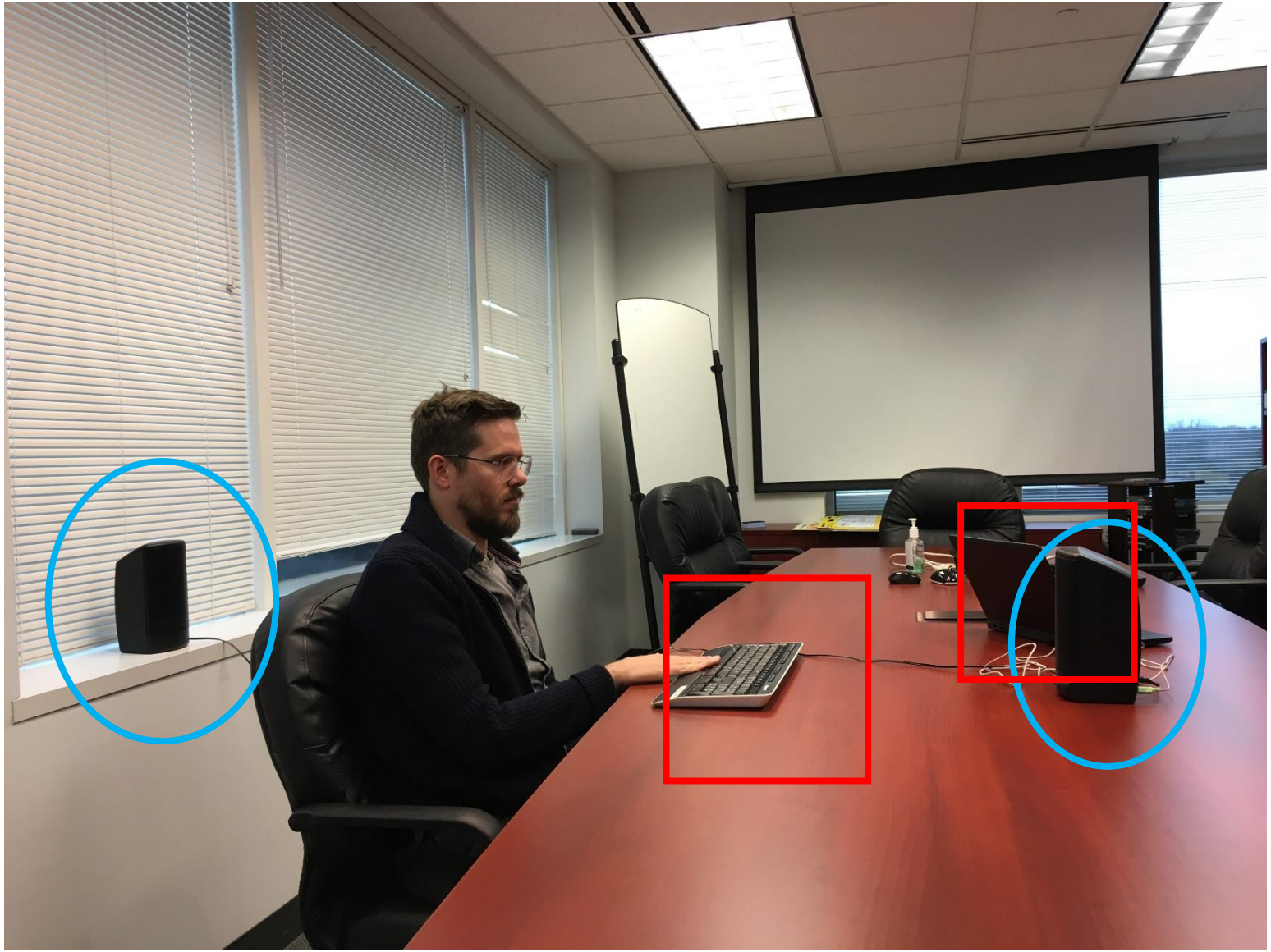


A NOISE ACCEPTANCE TEST FROM ORCA

TRACKING OF NOISE TOLERANCE (TNT)

- Measures to ensure reliability
  - Fixed speech input level
  - Tracking noise level for 2 min
  - Use multiple equivalent passages
- Measures to be more real-life
  - Speech filtered according to input level to approximate speech spectra of increased vocal effort
- Measures to ensure intelligibility as main criterion
  - Specify intelligibility criteria – > 90%
- Direct interpretation
  - **TNT** = TNL – speech
  - Higher TNT, greater noise acceptance

TRACKING OF NOISE TOLERANCE (TNT) - PHYSICAL **SETUP**



Headphone (unaided) also

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INSTRUCTIONS – TOLERABLE NOISE LEVEL

- *You will hear some noise in the background while you listen to the male talker. The noise will automatically get louder. I want you to monitor the noise level and maintain the loudest noise level you can put up with while still understanding 90% of the words in the story. If the noise becomes too loud, where you can no longer put up with it or understand less than 90% of the words in the story, you can turn the noise down by pressing and holding the space bar. If it appears softer than before, you should allow the volume to increase by letting go of the space bar. If it is louder than before, you should turn the volume down to keep at the same level by pressing the space bar again. Your ability to understand speech should never change to below 90%. The test will run for two minutes and then stop.*

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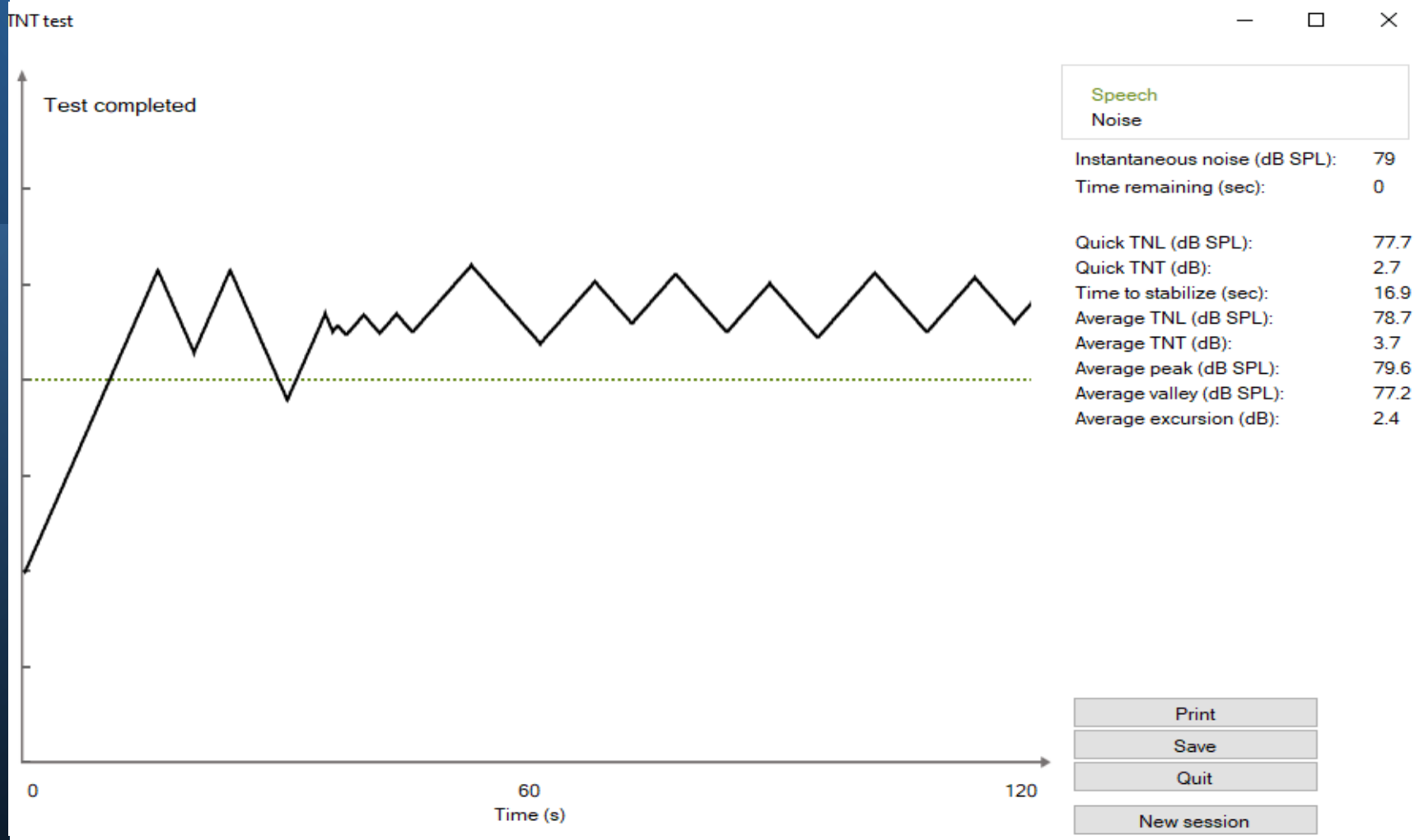
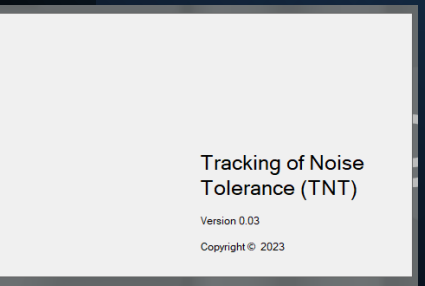
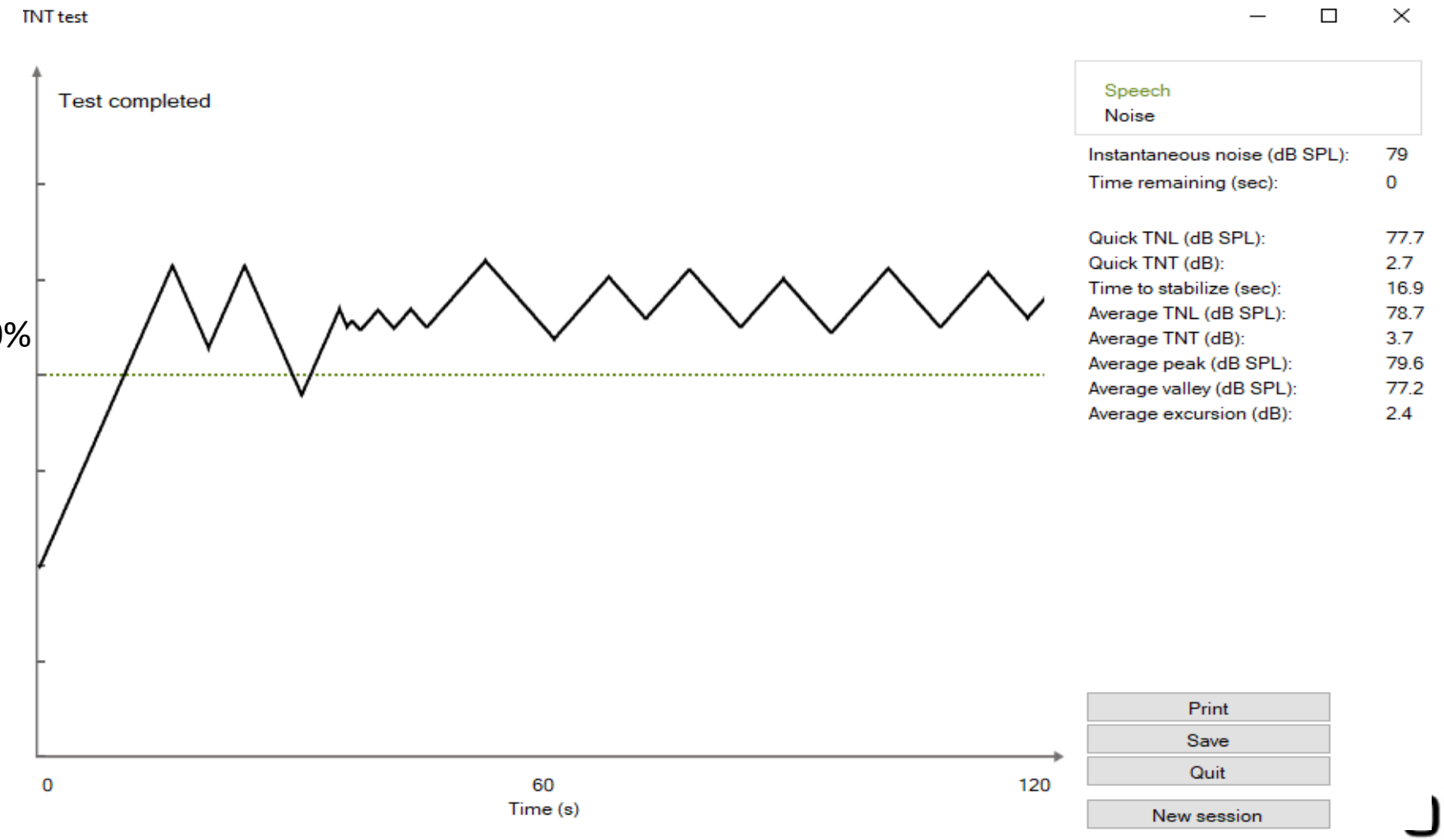
TNL TRACKING **RESULTS** (INDIVIDUAL)

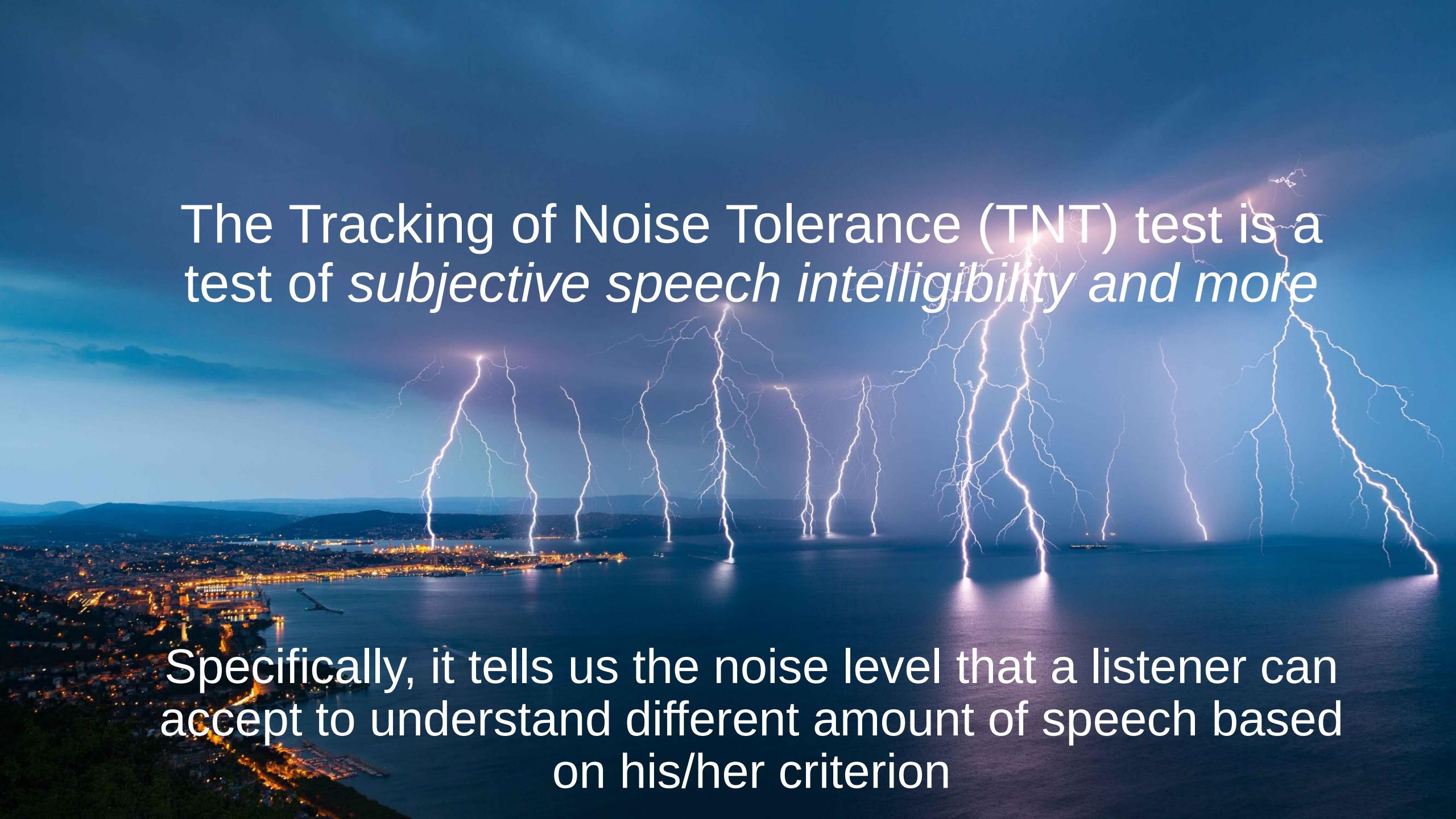




SUBJECTIVE SPEECH INTELLIGIBILITY DURING TNT TRACKING

Peaks - about 30-50%
Average – about 60-70%
Valleys – about 90%



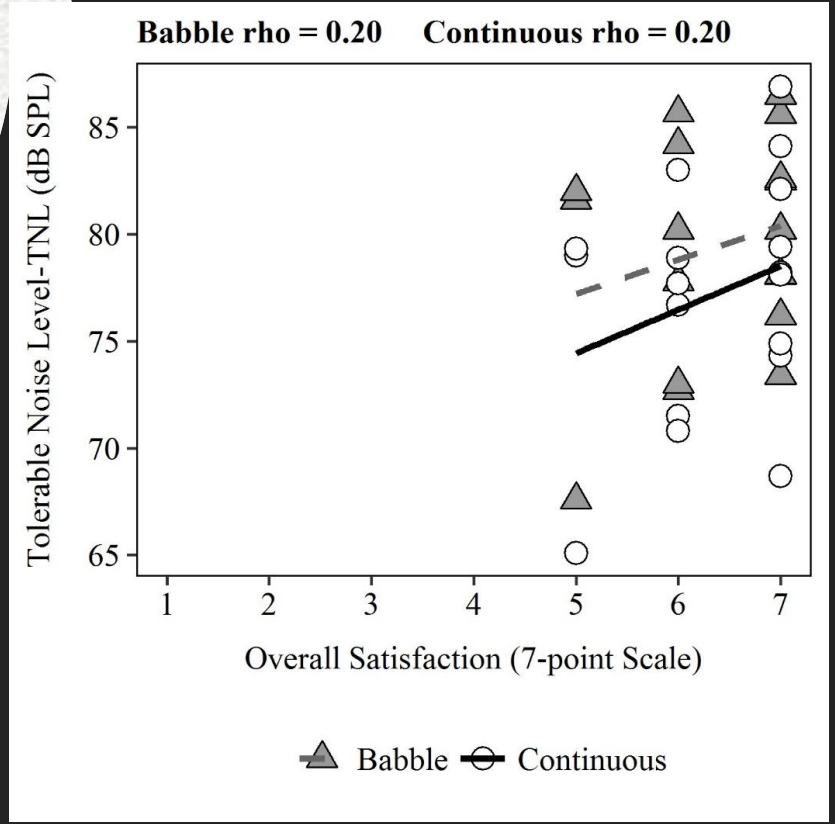


The Tracking of Noise Tolerance (TNT) test is a test of *subjective speech intelligibility and more*

Specifically, it tells us the noise level that a listener can accept to understand different amount of speech based on his/her criterion

PEOPLE WHO ARE **SATISFIED** WITH THEIR HEARING AIDS ACCEPT SIMILAR AMOUNT OF NOISE AS PEOPLE WITH **NORMAL HEARING**

- Seper et al (2018) found in 17 satisfied wearers of hearing aids that their TNL were:
  - Babble noise = 79.2 dB (vs normal 79.5)
  - Continuous noise = 77 dB (vs normal 76.5)
  - ALL but one subject had TNL much below 70 dB SPL



WEARERS WHO ARE MORE **SATISFIED** WITH THEIR HEARING AIDS ACCEPT **MORE NOISE**

THE **USEFULNESS** OF THE TRACKING OF NOISE TOLERANCE (TNT) TEST

It offers a ***new dimension*** of outcome measurement (i.e., *individual criterion of subjective intelligibility*)

SNR that listener thinks s/he needs to understand > 90% of passage materials of simple content based on his/her *own criterion* of 90%

Profiling	Fine-tuning and comparison of HAs/features	Measurement/ prediction of HA satisfaction/ success

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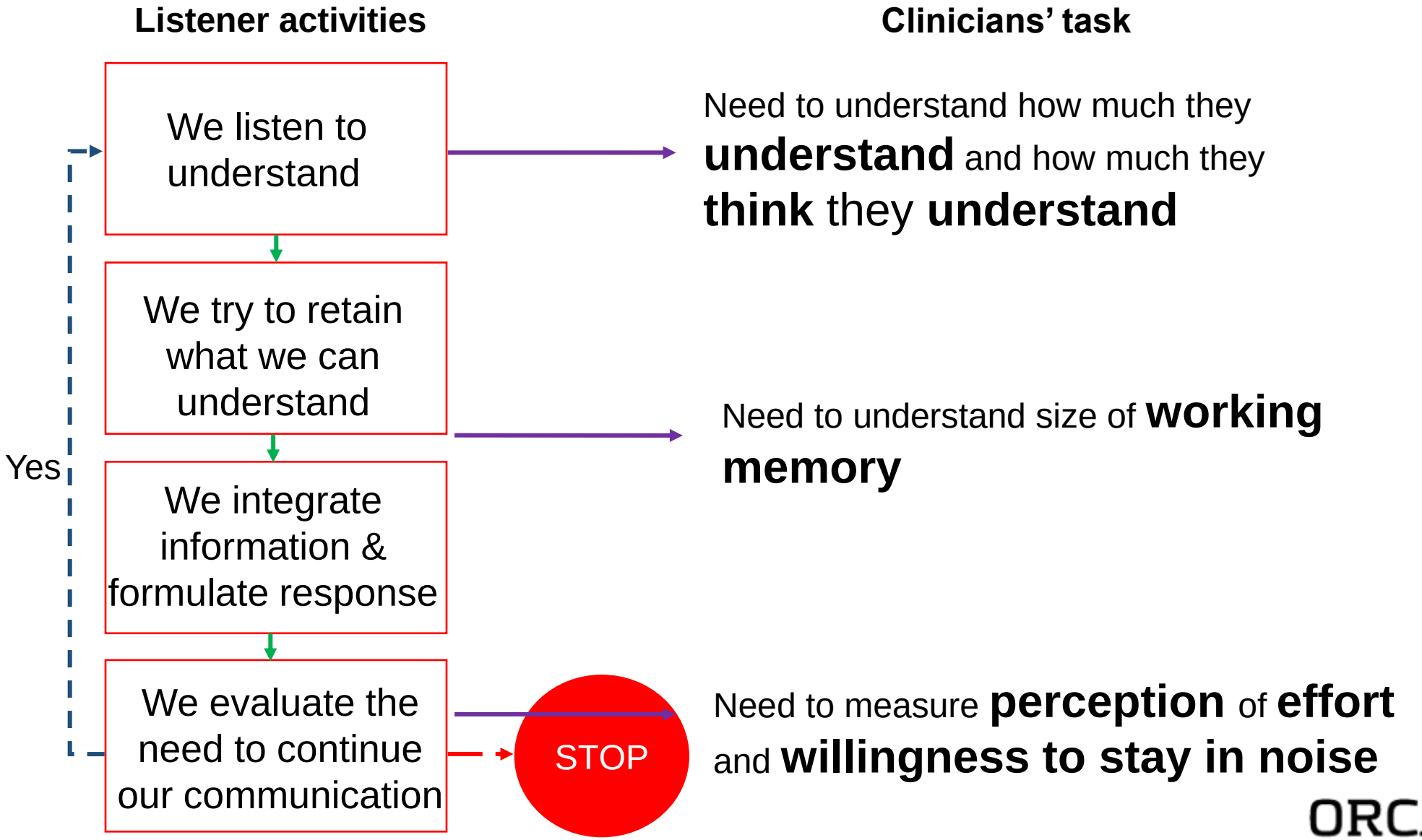

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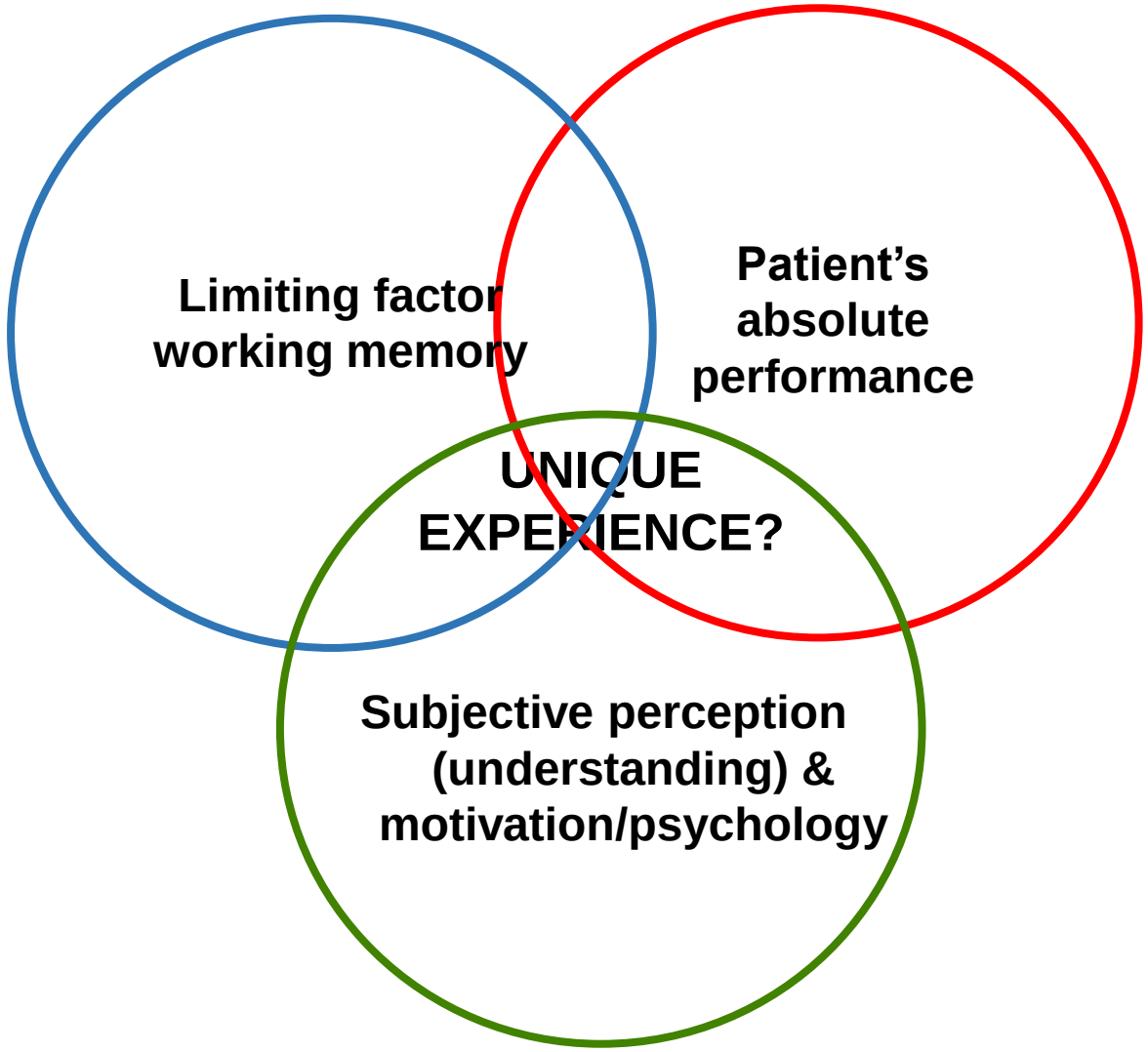
WE WANT TO **KNOW THESE** ABOUT OUR PATIENTS



So you can profile your patient, gauge/predict his success with intervention such as hearing aids, rehab training etc, intervene appropriately and optimally, and validate performance/success of intervention

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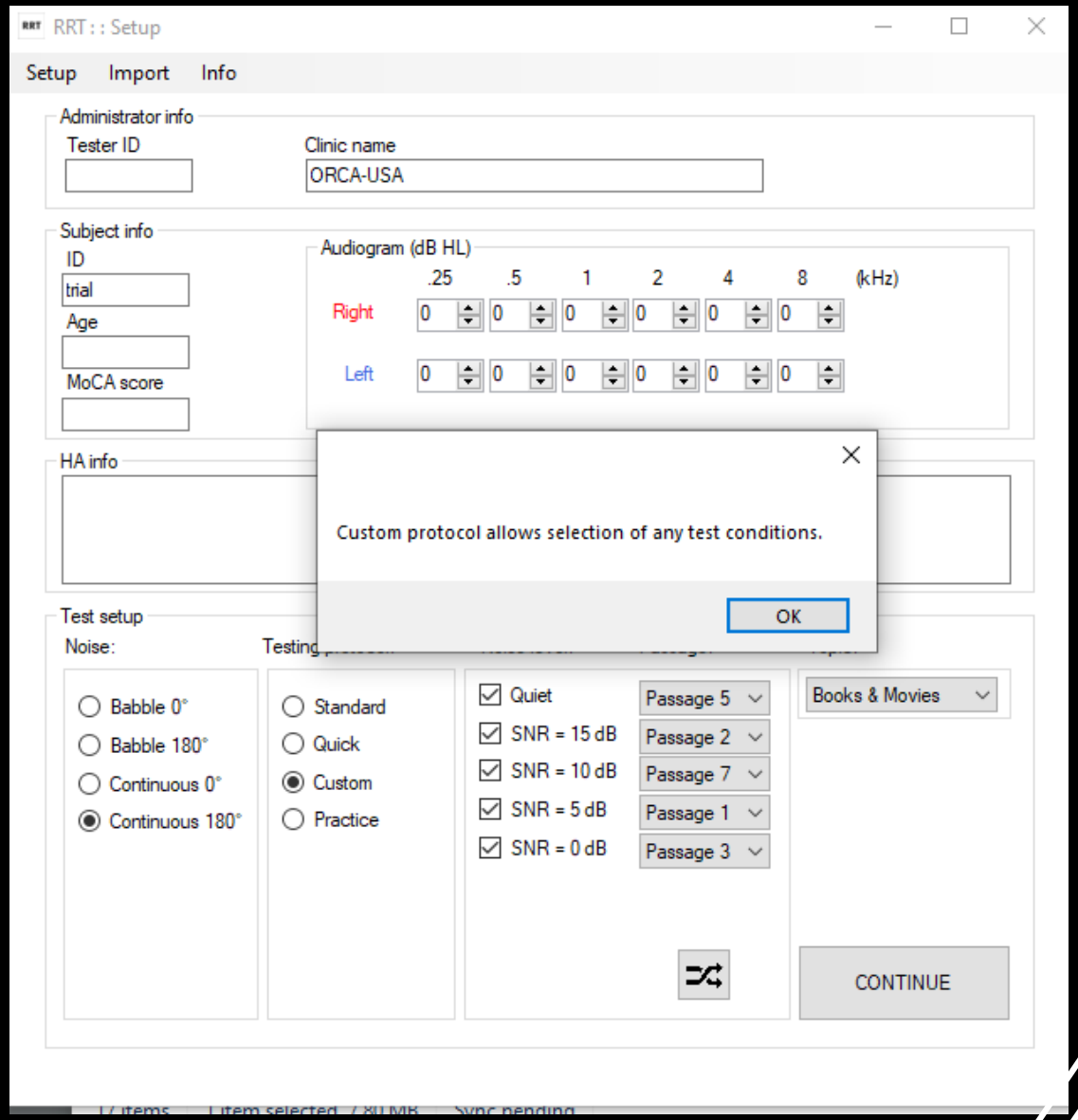
WHAT DO YOU **MEASURE** IN YOUR CLINIC?

- Objective speech test in ***quiet?***
  - NU-6, W-22, CCT, NST etc
- Objective speech test in ***noise***?
  - QuickSin, HINT, CST etc
- ***Subjective*** speech intelligibility measurement (in noise)?
  - QuickSin, CST
- Assessment of ***working memory*** (and or cognition)?
  - Reading (listening) span, MoCA, digit span etc?
- Assessment of listening ***effort***?
  - Subjective rating, pupillometry etc?
- Assessment of ***noise acceptance***?
  - ANL, TNT


TIME

THE **REPEAT-RECALL TEST (RRT)** ALLOWS YOU TO GATHER ALL THE ABOVE INFORMATION IN A REASONABLE AMOUNT OF TIME

LATEST REPEAT RECALL TEST (VERSION 0.4.1)



REPEAT-RECALL TEST (RRT) - CONSTRUCTION

5 themes
(4th grade)

FOOD AND COOKING | MOVIES AND BOOKS | SHOPPING | SPORTS | MUSIC

1 | 2 | 3 | 4 | 5 | 6 | 7

7 lists/passages

High context

Keep the **ice cream** in the **freezer.**
The **chef cooks** food in a **restaurant**.
The **barbecue grill** used **hickory wood**.
Wash the **fruit** in the **sink**.
The **tart pie** had too much **lemon**.
He tried **new foods** in **different countries**

6 sentences

Low context

Keep the **ice foods** in the **lemon**.
The **cream cooks food** in a **country**.
The **barbecue chef** used **hickory freezer**.
Wash the **grill** in the **restaurant**.
The **tart fruit** had too much **wood**.
He tried new **pie** in **different sinks**

- A Software program on Windows
- Speech front at 75 dB SPL.
- Noise options:
  - 2-talker babble & **speech shaped noise**
  - 0º and **180º**
- Each list tested at one SNR = 0, 5, 10, 15, Q
- Testing can be conducted unaided and aided in sound field

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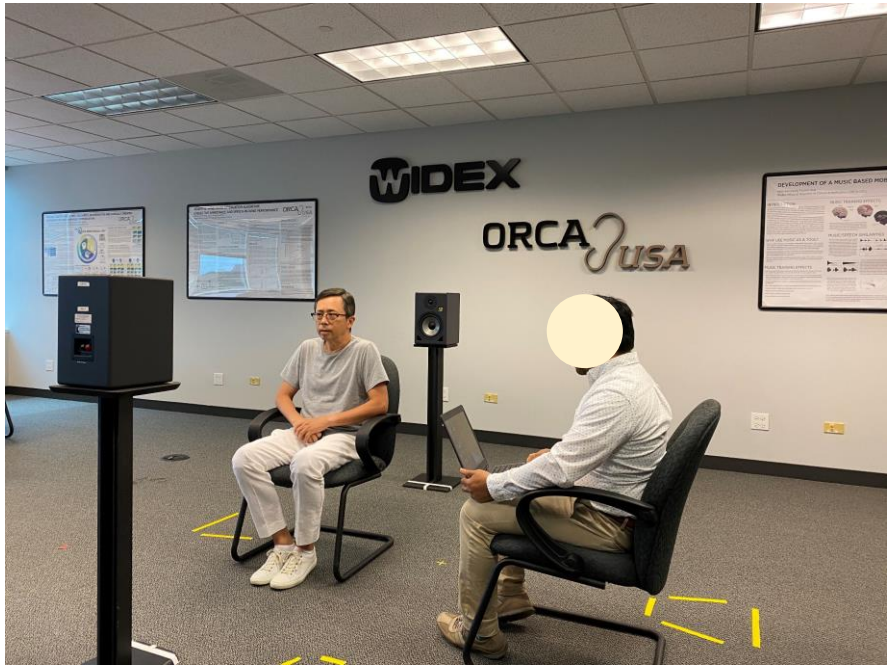
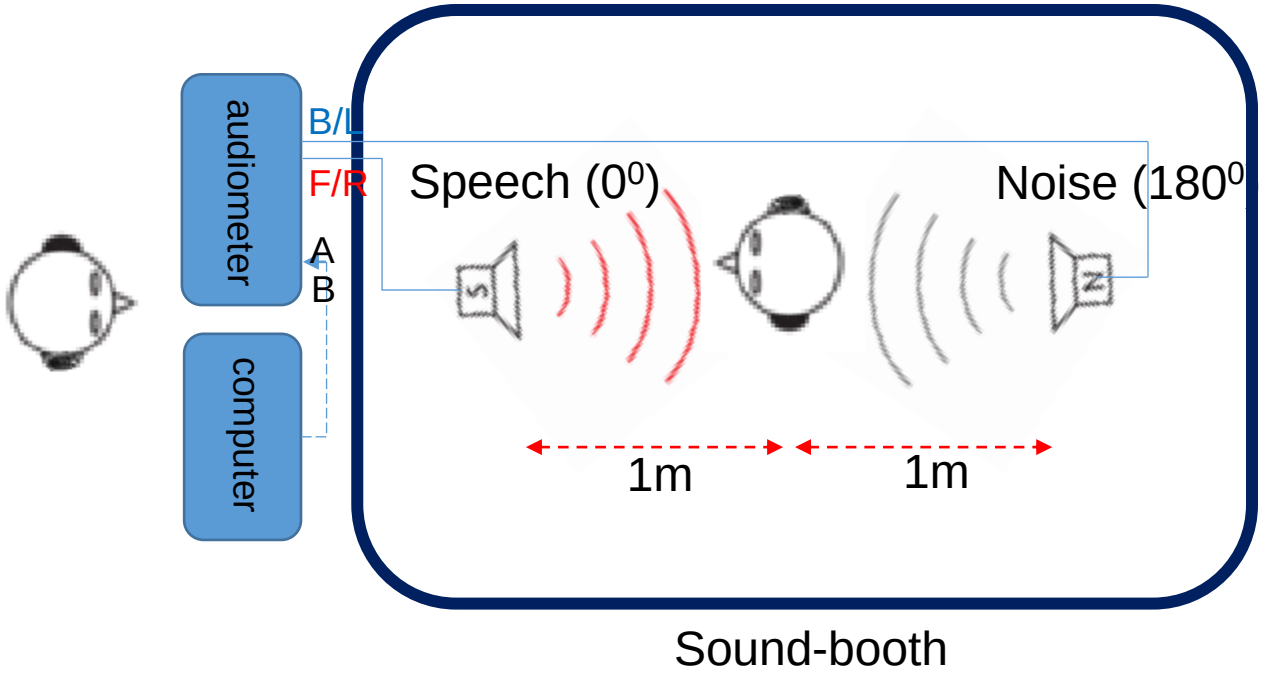
PHYSICAL SET-UP – STANDALONE OR VIA AUDIOMETER/BOOTH





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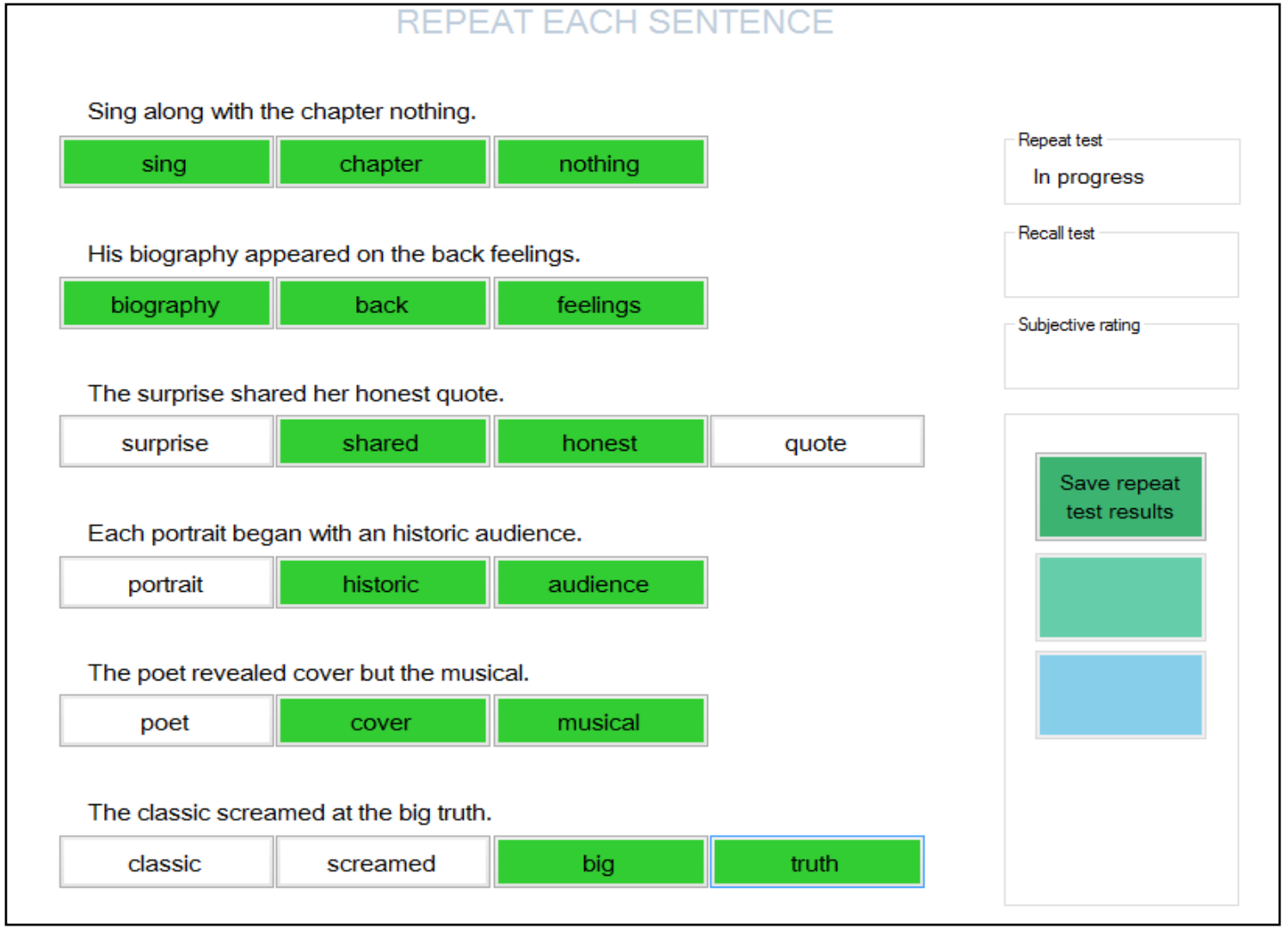
STEP 1 – REPEAT EACH SENTENCE



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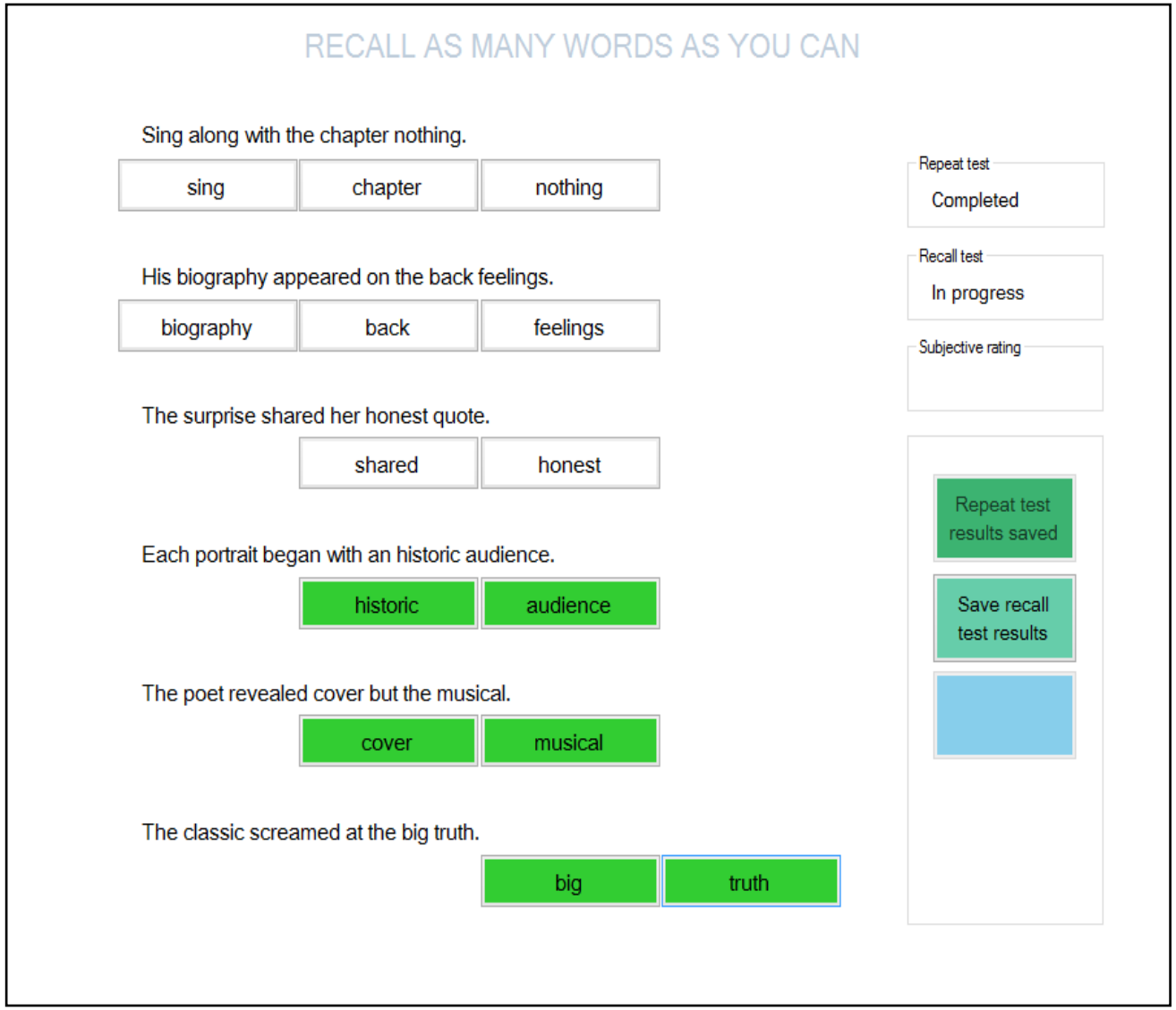
STEP 2 – RECALL ALL (SIX) 6 SENTENCES



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STEP 3: RATE **LISTENING EFFORT** AND REPORT **TOLERABLE TIME**

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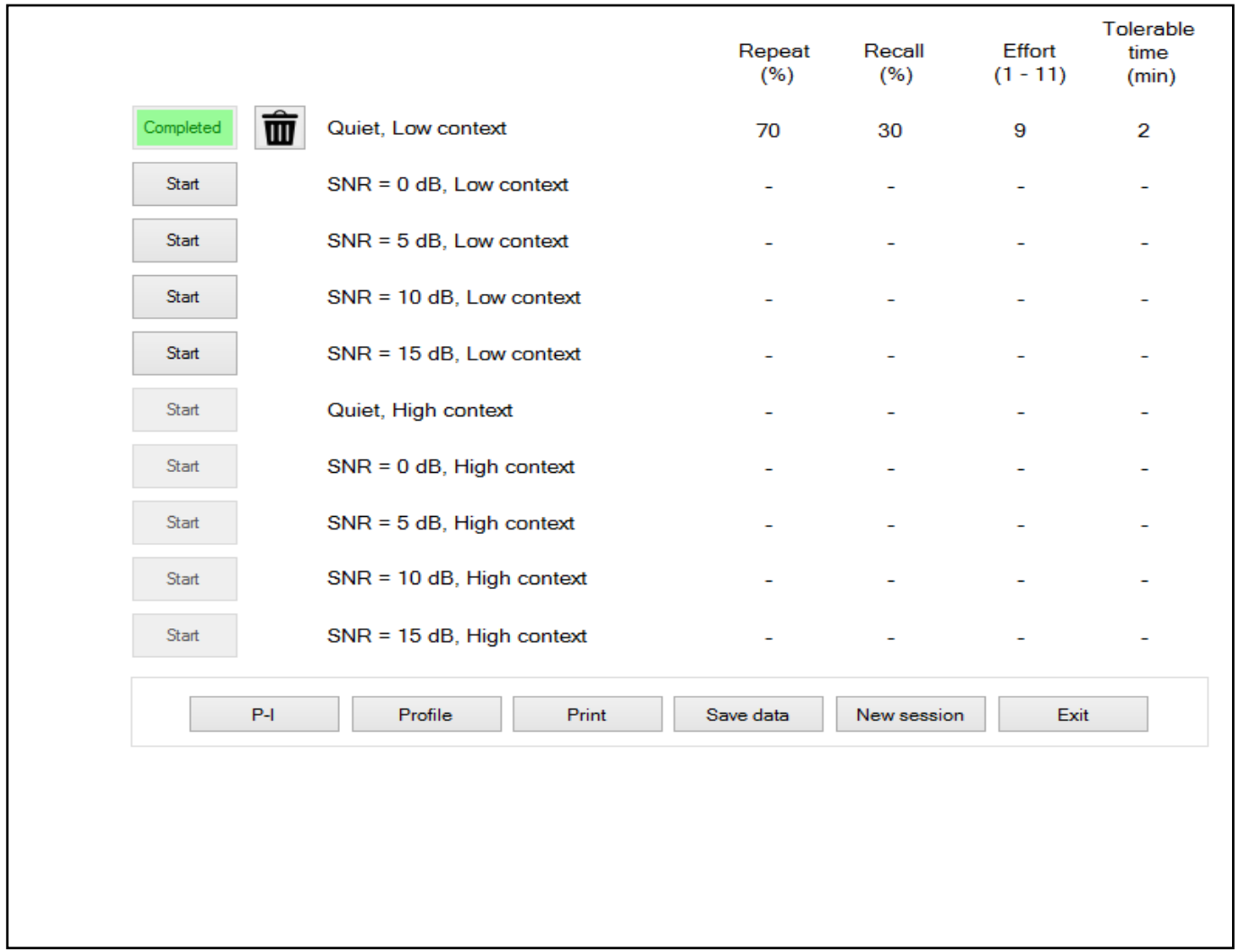
YOU HAVE COMPLETED TESTING AT **ONE SNR** …

REPEAT THE PROCESS AT ANOTHER SNR

Maximum administration time – 5 SNRs by 2 contexts or 20-25 minutes



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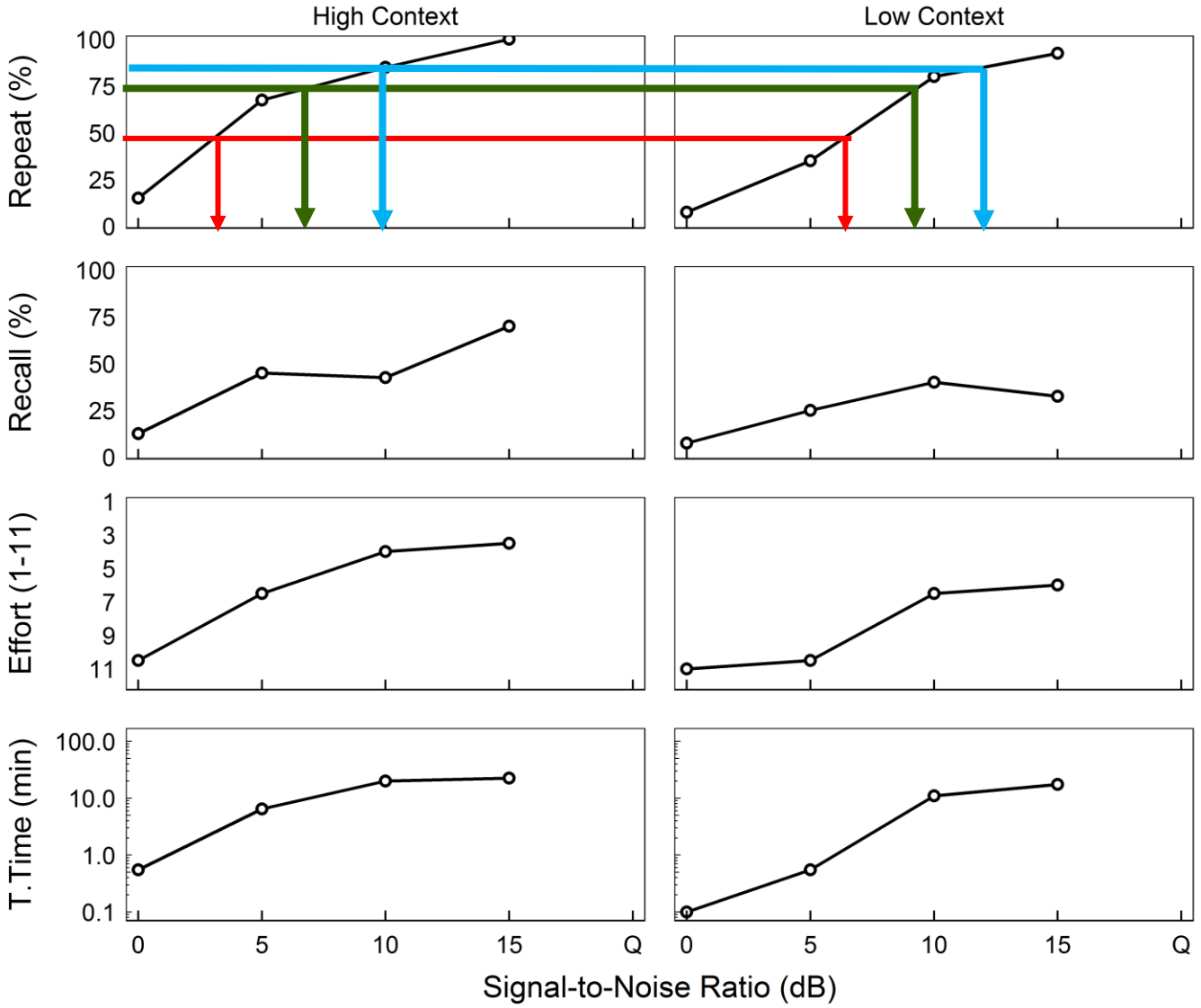
THE P-I FUNCTION ALLOWS ESTIMATION OF REPEAT **SNR AT DIFFERENT CRITERIA**



Estimating SRT at higher criteria (75%, 85%) yields more realistic appraisal of SNR needs in daily COMMUNICATION situations

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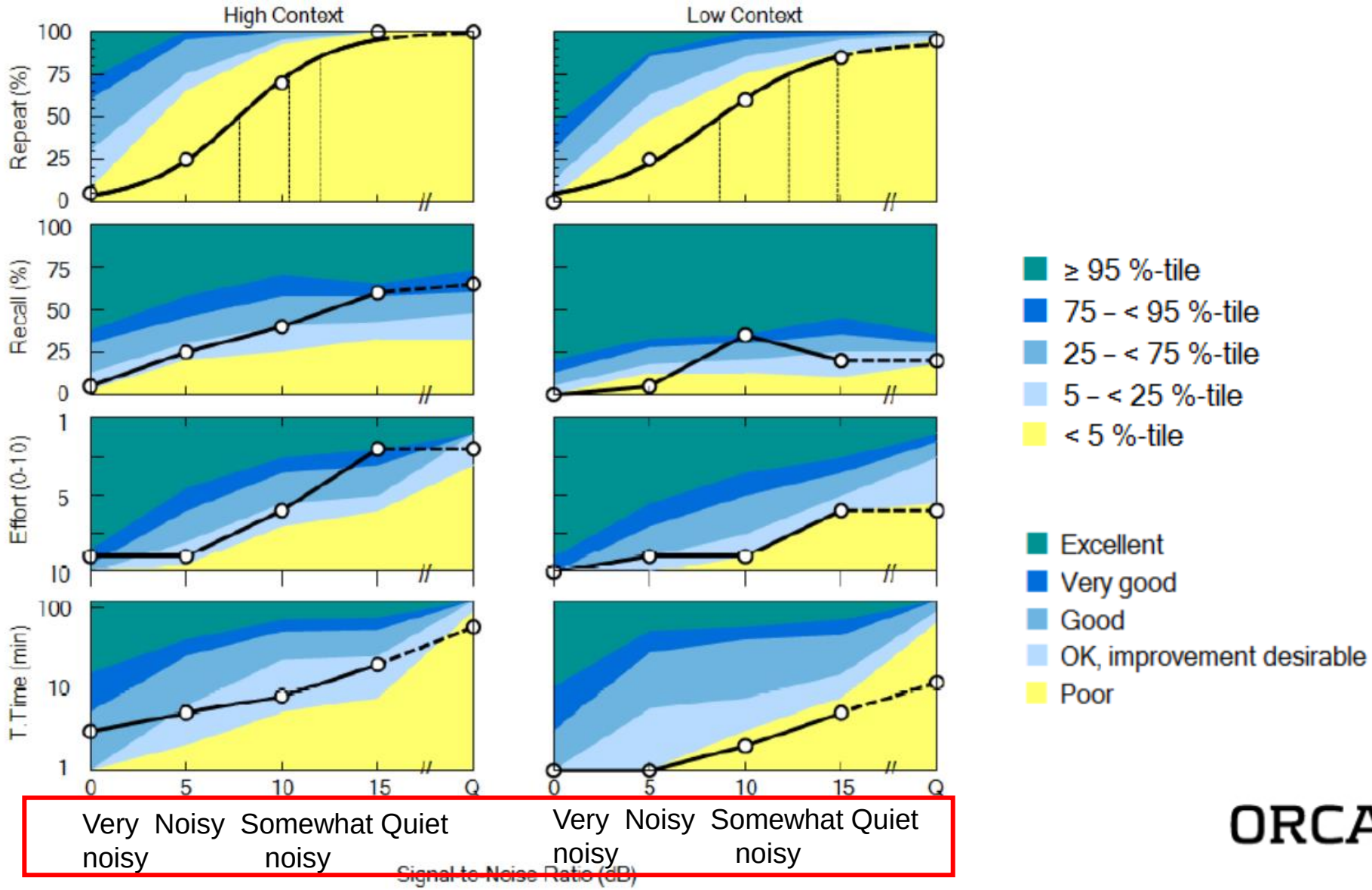
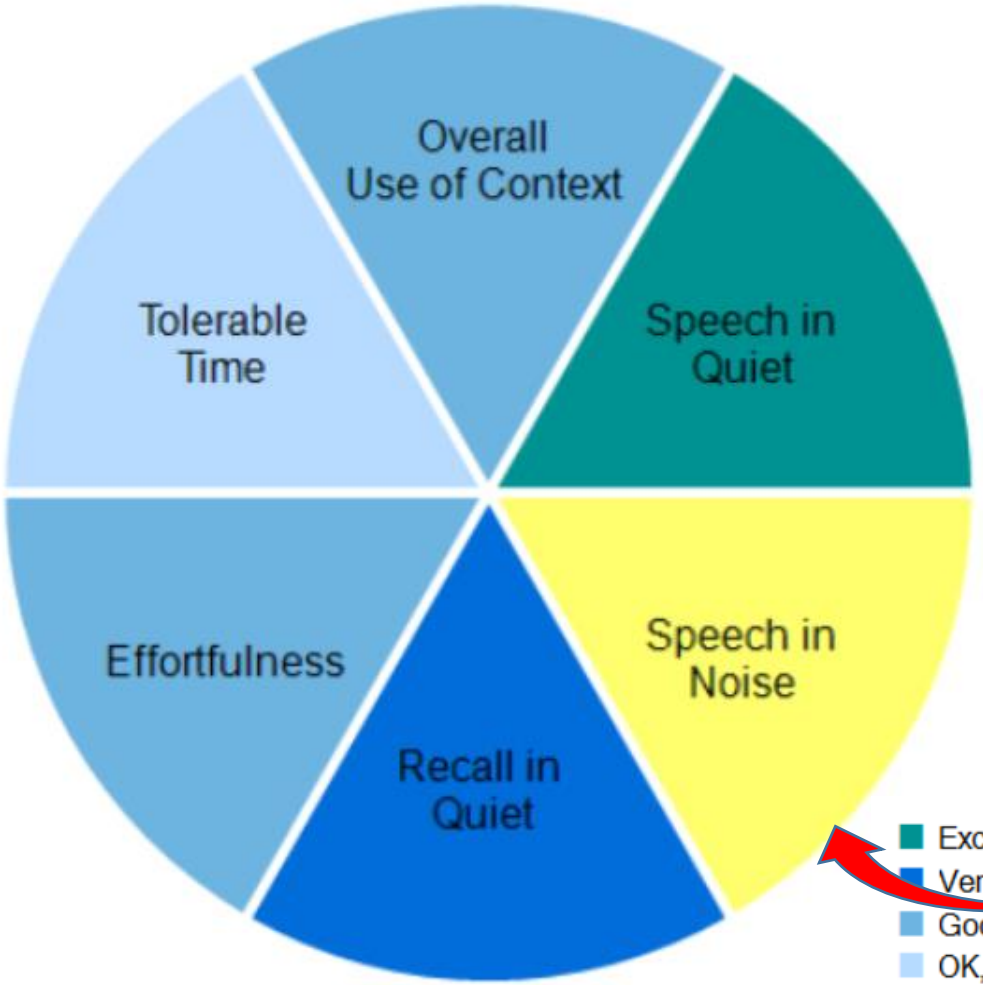
THE PATIENT'S PERFORMANCE IS COMPARED AGAINST **REFERENCE DATA**



Layman's terms for SNR (Wu et al, 2018)

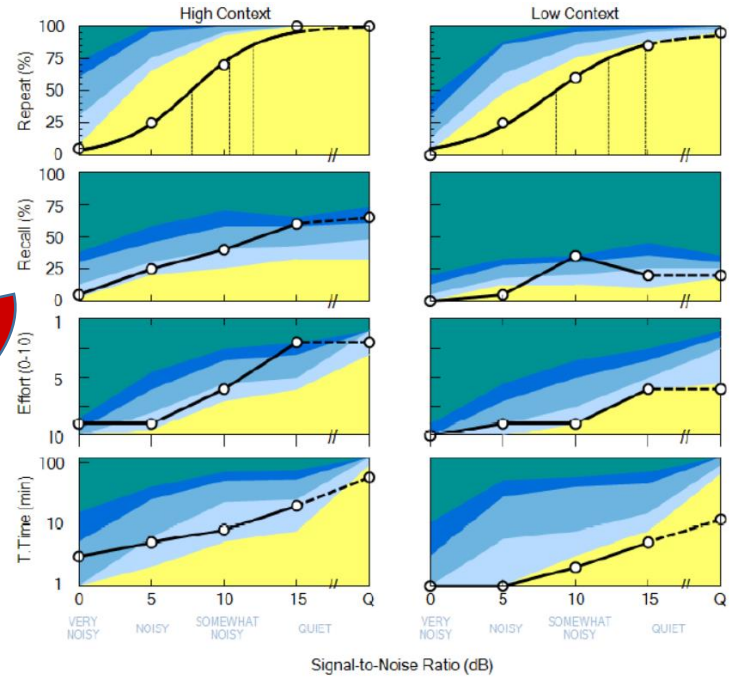
DISPLAY OF AVAILABLE INFORMATION



- Excellent
- Very good
- Good
- OK, improvement desirable
- Poor

Context	SNR (dB)	Repeat (%)	Recall (%)	Effort (1-11)	Tolerable time (mins)
High	0	5	5	9	3
	5	25	25	9	5
	10	70	40	6	8
	15	100	60	2	20
	Quiet	100	65	2	58
Low	0	0	0	10	1
	5	25	5	9	1
	10	60	35	9	2
	15	85	20	6	5
	Quiet	95	20	6	12

Context	SRT-50 (dB)	SRT-75 (dB)	SRT-85 (dB)
High	7.8	10.4	12
Low	8.7	12.3	14.8



- ≥ 95 %-tile
- 75 – < 95 %-tile
- 25 – < 75 %-tile
- 5 – < 25 %-tile
- < 5 %-tile

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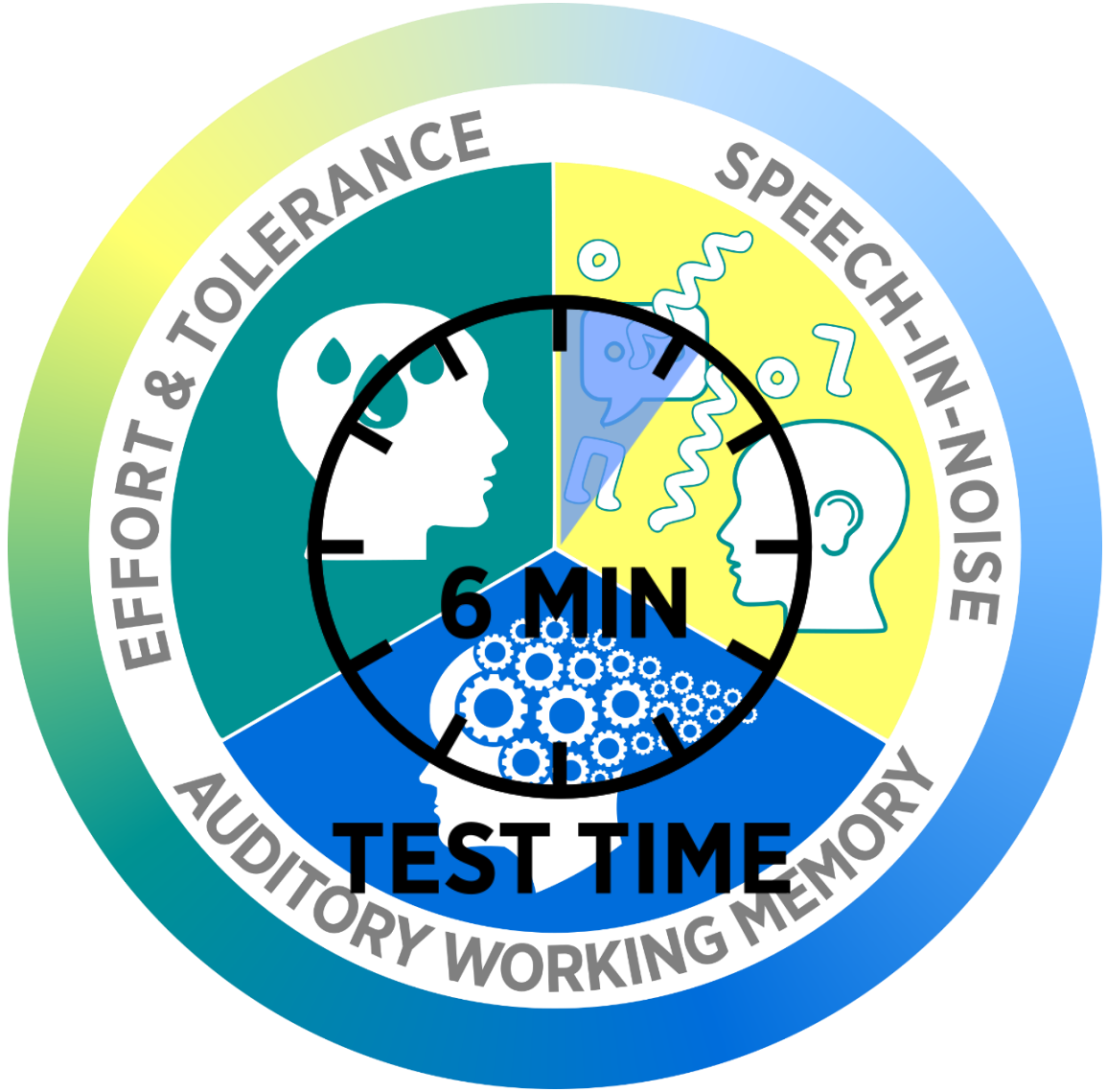
THE QUICK REPEAT-RECALL TEST



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QUICK RRT **TEST FLOW**

REPEAT

LC

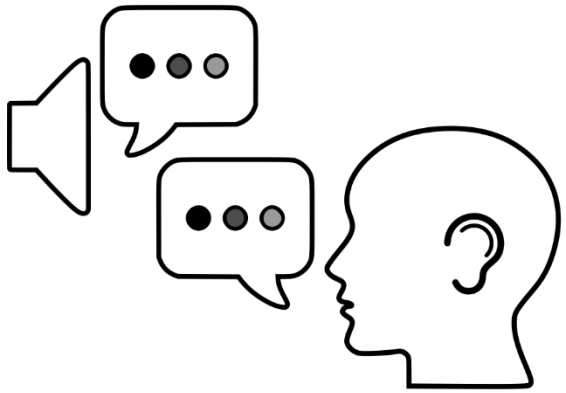
HC

x3 SNRs

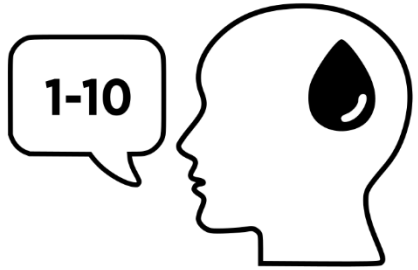
5 dB

EFFORT?

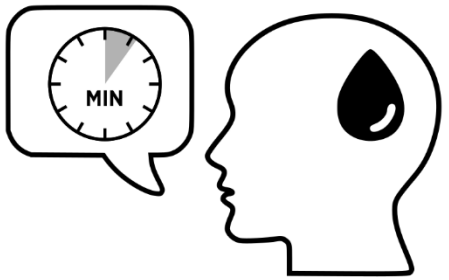
TOLERANCE?



"Repeat each sentence as you hear it."



"On a scale of 1-10, how effortful was it to hear the speech."



" How long would you spend in this environment?"

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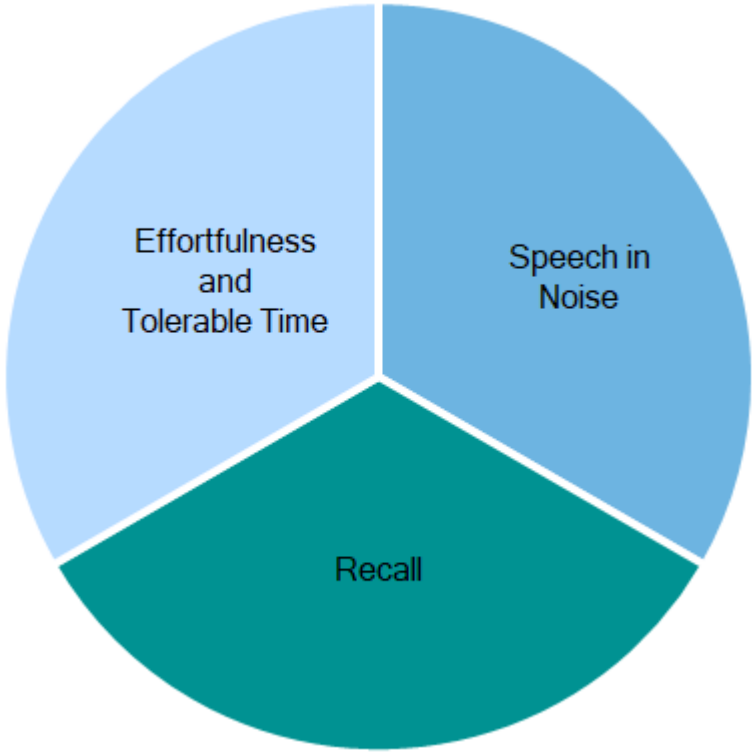
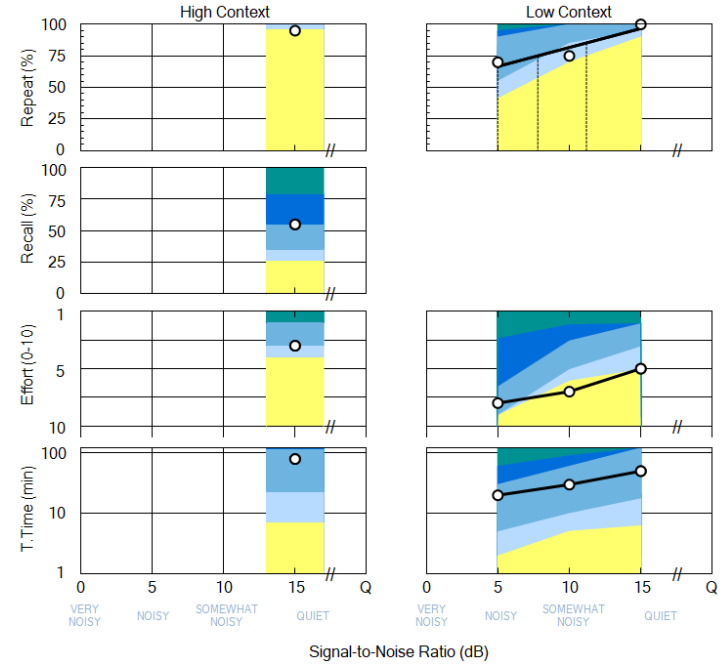
QUICK RRT **DISPLAY**



Context	SNR (dB)	Repeat (%)	Recall (%)	Effort (1-11)	Tolerable time (mins)
High	0				
	5				
	10				
	15	95	55	3	79
	Quiet				
Low	0				
	5	70		8	20
	10	75		7	30
	15	100		5	50
	Quiet				

Context	SRT-50 (dB)	SRT-75 (dB)	SRT-85 (dB)
High	-	-	-
Low	5	7.8	11.2



- Excellent
- Very good
- Good
- OK, improvement desirable
- Poor

- ≥ 95 %-tile
- 75 – < 95 %-tile
- 25 – < 75 %-tile
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WHAT ARE THE **DIFFERENCES** BETWEEN THE FULL-RRT AND Q-RRT?

Full-RRT

- Takes 20-25 minutes to complete
- Dual task (SiN + recall)
- Allows study of speech in noise, recall, LE, TT and use of ***context*** at all 5 SNRs
- LE and TT rating biased by recall
- Research tool

Quick-RRT

- Takes 6 minutes to complete
- Single task (i.e., SiN, recall)
- Allows study of speech in noise, LE, TT at 3 SNRs; recall at 1 SNR only
- LE and TT based on SiN perception
- Clinical tool

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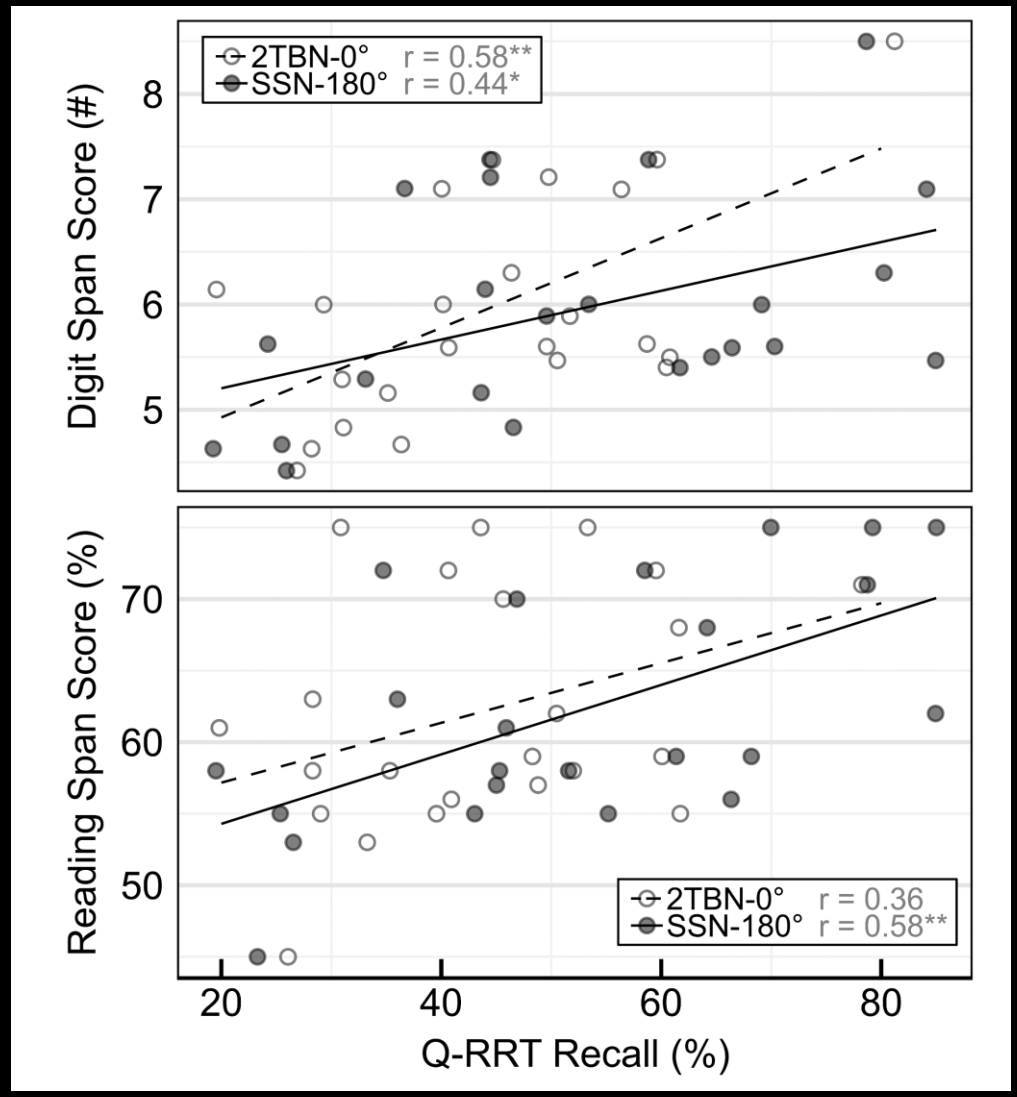
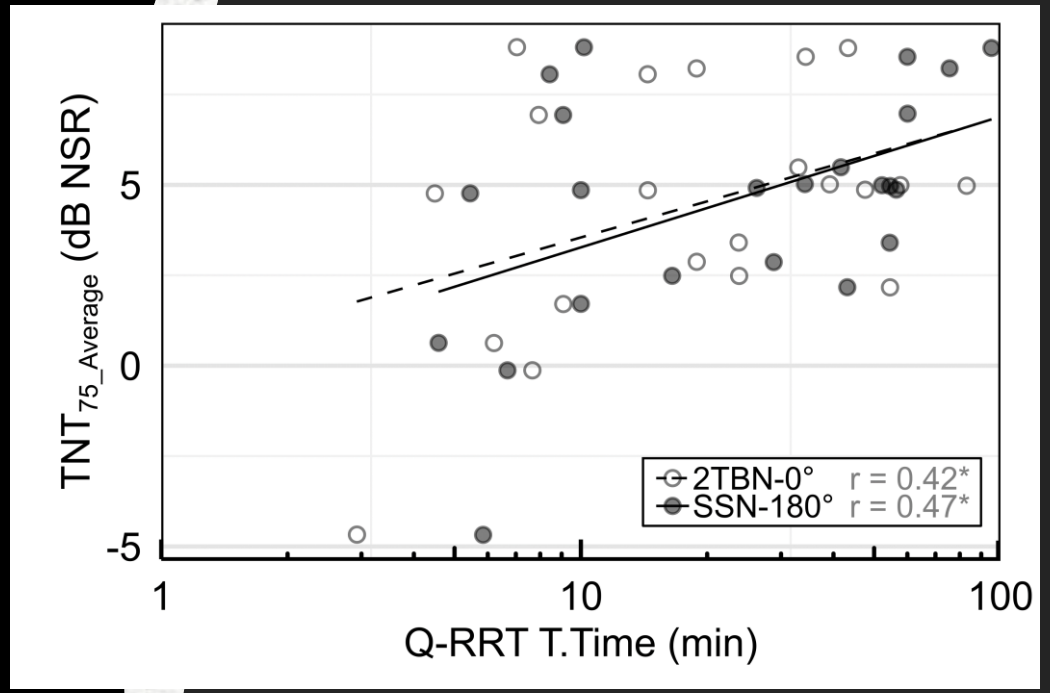
RECALL **CORRELATION** WITH RST AND DST

- Digit span test measures short-term memory
- Reading span test measures working memory
- Recall scores correlate moderately with both DST and RST, suggesting that Recall measures some of the variances shown in both measures
- Supports use of Recall scores as a screener/ profiler for memory issues



TOLERABLE TIME WITH **NOISE ACCEPTANCE** (TNT)

- Tolerable time (willingness to spend time in noise) correlates moderately with TNT (how much noise one is willing to accept without decreasing conversational speech understanding in noise to below 90%).
- TNT has been shown to correlate with hearing aid satisfaction in loud, noisy situations (Seper et al 2019)
- Would TT predict hearing aid satisfaction also?



CORRELATIONS AMONG **VARIOUS OUTCOME MEASURES** ON Q-RRT

RRT Outcome	RRT Noise	Recall	Effort	T.Time
Repeat	2TBN-0°	-0.25	-0.66**	-0.42
	SSN-180°	0.22	-0.57*	-0.30
Recall	2TBN-0°	--	0.28	-0.19
	SSN-180°	--	-0.31	0.13
Effort	2TBN-0°	--	--	-0.55*
	SSN-180°	--	--	-0.52*

*** p < 0.05, ** p < 0.01, *** p < 0.001; Benjamini & Hochberg adjusted.**

Repeat scores correlate with listening effort, suggesting LE was based on listeners' listening difficulty

Listening effort correlates with Tolerable time, suggesting more effortful listening, less willingness to spend time

Lack of correlation between Recall and LE/TT/Repeat, suggesting "memory" does not play major role on these tasks (on Q-RRT), and Recall is a separate measure

Repeat does not correlate with TT, suggesting that objective speech understanding alone is not what determines TT

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WHEN SHOULD I USE THE QUICK RRT?

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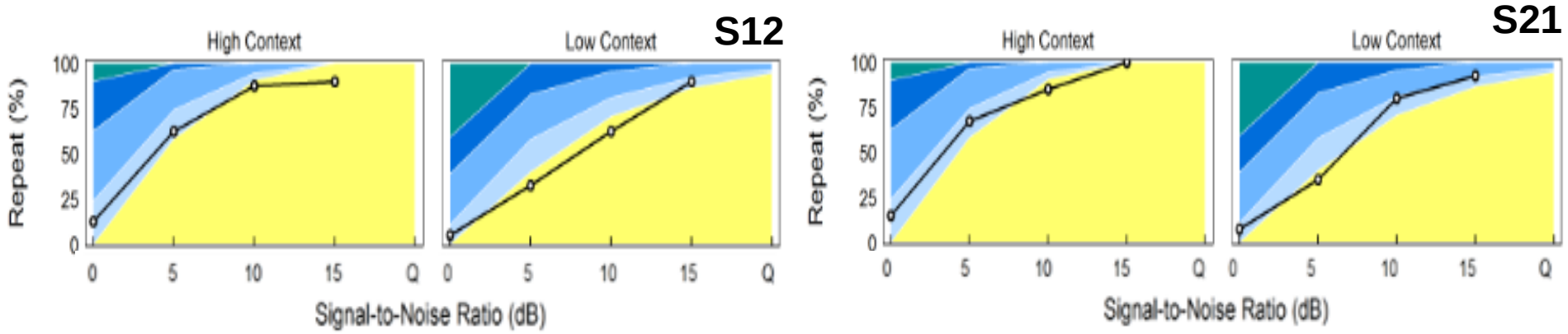
EVALUATING SPEECH IN NOISE **NEEDS**



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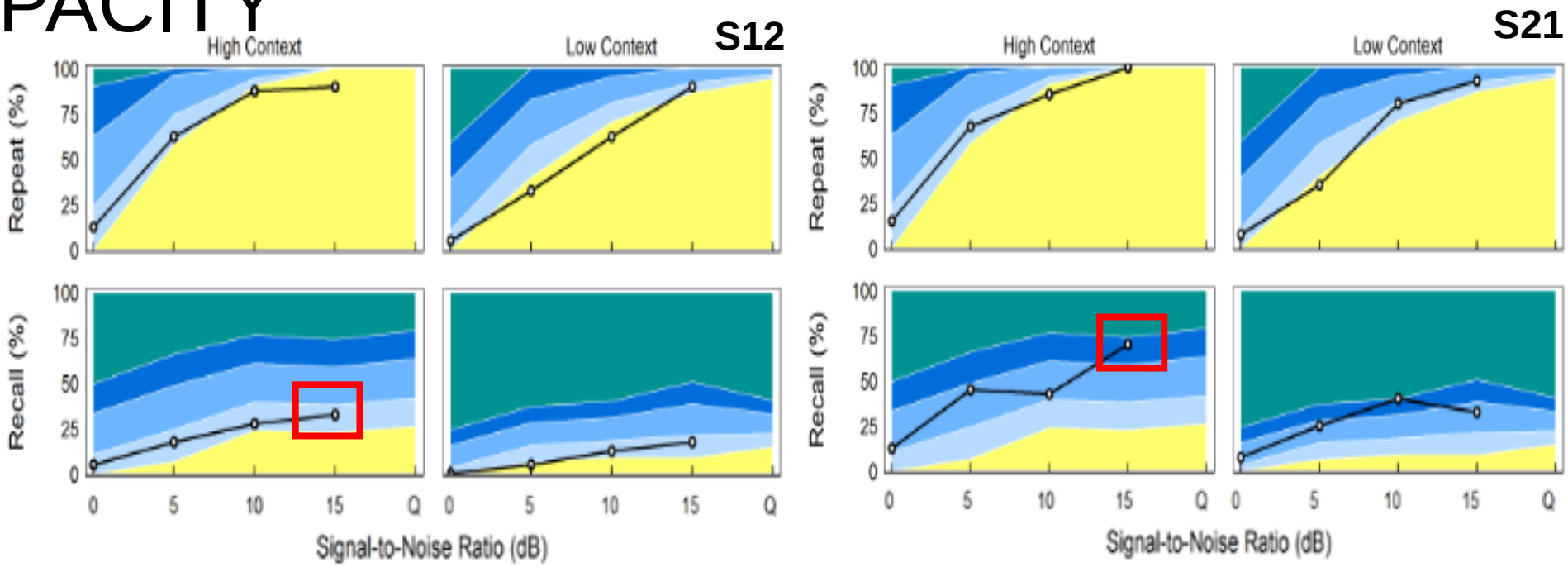
GATHERING INSIGHTS – WORKING MEMORY CAPACITY



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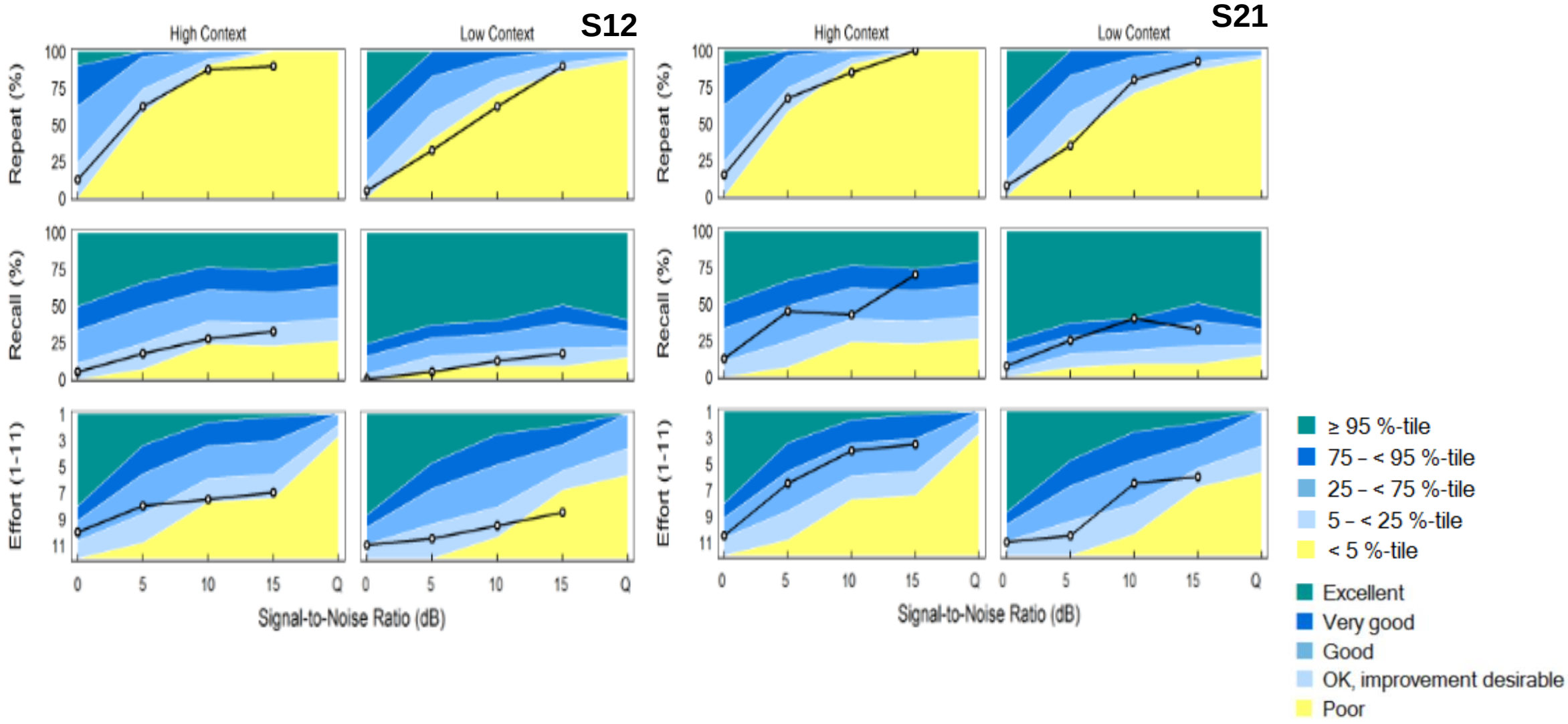
GATHERING INSIGHTS – EFFORTFUL LISTENING



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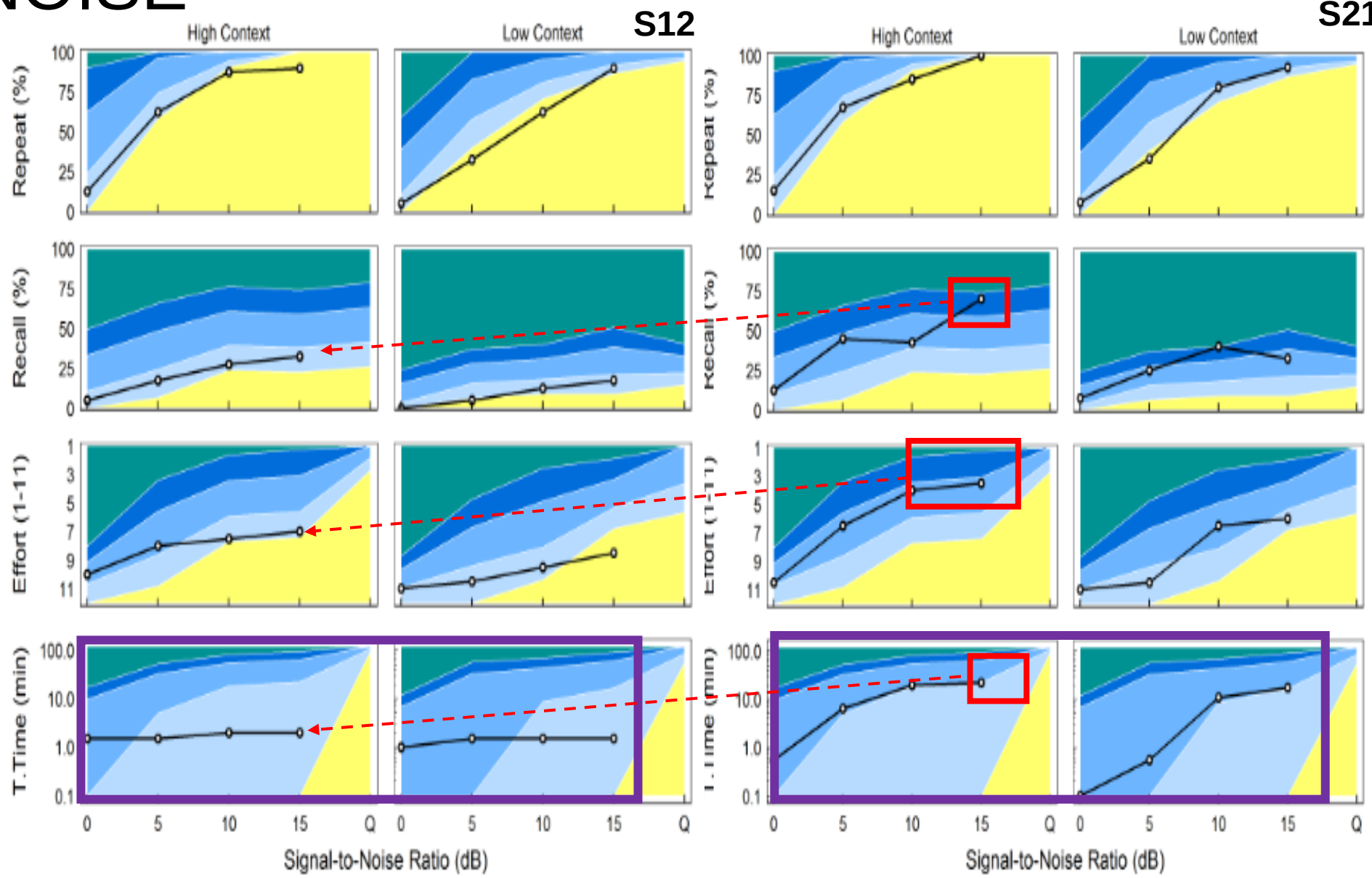
DIFFERENTIATING PATIENTS – WILLINGNESS TO STAY IN NOISE



Patient S21 is easier to manage/more satisfied

- Better WMC/ recall/ cognition
- LE decreases as SNR improves
- Greater willingness to stay in noise (acceptance of noise)

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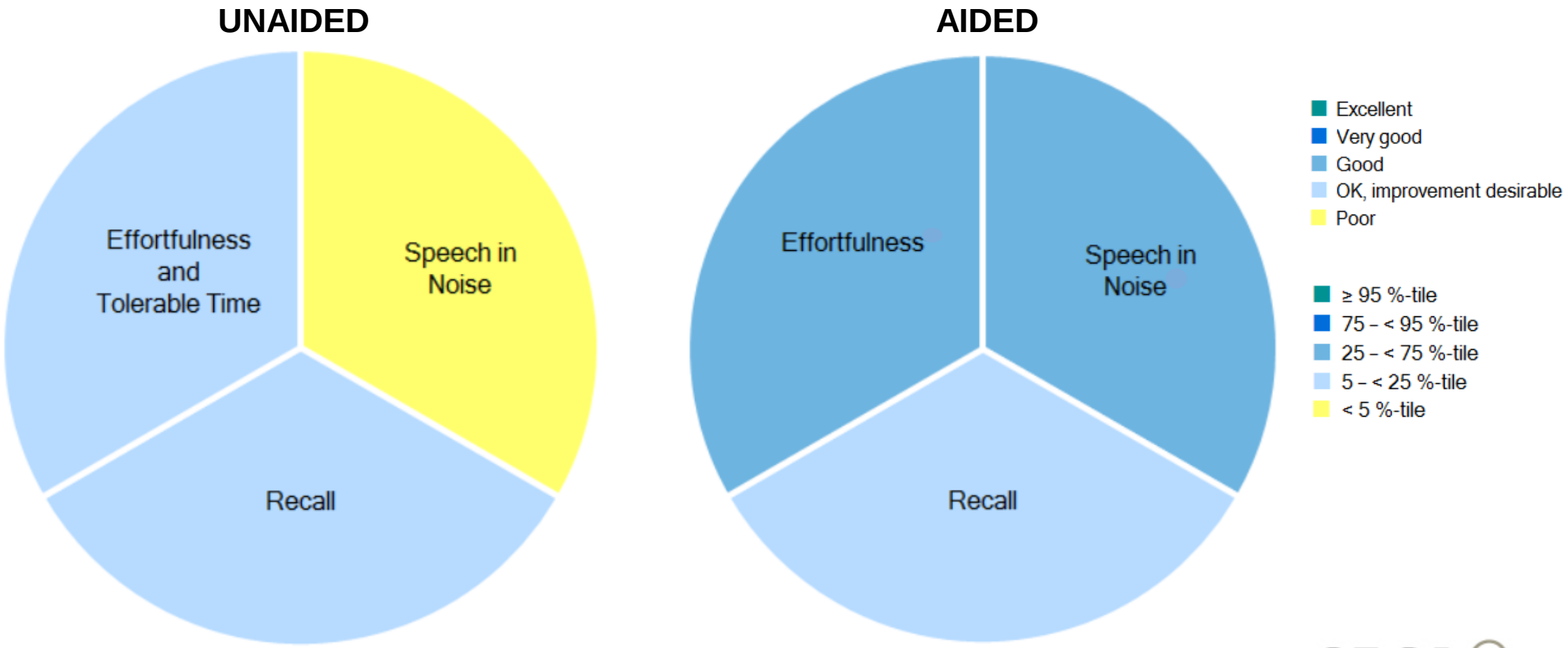
MEASURING SUCCESS: UNAIDED VS AIDED (QUICK RRT)



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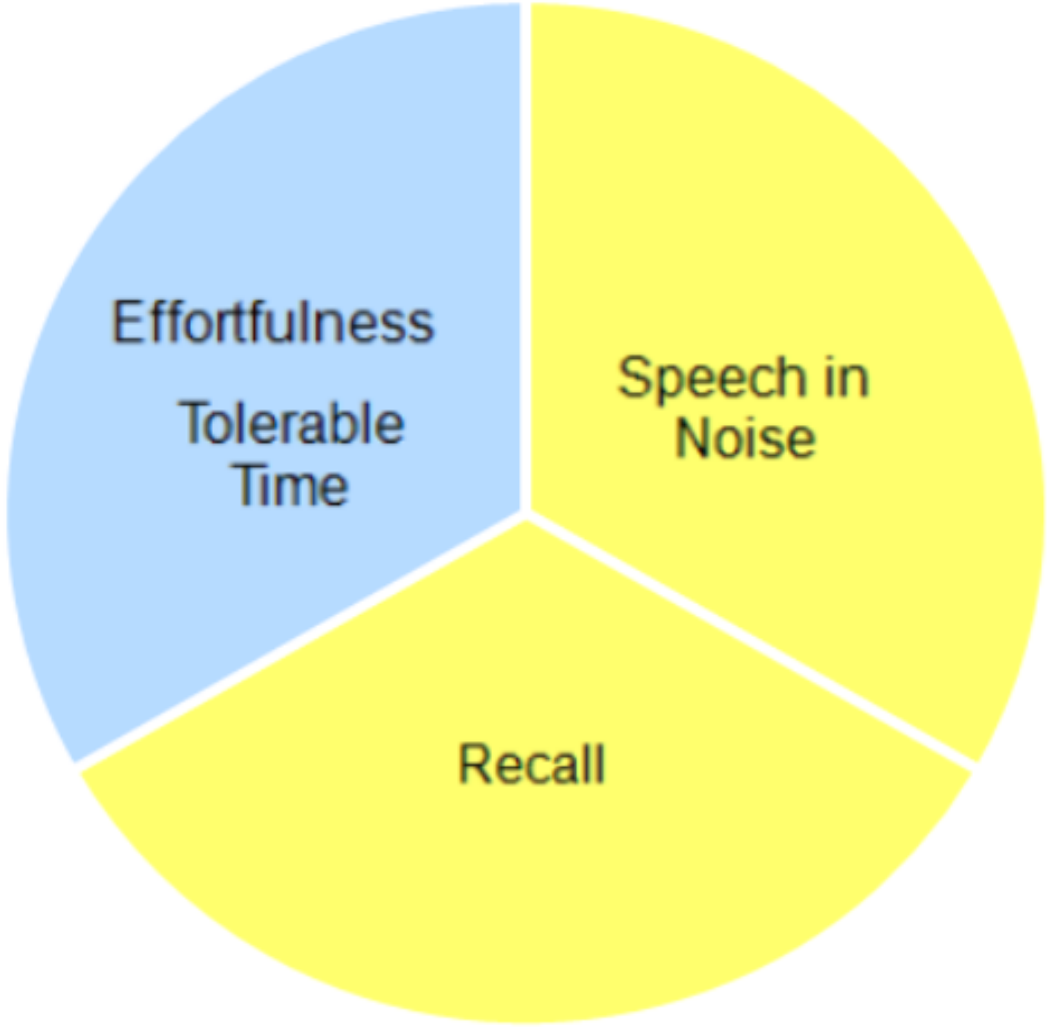
COUNSELING: AS **LEAD-IN** TO RECOMMENDATIONS (UNAIDED OR AIDED OWN AID)



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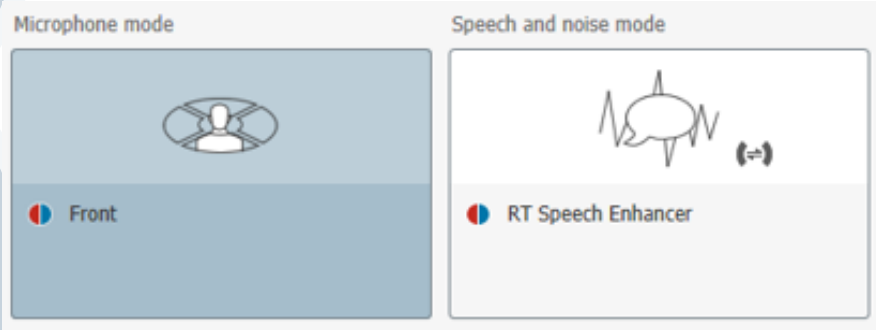
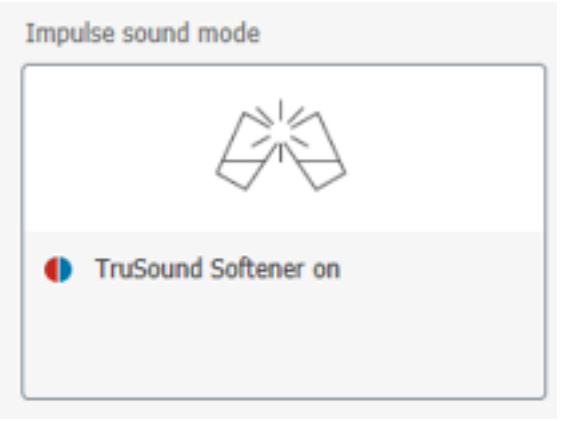
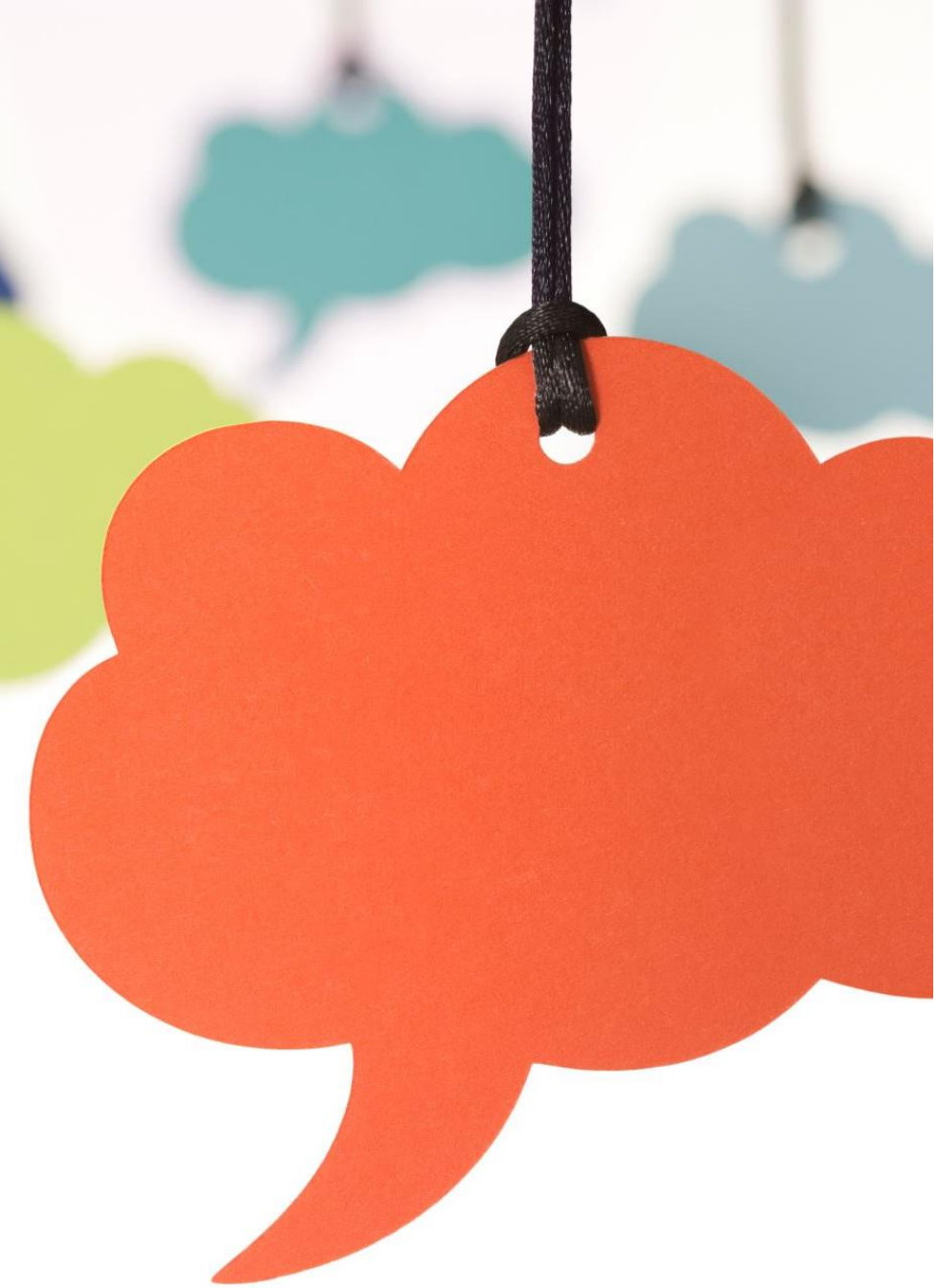
IMPROVING **SPEECH IN NOISE**

- Ensuring a proper fit
- Choose higher level technology
- Choose ones with speech enhancement algorithms
  - Directional microphones more at poorer SNRs
  - Speech enhancer optimizes comfort at SNR around 10 dB while ensuring speech intelligibility index
  - Also wind noise and impulse noise







PEOPLE WITH **BETTER vs POORER RECALL**

- **Better** repeat in noise, lower listening effort, longer tolerable time
- Both groups benefit from use of **HD Locator**
- People with **poorer recall** reported **less effort** with the **Speech Enhancer**
- Speech enhancement features are a MUST for people with poor working memory
- Planning for areas for **rehabilitation**

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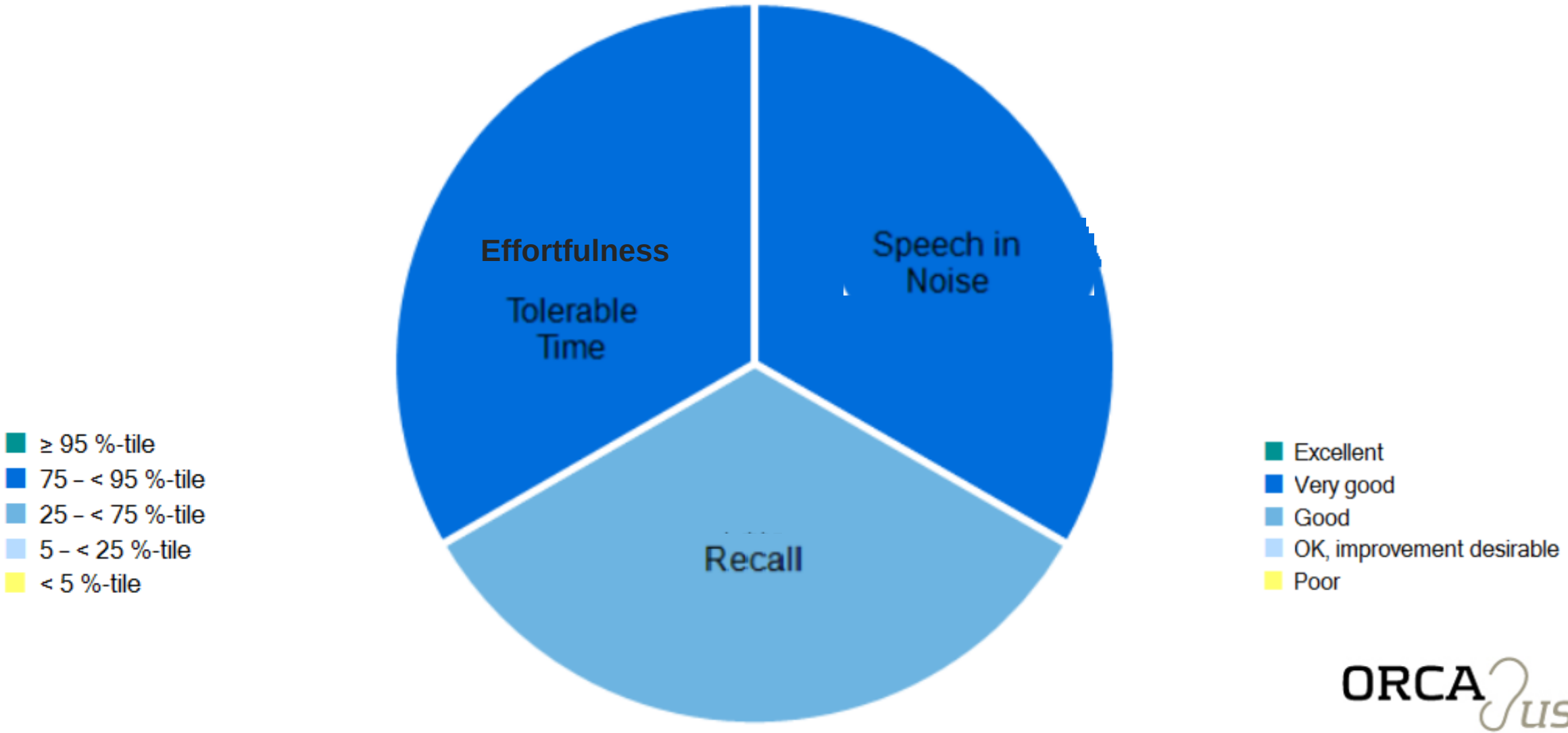
COUNSELING: MOTIVATION, DEMONSTRATION AND SETTING REALISTIC EXPECTATIONS (AIDED MOMENT)



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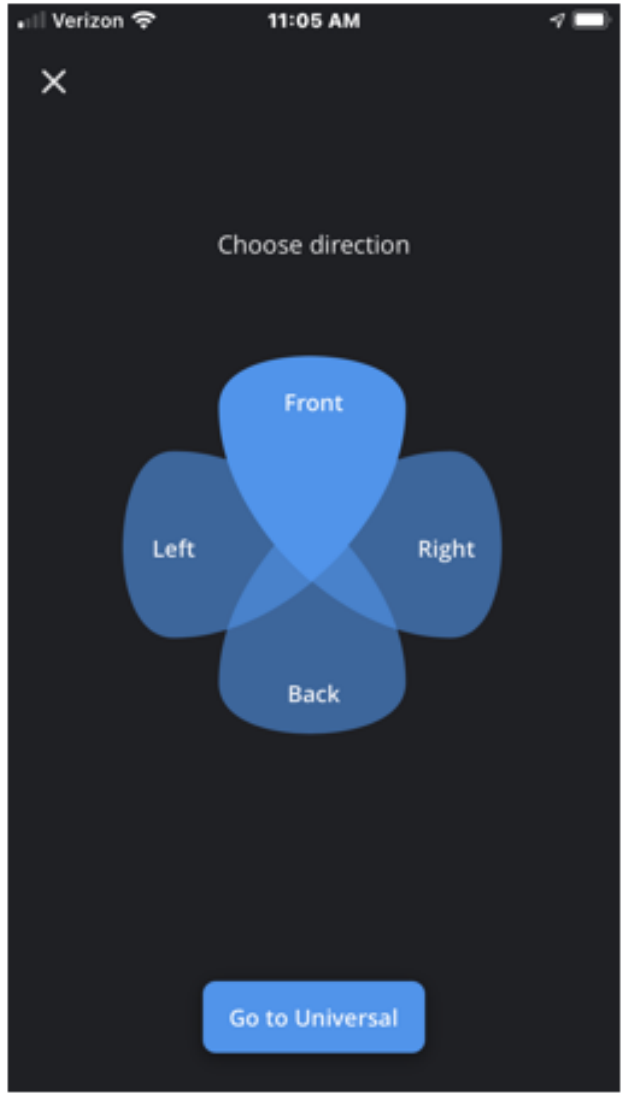
LEAD-IN TO INSTRUCTIONS ON FEATURE: **DIRECTIONAL FOCUS**



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SUMMARY: REPEAT-RECALL TEST

- **Measures more than speech-in-noise**
- **Efficient** (6 min for Quick-RRT; 20 minutes for full RRT)
- **Characterization** (or profiling) of patients
  - Pinpoint areas of strength & weakness
  - Direct focus for rehabilitation
  - Grouping patients for research
- **Validation -** Demonstration of hearing aid (feature) benefits
- **Counseling** - Comparison with norms to set realistic expectations

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THE REPEAT-RECALL TEST (RRT) **TUTORIALS**

- Rationale and development
- Operations
- Clinical applications
- Research applications

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Thank you for listening!!!

Visit our website (www.orca-us.info)
Email: Francis.kuk@wsa.com for link to software/collaborations