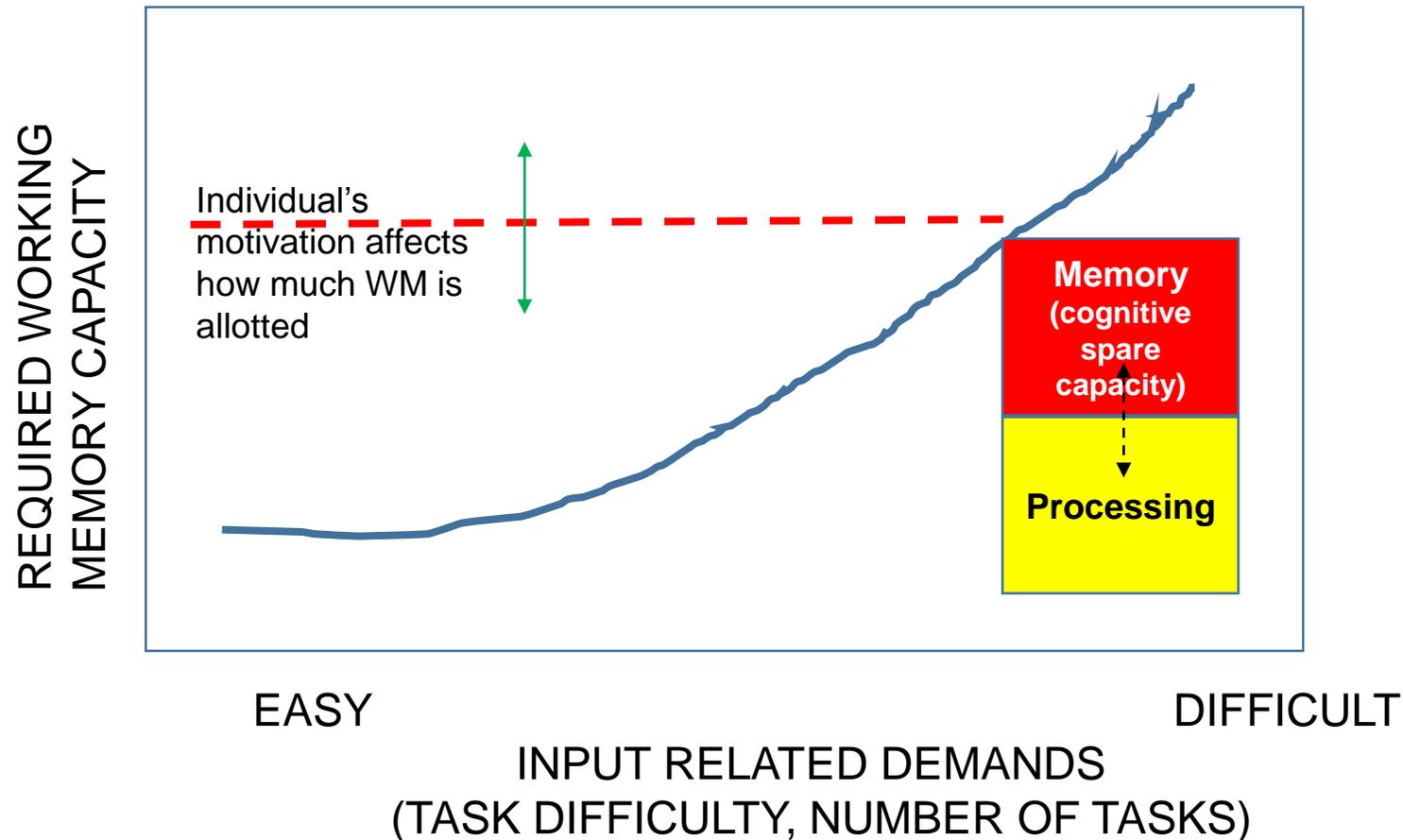


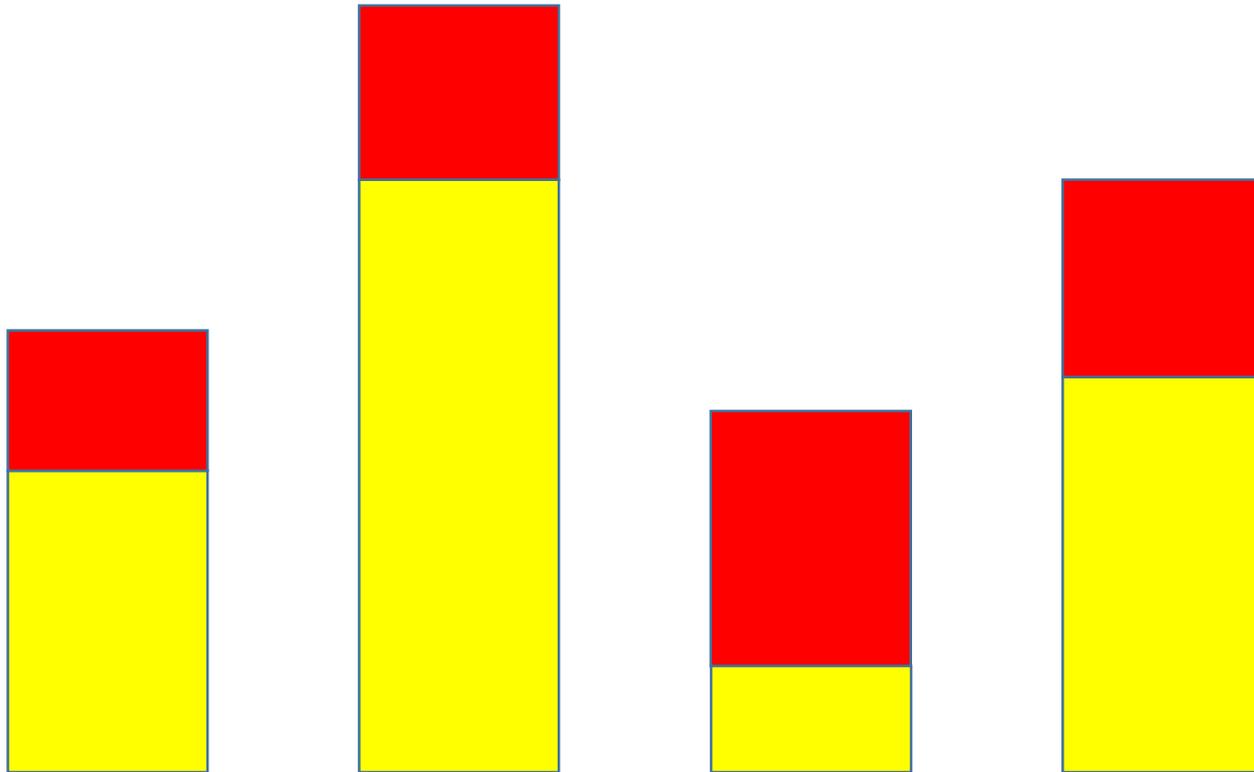
***Clinical measurement of working  
memory – introduction to the  
Repeat Recall Test (RRT)***

# A SIMPLIFIED EXPLANATION OF WORKING MEMORY

The retention of information in conscious awareness when the information is not present in the environment,... for its manipulation and use in guiding behavior (Postle, 2006, cited in Pichora-Fuller, 2016)



# DISTINCTION BETWEEN POOR WORKING MEMORY AND MCI/DEMENTIA



Poorer WM simply means smaller capacity  
Analogy: smaller RAM on computer

Cognitive impairment disintegrates some or all cognitive functions including WMC  
Analogy: Bad sectors on RAM, hard disk failure

# DISTINCTION BETWEEN POOR WORKING MEMORY, MCI & DEMENTIA

- Poor working memory – smaller WMC, individual differences, may decrease with age (not always). Seen as limited capacity (restricted memory or processing skills), not pathological and does not have functional impairment (i.e., cognitively normal)
  - With working memory tests
- Mild cognitive impairment (MCI) – 3 criteria
  - *Concern* about a change in cognition (self or others)
  - Objective evidence of *lower performance* on one or more cognitive tasks re: normal of same age and background
  - Preserved *functional independence*
  - Screened with Montreal Cognitive Assessment (MoCA)
- Dementia describes a ***functional*** impairment in 2 or more cognitive domains
  - Mini-Mental State Examination (MMSE) for dementia evaluation

Poor working memory does not imply cognitive impairment

Cognitive impairment (MCI, dementia) likely decreases working memory



# SHOULD AUDIOLOGISTS MEASURE COGNITIVE IMPAIRMENT?

- Many of our clients are elderly with cognitive issues
- We are interested to know *how their working memory affects* their speech understanding or communication, but
- Is it within our scope of practice?
- Is it our expertise?
- Do we have the resources to do so?
- How do we deal with the emotion of the patients?

# WHY MEASURE WORKING MEMORY?

- Variability among individuals, especially as we age
  - WM correlates with reading comprehension, and speech in noise ability
- For patients
  - Better understanding the reasons for difficulty
- For professionals
  - Another means of outcome measure
  - May help clinicians select more optimal form of amplification
  - May help guide rehabilitation
- For hearing aid manufacturers
  - Design more effective algorithms (***Effortless Hearing*** design rationale) and offer customized fitting guidelines (e.g. AE)



# HOW HAS WORKING MEMORY BEEN MEASURED? PLEASE READ ALOUD THESE SENTENCES TO YOURSELF

The French tourists had to choose between traveling to England by train or by boat.

These children grew up with a mother, who was suffering from a severe illness.

Her boss told her, she couldn't have a day off without giving a very good reason.

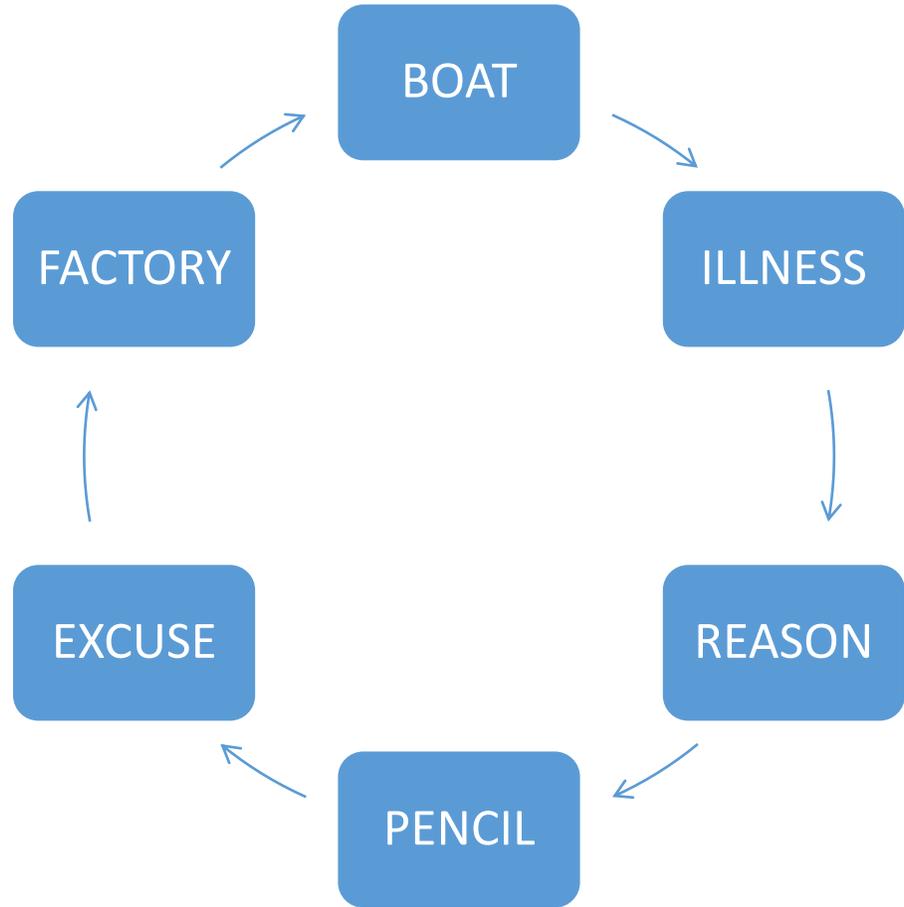
It's unbelievable what she can do with only a paper and a pencil.

This guy is a stubborn mule and for him it's impossible to accept an excuse.

The prime minister looked very cheerful during the opening of the new factory.

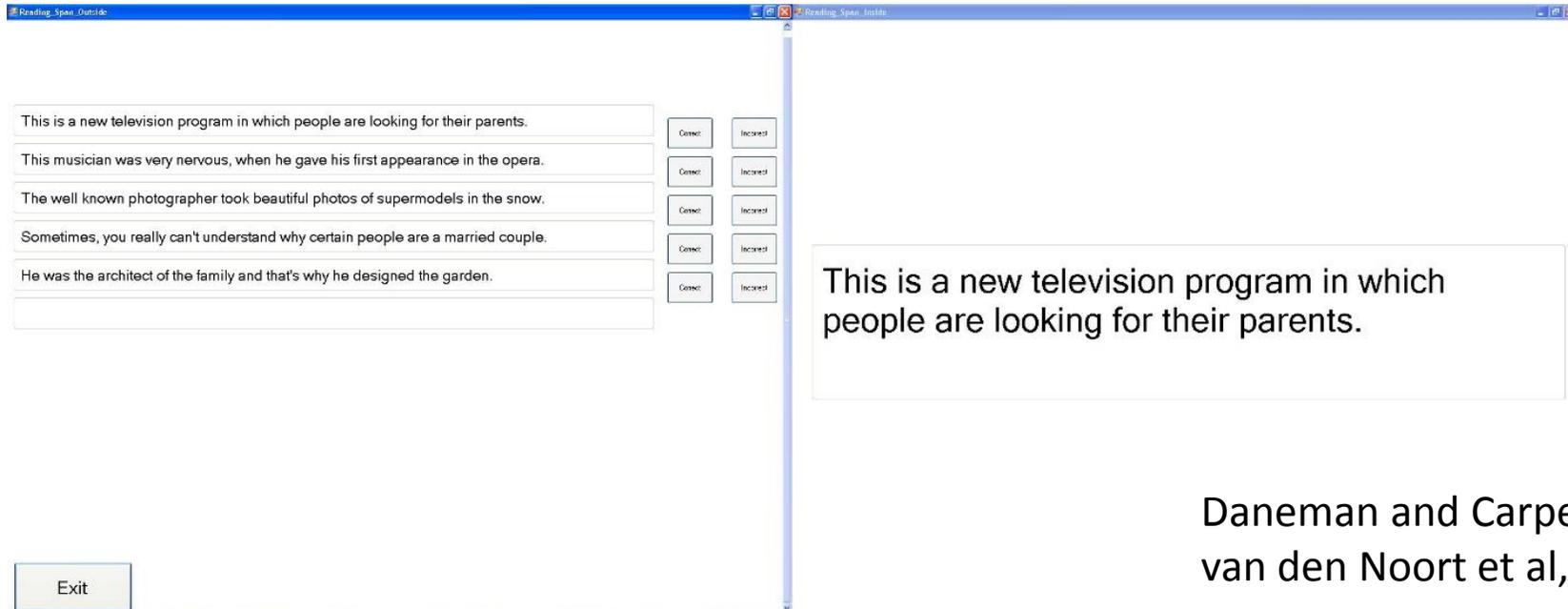


NOW, **RECALL** THE LAST WORD OF EACH SENTENCE  
IN ANY ORDER



# THE READING SPAN TEST – HOW WORKING MEMORY HAS BEEN MEASURED

- Sets of 2,3,4,5,6 sentences on screen
- Recall last word of sentence after each set



Daneman and Carpenter, 1980  
van den Noort et al, 2008

# A PARTIAL LIST OF COGNITIVE TESTS

- Woodcock Johnson Cognitive Test battery (Woodcock et al, 2001)
- Digit Span (forward and backward) on Wechsler Adult intelligence Scale (Wechsler 1997)
- Reading Span Test (Daneman & Carpenter, 1980; Ronnberg et al, 1989; van den Noort et al, 2008)
- Listening Span (Pichora-Fuller et al, 1995)
- Sentence final Word Identification and Recall (SWIR, Ng et al, 2013, 2015)
- Cognitive Spare Capacity test (CSCT, Mishra et al 2013, 2104)
- Auditory Inference Span test (AIST, Ronnberg et al, 2011, 2014)
- Simon Says measures (Humes & Floyd, 2005)
- N-back test (Jaeggi et al, 2010)
- Word Auditory Recognition and Recall Measure (WARRM, Smith et al, 2016)

# WOODCOCK JOHNSON TEST OF COGNITIVE ABILITIES

The Woodcock-Johnson® Tests of Cognitive Abilities is a standardized test that evaluates cognitive abilities of children and adults. These tests help to identify correlates of learning problems.

## Skill Assessment

The skills tested on the Woodcock-Johnson Tests of Cognitive Abilities are:

- Comprehension-Knowledge
- Long-Term Retrieval
- Visual-Spatial Thinking
- Auditory Processing
- Fluid Reasoning
- Processing Speed
- Short-Term Memory
- Quantitative Knowledge
- Reading-Writing Ability



# ONLINE VERSION OF DIGITAL SPAN

The screenshot shows a mobile-style interface for a 'Digit Span Memory Test'. At the top, there is a 'Share' button with a Facebook icon. Below it, the title 'Digit Span Memory Test' is displayed, followed by the instruction 'Click on **'New Test'** to start the test'. A large, empty rounded rectangular input field is positioned below the text. The main area contains a 4x3 grid of buttons. The first three rows contain numbers 7, 8, 9; 4, 5, 6; and 1, 2, 3 respectively. The bottom row contains 'Forward', '0', and 'New Test'. At the bottom of the interface, there are four orange buttons: 'Span', '- 5 +' (with a minus sign, the number 5, and a plus sign), 'Slow' (with a radio button), and 'Fast' (with a radio button).



# N- BACK TEST

## N-back working memory task

In this task, you will see a sequence of letters. Each letter is shown for a few seconds. You need to decide if you saw the same letter 3 trials ago, that is, this is a n=3-back task.

If you saw the same letter 3 trials ago, you type the letter M (M for Memory). If it was Not a letter shown 3 trials ago, you type the N (for No).

*press the space bar to next info screen*

## N-back working memory task

For example, if you get the letters, and below which key to press:

A B L T B R H I R  
n n n n m n n n m

This is actually very difficult! So you need some time to get better at it. When you respond correct, you see the bars around the key turn green, and red if wrong!

*press the letter "q" to start, or up arrow to go back.*

- The total stimulus set is 15 stimuli (letters)
- Each stimulus is presented for maximally 2000 milliseconds
- A new stimulus is presented every 2500 milliseconds
- Press “m” if the stimulus is the same as 2 trials ago, and the “n” if not

# OTHER COGNITIVE TESTS FOR MEASURING WORKING MEMORIES IN AUDIOLOGY RESEARCH

	Sentence-Final Word Identification and Recall	Cognitive Spare Capacity Test	Auditory Inference Span Test
<i>Material</i>	HINT sentences (in lists of seven, Ng et al. 2015, or eight, Ng et al. 2013)  “Dad is going to mend my <b>armchair</b> .” “The floor was covered by a white <b>carpet</b> .” “Grandma is going to the <b>golfcourse</b> .” ...	Two-digit numbers spoken by male (m) and female (f) talkers (in lists of 13 items). Audiovisual and audio-only versions. 1. “m-16, m-42, f-65, m-57, m- <b>73</b> , f-24, m-39, f-45, f- <b>84</b> , m-71, m-63, f-76, m-18” 2. “f-50, m-36, f-77, m- <b>13</b> , f-44, m- <b>59</b> , f96, f-89, m-52, m-40, f-61, f-20, f-66”	Matrix sentences (in lists of three)  1. “Britta moves eight black rings.” 2. “Elsa donated six black gloves.” 3. “Peter bought seven bright bowls.”
<i>Control task</i>	After each sentence (optional) Repeat the final word.	None	After each sentence Determine which of three visually presented words occurred in the sentence (e.g., “has, borrows, <b>moves</b> ” for sentence 1. above).
<i>Main task</i>	After each list <i>Free recall</i> Report as many sentence-final words as possible in any order.	After each list <i>Executive task (one of two):</i> 1. <i>Updating.</i> E.g., “Report the highest number spoken by each talker.” See list 1 bold items. 2. <i>Inhibition.</i> E.g., “Report the odd numbers spoken by the male talker.” See list 2 bold items. <i>In half the conditions, participants are instructed to additionally report the first item in each list, to increase memory load.</i>	After each list <i>Memory load level (MLL, one of three)</i> <i>Answer three questions at one of three different MLLs. Three alternative forced choice response.</i> <i>MLL1.</i> E.g., “Which of the following names were used in the sentences?” <i>MLL2.</i> E.g., “What item did Britta have?” <i>MLL3.</i> E.g., “Who had the highest odd number of items?”

# THESE ARE NOT TESTS OF WORKING MEMORY THEY ARE TESTS OF COGNITIVE IMPAIRMENT

**MONTREAL COGNITIVE ASSESSMENT (MOCA)**  
Version 7.1 Original Version

NAME: \_\_\_\_\_ Date of birth: \_\_\_\_\_  
Education: \_\_\_\_\_ Sex: \_\_\_\_\_ DATE: \_\_\_\_\_

VISUOSPATIAL / EXECUTIVE		POINTS																		
<p>Copy cube</p> <p>Draw CLOCK (Ten past eleven) (3 points)</p>	<input type="checkbox"/> Contour <input type="checkbox"/> Numbers <input type="checkbox"/> Hands	___/5																		
NAMING																				
	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	___/3																		
MEMORY																				
Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.	<table border="1"> <tr> <td></td> <td>FACE</td> <td>VELVET</td> <td>CHURCH</td> <td>DAISY</td> <td>RED</td> </tr> <tr> <td>1st trial</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>2nd trial</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table>		FACE	VELVET	CHURCH	DAISY	RED	1st trial						2nd trial						No points
	FACE	VELVET	CHURCH	DAISY	RED															
1st trial																				
2nd trial																				
ATTENTION																				
Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order	[ ] 2 1 8 5 4	___/2																		
Subject has to repeat them in the backward order	[ ] 7 4 2																			
Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors	[ ] FBACMNAAJKLBAFAKDEAAAJAMOF AAB	___/1																		
Serial 7 subtraction starting at 100	[ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65	___/3																		
4 or 5 correct subtractions: <b>3 pts.</b> , 2 or 3 correct: <b>2 pts.</b> , 1 correct: <b>1 pt.</b> , 0 correct: <b>0 pt</b>																				
LANGUAGE																				
Repeat: I only know that John is the one to help today. [ ] The cat always hid under the couch when dogs were in the room. [ ]		___/2																		
Fluency / Name maximum number of words in one minute that begin with the letter F	[ ] _____ (N ≥ 11 words)	___/1																		
ABSTRACTION																				
Similarity between e.g. banana - orange = fruit [ ] train - bicycle [ ] watch - ruler		___/2																		
DELAYED RECALL																				
Has to recall words WITH NO CUE	<table border="1"> <tr> <td>FACE</td> <td>VELVET</td> <td>CHURCH</td> <td>DAISY</td> <td>RED</td> </tr> <tr> <td>[ ]</td> <td>[ ]</td> <td>[ ]</td> <td>[ ]</td> <td>[ ]</td> </tr> </table>	FACE	VELVET	CHURCH	DAISY	RED	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUEd recall only								
FACE	VELVET	CHURCH	DAISY	RED																
[ ]	[ ]	[ ]	[ ]	[ ]																
Optional	<table border="1"> <tr> <td>Category cue</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Multiple choice cue</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	Category cue					Multiple choice cue													
Category cue																				
Multiple choice cue																				
ORIENTATION																				
[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City		___/6																		
<b>TOTAL</b>		___/30																		

© Z.Nasreddine MD [www.mocatest.org](http://www.mocatest.org) Normal ≥ 26 / 30  
Administered by: \_\_\_\_\_ Add 1 point if ≤ 12 yr edu

## MINI MENTAL STATE EXAMINATION (MMSE)

Name: \_\_\_\_\_  
DOB: \_\_\_\_\_  
Hospital Number: \_\_\_\_\_

One point for each answer

	DATE:		
ORIENTATION			
Year	Season	Month	Date
Time	Country	Town	District
Hospital	Ward/Floor		
___/5	___/5	___/5	___/5
___/5	___/5	___/5	___/5
REGISTRATION			
Examiner names three objects (e.g. apple, table, penny) and asks the patient to repeat (1 point for each correct. THEN the patient learns the 3 names repeating until correct).			
___/3	___/3	___/3	___/3
ATTENTION AND CALCULATION			
Subtract 7 from 100, then repeat from result. Continue five times: 100, 93, 86, 79, 65. (Alternative: spell "WORLD" backwards: DLROW).			
___/5	___/5	___/5	___/5
RECALL			
Ask for the names of the three objects learned earlier.			
___/3	___/3	___/3	___/3
LANGUAGE			
Name two objects (e.g. pen, watch).			
___/2	___/2	___/2	___/2
Repeat "No ifs, ands, or buts".			
___/1	___/1	___/1	___/1
Give a three-stage command. Score 1 for each stage. (e.g. "Place index finger of right hand on your nose and then on your left ear").			
___/3	___/3	___/3	___/3
Ask the patient to read and obey a written command on a piece of paper. The written instruction is: "Close your eyes".			
___/1	___/1	___/1	___/1
Ask the patient to write a sentence. Score 1 if it is sensible and has a subject and a verb.			
___/1	___/1	___/1	___/1
COPYING: Ask the patient to copy a pair of intersecting pentagons			
___/1	___/1	___/1	___/1
TOTAL:			
___/30	___/30	___/30	___/30

**MMSE scoring**  
24-30: no cognitive impairment  
18-23: mild cognitive impairment  
0-17: severe cognitive impairment



# THE ISSUE OF CLINICAL PRACTICALITY

- We are already (or at least should be) doing the following evaluations for good clinical practice
  - Hearing evaluation (AC, BC, tympanometry etc)
  - Speech recognition in quiet (at MCL or fixed 50 dB HL)
  - Speech recognition in noise (QuickSin, HINT or others)
  - If hearing aid dispensing, also
    - Hearing aid programming
    - Real-ear speech mapping
    - Demonstration and counseling
    - Etc



Where's the time???

# CAN CURRENT SPEECH TESTS BE USED TO MEASURE WORKING MEMORY?

- They could, as long as we invoke some kind of “recall” (not just repeating one sentence, but many) and “processing”
- Word level test
  - Meaningful (such as NU6, W-22) – both top down and bottom up
  - Nonsense syllable (such as NST) – mostly bottom up
- Sentence tests
  - Connected Speech test – mostly top down
  - HINT - both top down and bottom up
  - SPIN - both top down and bottom up, but can be separated
- None of the current speech test involves RECALL

# CONNECTED SPEECH TEST (CST)

The Connected Speech Test (CST) is used to measure the intelligibility of everyday speech; it is intended primarily for quantifying hearing aid benefit. The test consists of 48 passages of conversationally produced connected speech, each passage concerning a familiar topic and comprising 10 sentences. Listeners are apprised of the passage topic in advance and are required to repeat the sentences one at a time. Each passage contains 25 scoring words. The test is recorded audio-visually.

## **Psg: 5-LUNG**

The lungs are the **ORGANS** of breathing.

They **LIE** in the **CENTER** of the chest.

The heart lies **BETWEEN** the lungs.

The two lungs **ARE SURROUNDED** by the **RIBS**.

**BOTH ARE JOINED** together by the **WINDPIPE**.

This airway **EXTENDS FROM** the mouth and **NOSE**.

The lungs **CONTAIN SEVERAL MILLION AIR** cells.

**BLOOD** is pumped **THROUGH** the lungs by the **HEART**.

**OXYGEN** is carried to the **CELLS THIS WAY**.



# HEARING IN NOISE TEST (HINT)

- The HINT is a 21 sentence test that is presented at a fixed noise level (e.g., 68 dB SPL) and speech level is adaptively varied to yield a speech reception threshold at a 50% correct criterion.

(A/the) boy fell from (a/the) window.

(A/the) wife helped her husband.

Big dogs can be dangerous.

Her shoes (are/were) very dirty.

(A/the) player lost (a/the) shoe.

Somebody stole the money.

(A/the) fire (is/was) very hot.

She's drinking from her own cup.

(A/the) picture came from (a/the) book.

(A/the) car (is/was) going too fast.

The paint dripped on the ground.

(A/the) towel fell on (a/the) floor.

(A/the) family likes fish.

The bananas (are/were) too ripe.

He grew lots of vegetables.

She argues with her sister.

# SPEECH PERCEPTION IN NOISE (SPIN)

- The SPIN is a 50 sentence test with both high probability and low probability words at end of each sentence. Listeners repeat the last word of each sentence. Test is presented at a +8 SNR with speech at a comfortable level

31. The fir1 talked about the GIN.  
32. The guests were welcomed by the HOST.  
33. Mary should think about the SWORD.  
34. Ruth could have discussed the WITS.  
35. The ship's Captain summoned his CREW.  
36. You had a problem with a BLUSH.  
37. The flood took a heavy TOLL.  
38. The car drove off the steep CLIFF.  
39. We have discussed the STEAM.  
40. The policemen captured the CROOK.  
41. The door was opened just a CRACK.  
42. Tom is considering the CLOCK.  
43. The sand was heaped in a PILE.  
44. You should not speak about the BRAIDS.  
45. Peter should speak about the MUGS.  
46. Household goods are moved in a VAN.  
47. He has a problem with the OATH.  
48. Follow this road around the BEND.  
49. Tom won't consider the SILK.  
50. The farmer baled the HAY.

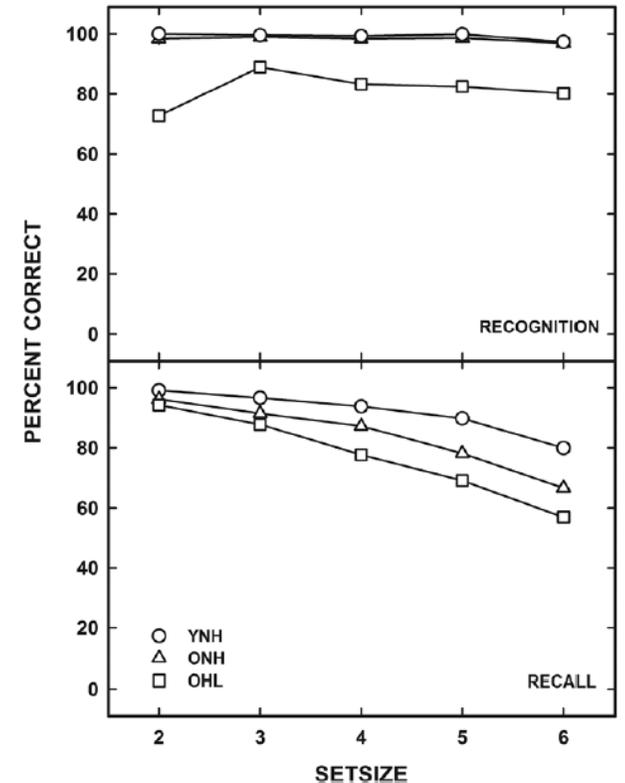
	L	31	_____
H		32	_____
	L	33	_____
	L	34	_____
H		35	_____
	L	36	_____
H		37	_____
H		38	_____
	L	39	_____
H		40	_____
H		41	_____
	L	42	_____
H		43	_____
	L	44	_____
	L	45	_____
H		46	_____
	L	47	_____
H		48	_____
	L	49	_____
H		50	_____

# WARRM - INTEGRATING CURRENT SPEECH TEST MATERIALS FOR RECALL TESTING

## Development of the Word Auditory Recognition and Recall Measure: A Working Memory Test for Use in Rehabilitative Audiology

Sherri L. Smith,<sup>1,2</sup> M. Kathleen Pichora-Fuller,<sup>3,4,5,6</sup> and Genevieve Alexander<sup>1</sup>

who may have pure-tone hearing loss. The test consists of 100 monosyllabic words based on widely used speech-recognition test materials. The 100 words are presented in recall set sizes of 2, 3, 4, 5, and 6 items, with 5 trials in each set size. The WARRM yields a word-recognition score

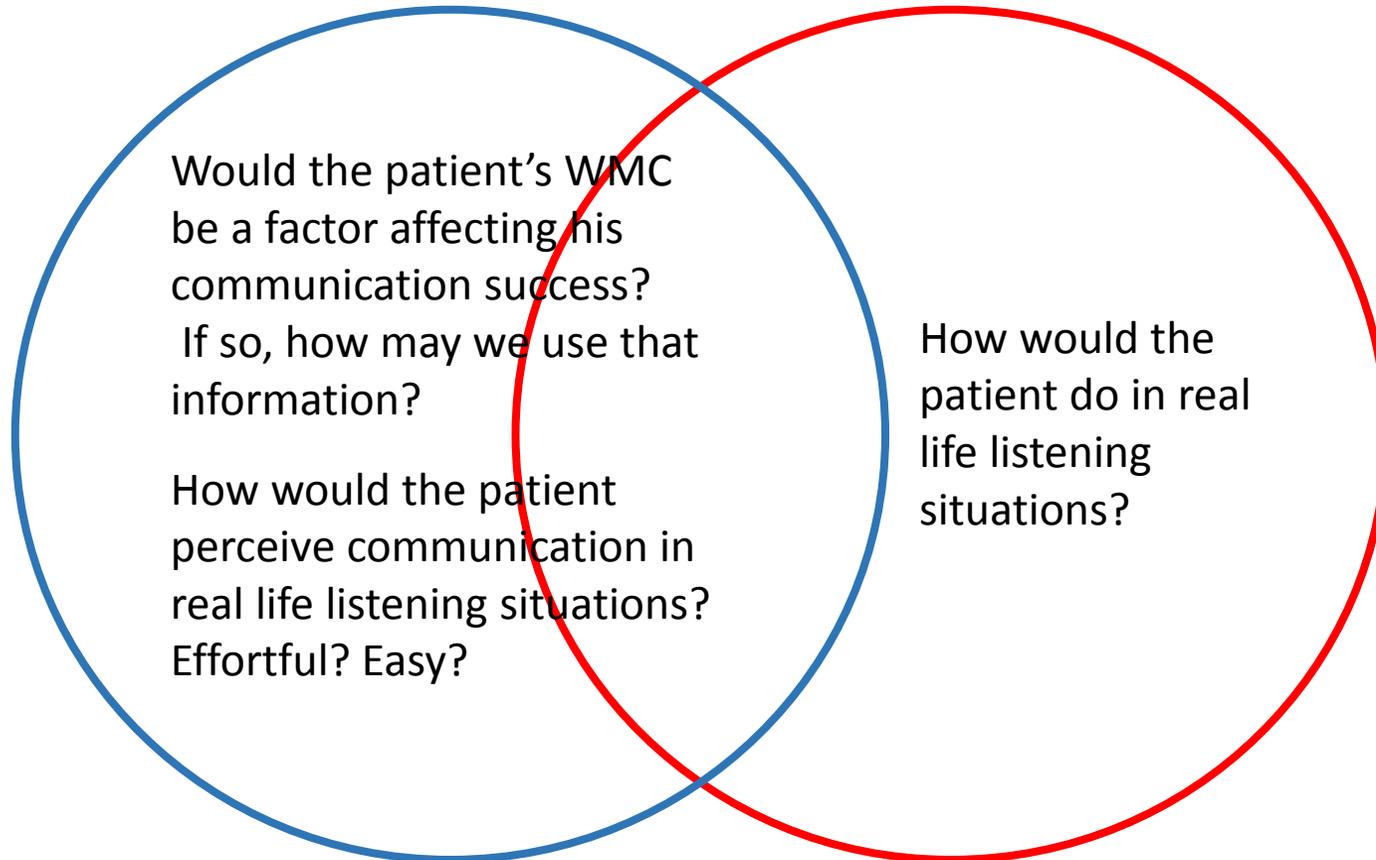


# SHOULD WE STOP AT SIN AND WMC? WHAT HAPPENS IN A REALISTIC COMMUNICATION SITUATION?

- We listen to understand
- We retain what the other party says so we can interpret it and respond accordingly
- If the environment is noisy, we hear less and retain even fewer. We put in extra effort. We use context more to help “fill-in” the gaps.
- We set an internal criterion for acceptable level of understanding (say >80%, etc)
- When our criterion of acceptable level is reached, we continue in the communication
- When our criterion of acceptable performance is not reached over a period of time, we quit and leave dissatisfied
- Our motivation dictates what our acceptable criterion is and how much effort we are willing to put in
- These speculations suggest that when we evaluate a person’s realistic communication difficulty, we need to include several criterion measures and not just speech in noise (SIN) testing



# THUS WE WANT TO KNOW THESE ABOUT OUR PATIENTS



Is the patient's experience unique? How does it compare to others, ie, normal hearing?

# OUTCOME MEASURES TO INCLUDE IN REALISTIC COMMUNICATION ASSESSMENT

Our hearing loss limits our ability to “hear” words – repeat in quiet reflects potential despite sensory loss

In noise, we pay more attention to hear (repeat and recall) so we can understand or perform satisfactory – effort reflects perceived expenditure of resources

In noise, we have to separate speech from noise to identify words – repeat in noise reflects effectiveness of cognitive processing

Noise can be viewed as a disruption – how much can we tolerate the disruption such that it does not affect our well being – feeling of understanding – tolerable time could reflect willingness of listener to remain engaged in noise (or potential success in daily noisy situations)

The remaining cognitive resources we use to remember what we heard so we can respond appropriately – recall (of cognitive spare capacity) reflects size of cognitive resource

Context can facilitate performance in all listed areas. How much context is effectively used could reflect cognitive capacity and communication difficulty of listener

**AN AUDIOLOGY-BASED,  
ECOLOGICALLY RELEVANT  
TEST THAT ALSO INCLUDES  
MEASURES OF WMC AND  
MOTIVATION IS NEEDED**



# REPEAT-RECALL TEST (RRT) - CONSTRUCTION

5 Themes  
(4<sup>th</sup> grade)

FOOD AND COOKING

MOVIES AND BOOKS

SHOPPING

SPORTS

MUSIC



7 list/passages

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

High context

Low context

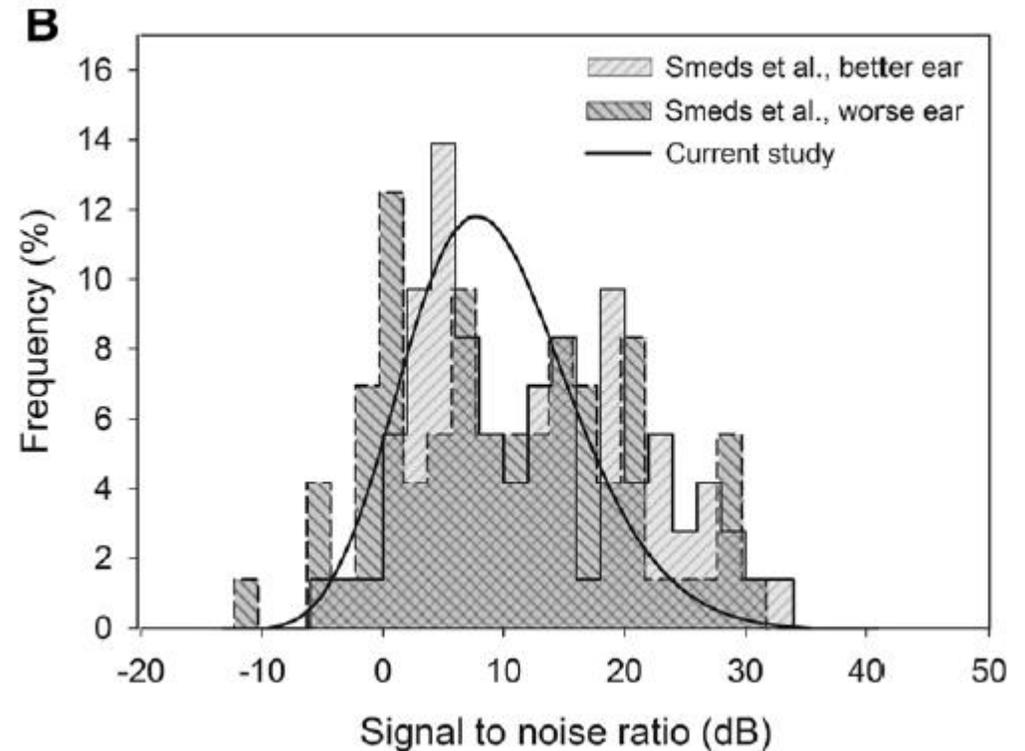
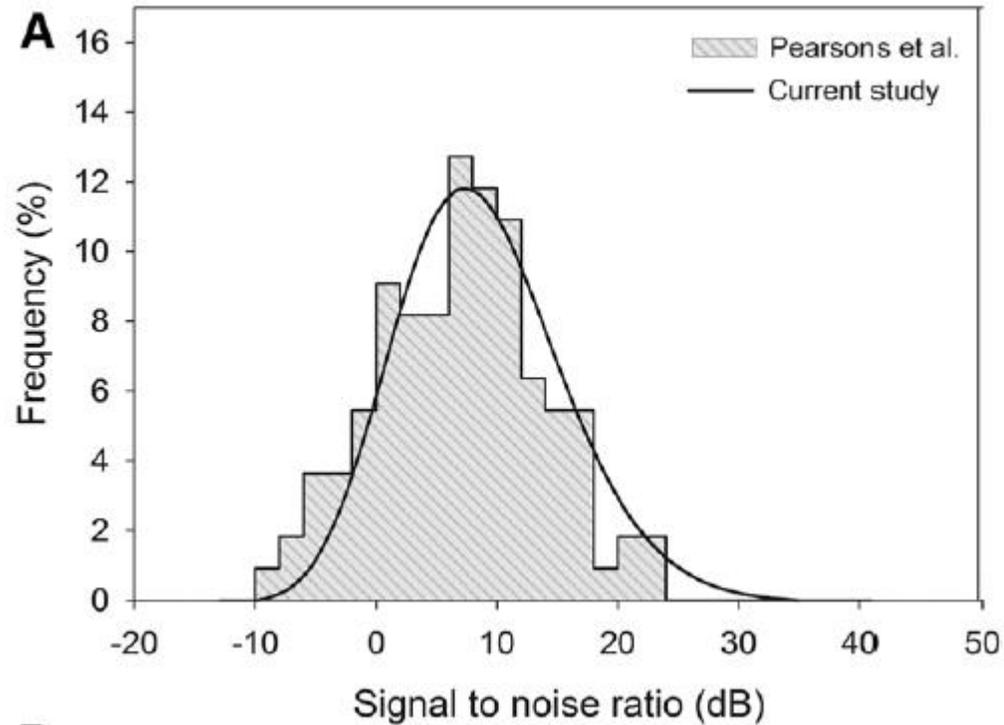
Keep the **ice foods** in the **lemon**.  
The **cream cooks food** in a **country**.  
The **barbecue chef** used **hickory freezer**.  
**Wash** the **grill** in the **restaurant**.  
The **tart fruit** had too much **wood**.  
He tried new **pie** in **different sinks**

Speech is presented at 75 dB SPL.  
Noise is 2-talker babble from same azimuth (0°) (can be from back also)

Each list tested at one SNR = 0, 5, 10, 15, Q

Testing can be conducted unaided (through headphones) and aided (in sound field)

# WHY THE CHOSEN SNRs? DISTRIBUTION OF REALISTIC SIGNAL TO NOISE RATIOS



(Wu et al, 2017)

# WHY ONLY 6 SENTENCES FOR EACH CONDITION?

- The reliability of a speech test is dependent on the number of items on the tests (Thornton and Raffin's binomial theory)
  - The more items there are, the more stable is the score, but the longer it takes to complete
  - Thus, we use a speech test of 50 words (but many use half list of 25 words to save time)
- Cox has demonstrated good reliability of the CST with using 10 sentences in a list; however, each list covers 25 target words
- 6 sentences are the maximum number of sentences used in the recall tests (or that people can recall)
- Thus we chose to use 6 sentences, each of 3-4 target words to cover 20 words in each passage/list

# THE RRT TEST FLOW

Consider adding 15 – 30 s rehearsal period before recall - **NEW**



Repeat each sentence

Recall all 6 sentences

Rate effort level & tolerable time

Display results

## ONE SNR BY CONTEXT CONDITION

(Takes two minutes)

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



# DEMONSTRATION



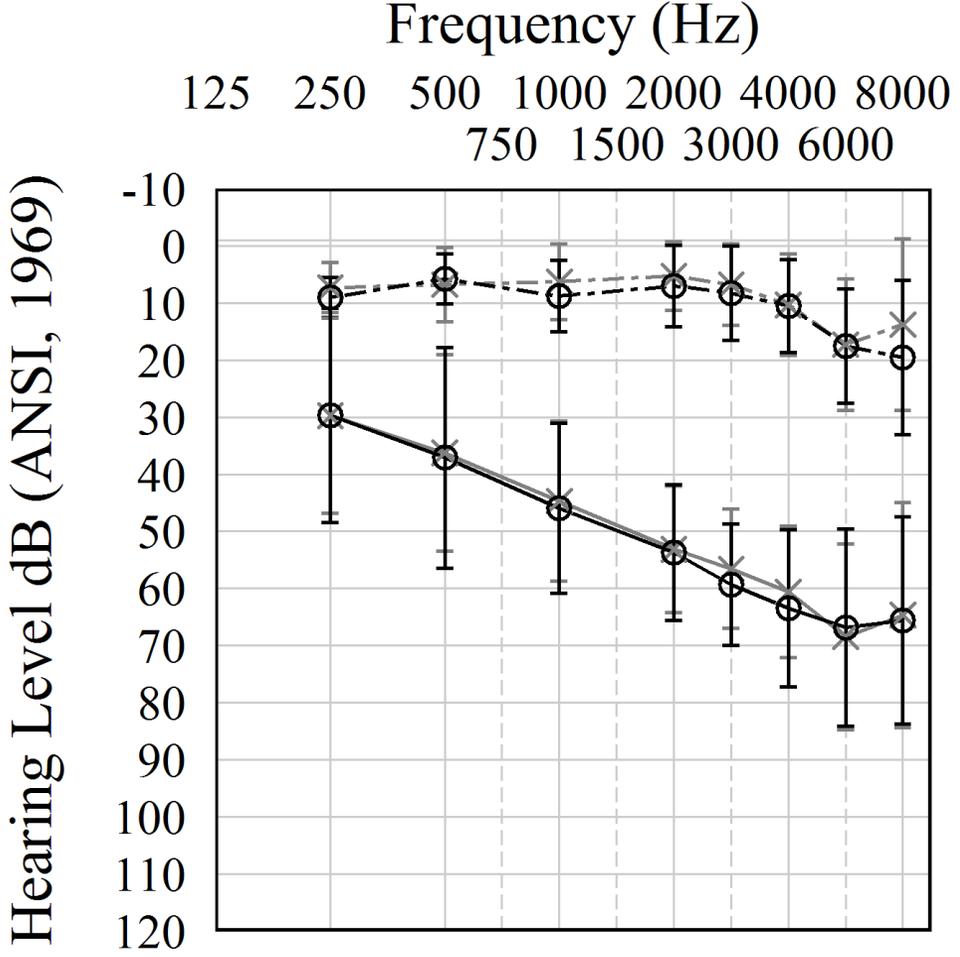
# WHAT IS ESTIMATED WITH EACH MEASURE?

- Repeat – *word/sentence recognition* with mostly bottom-up processing with minimal need to remember (or memory) with LC sentences. Top down processing is used to help recognize words/sentence at poor SNR. Extent of top down processing may be examined as difference between HC and LC sentences
- Recall – *working memory capacity* as affected by noise
- Listening effort – *cognitive resources* to attend/separate speech from noise and remember the identified speech. Perception of difficulty
- Tolerable time – *willingness to stay* in the noisy situation, a reflection of motivation/stamina of individual for the situation

# NORMATIVE STUDY ON RRT - DEMOGRAPHICS

	Normal Hearing				Hearing-Impaired				
	<i>n</i>	<i>nF</i>	<i>Mean</i>	<i>SD</i>	<i>n</i>	<i>nF</i>	<i>mean</i>	<i>SD</i>	<i>sig</i>
<i>Age (yrs)</i>	20	14	50.06	15.59	16	11	64.12	15.22	*
<i>PTA (dB HL)</i>	20	14	7.57	5.40	16	11	49.05	11.66	***
<i>HINT (SRT-50)</i>	20	14	0.03	0.91	16	11	4.82	3.69	***
<i>RST (/100 words)</i>	20	11	60.60	10.38	16	11	63.62	11.45	n.s.
<i>MoCA (/30)</i>	17	11	27.24	1.82	16	11	26.31	2.12	n.s.

# NORMATIVE STUDY ON RRT - AUDIOGRAM

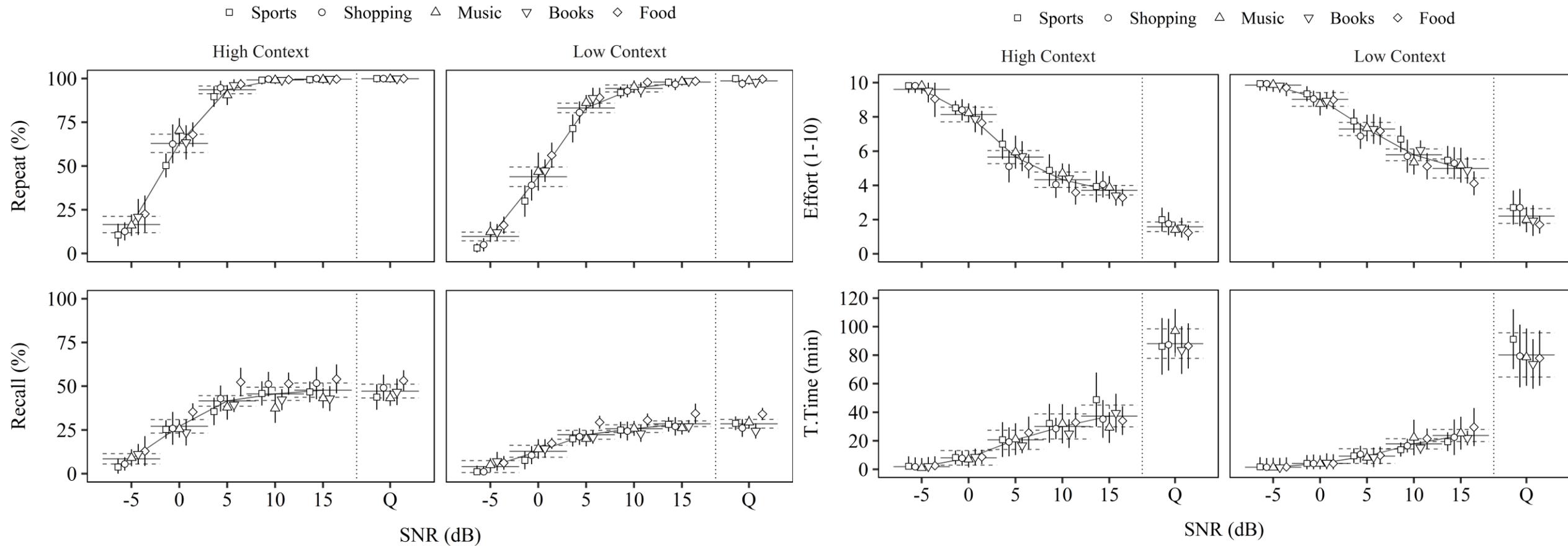


Hearing impaired listeners tested with BEYOND aids in omni mic and ALL features deactivated.

— HI    - - - - NH            × L    o R



# NORMAL PERFORMANCE - LIST EQUIVALENCE



ALL lists are fairly similar (within 5-10%) on all measures. Statistically, “sports” is the most difficult and “food” is the easiest. Other 3 lists are interchangeable.



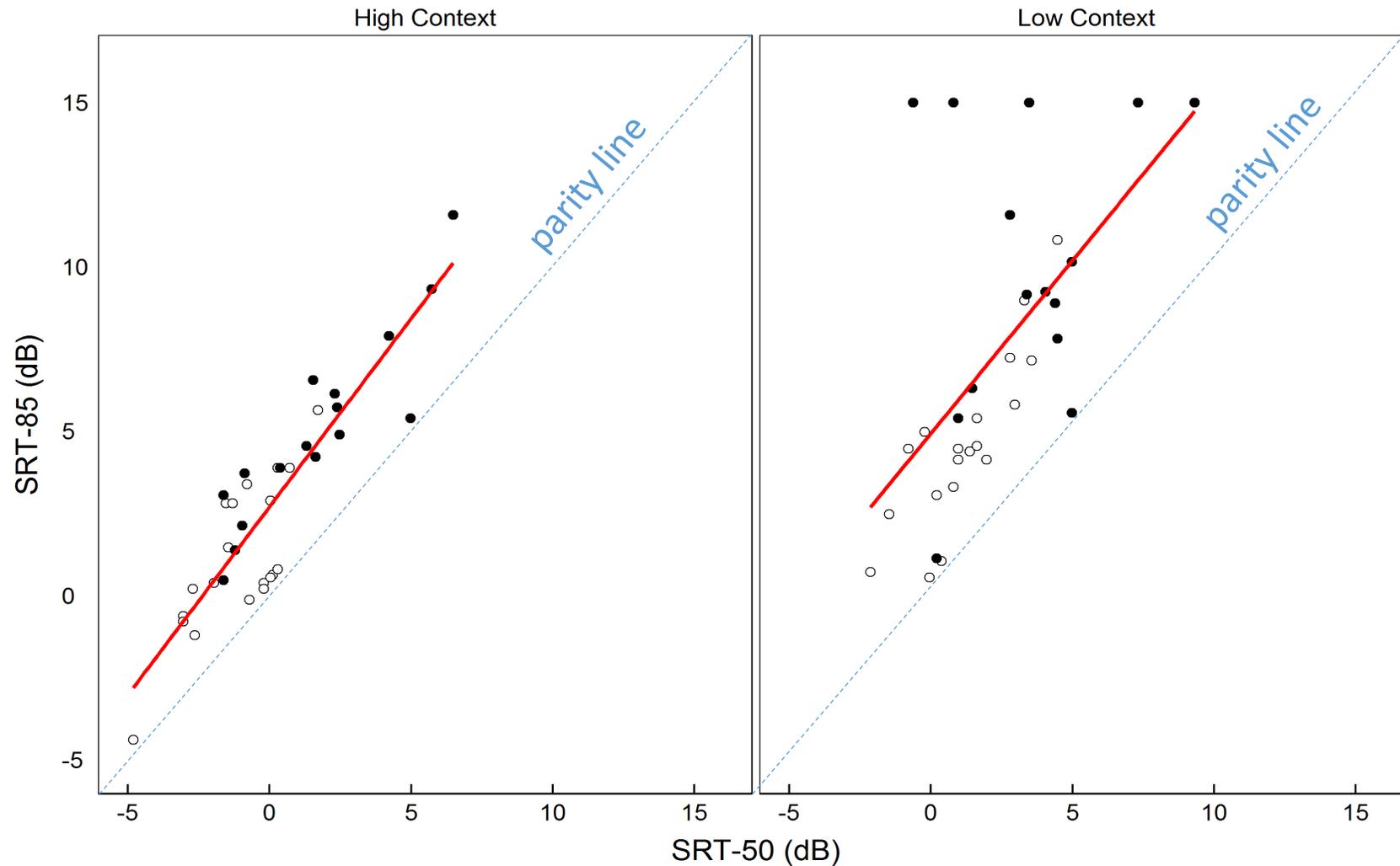
# COMPARING NORMAL HEARING AND HEARING IMPAIRED LISTENERS





# IS SRT<sub>85</sub> PREDICTABLE FROM SRT<sub>50</sub>?

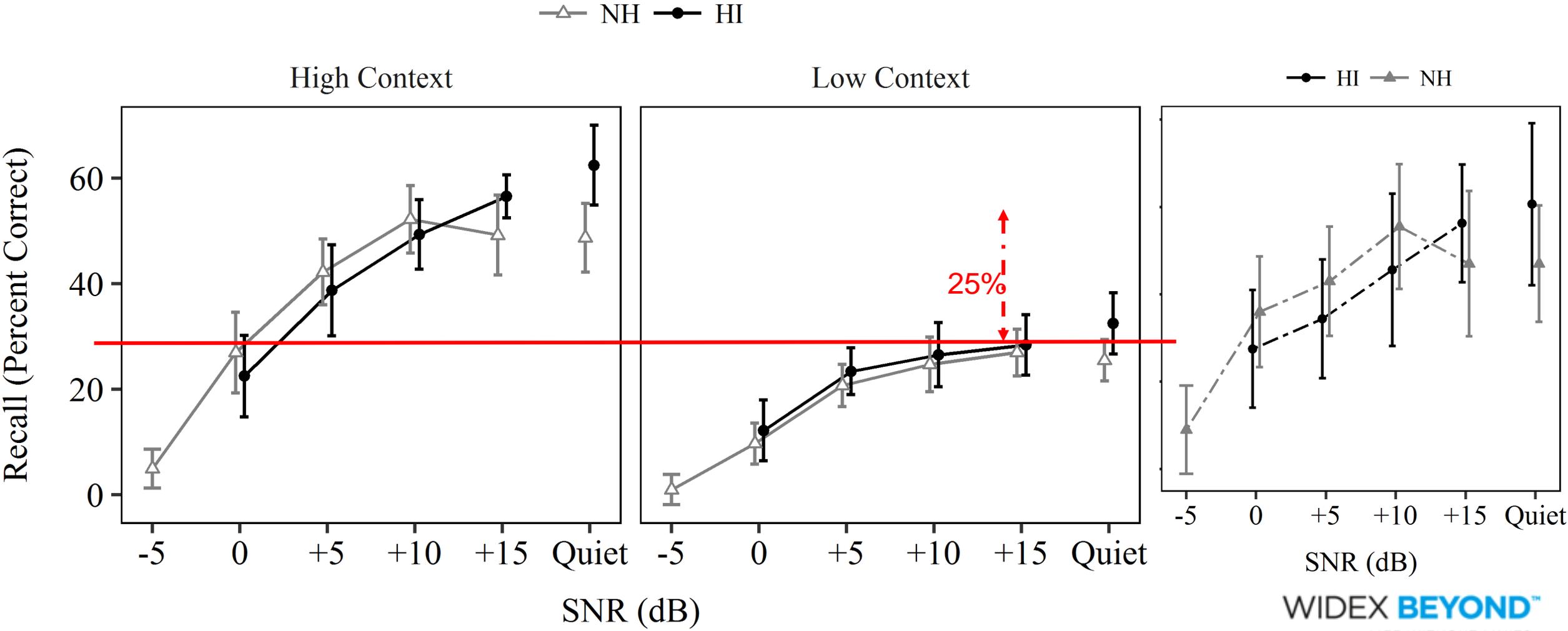
High  $r = 0.90$  \*\*\*    Low  $r = 0.57$  \*\*\*



• Hearing-impaired    ○ Normal-hearing



# RRT PERFORMANCE-INTENSITY FUNCTION: RECALL



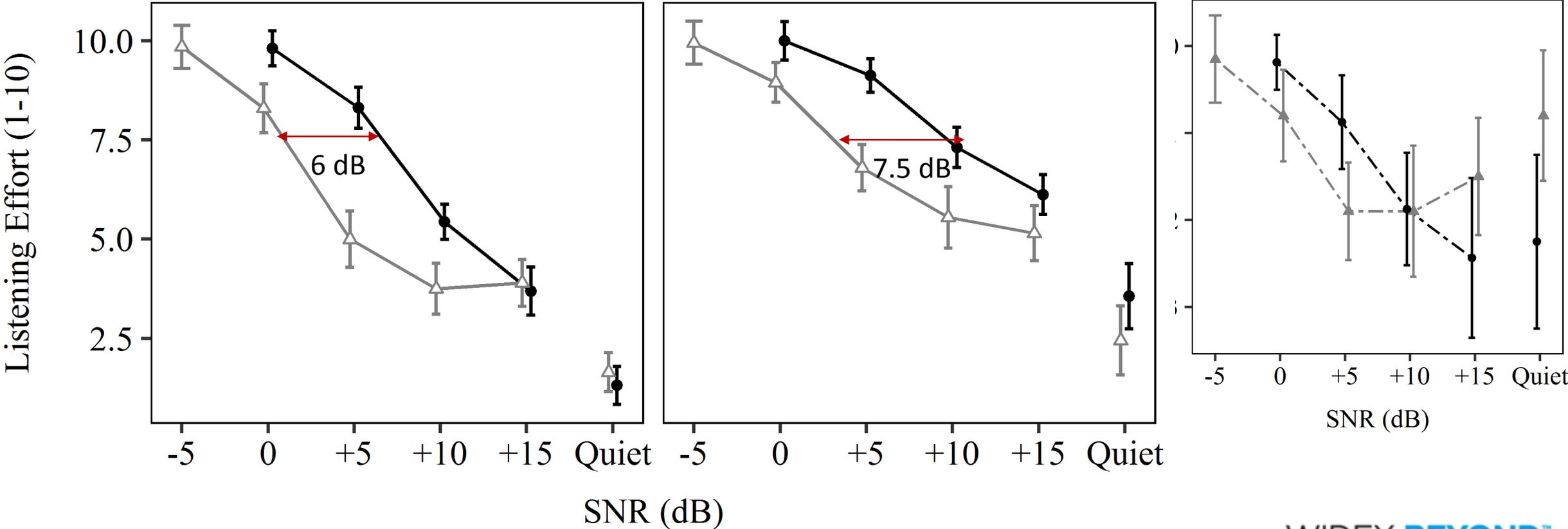
# RRT PERFORMANCE-INTENSITY FUNCTION: LISTENING EFFORT

—△— NH —●— HI

High Context

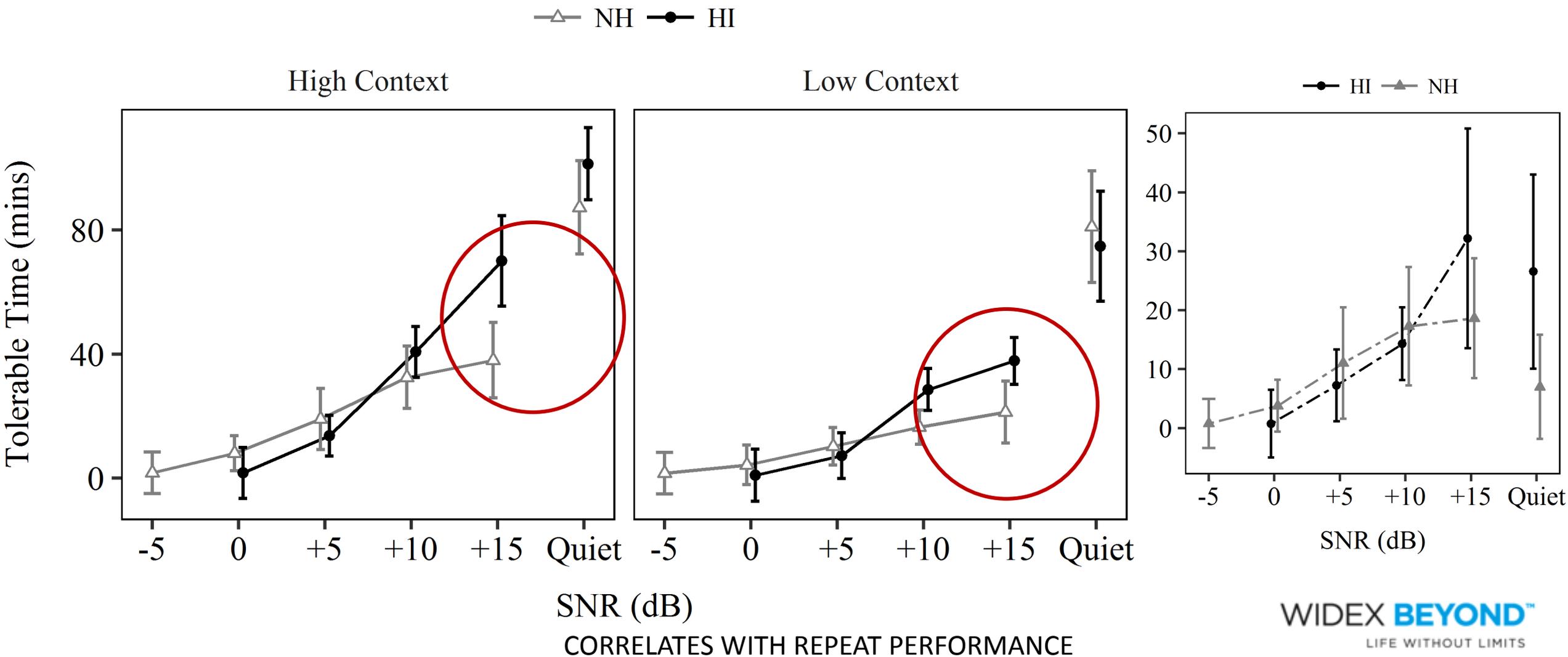
Low Context

—●— HI —△— NH



CORRELATES WITH RECALL AND REPEAT PERFORMANCE

# RRT PERFORMANCE-INTENSITY FUNCTION: TOLERABLE TIME

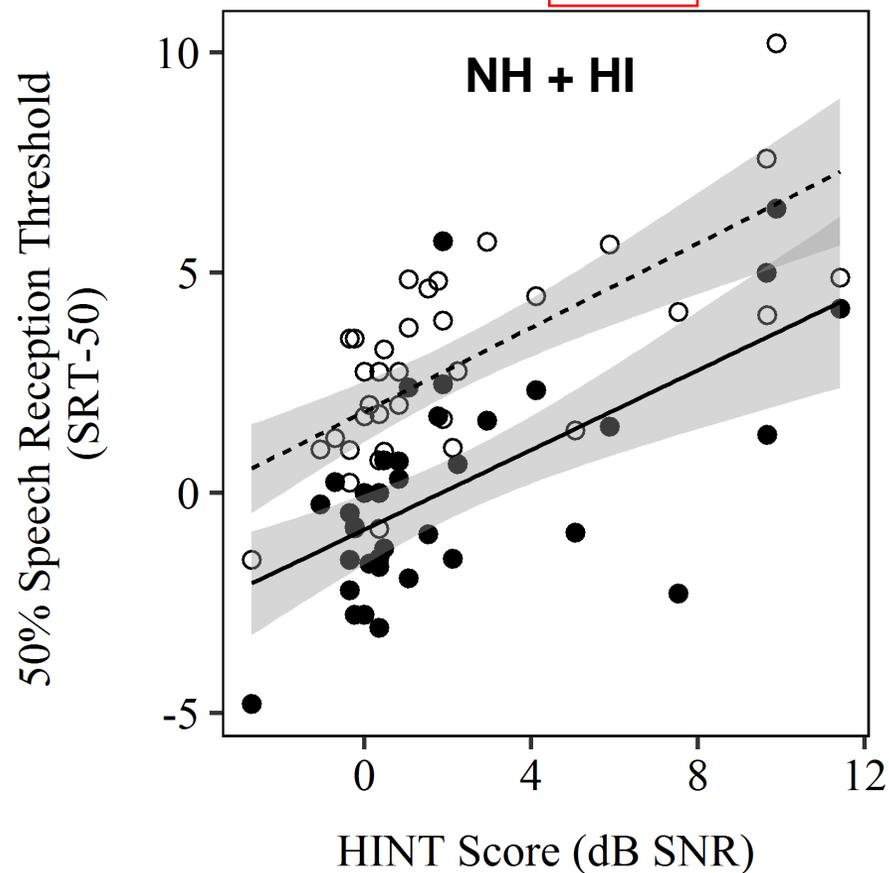


# SUMMARY

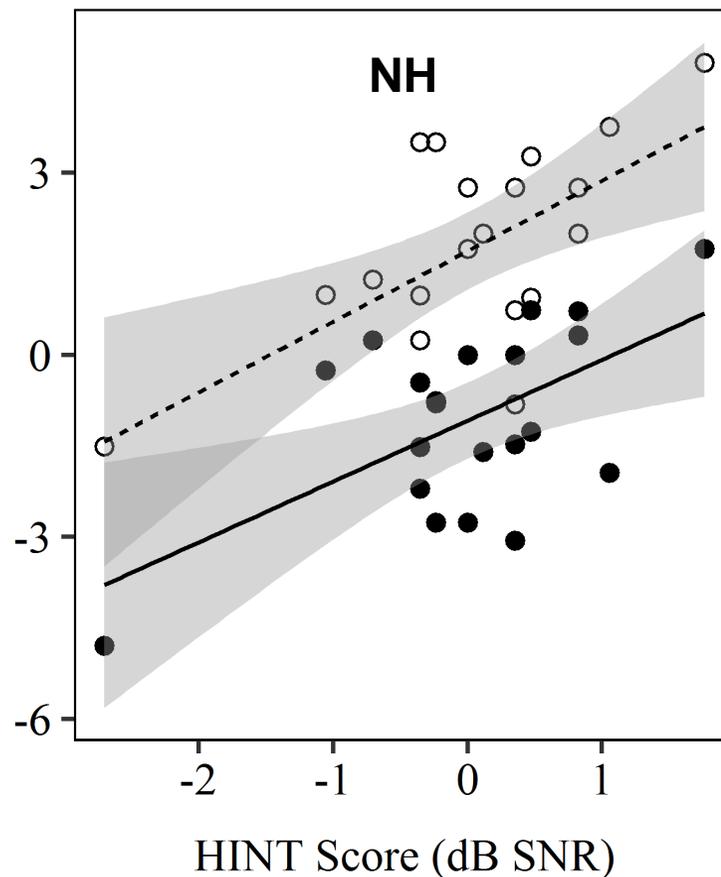
- HI had shifted P-I function (about 2-3 dB) and elevated  $SRT_{50}$  (about 2 dB) compared to NH for both HC and LC; however  $SRT_{85}$  shifted by about 5 and 8 dB between NH and HL for HC and LC respectively
- Both NH and HI had similar recall ability (esp when audibility is accounted)
- HI reported greater listening effort than NL, and more for LC than HC
- HI and NH had similar tolerable time except when  $SNR \geq +15$  dB where HI can spend more time than NH
- Both groups depend on context on all measures, and context dependence decreases as SNR increases. While NH minimally depends on context at  $> +15$ , HI people still rely on context greatly

# SRT-50 CORRELATION WITH HINT

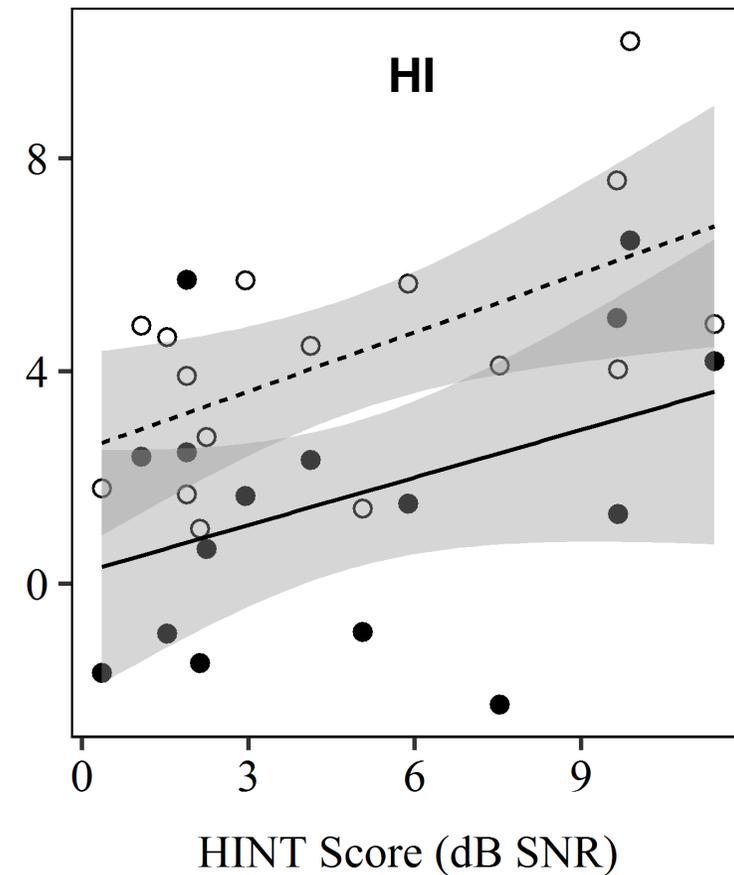
High Context  $r = 0.62$   
Low Context  $r = 0.70$



High Context  $r = 0.58$   
Low Context  $r = 0.63$



High Context  $r = 0.41$   
Low Context  $r = 0.57$

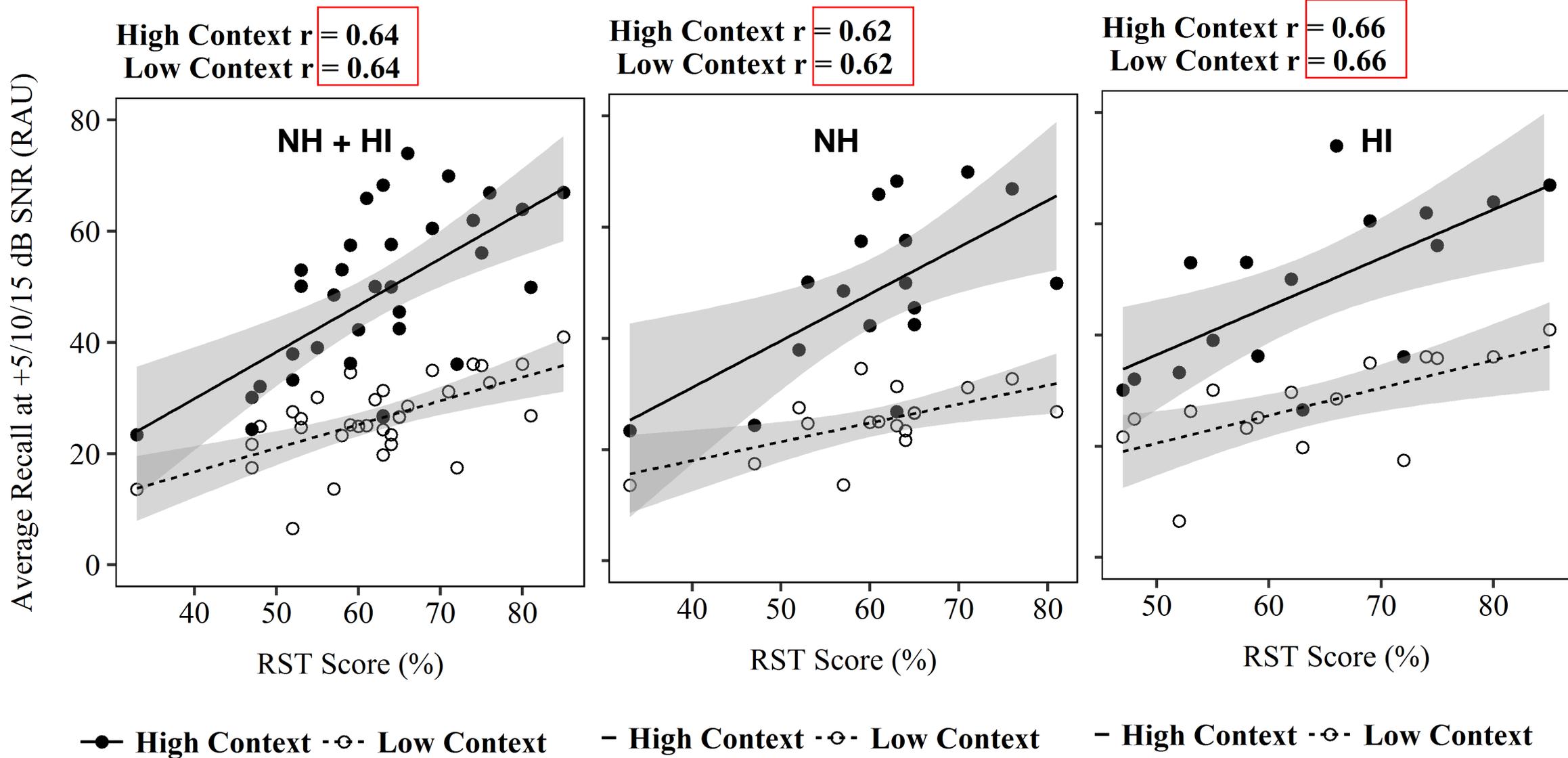


● High Context -○- Low Context

● High Context -○- Low Context

● High Context -○- Low Context

# RECALL CORRELATION WITH READING SPAN TEST



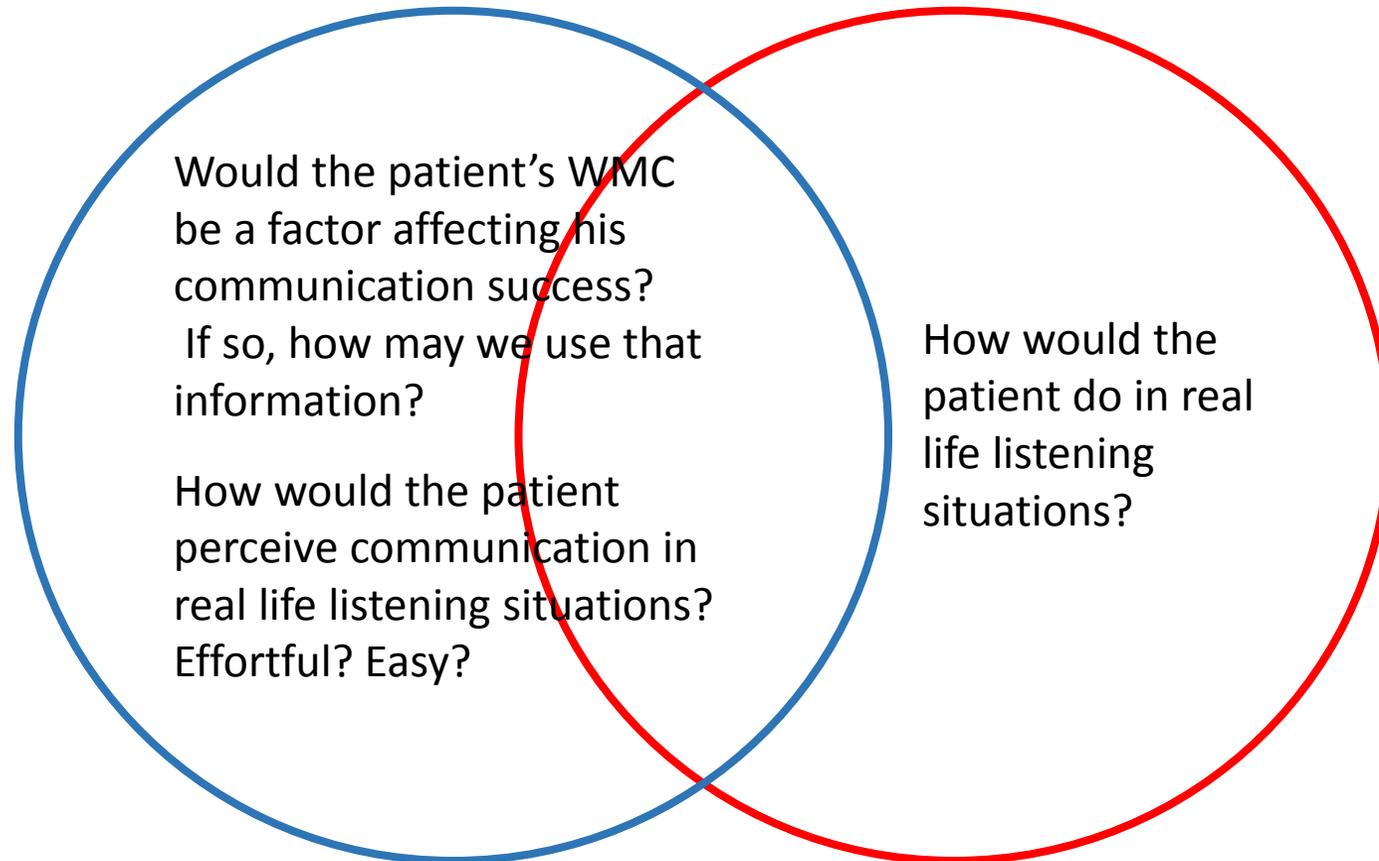
# SUMMARY

- HINT and SRT-50 are moderately correlated (around 0.5 -0.6). However, both are correlated to PTA. When PTA is taken out, correlation between HINT and SRT-50 was  $< 0.4$ .
- Recall ability is correlated to RST with a moderate correlation around 0.6. It is slightly higher when presented in noise at SNR = +10 & +15 dB.
- Listening effort is significantly correlated to both repeat and recall scores
- Tolerable time is correlated to repeat score only.
- Test-retest reliability of all 4 measures are moderate to good. Test multiple lists (i.e., increase items) to increase reliability.

# HOW DO I USE THE RRT RESULTS WITH MY PATIENTS?



# PREVIOUSLY WE SAID WE WANT TO KNOW THE FOLLOWING ABOUT OUR PATIENTS ...



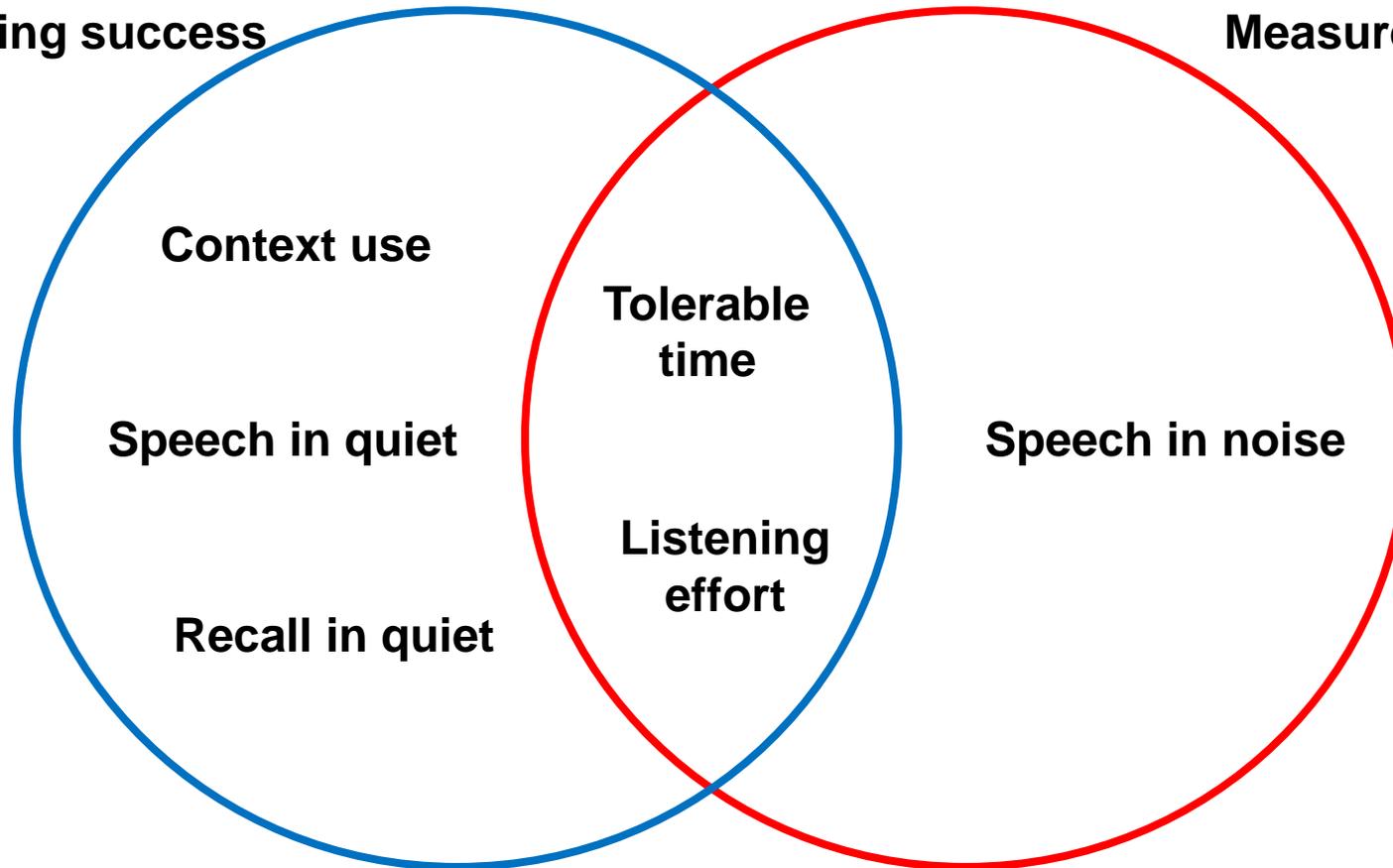
Is the patient's experience unique? How does it compare to others, ie, normal hearing?



# RRT SCORES PROVIDE INSIGHTS INTO PATIENT'S COMMUNICATION SUCCESS

Factors limiting success

Measure of success



Motivation



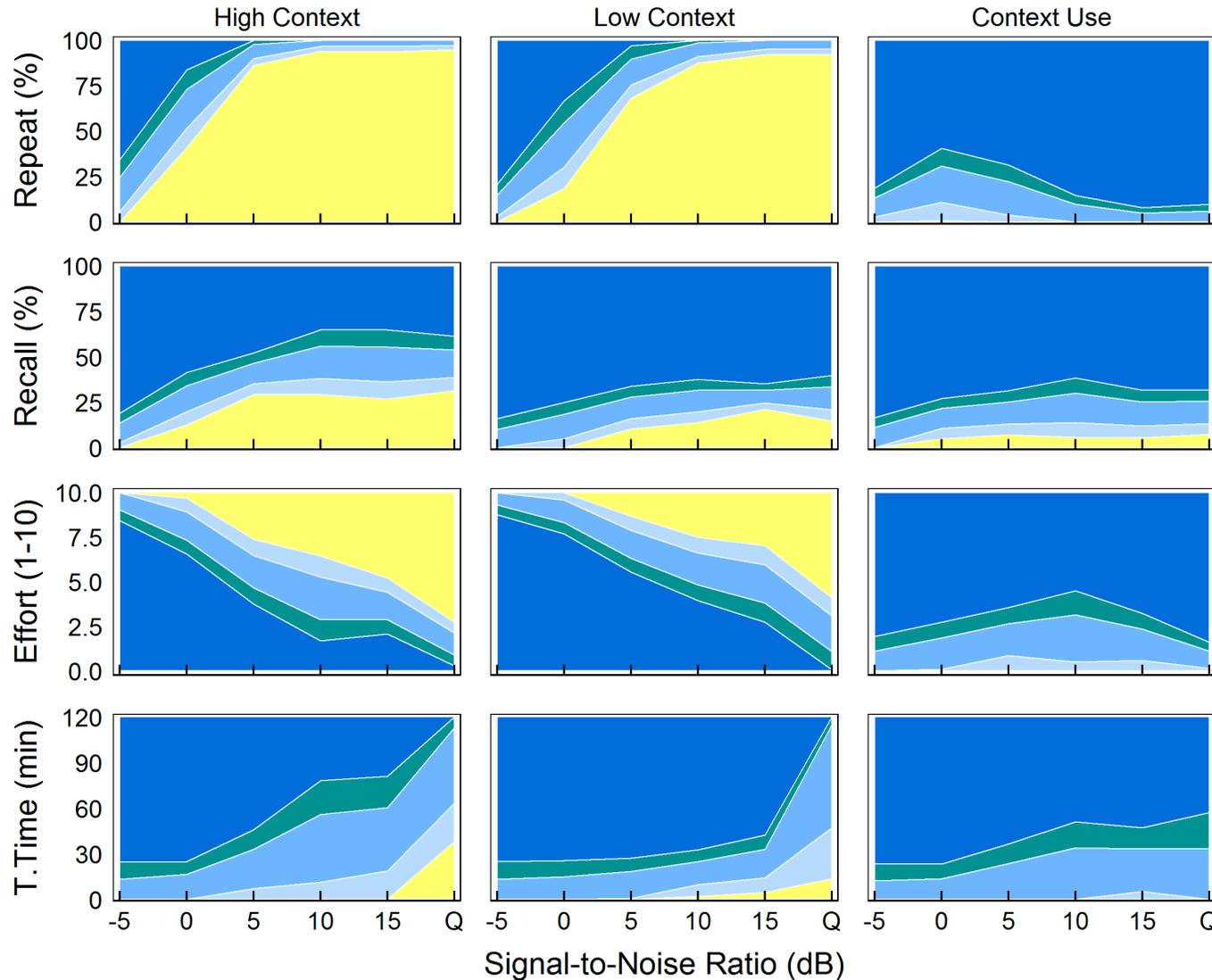
Comparisons to “Normal” performance  
addresses the issue of  
*realistic expectations*



# COMPARISON TO NORMAL\* USING TEMPLATE

Subject:  
Age: , , PTA: , HINT: , RST:

Speech = babble noise = front



Performance plateaus at SNR > 10

Context makes biggest difference at SNR = 0

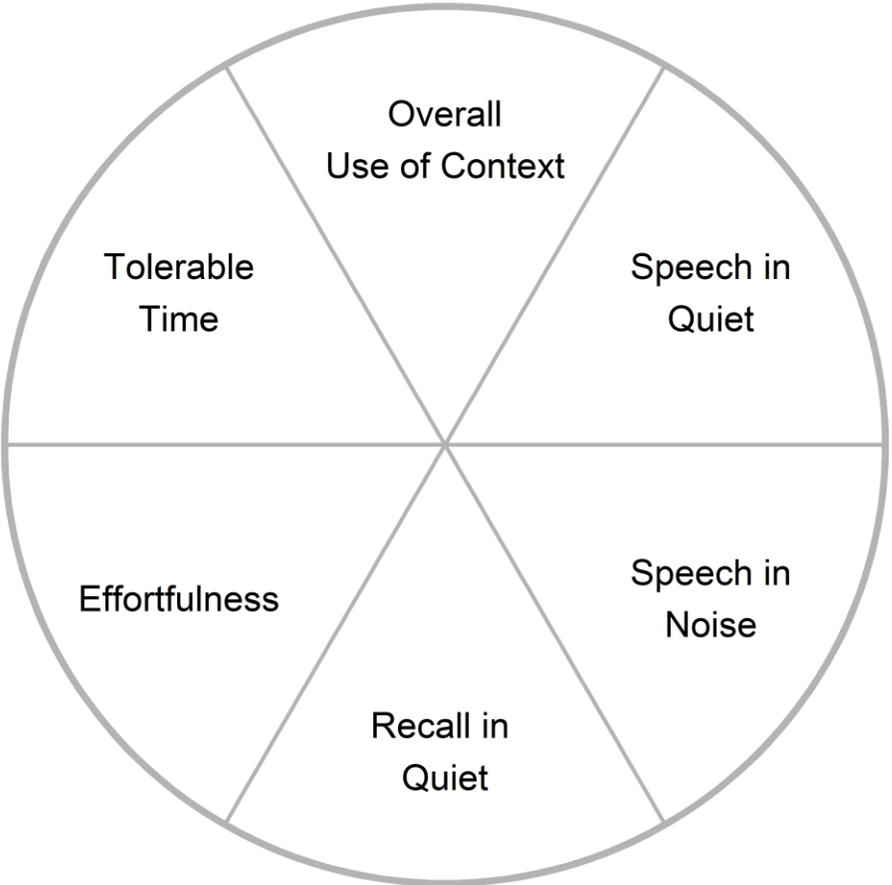
Context makes biggest difference at SNR = 10

Context makes biggest difference at SNR = 10 and then decreases

Context makes biggest difference at SNR = 10 and stay the same/increase



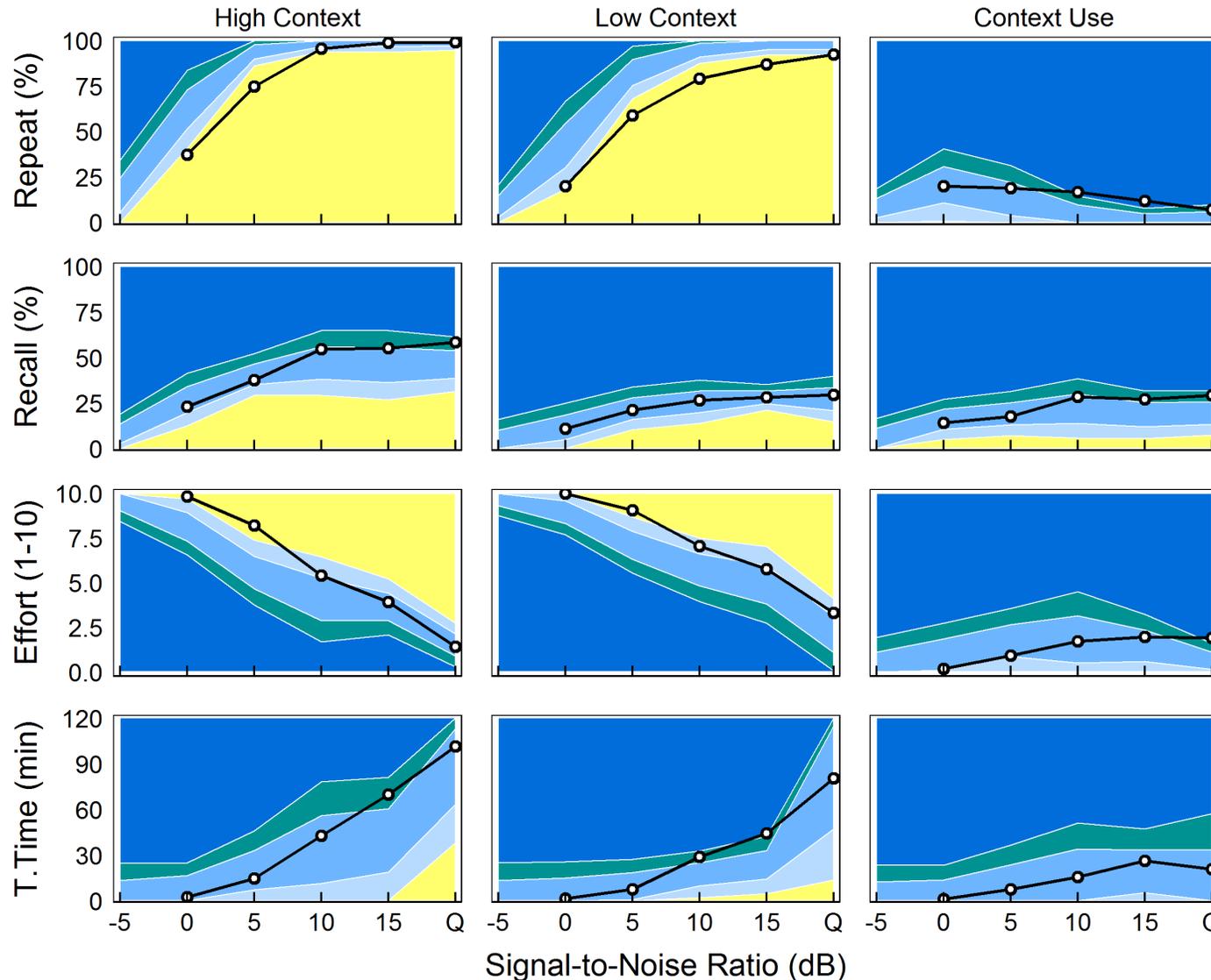
# SUMMARY - INDIVIDUAL PROFILE



# THE AVERAGE HEARING IMPAIRED SUBJECT

Subject: Average Hearing-Impaired Data  
 Age: 64.75, 11 F , PTA: 49.05, HINT: 4.82, RST: 63.62

Examine  $SRT_{50}$  and  $SRT_{85}$  for HC & LC



HC – poorer < SNR =10  
 LC – poorer at all SNR  
 Context – more dependent at all SNR

HC = LC – similar to normal  
 Recall plateaus at SNR > 10  
 Context – similar dependence at all SNR, slightly higher at SNR > 10



HC = LC – more effortful, but w/in 2 SD  
 Context – reduces effort at all SNR

HC = LC – tolerate longer, but w/in 2 SD  
 Context – similar to normal

Close to normal performance w/ HC at SNR > 10 at greater effort



# GROUPING OF PATIENTS RE: NORMAL

	<b>REPEAT</b> EQUAL TO OR BETTER THAN NORMAL	<b>REPEAT</b> POORER THAN NORMAL
<b>RECALL</b>  EQUAL TO OR BETTER THAN NORMAL	(current amplification is adequate – most likely to be satisfied)	(current amplification is insufficient – need to improve SNR for “noisy” situations to be satisfied)
<b>RECALL</b>  POORER THAN NORMAL	(current amplification is adequate but poor WMC – not likely frequent scenario)	(current amplification is insufficient, compounded by poor WMC)

No one reported less effort than normal hearing listeners

Majority of HI listeners reported same or longer tolerance in noise than normal at SNR > 10/15

# INTERVENTION BASED ON GROUPING

	<b>REPEAT</b> EQUAL TO OR BETTER THAN NORMAL	<b>REPEAT</b> POORER THAN NORMAL
<b>RECALL</b> EQUAL TO OR BETTER THAN NORMAL	(current amplification is adequate – most likely to be satisfied)	(current amplification is insufficient – need to improve SNR for “noisy” situations to be satisfied)  - Use of NR that activates at poor SNR, dir mic, improve context use by asking questions
<b>RECALL</b> POORER THAN NORMAL	(current amplification is adequate but poor WMC – not likely scenario – would have moved to poor repeat and poor recall category)	(current amplification is insufficient, compounded by poor WMC)  - Use of NR that activates at poor SNR, dir mic, improve context use by asking questions, rehab training



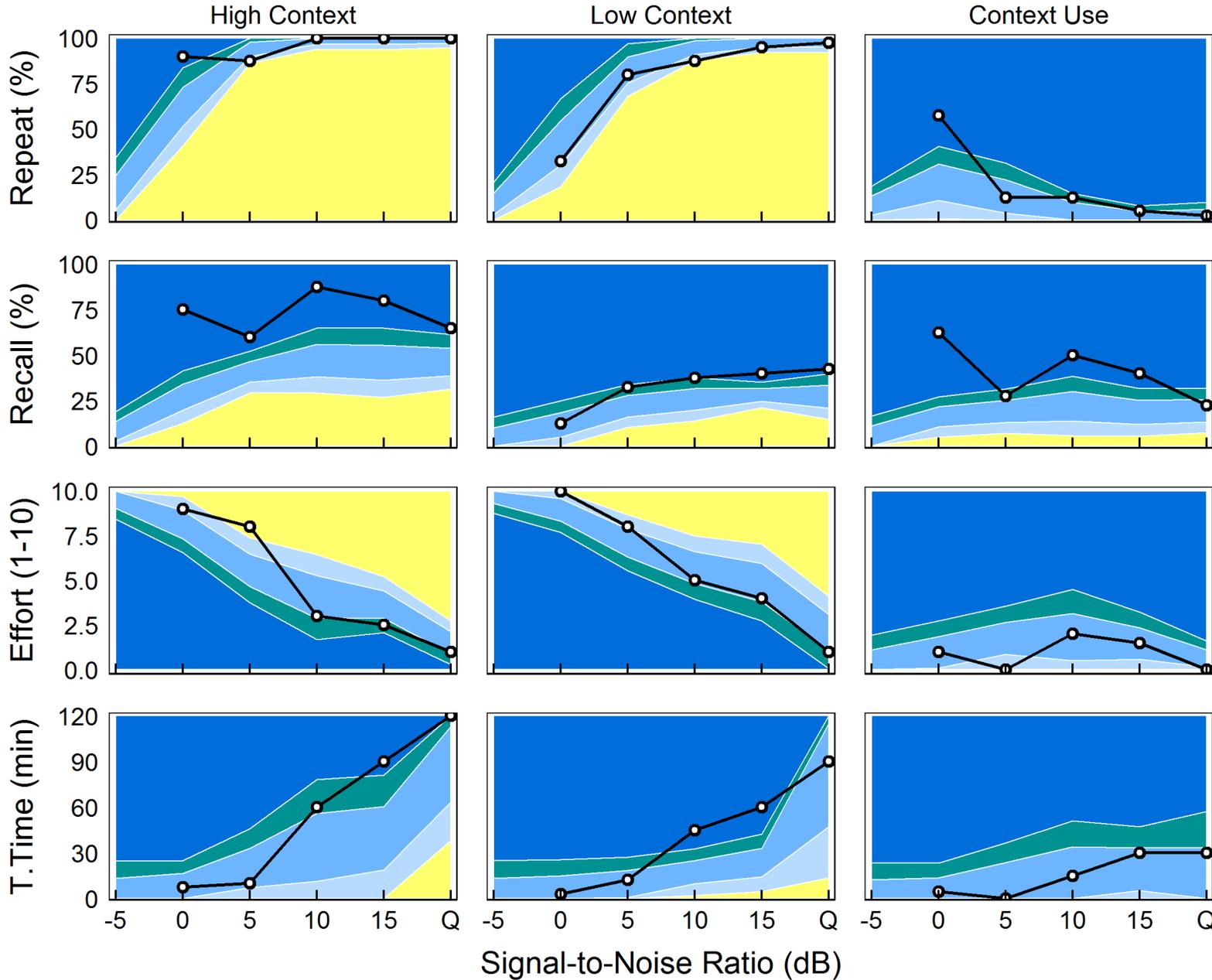
# REVIEW OF CASES: NORMAL REPEAT AND RECALL

	REPEAT EQUAL TO OR BETTER THAN NORMAL	REPEAT POORER THAN NORMAL
RECALL  EQUAL TO OR BETTER THAN NORMAL	<p>2, 3, 6, 8, 9</p> <p>(current amplification is adequate – most likely to be satisfied)</p>	
RECALL  POORER THAN NORMAL		



**Subject: 6**  
**Age: 33, F, PTA: 50, HINT: 0.35, RST: 85**

Young person with good HINT and RST  
 Bear in mind no dir mic/NR used, noise front



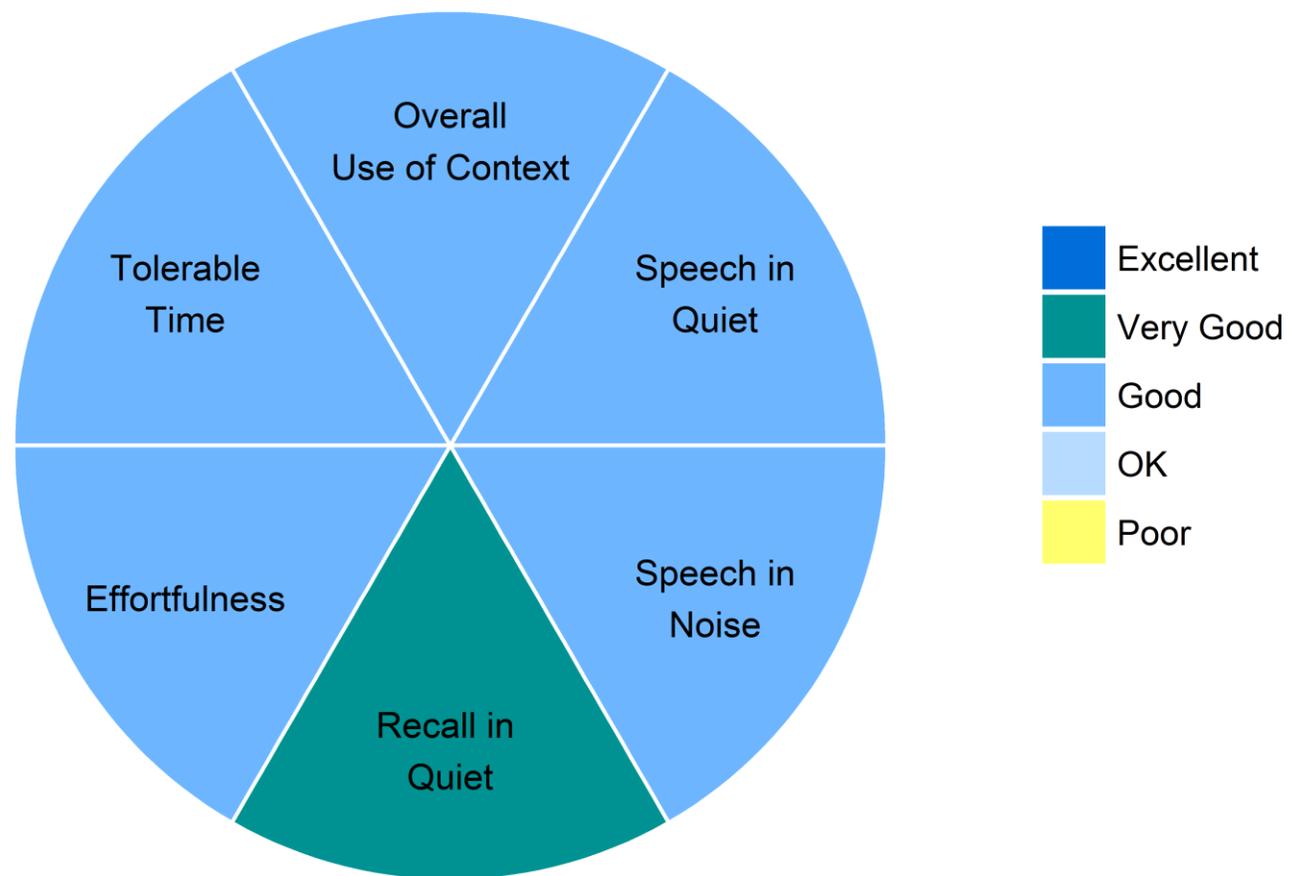
Similar or better SIN  
 Quiet OK  
 Use context like normal

Better recall  
 Context improve recall  
 ??using recall strategy??

Similar effort  
 Context does not improve  
 effort except SNR = 10, 15

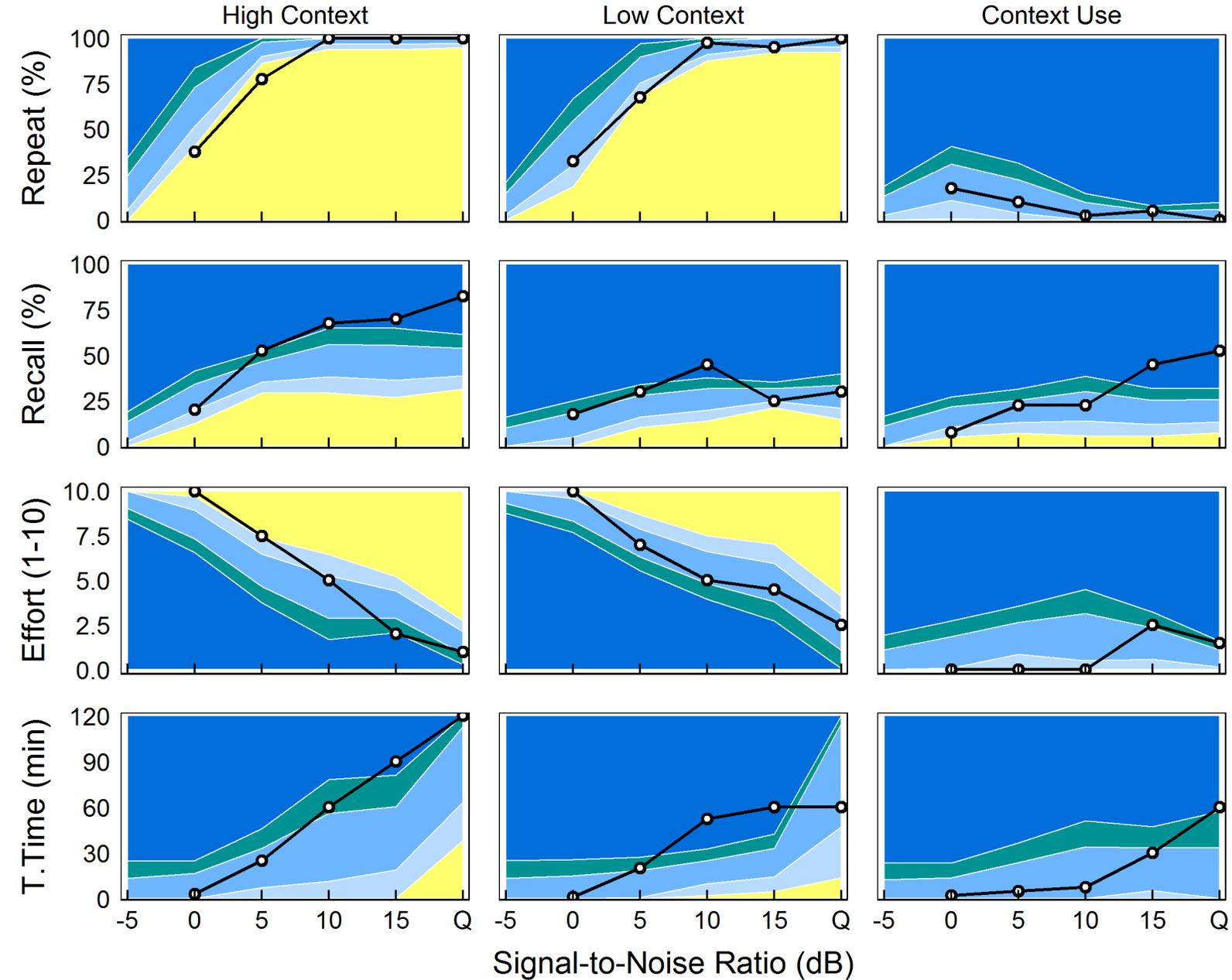
Better tolerance in noise  
 than normal  
 Context at SNR > 10 helps

**Subject: 6**  
**Age: 33, F, PTA: 50, HINT: 0.35, RST: 85**



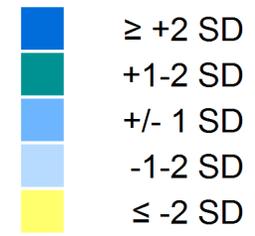
**Subject: 9**  
**Age: 80, F, PTA: 43.125, HINT: 1.88, RST: 74**

Older person with good HINT and RST



Low normal SIN  
 Quiet OK  
 Use context only at poor SNR  
 Most likely because of good memory

Better recall  
 Context improve recall  
 esp > SNR =15

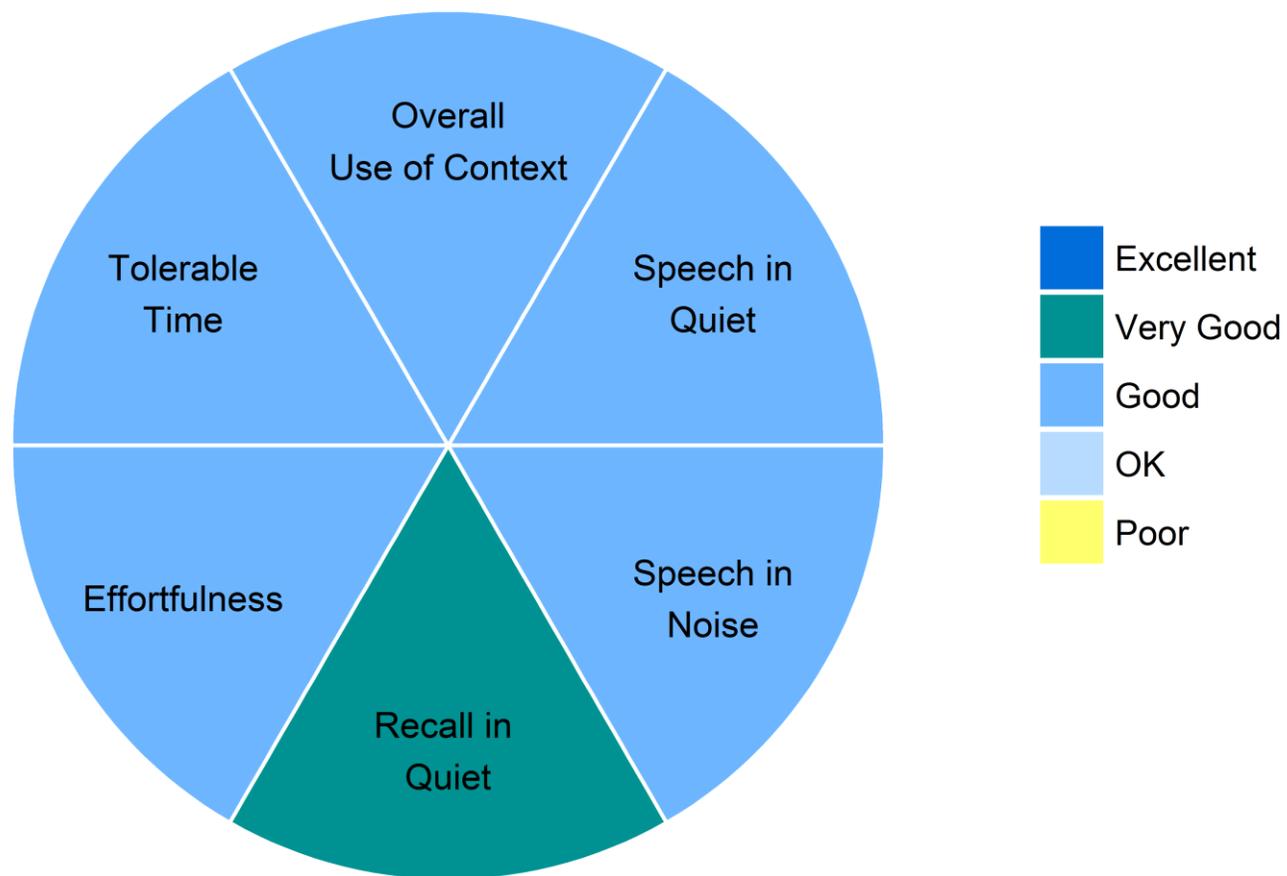


Similar effort  
 Context does not improve  
 effort except SNR > 15

Slightly more tolerant in noise  
 Context at SNR > 10 helps

**Subject: 9**

**Age: 80, F, PTA: 43.125, HINT: 1.88, RST: 74**



# REVIEW OF CASES: POORER REPEAT BUT NORMAL RECALL

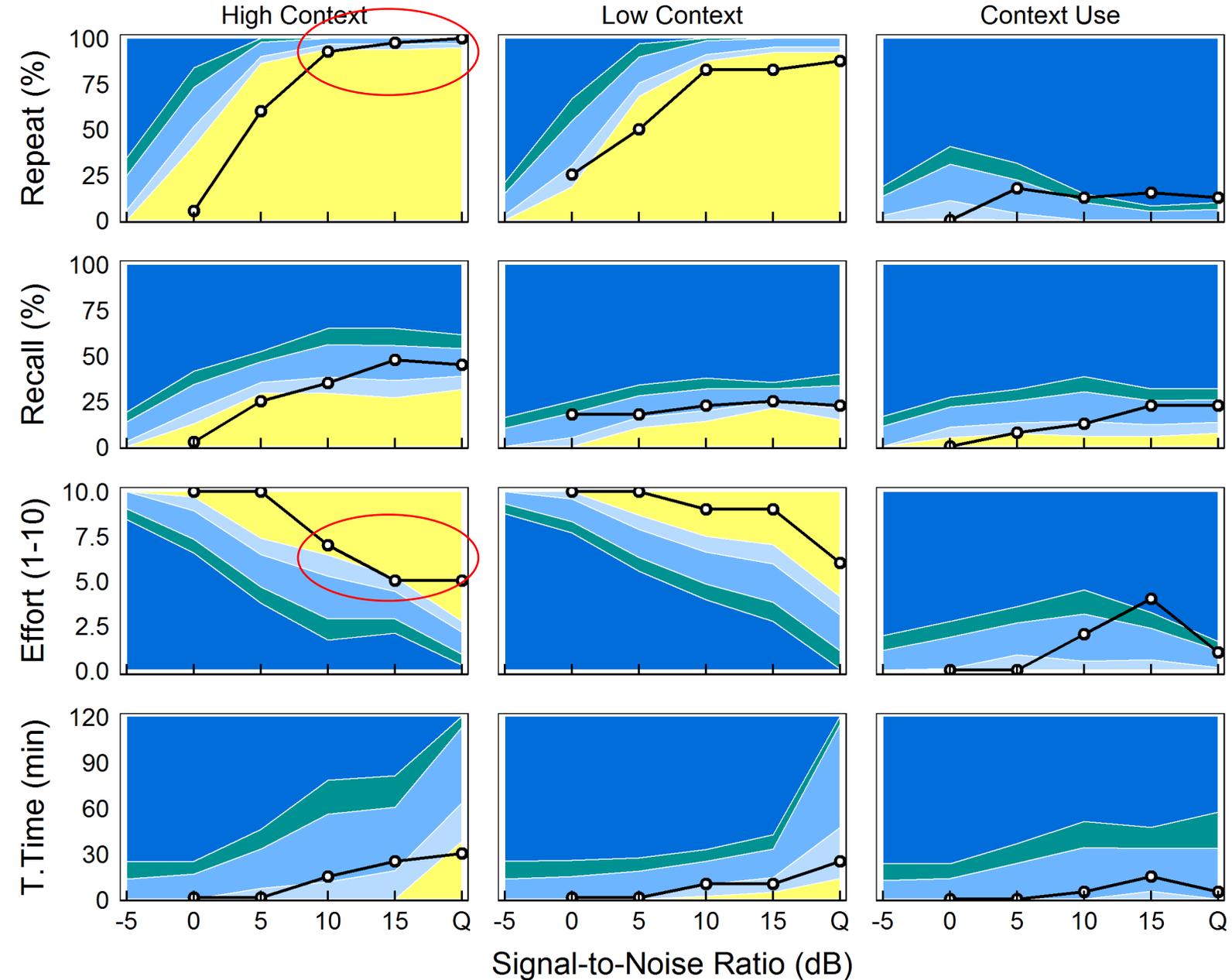
	REPEAT EQUAL TO OR BETTER THAN NORMAL	REPEAT POORER THAN NORMAL
RECALL  EQUAL TO OR BETTER THAN NORMAL		1, 4, 5, 8, 9, 10, 12, 13, 14, 15,16  (current amplification is insufficient – need to improve SNR for “noisy” situations to be satisfied)
RECALL  POORER THAN NORMAL		

## REMINDER

- Noise is 2-talker babble from front
- No NR/DM active

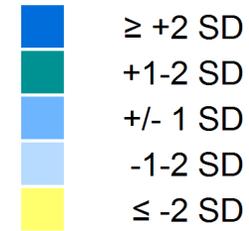


**Subject: 5**  
**Age: 71, M, PTA: 61.875, HINT: 1.88, RST: 59**



Poorer SIN  
 Quiet not OK - LC  
 Use context at all SNR

Poorer recall in noise,  
 similar quiet  
 Context improve recall in  
 quiet



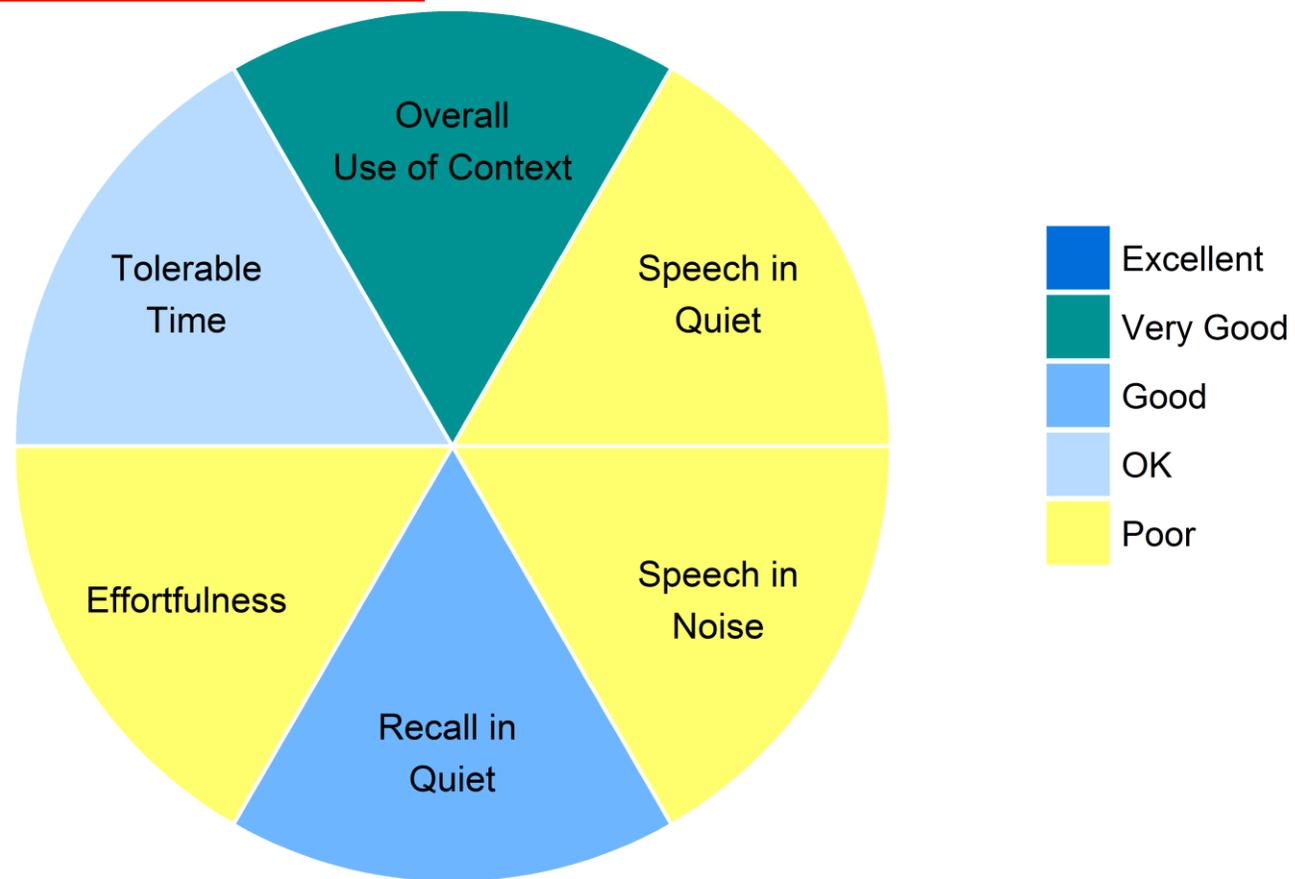
More effortful HC/LC  
 Context does not improve  
 effort except SNR = 15  
 More effort than NH for  
 HC at SNR > 10

Poorer tolerance in noise  
 Context does not help at any  
 SNR

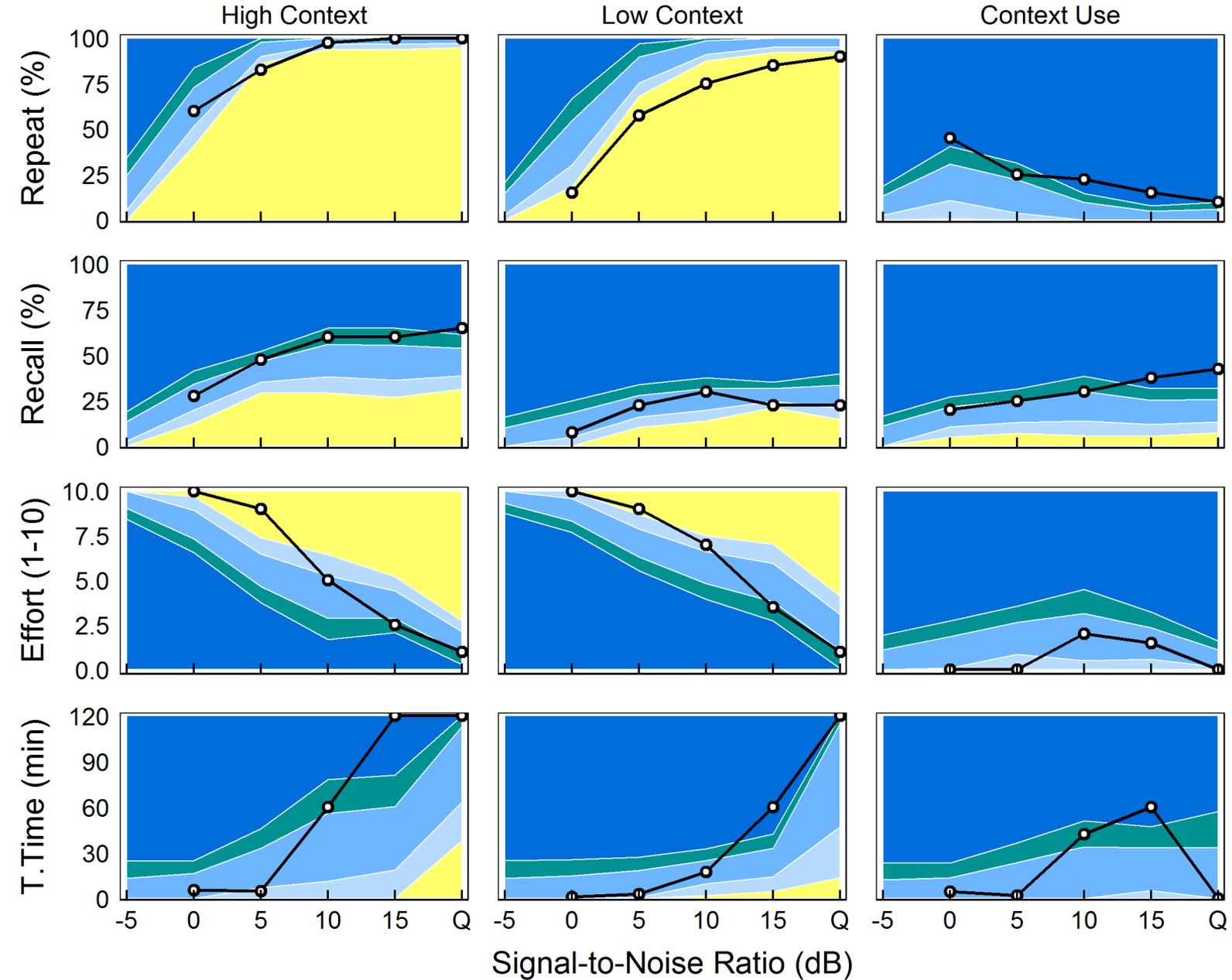
??cannot function in noise??

**Subject: 5**

**Age: 71, M, PTA: 61.875, HINT: 1.88, RST: 59**



**Subject: 13**  
**Age: 81, M, PTA: 42.5, HINT: 7.53, RST: 53**



Poorer SIN, esp LC  
 Quiet OK  
 Use context like normal

High normal recall  
 Context improves recall  
 ?Use strategy?

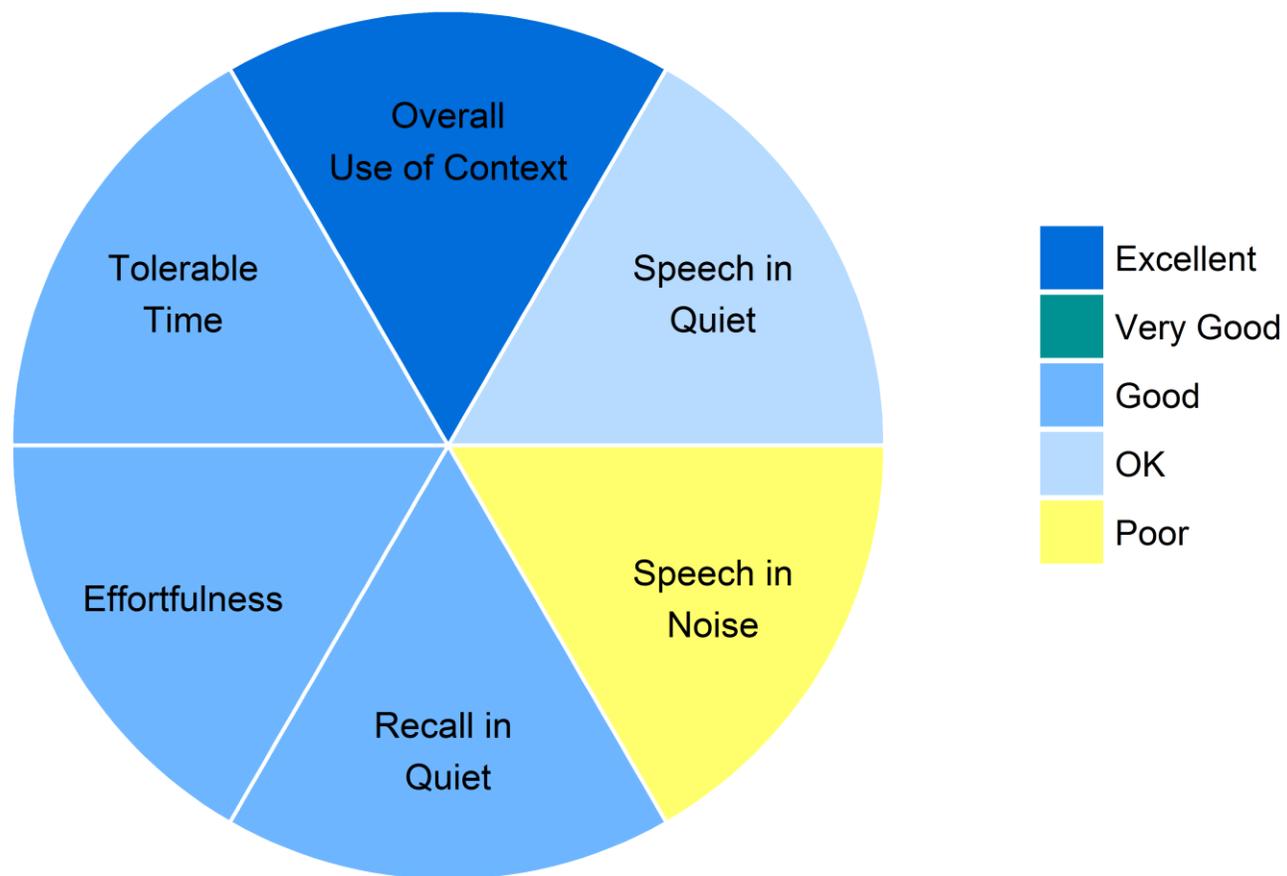


High normal effort  
 Context does not improve effort much

More tolerance in noise  
 Context at SNR > 10

**Subject: 13**

**Age: 81, M, PTA: 42.5, HINT: 7.53, RST: 53**

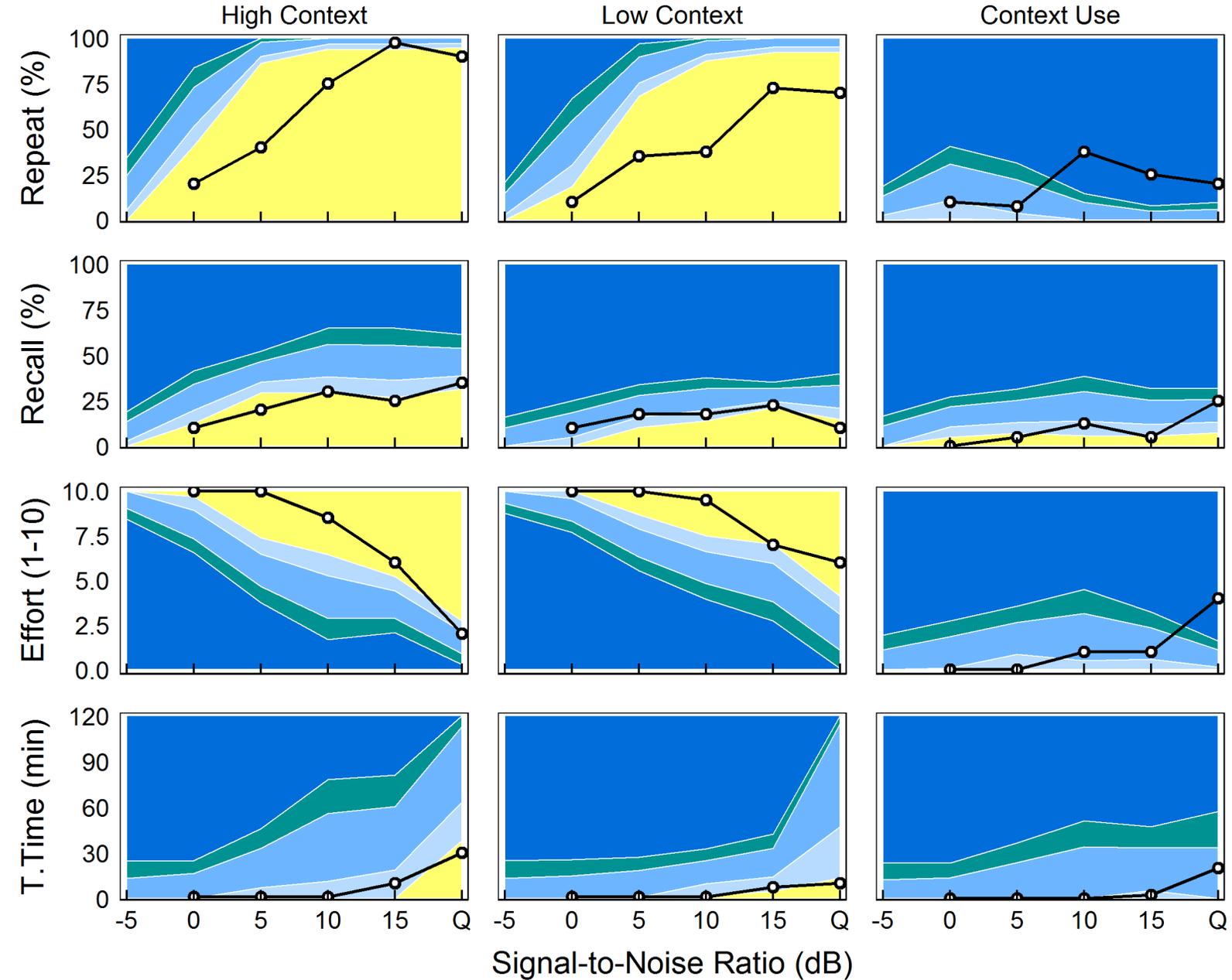


# REVIEW OF CASES: POOR REPEAT AND RECALL

	<b>REPEAT</b> EQUAL TO OR BETTER THAN NORMAL	<b>REPEAT</b> POORER THAN NORMAL
<b>RECALL</b> EQUAL TO OR BETTER THAN NORMAL		
<b>RECALL</b> POORER THAN NORMAL		<b>7, 11</b>  (current amplification is insufficient, compounded by poor WMC)



Subject: 11  
 Age: 74, M, PTA: 65.625, HINT: 9.88, RST: 63



Poorer SIN  
 Quiet poor  
 Use context at SNR  $\geq 10$   
 ?cannot function below 10?

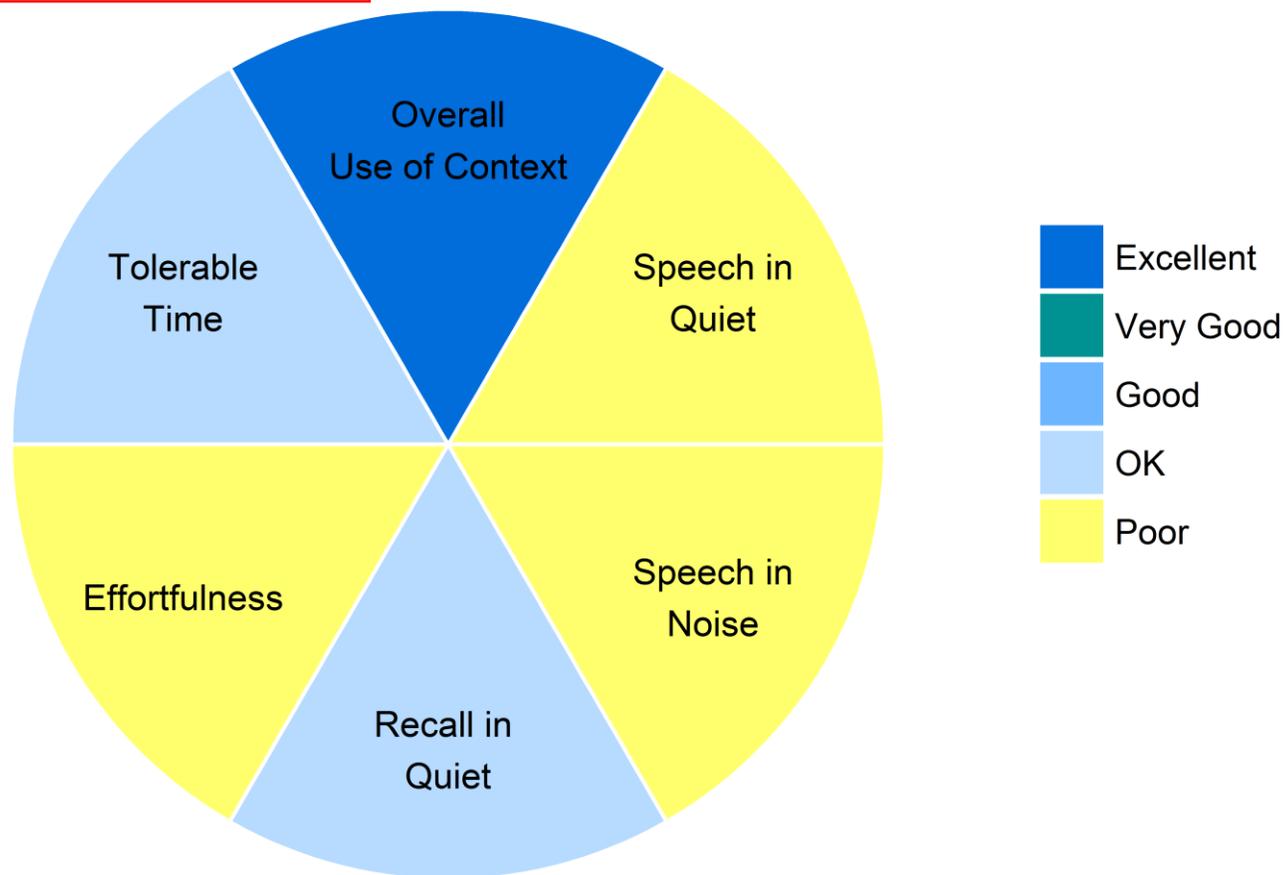
Poorer recall HC/LC  
 Context does not improve recall except quiet

More effortful HC/LC  
 Context does not improve effort except quiet

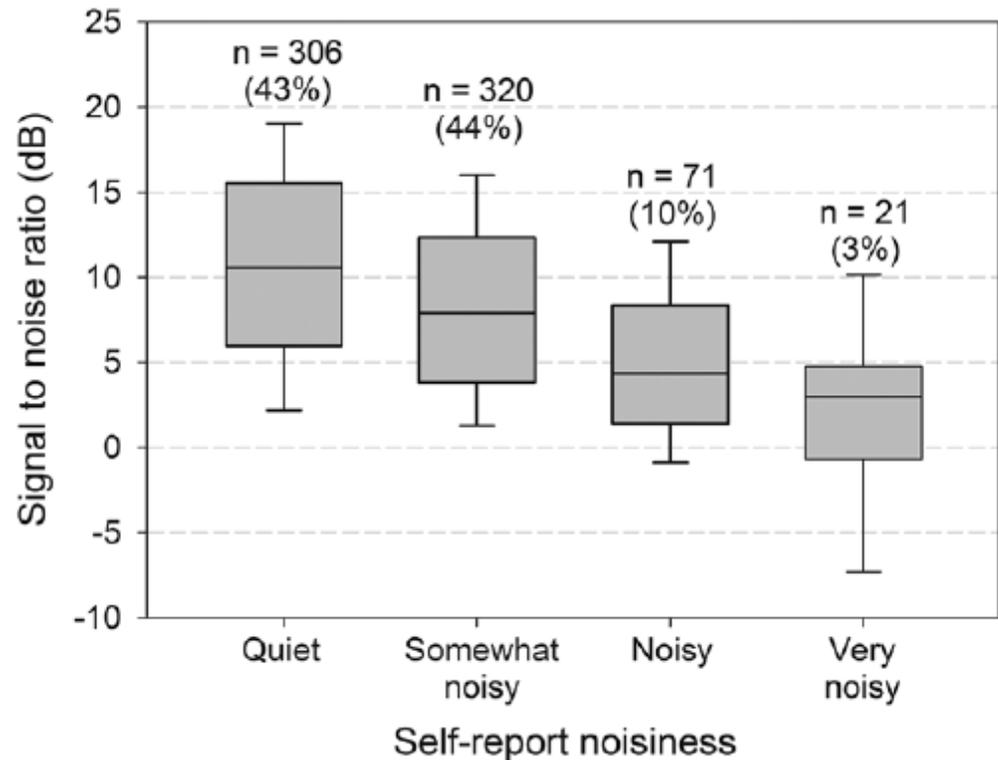
Much poorer tolerance in noise than normal  
 Context does not help

**Subject: 11**

**Age: 74, M, PTA: 65.625, HINT: 9.88, RST: 63**



# COUNSELING OF PATIENTS RE: REALISTIC NOISY SITUATIONS



SNR < 5 dB

10 > SNR > 5

15 > SNR > 10

SNR > 15

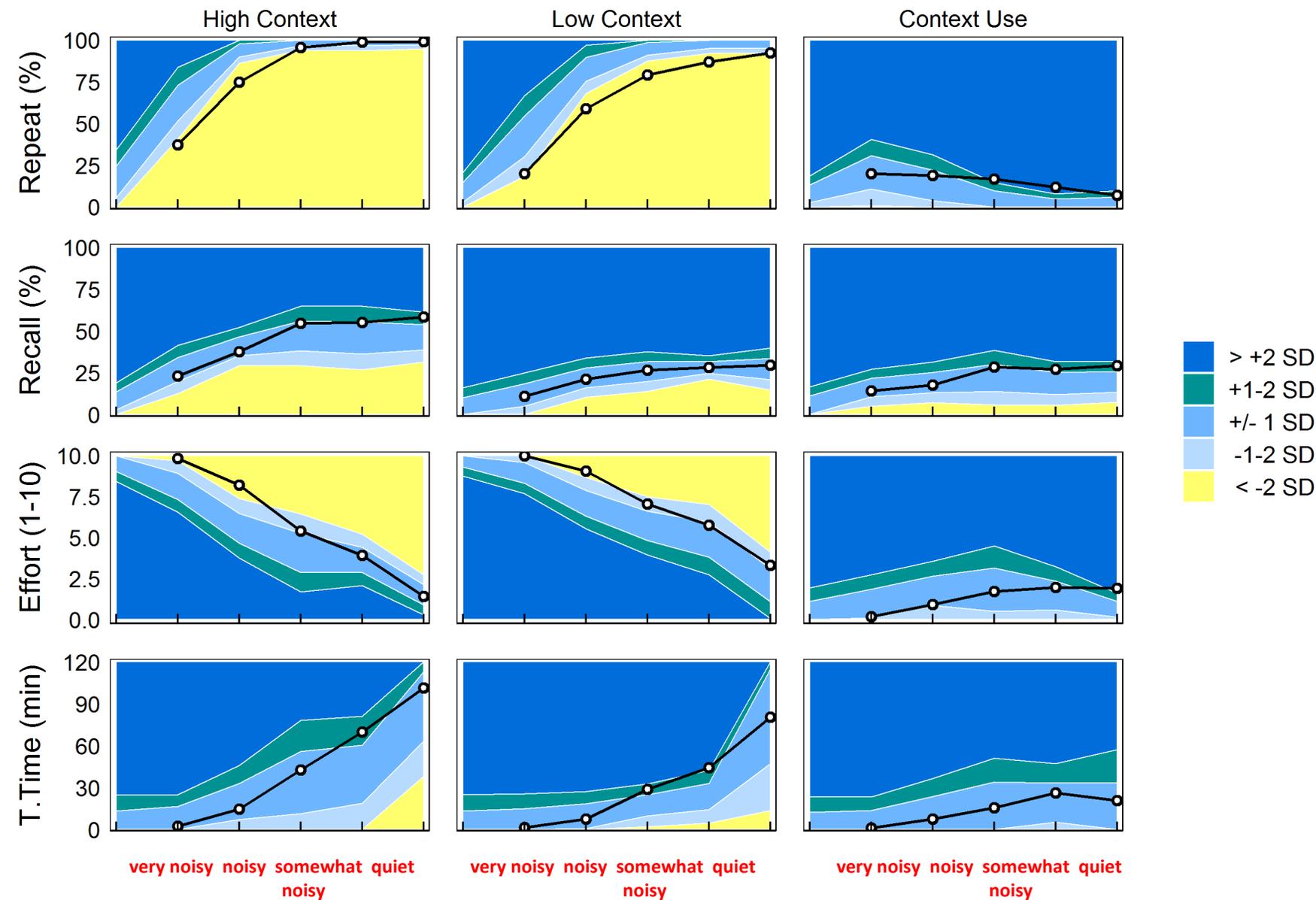
Very noisy

Noisy

Somewhat noisy

Quiet

# COUNSELING HEARING IMPAIRED LISTENERS



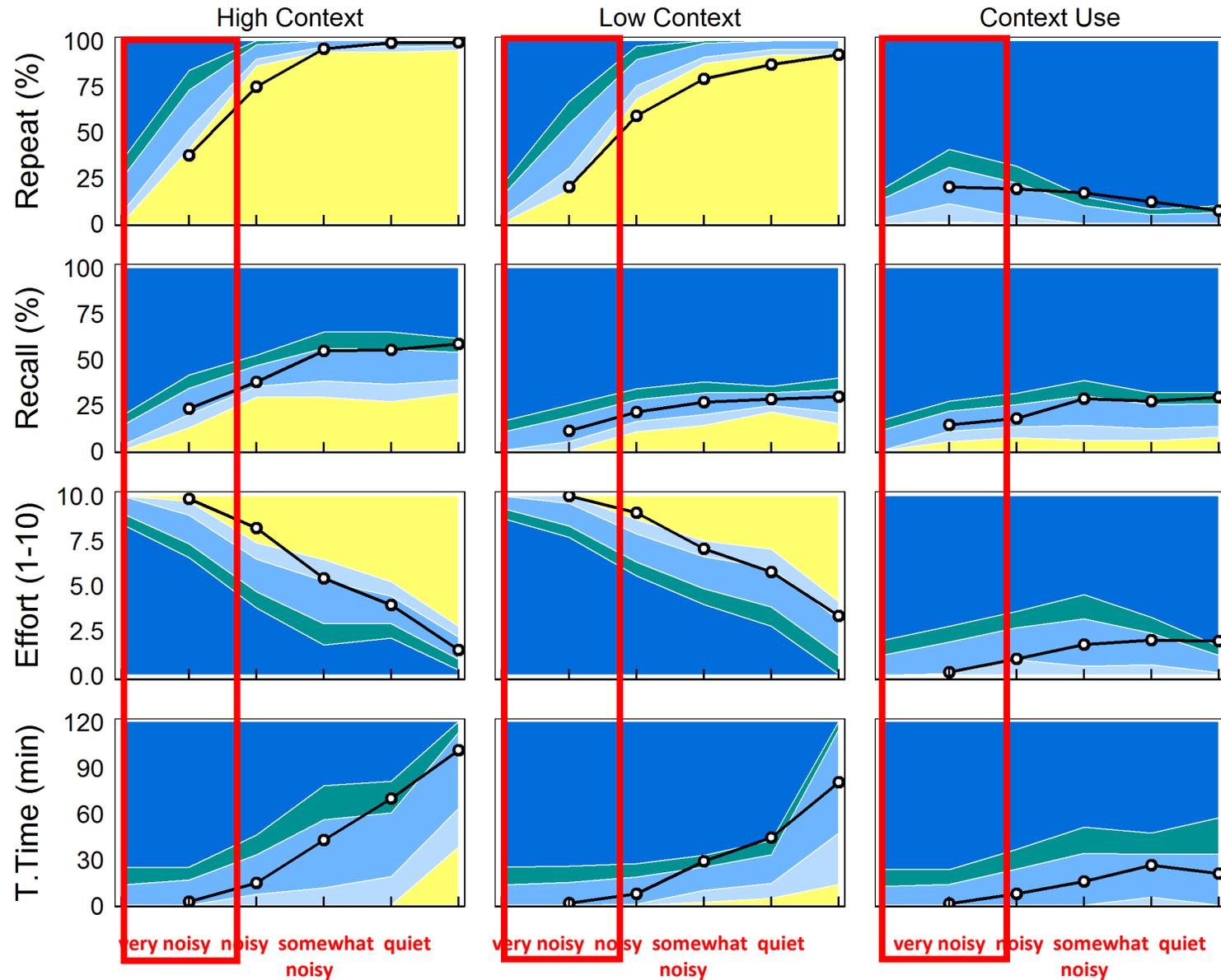
Poorer SIN than normal even in somewhat noisy situations  
Context helps understanding  
Technology to help at poor SNR

Ability to remember gets better when it is quieter, because hears better  
Similar to normal listeners in recall

Slightly more effortful than normal  
Context – reduces effort above “somewhat noisy” situations

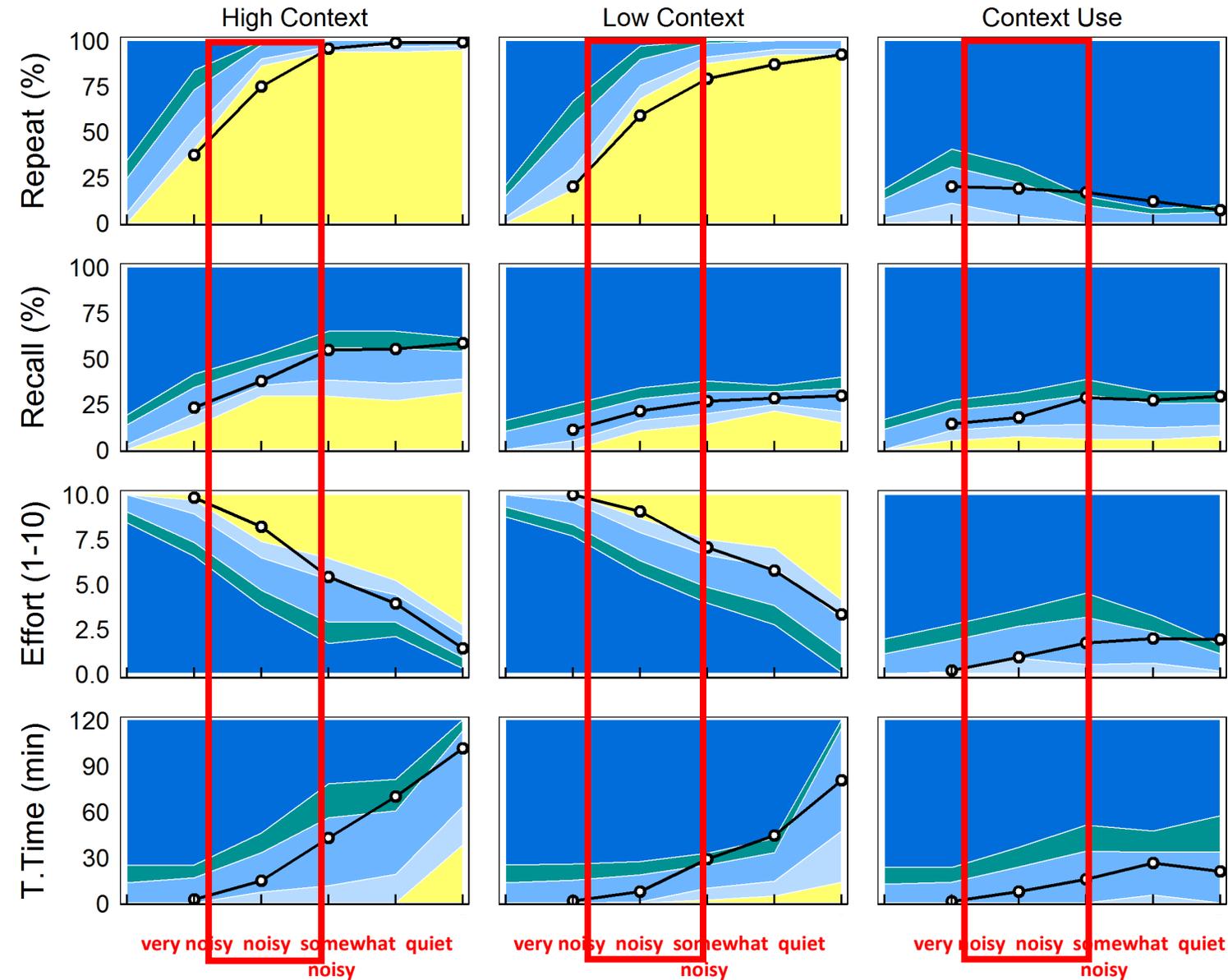
Tolerate less noise than normal when it is “noisy” and “very noisy”; tolerates more when it is “somewhat noisy” or “quiet”

# COUNSELING HEARING IMPAIRED LISTENERS



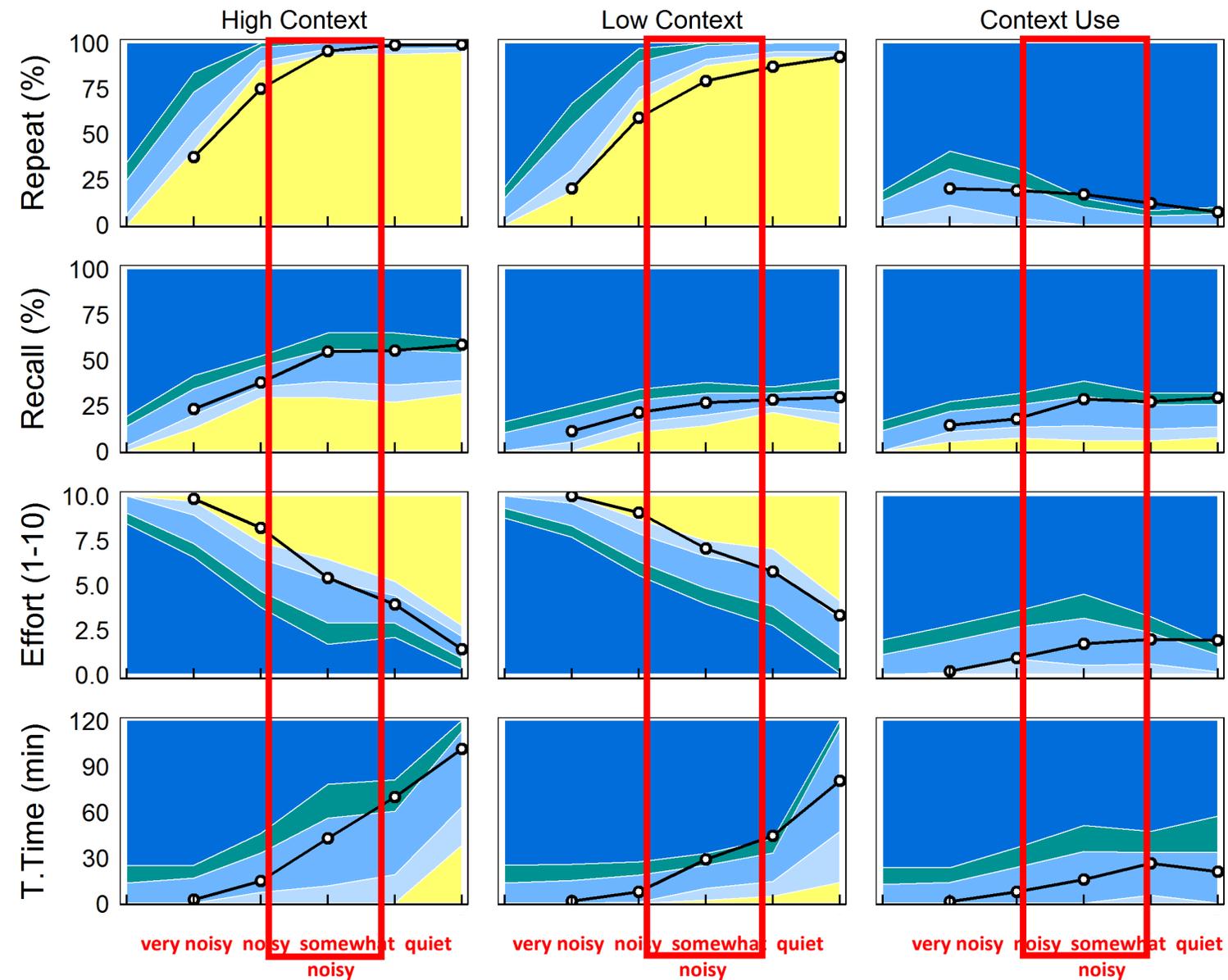
- For **very noisy** situations (noise louder or similar to speech), you understand between 30 and 75% of the conversation, depending on whether you are familiar with the topic/speaker etc. In those situations, noise interferes with your ability to remember what is said in the same way it affects people with normal hearing. To achieve that level of understanding, you have to spend more effort than a normal hearing person would. This makes you feel less willing to stay in that noisy background as someone with normal hearing would.

# COUNSELING HEARING IMPAIRED LISTENERS



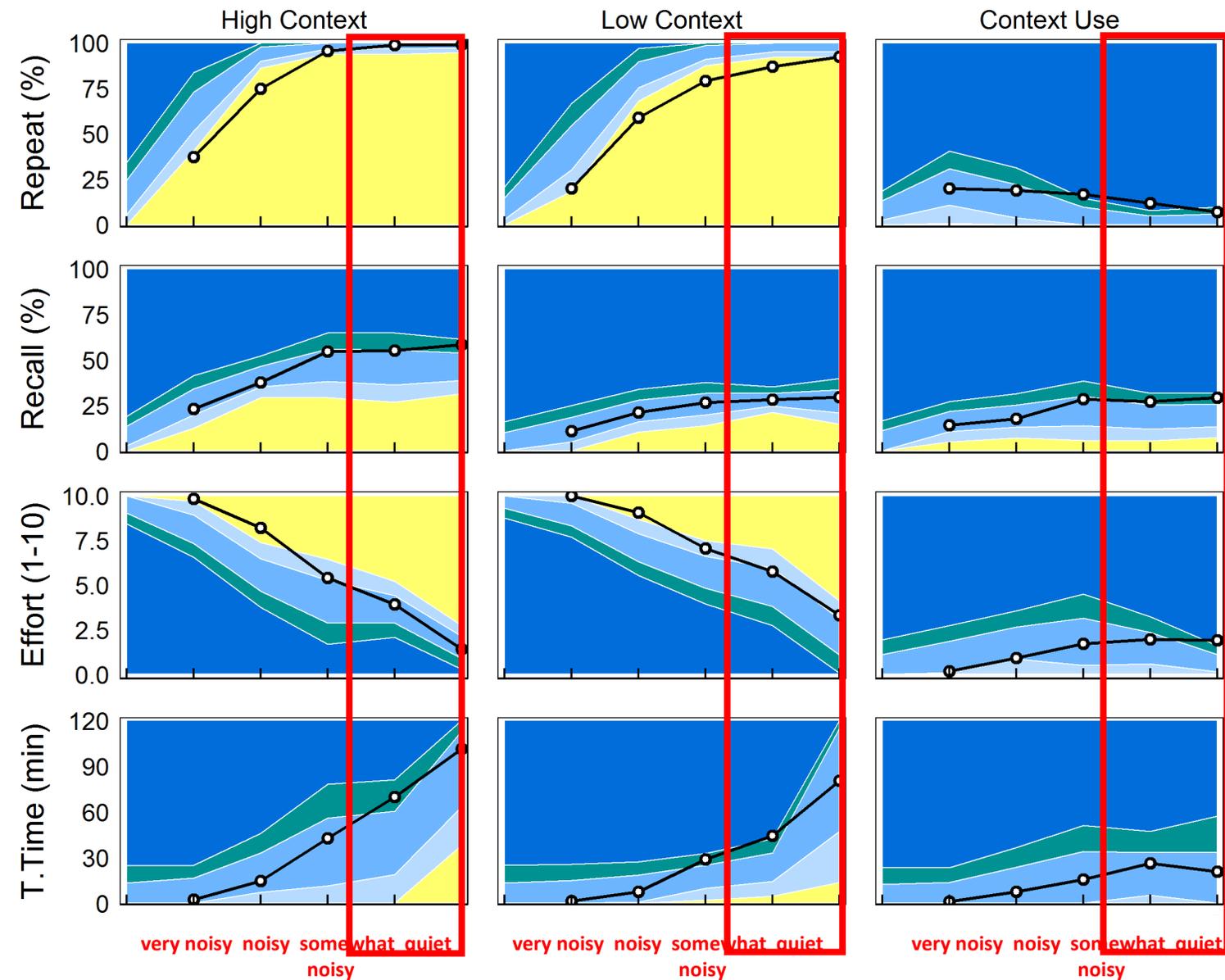
- In a **noisy** situation, where speech is just slightly louder than noise, you understand more – between 50 and 90% of the conversation, depending on whether you are familiar with the topic/speaker etc. In those situations, noise interferes with your ability to remember what is said in the same way it affects people with normal hearing. To achieve that level of understanding, you have to spend more effort than a normal hearing person would. This makes you feel less willing to stay in that noisy background as someone with normal hearing would.

# COUNSELING HEARING IMPAIRED LISTENERS



- In a **somewhat noisy** situation where speech is clearly louder than noise, you understand 75 to 95% of what is said, depending on context. This is pretty good. You are also using less effort than you would in noisier places, and you are more willing to stay longer in that environment, much like a normal hearing person would.

# COUNSELING HEARING IMPAIRED LISTENERS

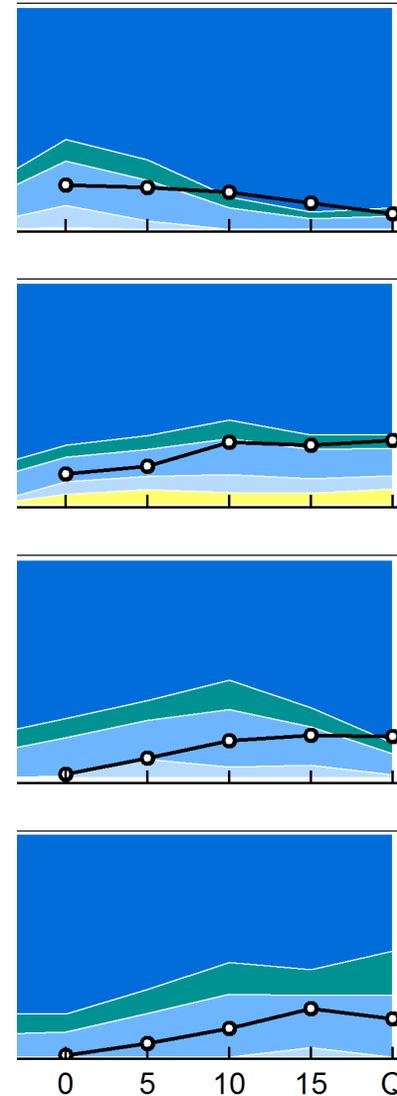


- In a **quiet** environment, you are achieving between 90 and 100% understanding, depending on the context. This is very good and it is similar to what normal hearing people may achieve. We can also see that you spend as much effort as people with normal hearing would in these environments to achieve this performance.
- In all, the hearing aids you are wearing allow you to understand in a similar manner as someone with normal hearing would for quiet and mildly noisy situations. In a noisy and very noisy situation, you are getting very close to what normal hearing people would do, however, you spent more effort to achieve that level of performance. Thus technology to reduce noise in those noisy backgrounds, and means to improve your understanding of the talker, topic of conversation etc would help you in those situations.

# SCRIPT ON EXPLAINING USE OF CONTEXT

- Knowing the context of the conversation helps in our communication. That is, something about what is being talked about. This will help you “fill in” what you may have missed, and/or affirm what you heard. You remember that we tested you with some meaningful sentences and some meaningless sentences. The difference in your performance gives us a sense of how you use context.
- We can see when it is very noisy and noisy, you use a lot of context to understand what you heard to repeat them. But that doesn't help you remember the words, lessen your effort to communicate or willingness to stay longer in those situations. However, as the listening situation becomes less noisy (as in somewhat noisy and quiet), we can see that you use context less to help you understand, but more to help you remember what is said and give you a sense of less effortful to communicate (because you understand) and willingness to stay longer. This is similar to what people with normal hearing does.
- To further improve how well you use context to help in your communication, ask questions to clarify, know in advance what will be discussed, get to know the person better

Context Use



# WHY MAY THE RRT BE USEFUL?

- Audiological & clinically based, ecologically relevant
- Measures 5 separate performances – repeat, recall, context, effort & tolerance (Q&N)
  - Repeat performance in noise correlates with PTA, HINT ( $r = 0.6$ )
  - Recall performance correlates with Reading Span Test ( $r = 0.6$ )
  - Listening effort
  - Tolerable time
  - Context dependence
- Efficiently (< 25 minutes for 5 SNRs)
- Without the appearance of MCI/dementia testing (yet it measures WMC)
- Characterization (or profiling) of patients
  - Comparison with normal sets realistic expectations
  - Pinpoint areas of strength & weakness
  - Direct focus for rehabilitation
  - ?Grouping patients for research
- Comparison between aided and unaided listening, feature differences etc

# PROTOCOL TO PERFORM RRT

- Provide training/practice using HC list at SNR = 15 (more practice, more reliable; may practice more than 1 -2 lists)
- Perform tests at all SNR from 0, 5, 10, 15, and quiet (20 min)
  - Randomize SNR (except SNR = 0 and quiet should not be first)
  - Use a new list for each SNR
  - Use low context list first
  - Then use high context list in same order as low context list
- Compare results with norm

# SUMMARY AND CONCLUSIONS

- Demonstrated trend towards incorporating listening effort and cognition into clinical practice
- Widex continues its innovative spirit in the cognitive arena
  - Continued refinements of Effortless Hearing design
    - Dual variable speed compressor (VSC)
  - Evaluation of potential clinical tools to facilitate clinical practices
    - Tracking of noise tolerance (TNT) test
    - Repeat-Recall Test (RRT)

