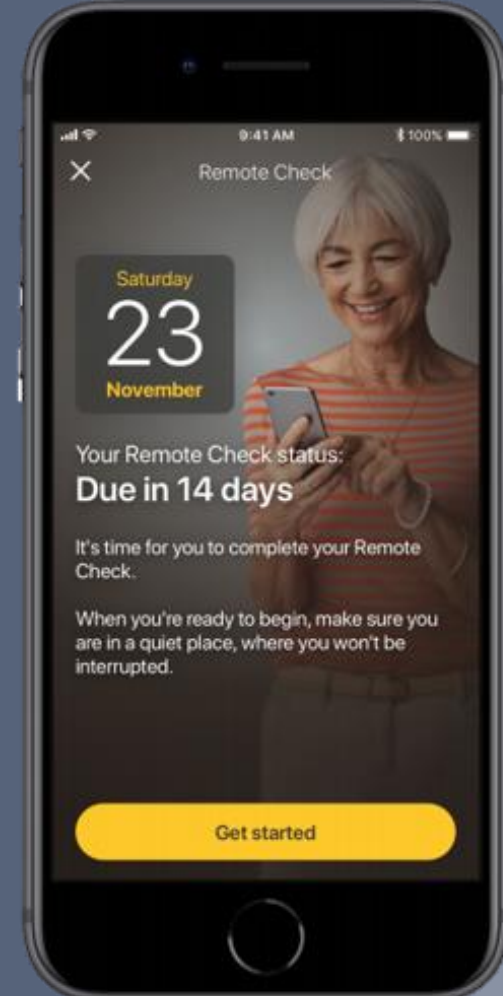


Hear now. And always



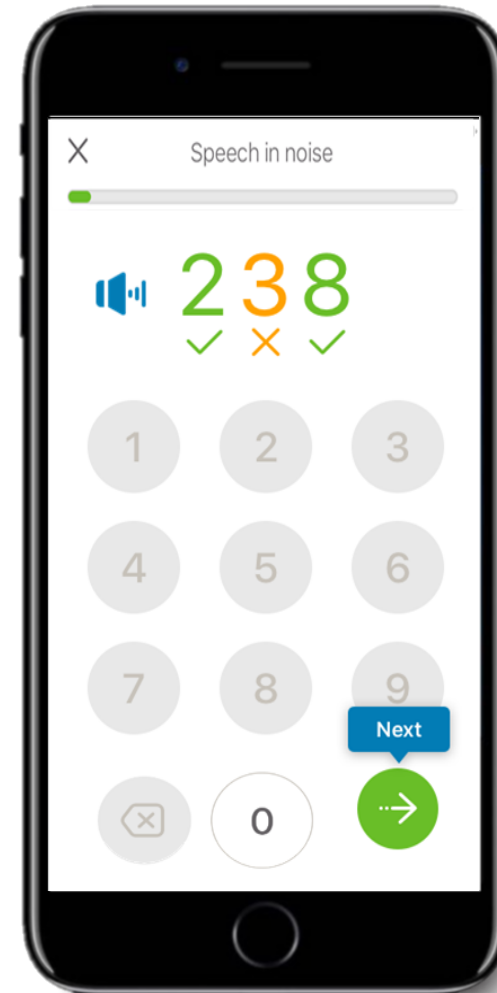
# Use of the Digit Triple Test in CI recipients

Dr Kelvin Hawker  
Senior Marketing Manager Connected Care



# What is the Digit Triple Test (DTT)?

- Developed in the Netherlands (Smits *et al* 2004)
- Subjects are asked to key in 3 digits which are presented randomly in background noise
- The closed-set test is adaptive
- It has been widely used as a screening tool in Adult recipients and validated in many languages and in recipients with cochlear implants
- Ideal for people with limited language ability and children



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# Why is DTT part of Remote Check?

# Introduction to Remote Check

Remote Check was the world's first virtual assessment tool for CI recipients

Allows a routine review to be completed without the need for a clinic visit.

Remote Check is designed to reflect the tasks completed in a routine review

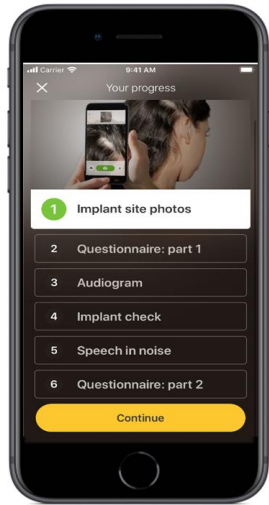
Research has shown it has >98% sensitivity at detecting issues normally picked up in clinic<sup>1</sup>.

The Digit Triple Test is used to measure speech-in-noise performance

Test was chosen due to ease of use, mobile friendly, no ceiling effect, range of languages and not dependent on advanced language ability



# Remote Check activities

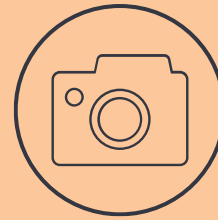


- **Customisable** set of tasks
- Broad coverage of **validated metrics**
- **Real-world insights** and usage data
- **Quick and easy** to complete<sup>1,2</sup>
- Optimised for **patient use**
- **Clinic controlled** feedback

1. Average time for a unilateral recipient to complete a full set of Remote Check activities is 21 minutes. Timing data based on cumulative Remote Check data as at September 2020, captured via the Cochlear Limited Global launch dashboard.

2. Cochlear Limited Global Remote Check Pilot Recipient Evaluation. October 2020.

## Customisable patient tasks



Implant site photos



Questionnaire Part 1



Aided Audiogram



Implant Check



Speech in Noise



Questionnaire Part 2

## Data captured from the sound processor

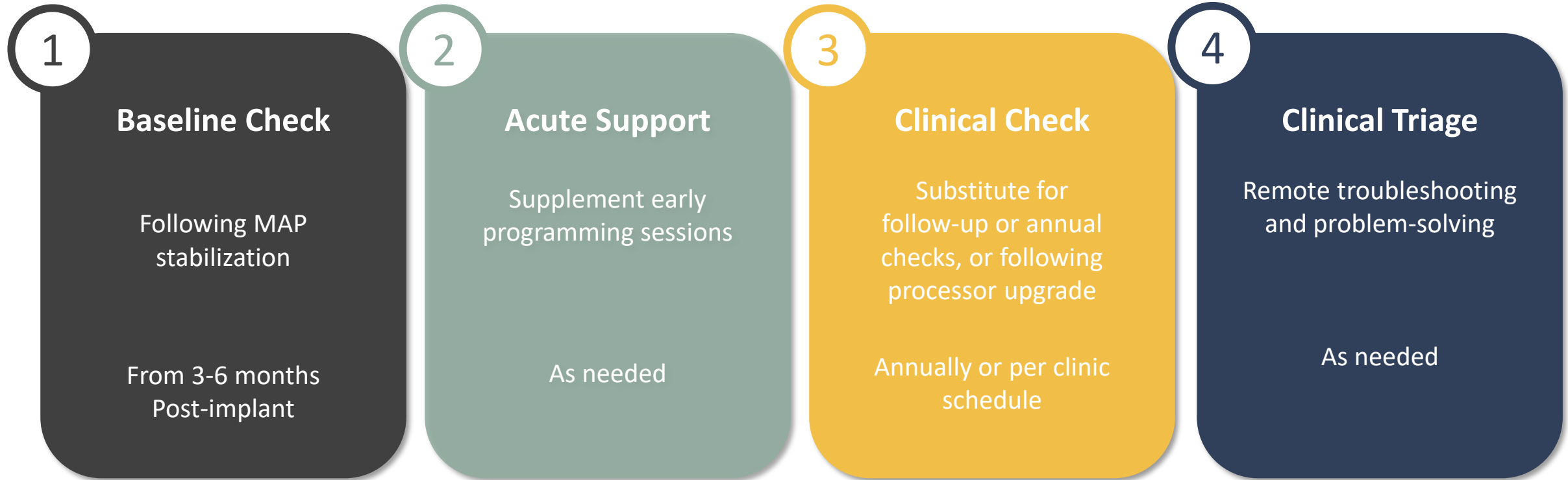


Hardware Health

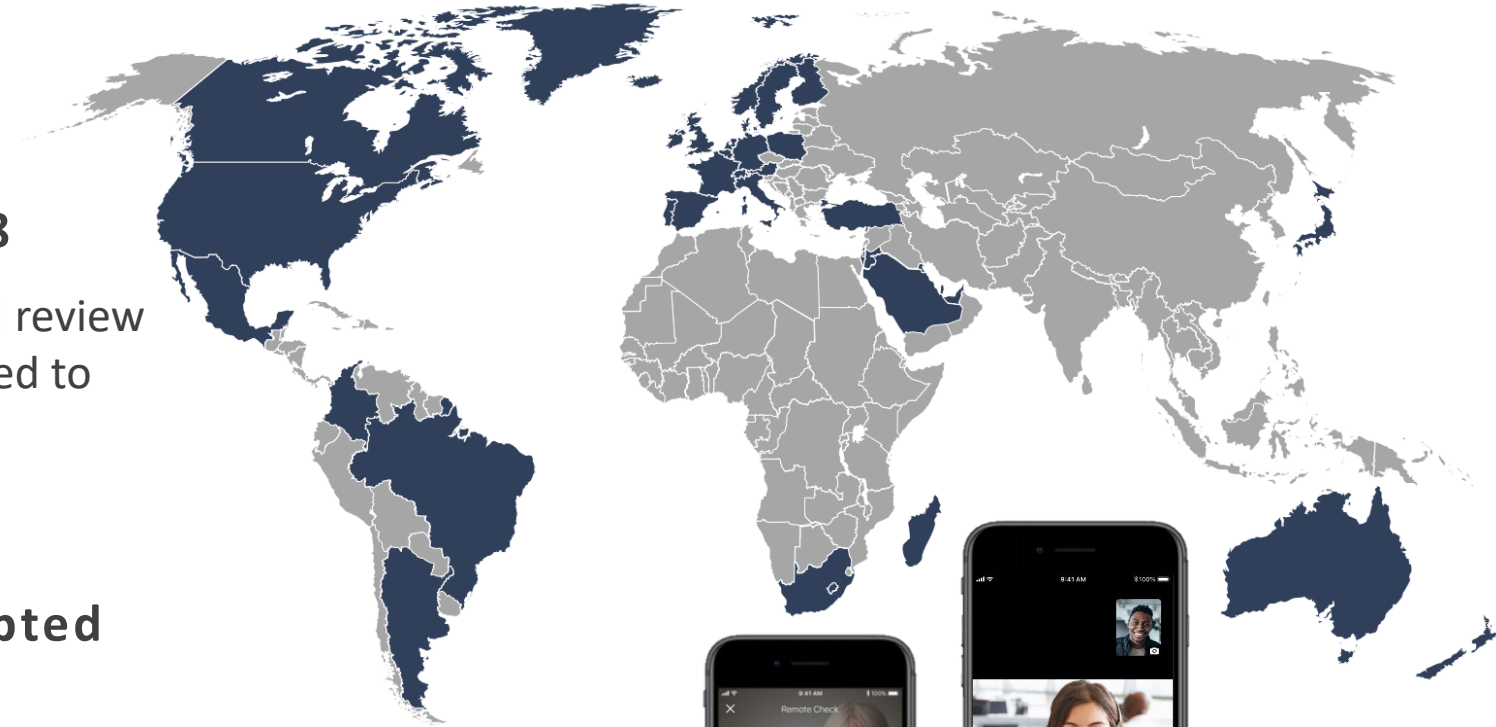


Usage Data

# When to use Remote Check



# Cochlear™ Remote Check is well established across the Globe



## Remote Check was launched in 2018

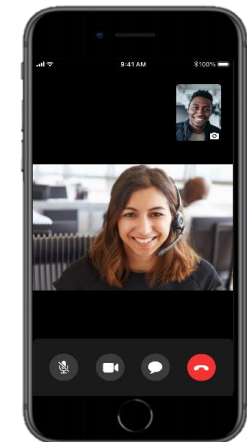
The **first of its kind** that allows a routine clinical review to be completed by a CI patient without the need to visit the clinic

## Remote Check has been widely adopted across the Globe

Now used by **hundreds** of clinics, with **tens of thousands** of patients enrolled and available in **36** countries



Remote Check



Remote Assist

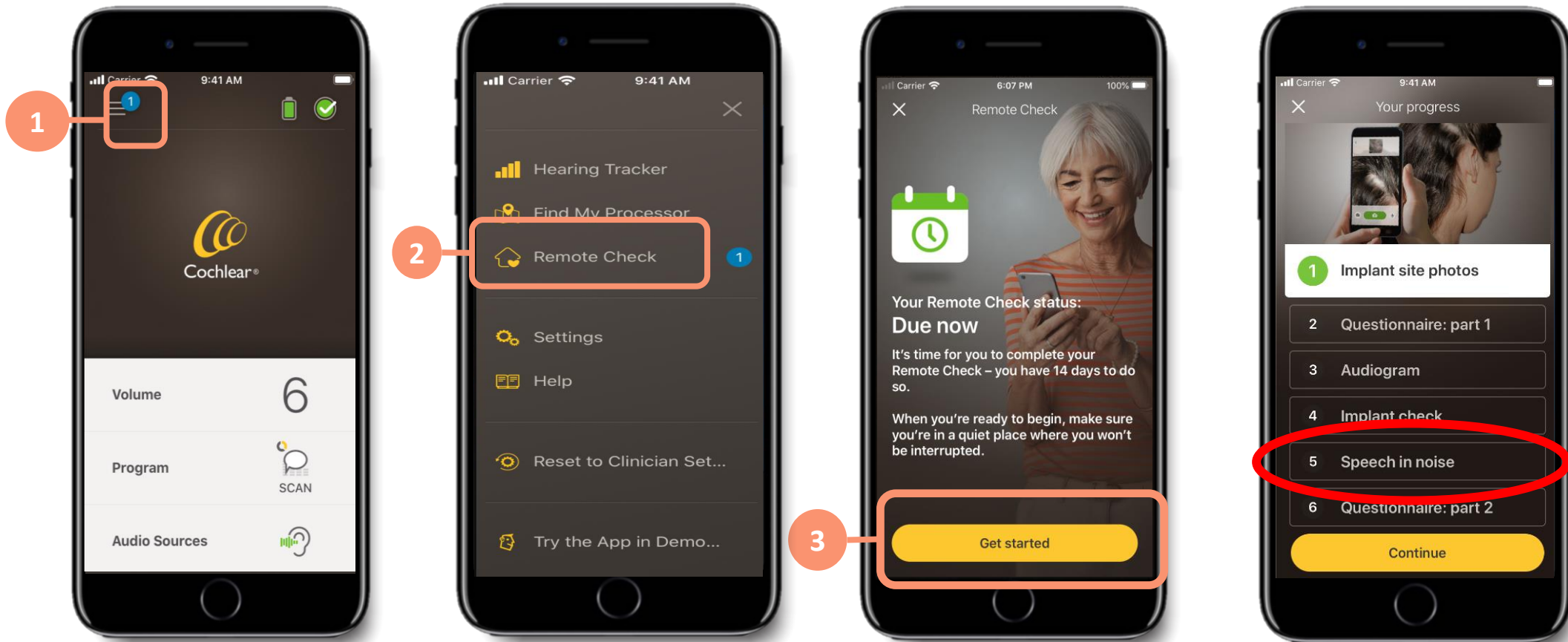
Hear now. And always



# DTT use in Remote Check



# Accessing Remote Check in the Nucleus® Smart App



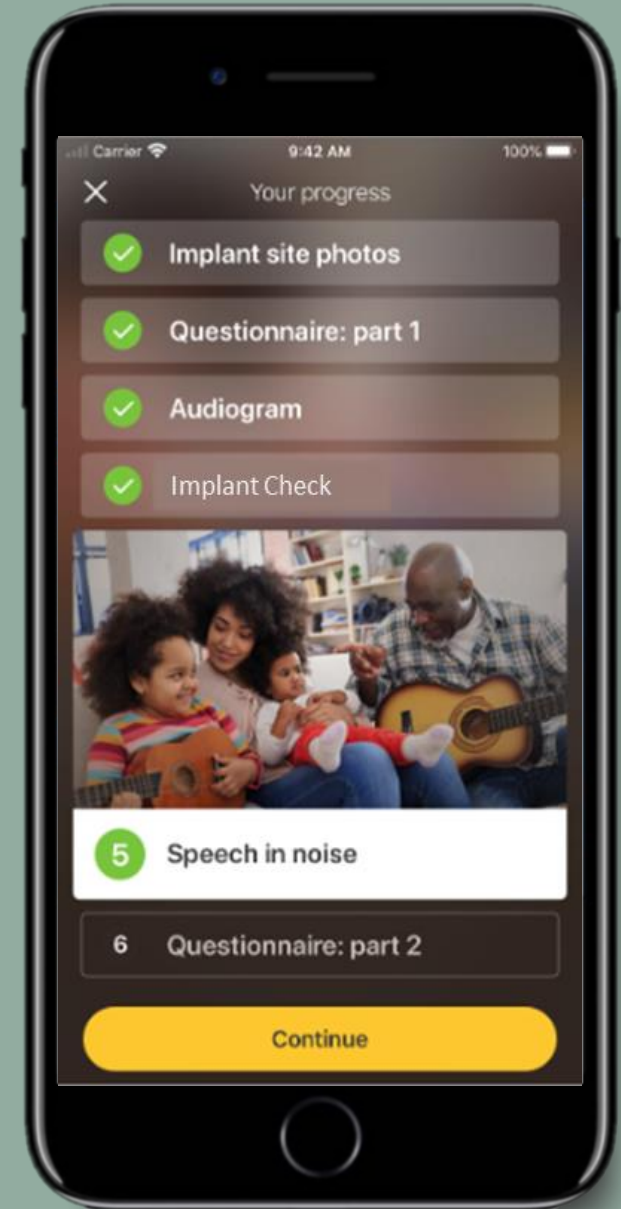
# Speech in Noise

- Patients take the well-established **Digit Triplet Test (DTT)** <sup>1</sup>
- Purpose is to assess and monitor changes **in hearing ability in noise**
- During testing, the digits are **directly streamed** to the sound processor, eliminating external background noise
- A **practice mode** is provided to train patient responses
- Digits are easily understood making it **suitable for many patients** including children<sup>2,3</sup>

1. Smits C, Kapteyn, TS, Houtgast T. Development and validation of an automatic speech-in-noise screening test by telephone. *International journal of audiology*. 2004. 43(1), p.15–28

2. Cullington HE, Aidi T. Is the digit triplet test an effective and acceptable way to assess speech recognition in adults using cochlear implants in a home environment?. *Cochlear implants international*. 2017 Mar 4;18(2):97-105

3. Kaandorp MW, Smits C, Merkus P, Govers ST, Festen JM. Assessing speech recognition abilities with digits in noise in cochlear implant and hearing aid users. *International journal of audiology*. 2015 Jan 2;54(1):48-57. D1817702 V3 2022-02

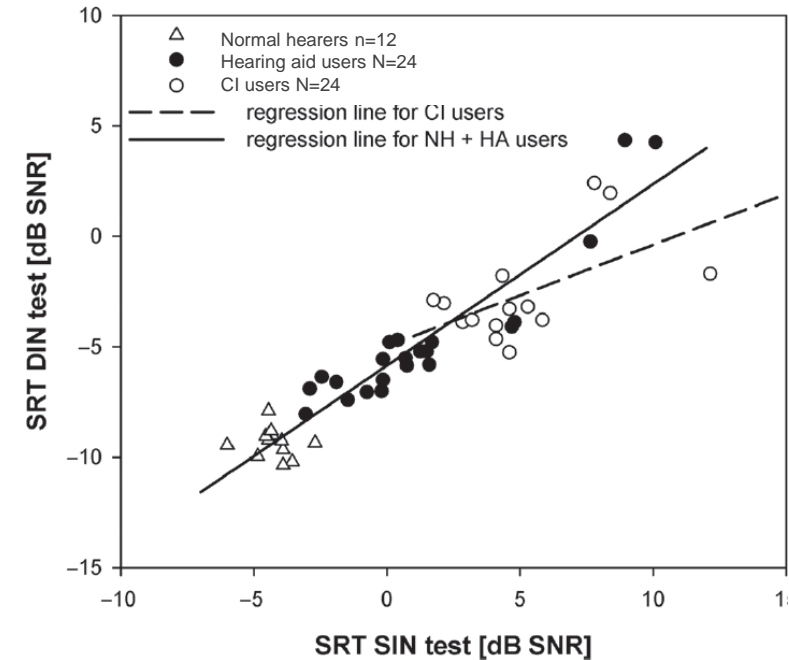


# Digit Triplet Test suitability

- Proven to be **clinically sensitive**<sup>1,2</sup> with minimal learning effects<sup>3</sup>
- **High test-retest reliability** and sensitivity in detecting hearing loss<sup>4</sup>
- **Well correlated** with other speech in noise tests including BKB sentences<sup>5,6</sup>
- **Simple in both design and user instructions** suitable for recipient remote use<sup>7</sup>
- Applicable for a **broad range of patients** including children<sup>8</sup>

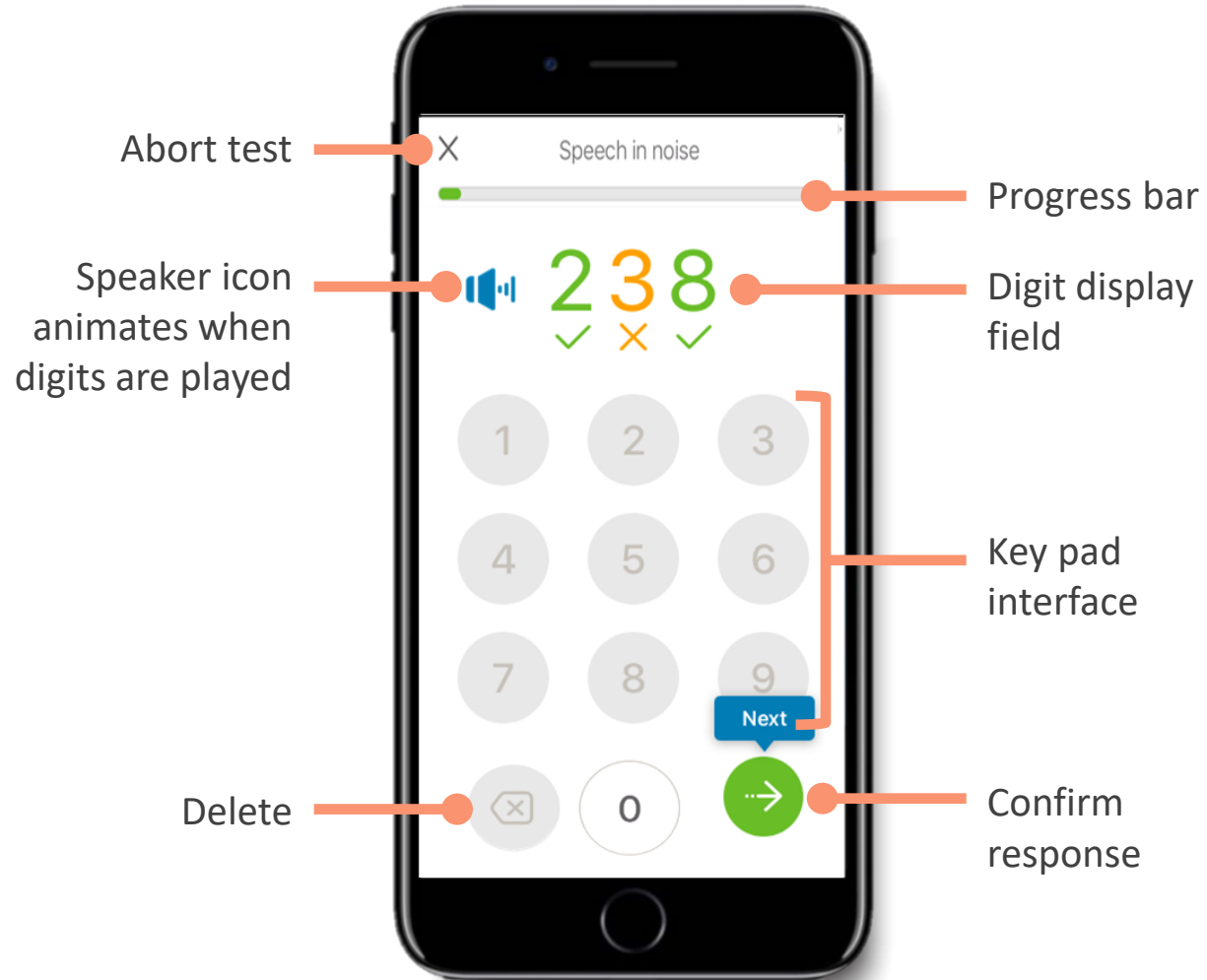
DTT for different groups of adult subjects

Kaandorp et al, 2015



1. Smits C, Houtgast T. Results from the Dutch speech-in-noise screening test by telephone. *Ear and hearing*. 2005 Feb 1;26(1):89-95.
2. Smits C, Kapteyn TS, Houtgast T. Development and validation of an automatic speech-in-noise screening test by telephone. *International journal of audiology*. 2004 Jan 1;43(1):15-28.
3. Kaandorp MW, Smits C, Merkus P, Goverts ST, Festen JM. Assessing speech recognition abilities with digits in noise in cochlear implant and hearing aid users. *International journal of audiology*. 2015 Jan 2;54(1):48-57.
4. Watson CS, Kidd GR, Miller JD, Smits C, Humes LE. Telephone screening tests for functionally impaired hearing: Current use in seven countries and development of a US version. *Journal of the American Academy of Audiology*. 2012 Nov 1;23(10):757-67.
5. Cullington HE, Aidi T. Is the digit triplet test an effective and acceptable way to assess speech recognition in adults using cochlear implants in a home environment?. *Cochlear implants international*. 2017 Mar 4;18(2):97-105.
6. Jansen S, Luts H, Wagener KC, Kollmeier B, Del Rio M, Dauman R, James C, Fraysse B, Vormès E, Frachet B, Wouters J. Comparison of three types of French speech-in-noise tests: A multi-center study. *International Journal of Audiology*. 2012 Mar 1;51(3):164-73.
7. De Sousa KC, Swanepoel DW, Moore DR, Smits C. A smartphone national hearing test: Performance and characteristics of users. *American Journal of Audiology*. 2018 Nov 19;27(35):448-54.
8. Smits C, Theo Goverts S, Festen JM. The digits-in-noise test: Assessing auditory speech recognition abilities in noise. *The Journal of the Acoustical Society of America*. 2013 Mar;133(3):1693-706.

# Digit Triplet Test (DTT)



## DTT set up and scoring

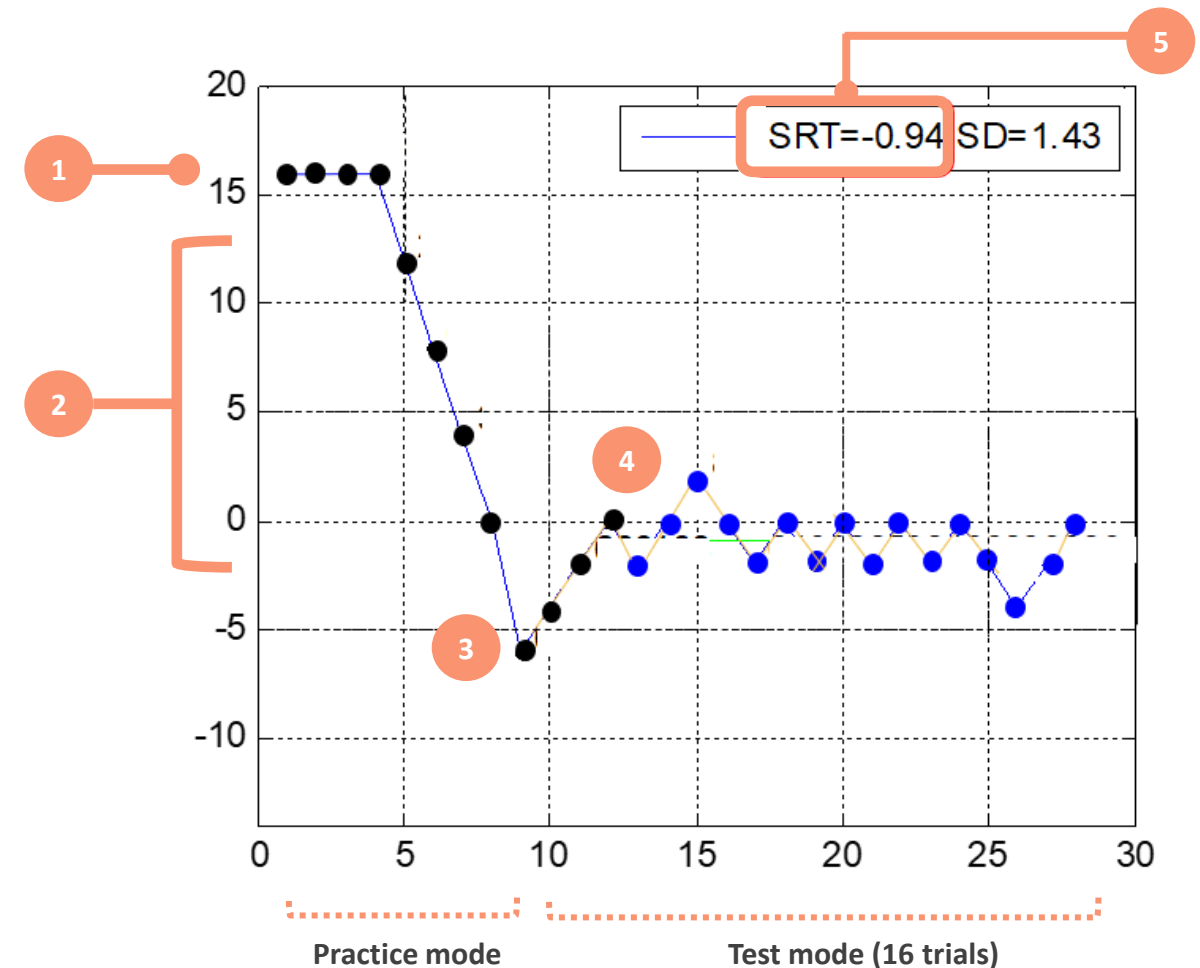
- Digit triplets are presented at **different signal-to-noise ratios (SNR's)** to estimate a patient's **speech reception threshold (SRT)**
- Fixed presentation level of **65 dB** is maintained
- A **non-modulated masking noise** is used created with the same average spectrum of digits
- The **practice mode** must be passed in order to move on to the test mode
- Results are reported as a **Speech Reception Threshold (SRT)** in dB SNR
- **'Participant's responses unreliable'** will be reported if results are inconsistent after one repeat



# Speech in Noise test

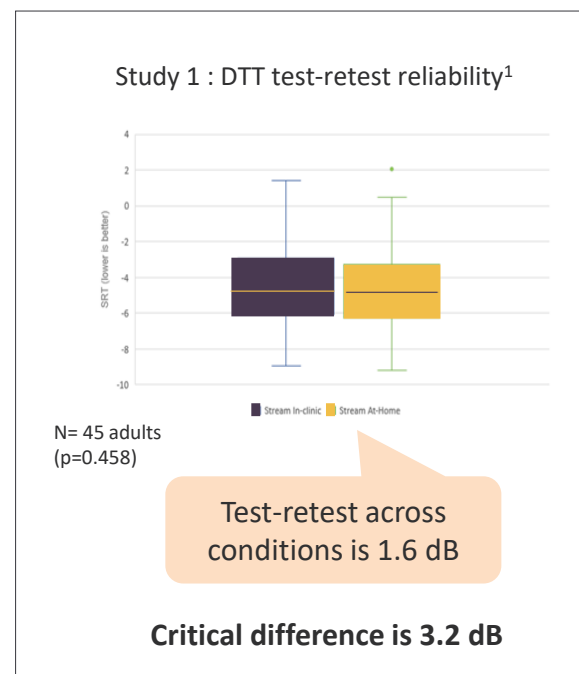
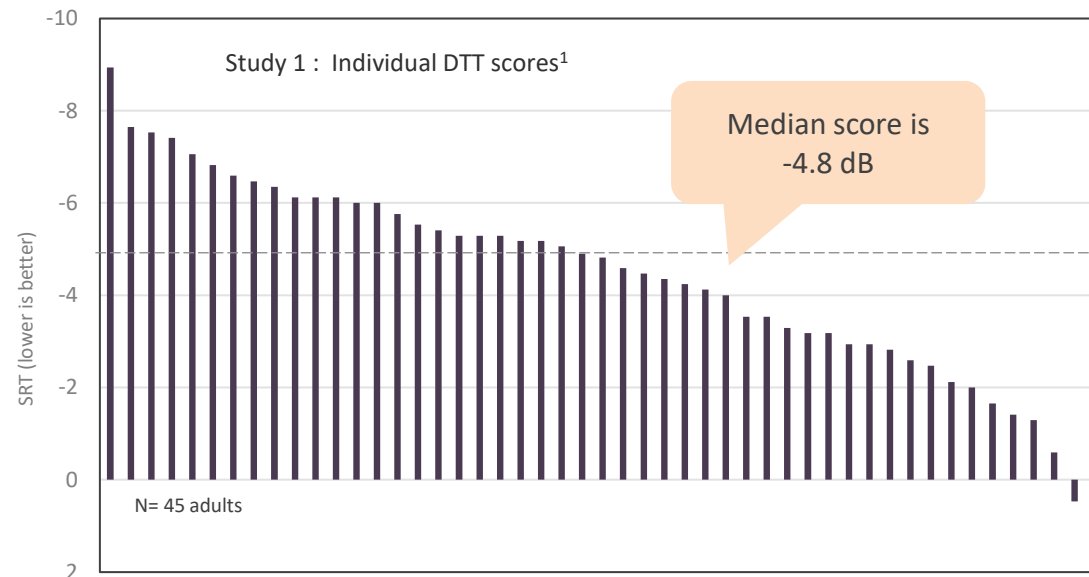
Uses an adaptive procedure where the SNR is varied per triplet and an averaged SNR over 16 presentations is calculated

- 1 Practice mode starts with 4 triplets at an easy SNR
- 2 Next 4 triplets presented at an adjusted SNR
- 3 If training is reliable, the test mode is started. Beginning at -6dB, the first triplet is repeated to determine the starting SNR for testing (does not count in scoring)
- 4 Test commences with two sets of 8 triplets with a short break between (counts towards scoring)
- 5 16 trials are averaged to give a final SRT score



# Remote Check test results

- Individual DTT scores show a **spread across a range** of performance
- In one study the **median** DTT score was **-4.8 dB for adults**, while in another the **mean SRT was -4.3 dB for adults and -4.5 dB for children**
- A comparison of in-clinic vs at home DTT scores showed a **non-significant SRT difference of 1.6 dB**
- The one tail **critical difference was 3.2 dB** at the 95% confidence limit
- Findings suggest DTT results in-clinic can be **reliably replicated by patients remotely**



Study 2 : Average DTT scores in dB<sup>2</sup>

Group	Mean SRT	SNR range
Adults (n=66)	-4.3	-11.2 to 11.6
Children (n=18)	-4.5	-10.3 to 8.5

N= 84 subjects

1. Cochlear Limited. D1698858 Evaluation of Remote Care App and Nucleus Smart App with CP1000 sound processor (CLTD5704) Clinical Investigation Report. 18 Mar 2020.

2. Cochlear Limited. D1591643 Evaluation of test battery for remote monitoring (CLTD5654) Clinical Investigation Report. 28 Feb 2020.

# Reviewing speech-in-noise results



Review SRT's for each ear noting the degree of change since previous test

1

The change in score from previous test is reported under the SRT

Indicates the patient's responses were unreliable on this side

2



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# Determining the relationship and reliability of the Digit Triple Test in Cochlear™ Remote Check with routine clinical tests.

*A collaborative study in partnership with the National Acoustics Laboratory*

# Situation



CLINICIANS ARE UNSURE HOW TO INTERPRET THE DTT



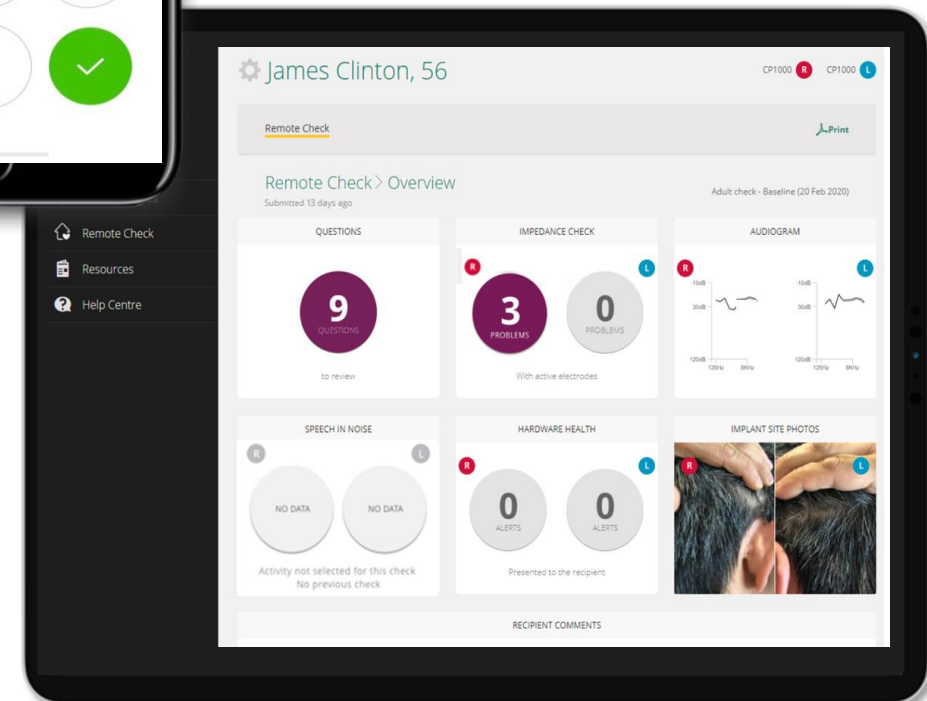
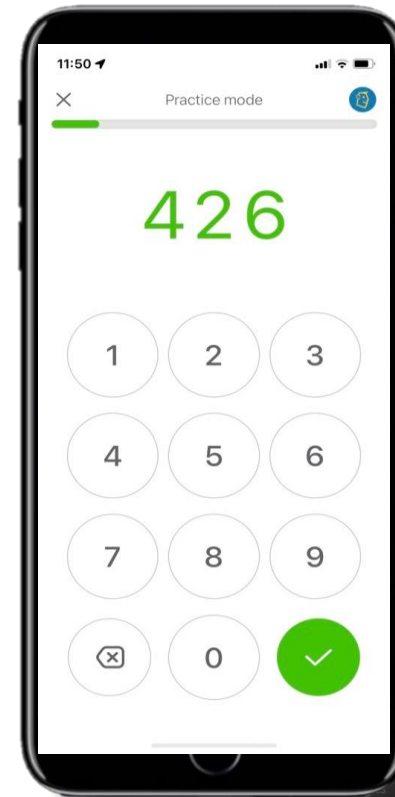
THERE IS A NEED TO SHOW HOW DTT SCORES RELATE  
TO OTHER CLINICAL SPEECH TESTS



CAN THE DTT BE USED TO ASSESS LONG-TERM OUTCOMES?

# Objective

To investigate the relationship between scores on the Remote Check Digit Triple Test and routine clinical tests such as CNC, AuSTIN and LIT and assess its reliability within and across appointments.



# Situation

## 25 Adult CI users were invited

17 unilateral, 8 bilateral

Age >18 years (mean = 50 years)

## A repeated, within-subject design

Each participant acted as their own control to accommodate for the wide variability in outcomes of the population

## Inclusion Criteria

Compatible implant and Sound Processor

Loaned a compatible smartphone with Nucleus Smart App/ Remote Check

## Two appointment design

DTT was presented via the mobile device which replicated Remote Check

# Study Procedures

## Appointment 1

Aided Audiogram



DTT via Remote Check



CNC word test: 65 db SPL free-field



AuSTIN sentence in noise (4 talker babble)



LIT-AD discrimination (non-sense syllables)



DTT via Remote Check

2 weeks

## Appointment 2

DTT via Remote Check

# Results: DTT Test Re-test reliability

## DTT scores

### Mean thresholds:

Appointment 1 Run 1	-4.83 dB (SD = 2.09)
Appointment 1 Run 2	-5.55 dB (SD = 1.98)
Appointment 2	-5.72 dB (SD = 1.63)

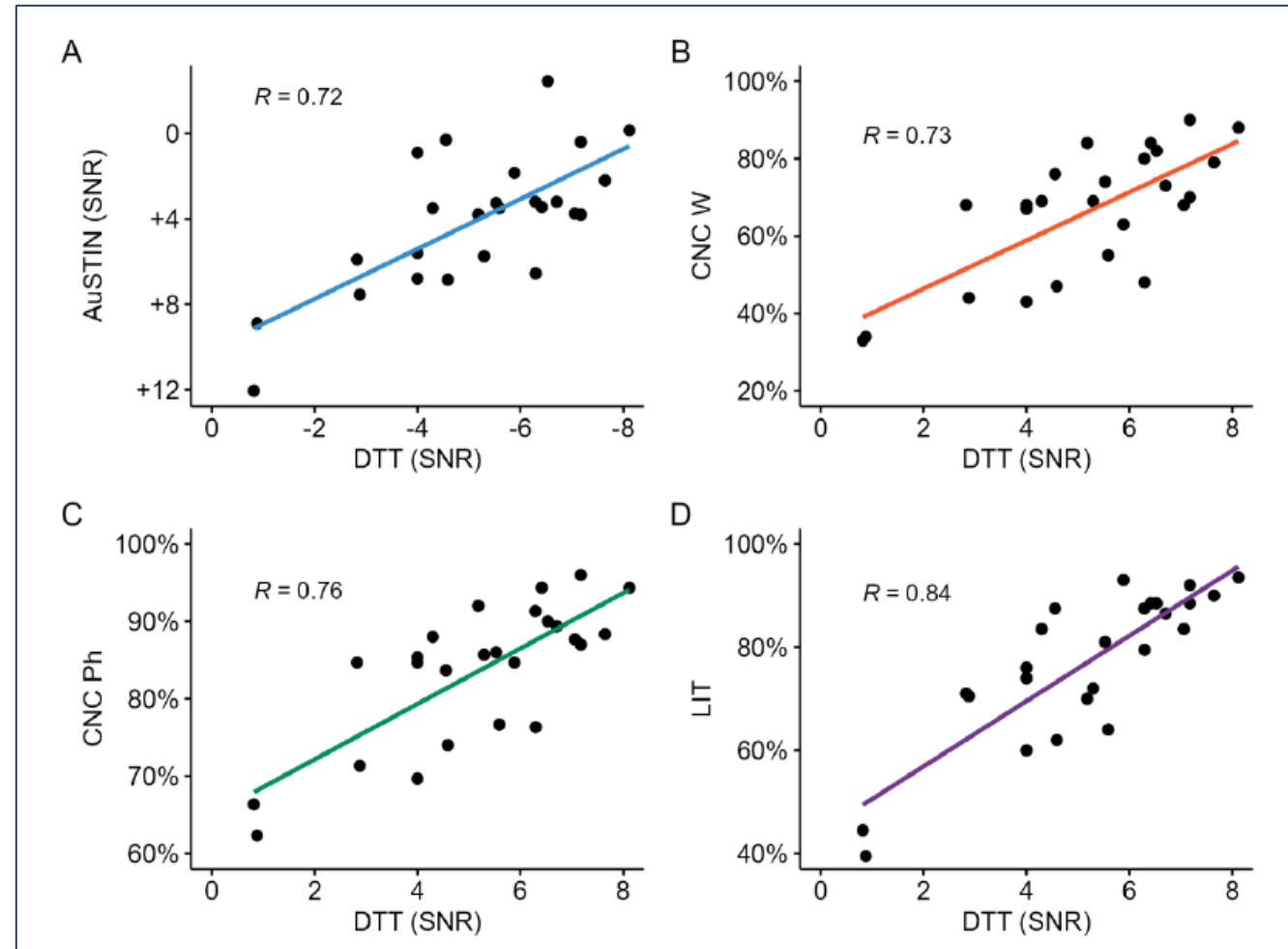
### Mean absolute test-retest difference was

Appointment 1 (run 1 vs run 2)	0.71 dB (SD = 1.29)
Appointment 1 vs 2 (run 1 vs run 3)	0.89 dB (SD = 1.23)

Analysis showed that test-retest agreement was similar regardless of the level of performance.  
The DTT could detect differences in scores as small as 2.62 dB (critical difference)

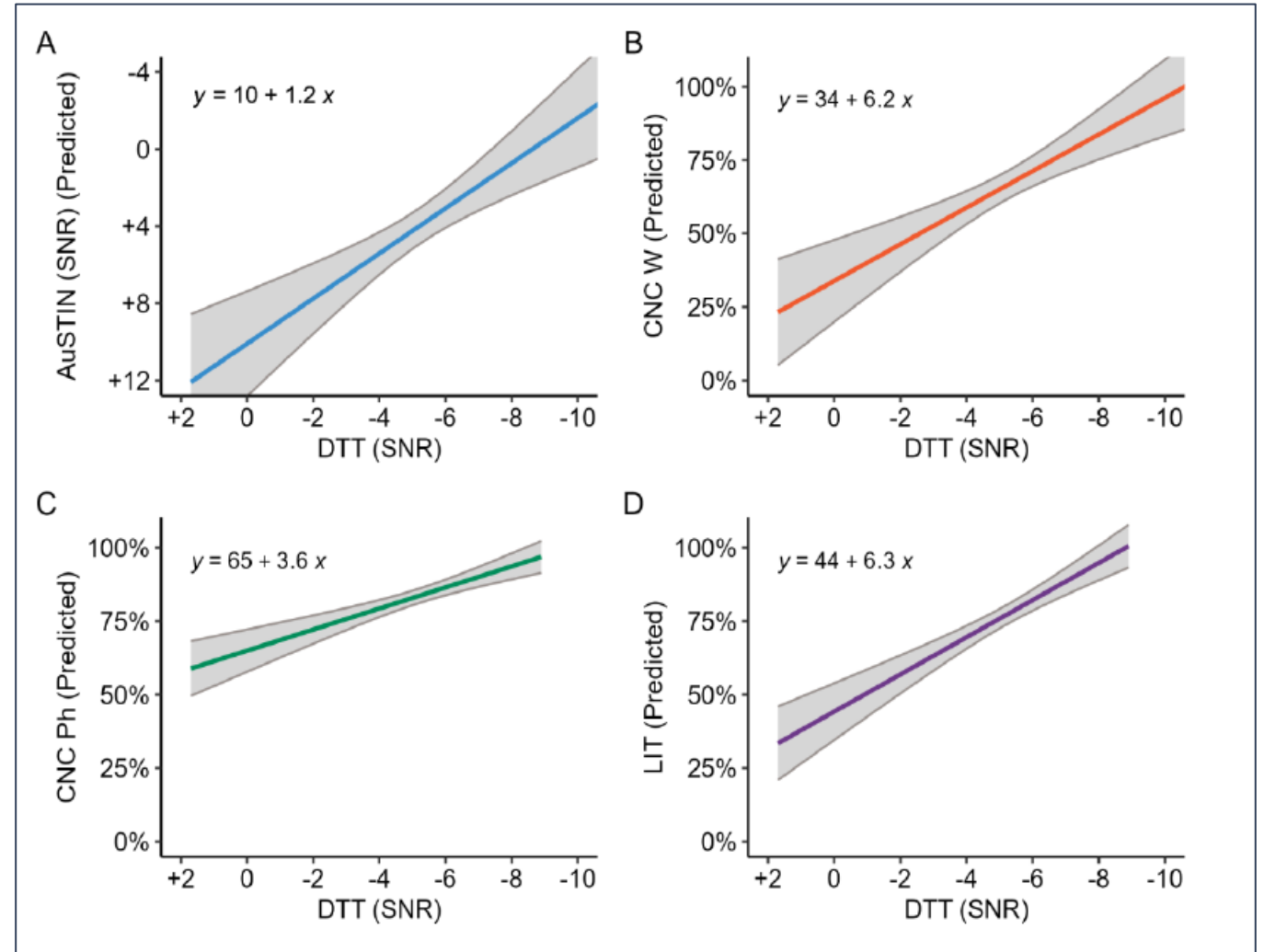
# Results: Correlation between DTT scores and Speech scores

There was a strong correlation between DTT scores and all clinical speech tests used in this study



# Results: DTT as a predictor of clinical speech scores

Clinical speech scores can be predicted using DTT scores with 95% confidence levels





# Conclusions

## Reliability

Participant DTT scores were reliable both within and across appointments

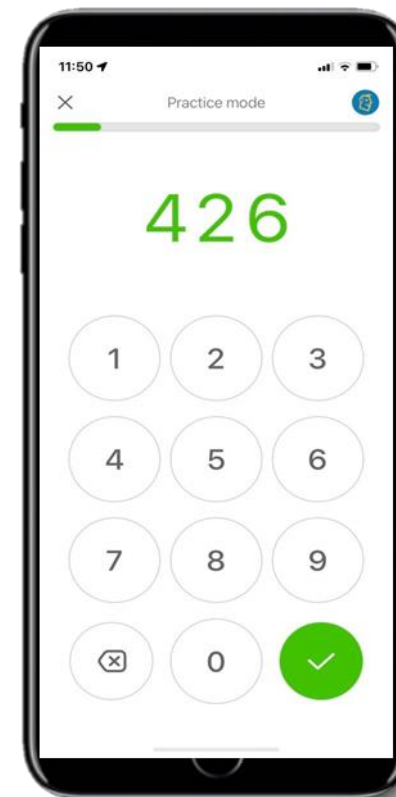
Based on reliability assessments, it is possible that the DTT could be used to detect a difference in score of as small as 2.6 dB (one-tailed 95% critical difference)

Simulations of test performance did not identify any changes to the methodology that could significantly improve reliability further without increasing the number of test trials

## Correlation with Clinical Assessments

DTT scores were correlated with standard clinical assessments (i.e. AuSTIN, CNC Words, and LIT), and the correlation appeared to be strongest with word and phonemic tests

Participant's DTT scores can be used to predict their performance on standard clinical assessments and changes in their DTT can be related to equivalent changes on standard clinical assessments to aid clinical interpretation



# Summary

- The DTT within Remote Check offers good test-retest reliability
- There is a strong correlation between DTT scores and clinical speech tests
- The DTT score can be used as a predictor of commonly used speech scores such as CNC



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Any questions?



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# Disclaimers



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