The Effect of Stimulation Rate and Number of Maxima on Music and Speech Perception for CI patients

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Background & Literature

- Cochlear Implant (CI) Research
  - Well documented as a hearing prosthesis for profound hearing loss[1]
  - Speech focused due to primary goals in CI design targeting speech and language perception
  - Speech perception outcomes able to be reasonably good[2]
  - Limited studies on CI music perception and effects of CI parameters on music perception

Quick refresher on CI parameters..

- Stimulation rate
  - Rate of electrical pulses delivered to the auditory nerve from the implant
- Number of Maxima
  - Number of peaks selected from all the active channels to deliver the impulses through based on the Advanced Combination Encoding (ACE) algorithm

Background & Literature (cont'd)

- Key studies on stimulation rate & maxima for CI recipients
  - Arora et al (2009)
    - Overall best speech performance with stimulation rate between 500Hz to 900Hz when testing 275Hz/350Hz/500Hz/900Hz[3]
  - Plant et al (2002)
    - Overall best speech performance at 8 maxima and no further improvement with further increase when testing 6/8/12/16 maxima[4]
  - Kang et al (2009)
    - Pitch discrimination intervals average around three semitones but range from one to 8 semitones[5]

Research Question

- Can we improve speech and music perception by changing the stimulation rate and number of maxima?

Method

- Participants
  - 5 Singaporean bilateral/bimodal CI users aged 16 to 57
  - Cochlear Nucleus 5/Nucleus 6 processor w/ 6 months experience
  - CI24M or later electrode array w/ minimum 20 intra-cochlear electrodes in use
  - English-speaking
  - ACE strategy

Method (cont'd)

- Three Test Conditions
  - Base
    - Stimulation Rate = 720Hz
    - Maxima = 8
  - High Rate Condition (HRC)
    - Stimulation Rate = 1800Hz
    - Maxima = 8
  - High Maxima Condition (HMC)
    - Stimulation Rate = 720Hz
    - Maxima = 20

Method (cont'd)

- Test Battery
  - Music Perception Tests
    - University of Washington – Clinical Assessment of Music Perception (UW-CAMP)
      - Pitch ranking task
    - Music Quality Rating Test (MQRT)
      - Subjective music ratings
  - Speech Perception Tests
    - CNC50
      - Monosyllabic words in quiet
    - Australian Speech Test in Noise (AuSTIN)
      - Open-set sentences in noise

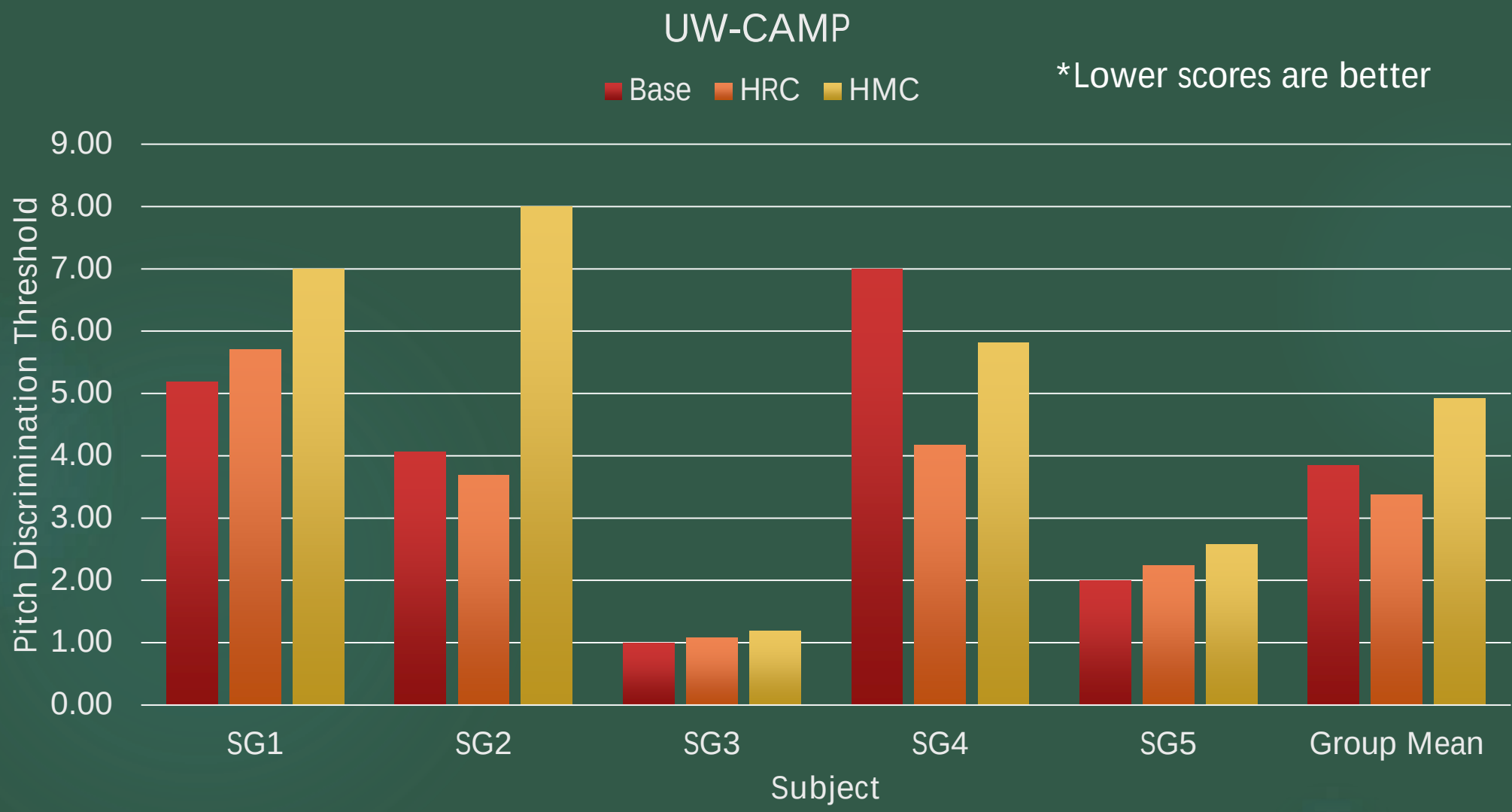
Method (cont'd)

- Reading Span Test
  - Verbal working memory to check if working memory affected perceptive test results
- Music Background Questionnaire
  - Gather information on formal music training, self-rated music ability and music listening habits

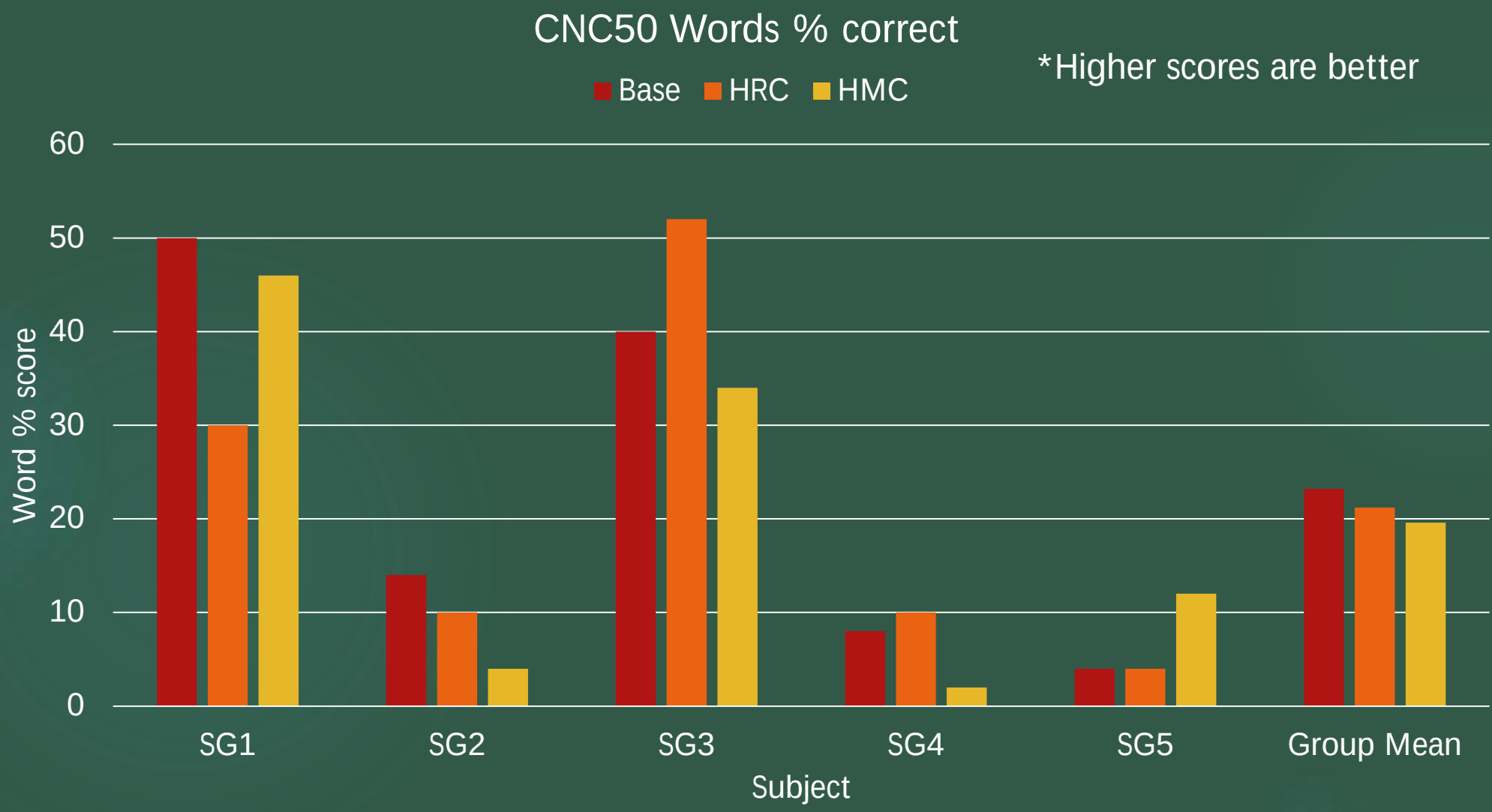
Results & Findings

- Between-subject analyses: no statistically significant differences from changing the stimulation rate and number of maxima on perceptive tests
- Within-subject analyses: variable clinically significant differences within each participant from changing the stimulation rate and number of maxima on perceptive tests

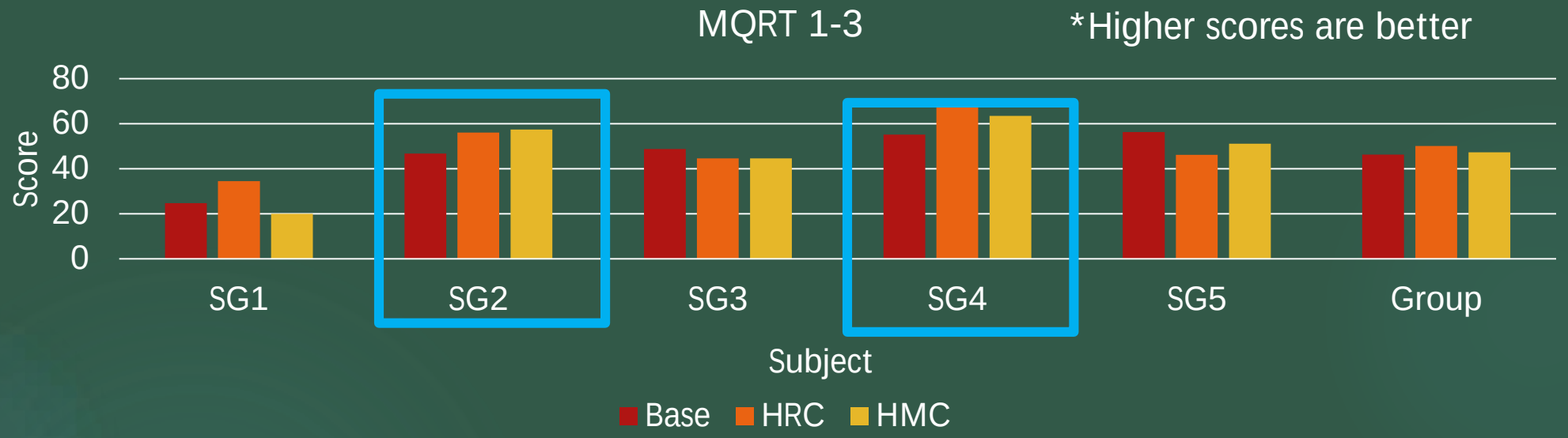
UW-CAMP

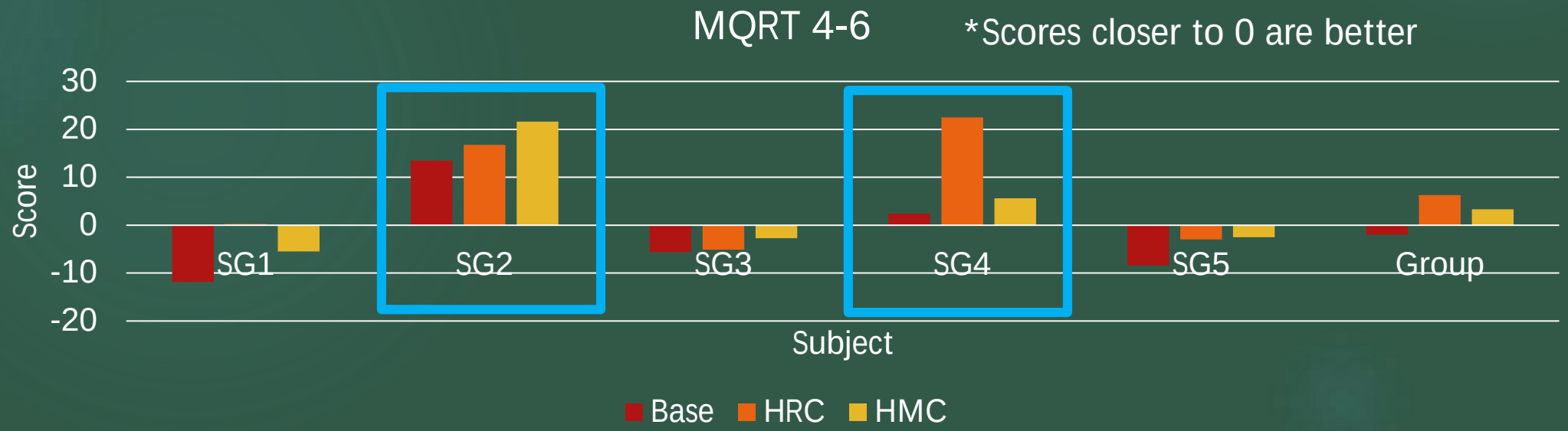

UW-CAMP
Base
HRC
HMC
*Lower scores are better
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Pitch Discrimination Threshold
SG1
SG2
SG3
SG4
SG5
Group Mean
Subject

CNC50


CNC50 Words % correct
*Higher scores are better
Base
HRC
HMC
60
50
40
30
20
10
0
Word % score
SG1
SG2
SG3
SG4
SG5
Group Mean
Subject

MQRT (1-3), (4-6)


MQRT 1-3
*Higher scores are better
80
60
40
20
0
Score
SG1
SG2
SG3
SG4
SG5
Group
Subject
Base
HRC
HMC


MQRT 4-6
*Scores closer to 0 are better
30
20
10
0
-10
-20
Score
SG1
SG2
SG3
SG4
SG5
Group
Subject
Base
HRC
HMC

Discussion

- Integrating between-subject findings with previous studies
  - Arora et al (2009): Best speech perception with stimulation rate at 500 to 900Hz + variable results when increasing stimulation rate from 720Hz to 1800Hz => Increasing stimulation rate beyond 900Hz to 1800Hz may not improve speech perception
  - Plant et al (2002): Best speech perception no lesser than 8 maxima + variable results when increasing number of maxima => increasing number of maxima beyond 8 up to 20 may not improve speech perception
  - Kang et al (2009) Pitch discrimination results from our findings were consistent with the findings from Kang et al's study => Average of 3 semitones, range from 1 to 8 semitones.

Conclusion

- Changing the stimulation rate and number of maxima may result in variable effects on the patient's speech and music perception
- Effects on speech and music perception are mutually exclusive
- Effects on subjective music quality suggest different parameters may affect different aspects of music listening for different CI candidates
- Answer to research question: Yes, improvement to speech or music perception is possible, but results vary across individuals.

Limitations & Future Research

- Small sample size - affects statistical analyses
  - Future studies will benefit from larger sample size allowing more accurate statistics and trends to be found
- Non-localised speech samples – affects speech scores due to accent differences
  - Beer can - > beacon
  - They are playing -> the air plane
  - Future studies can use localised speech samples to avoid accent unfamiliarity
- No acclimatisation period to test MAPs – test result may not accurately reflect test performance, introduces bias toward base MAP due to familiarity
  - Allow user to have time to get used to the new MAPs, results may change with familiarity
- More research into other parameters and their effects on music e.g. pulse width, inter-stimulus interval, etc

References

- 1. Low, W. K. (2005). Managing hearing loss in children and adults: Singapore context. Ann Acad Med Singapore, 34(4), 295-300.
- 2. Dowell, R. C., Hollow, R., & Winton, E. (2004). Outcomes for cochlear implant users with significant residual hearing: implications for selection criteria in children. Arch Otolaryngol Head Neck Surg, 130(5), 575-581. doi:10.1001/archotol.130.5.575
- 3. Arora, K., Dawson, P., Dowell, R., & Vandali, A. (2009). Electrical stimulation rate effects on speech perception in cochlear implants. *Int J Audiol, 48*(8), 561-567.
- 4. Parameter selection and programming recommendations for the ACE and CIS speech-processing strategies in the Nucleus 24 cochlear implant system
- 5. Development and validation of the University of Washington Clinical Assessment of Music Perception test

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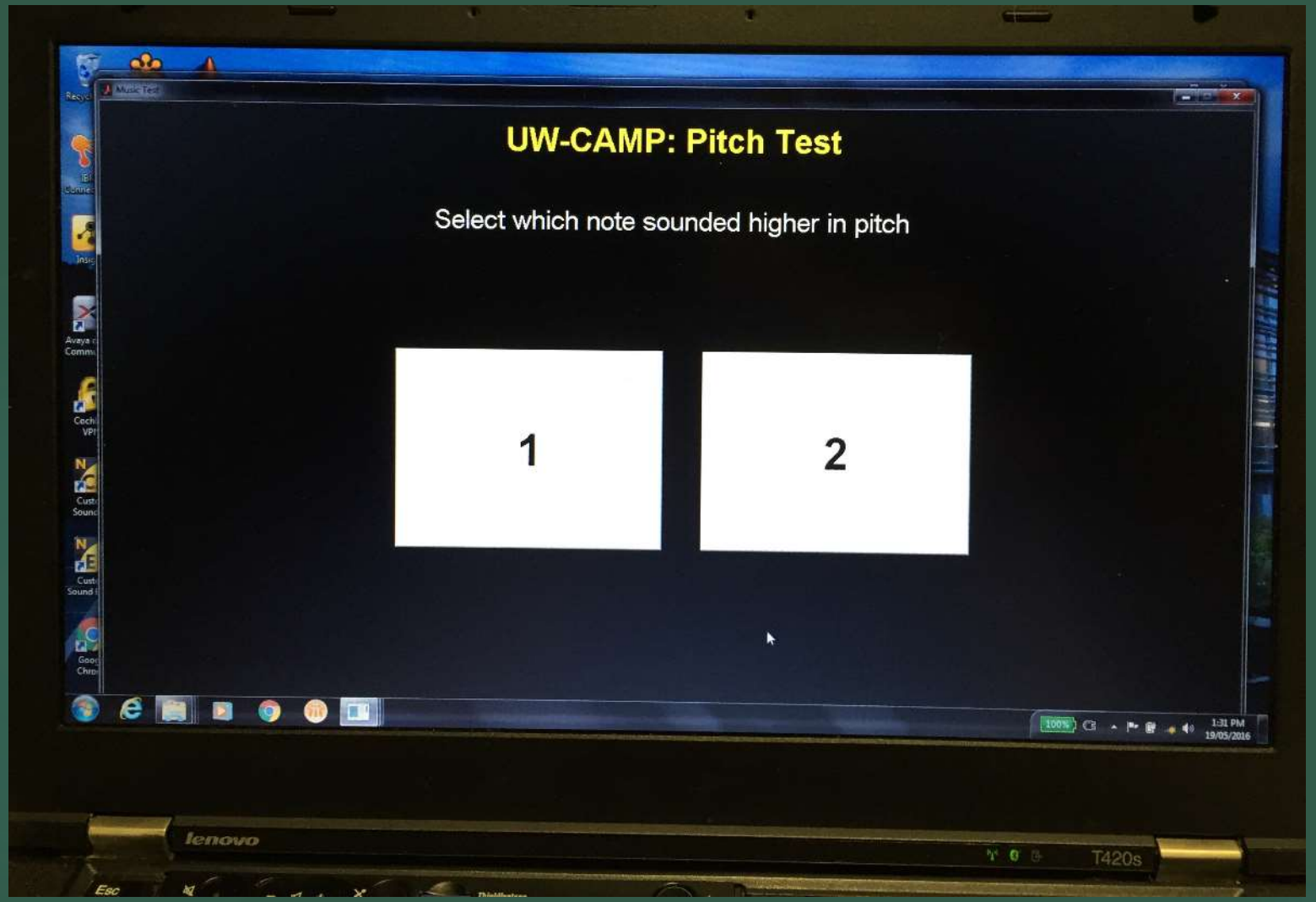
- Classmates

Q&A

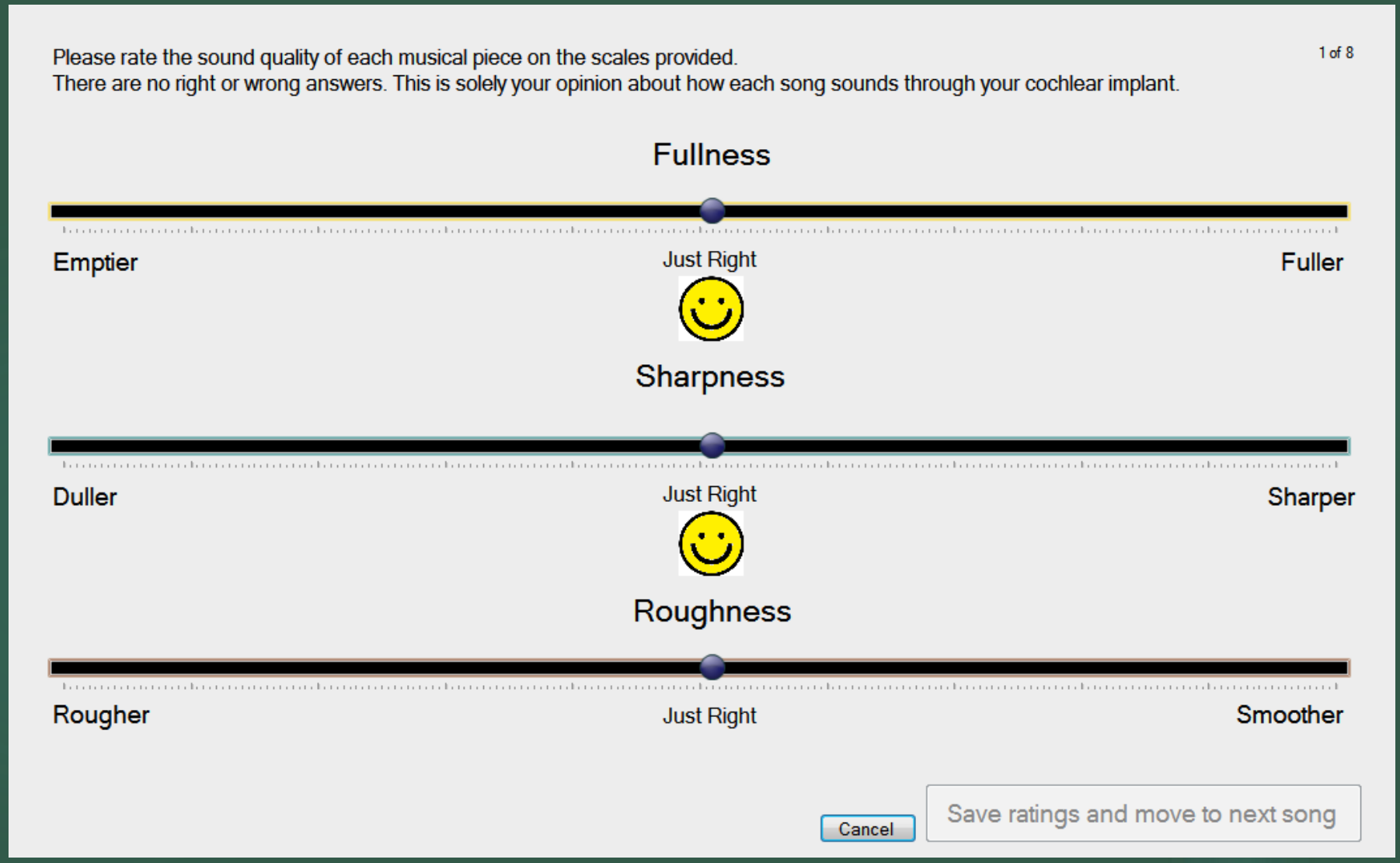
UW-CAMP


UW-CAMP: Pitch Test
Select which note sounded higher in pitch
1
2
lenovo
T420s

MQRT (1-3)

Please rate the sound quality of each musical piece on the scales provided.
There are no right or wrong answers. This is solely your opinion about how each song sounds through your cochlear implant.
1 of 8
Pleasantness
Unpleasant
Pleasant
Naturalness
Unnatural
Natural
Richness
Tinny
Rich
Cancel
Next 3 Scales

MQRT (4-6)


Please rate the sound quality of each musical piece on the scales provided.
There are no right or wrong answers. This is solely your opinion about how each song sounds through your cochlear implant.
1 of 8
Fullness
Emptier
Just Right
Fuller
Sharpness
Duller
Just Right
Sharper
Roughness
Rougher
Just Right
Smoother
Cancel
Save ratings and move to next song

Test Setup