Can Performance - Intensity functions reveal optimal release time in listeners with high cognitive ability?

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Introduction

- The advantages of using compression in hearing aid is widely established when hearing loss is of cochlear origin.

- However, the literature about the effectiveness of time constants used for compression is inconclusive.

- Due to lack of consensus on how to set release time, clinicians shy away from adjusting the time constants provided by the hearing aid manufacturers.
  - As a result, hearing aid users are fit with release times ranging from a few to several hundred milliseconds (Jenstad & Souza, 2005).

Introduction

- Release time (RT):
  - Length of time that it takes the compression circuit in a hearing aid to respond to a decrease in input level.
  - Time taken for the output to decrease within 4dB of its steady value.
  - Dynamic aspect of compression.

Introduction

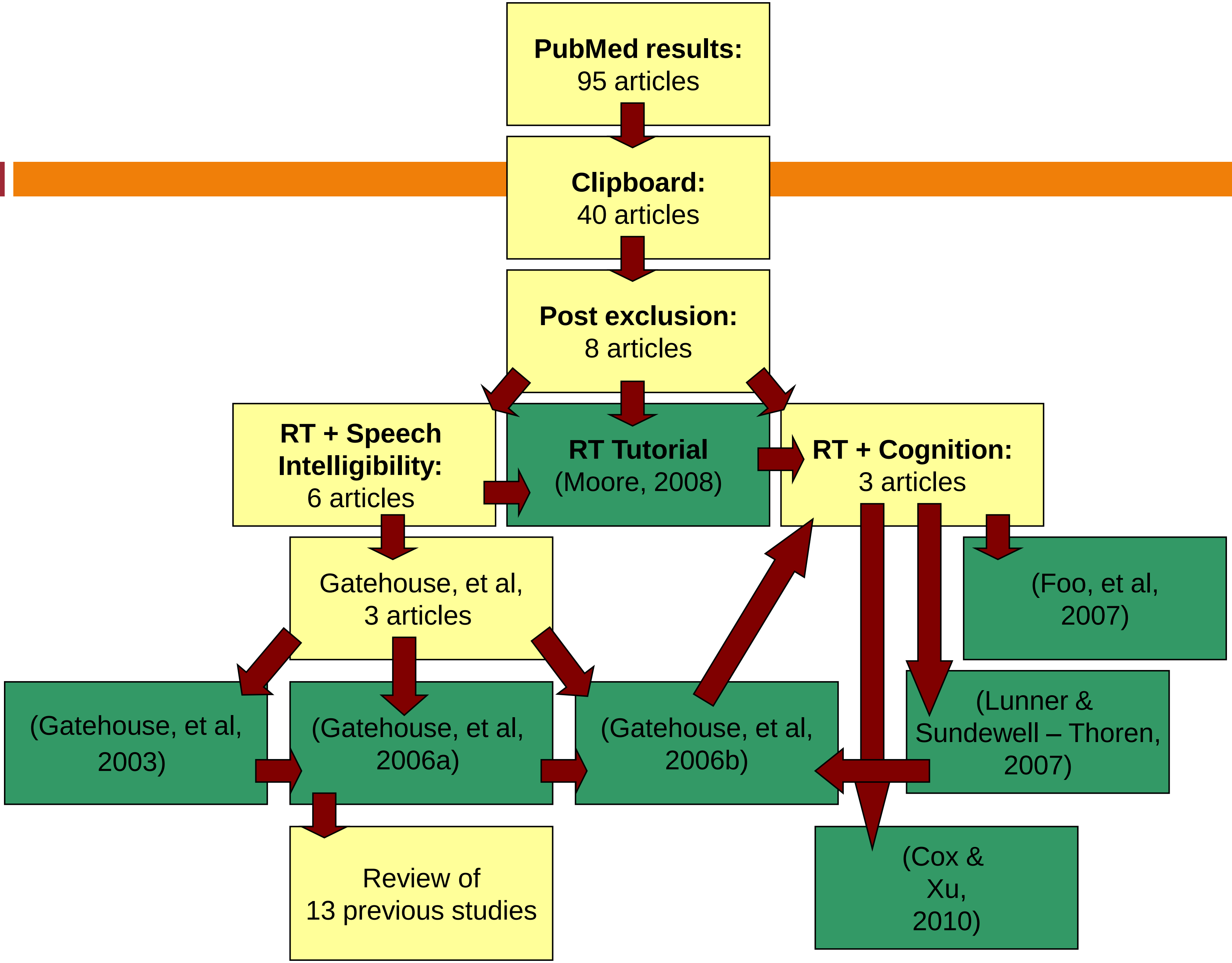
- Fast – acting compression
  - Short release time, syllabic/phonemic compressor
  - 5 – 200 ms

- Slow-acting compression
  - Long release time, dual compressor
  - 500 ms – 20 s
    - Dual compressor: essentially long AT & RT
      - However, switches to a short AT & RT for transient sounds
        - Rationale: Protecting listener from brief intense sounds without affecting audibility

Introduction (Moore, 2008)

- Fast – acting compression (short RT)
  - Assumed to improve audibility by reducing the short-term amplitude contrasts among elements of speech.
  - The speech envelope becomes more flat and smooth, allowing the low – intensity speech sounds to be amplified to a greater extent than the high – intensity speech sounds.

- Slow – acting compression (long RT)
  - Assumed to preserve the intensity relationship among phonemes, while adapting to the long – term changes in the listener's auditory environment.
  - Allows listeners to use level – difference to identify syllables and/or place of articulation.


PubMed results:
95 articles
Clipboard:
40 articles
Post exclusion:
8 articles
RT + Speech Intelligibility:
6 articles
RT Tutorial
(Moore, 2008)
RT + Cognition:
3 articles
Gatehouse, et al,
3 articles
(Foo, et al, 2007)
(Gatehouse, et al, 2003)
(Gatehouse, et al, 2006a)
(Gatehouse, et al, 2006b)
(Lunner & Sundewell – Thoren, 2007)
Review of
13 previous studies
(Cox & Xu, 2010)

Introduction (Gatehouse, Naylor, Elberling, 2003, 2006 a, b)

- Listeners with similar characteristics showed divergent preference or optima with release times.
  - Multidimensional nature of hearing disability and hearing aid benefit.
- In general, fast – acting compression was superior for reported and measured speech intelligibility in quiet and in noise.
- Benefit from fast – acting compression was associated with more varied auditory lifestyle and higher cognitive capabilities.

Introduction

- Cognition plays a role in aided speech recognition in noise (Cox & Xu, 2010; Gatehouse, et. al., 2006b; Foo, Rudner, Ronnberg, & Lunner, 2007; Lunner & Sundewall, 2007).

- Subjects with higher cognitive ability performed better with both short and long release times than subjects with lower cognitive abilities (Cox & Xu, 2010; Foo, Rudner, Ronnberg, & Lunner, 2007).

- However, mixed findings regarding which listeners (high or low cognitive functioning) benefited most from which release time (short or long) setting.

Introduction

- Subjects with higher cognitive abilities received more benefit from short release times, particularly in modulated noise (Gatehouse, Naylor, Elberling, 2006b, Lunner & Sundewall, 2007).

- Release time setting was more critical for subjects with lower cognitive scores (Cox & Xu, 2010; Foo, Rudner, Ronnberg, & Lunner, 2007; Lunner & Sundwell-Thoren, 2007).
  - Subjects with lower cognitive function did better with long release times, particularly when test material was of low-context (i.e. Ss need to identify word based on audibility alone).

Purpose

- This study was designed to expand upon previous work on cognitive function, release time, and speech understanding in noise.
  - More specifically, this study aimed to explore the effects of RT on speech understanding in noise for listeners assumed to have high – cognitive function.
- Additionally, this study examined whether the Performance – Intensity (PI) function obtained with short RT differed from the PI function obtained with long RT at different signal-to-noise (SNR) ratios.
  - To observe release time effects on speech intelligibility under limited controlled conditions, using generalizable SNRs and clinically realistic compression parameters.
- This study represents the first step at resolving the clinical question of how audiologists should set the RT parameter in hearing aids.

Research Questions

- 1.) Can performance-intensity (PI) functions be used to examine the effects of different compression processing parameters?

- 2.) Do cognitively – high functioning listeners benefit more from fast – acting compression processing than slow-acting compression processing when listening to speech in noise?

Hypothesis

- This study anticipates that subjects will have improved speech intelligibility in noise with fast – acting (short RT) compression.

- Consequently, the PI function will be steeper for fast-acting compression processing than slow-acting compression processing as SNR changes.

- This will suggest that listeners of high – cognitive ability are able to benefit from additional speech cues provided by fast – acting compression.
  - "Listening in the dips"

Methods

- Subjects
  - 30 adults (21+ years old)
  - Recruited via convenience sampling from the University of Memphis Speech and Hearing Center
  - Normal hearing, bilaterally
    - Screened at 25 dB HL using a Grason – Stadler GSI – 61 clinical audiometer.
    - Ear that subject prefers to use on the telephone was selected as the test ear.

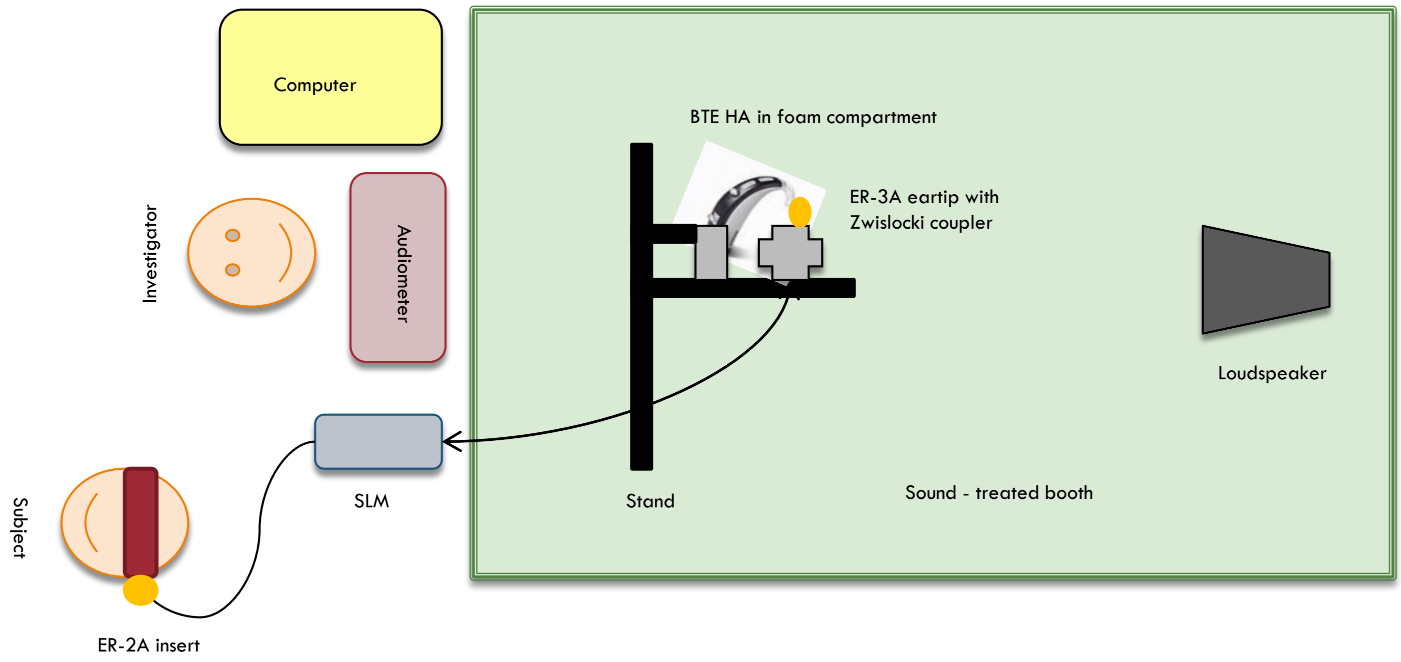
Methods

- Experimental Conditions
  - Two Siemen's Cielo behind-the-ear (BTE) 6 – channel digital hearing aids
    - Programmed identically using Siemen's software & NOAH
      - 30 dB overall gain
      - NAL-NL1
      - Additional features deactivated
    - Differed in release time constant
      - One HA programmed to "dual" (slow) release time
        - AT ~ 520 ms, RT ~ 520 ms
      - Second HA programmed to "syllabic" (fast) release time
        - AT ~ 15 ms, RT ~ 80 ms
    - Verified using Fonix system (ANSI '96, I/O curves, attack and release times)

Methods

- Words – in – Noise Test
  - Monosyllabic NU – 6 words (n = 70)
  - Female speaker
  - Two lists (List 1 and 2), 4 randomizations of each list
  - Several words given at 20 dB SNR for practice
  - 5 SNR levels: 16 dB to 0 dB, in 4 dB decrements
- Subjects presented with each list and randomization
  - Presentation order of test condition (fast or slow RT) was counterbalanced
  - Results for each SNR for each condition were combined
    - e.g. 16/20 words correct at 8 dB SNR for long RT, 12/20 words correct at 8 dB SNR for short RT

Procedure


Computer
BTE HA in foam compartment
ER-3A eartip with
Zwislocki coupler
Investigator
Audiometer
Loudspeaker
SLM
Stand
Sound - treated booth
Subject
ER-2A insert

Procedure

- Presentation of the WIN Test
  - WIN test CD recording → Windows Media Player on desktop computer
  - Signal amplified via GSI – 61 audiometer → Routed to loudspeaker in sound – treated booth
  - BTE mounted on stand ~ 3 feet away from loudspeaker (0° azimuth)
  - BTE earhook coupled to ER-3A eartip
  - BTE microphone picks up signal from loudspeaker → signal directed into Zwislocki coupler via ER – 3A eartip
  - Zwislocki coupler connected to SLM
  - SLM directs signal into ER-2A insert earphone, which is positioned in the subject's test ear
    - ER – 2A used since it has a flat frequency response (i.e. doesn't add any additional resonances into signal going into the ear)

Procedure

- Subject seated outside of the sound-treated booth
  - Near investigator, facing away from audiometer
  - ER-2A insert earphone in test ear, foam earplug in nontest ear
  - Blindfolded to avoid visual distractions

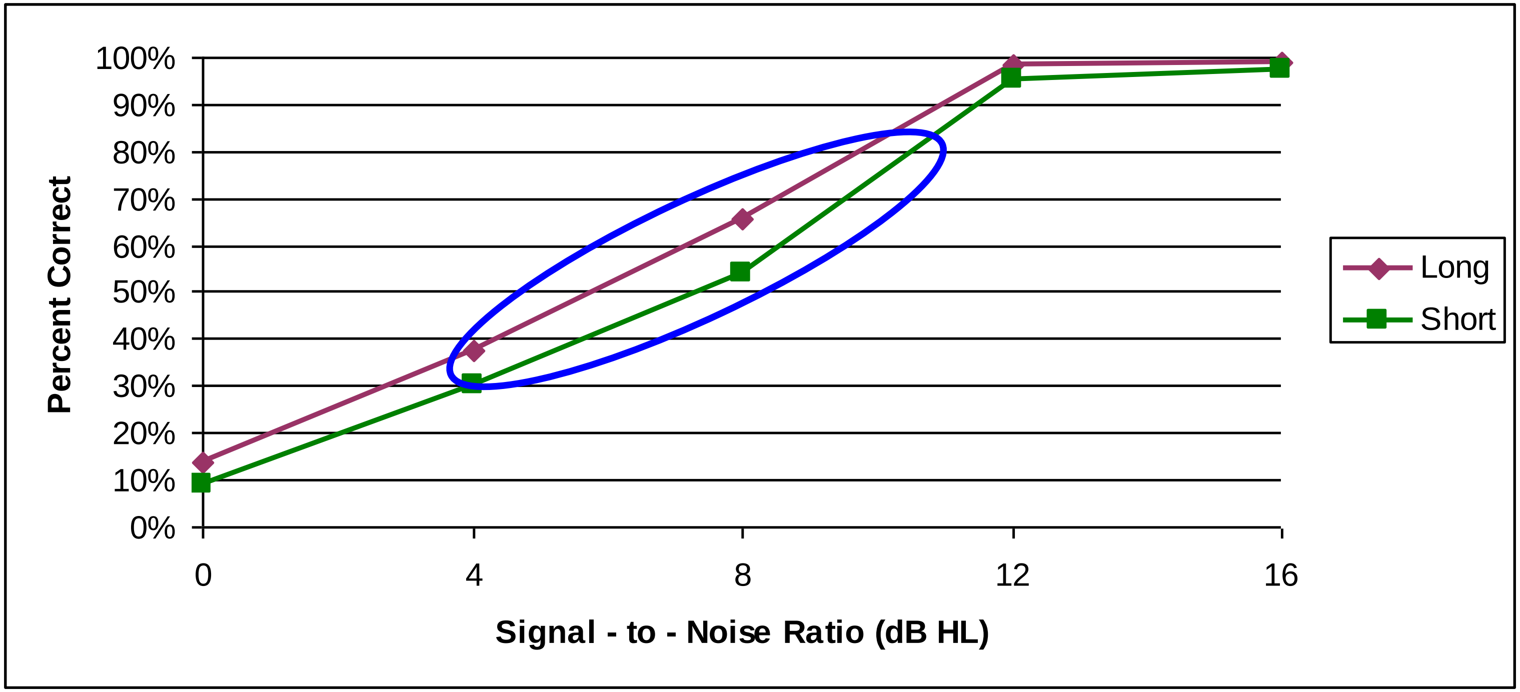
- Single 1 – hour test session
  - 8 WIN test lists, 4 lists in each condition
    - Presentation level of noise fixed at comfortable level
    - Level of speech varies from 16 dB to 0 dB, in 4 dB decrements
  - Subject asked to repeat the words heard
  - BTE (RT condition) was switched after 2nd and 6th word list
  - Responses were recorded at each SNR for each word list

Results

- 1.) Can performance-intensity (PI) functions be used to examine the effects of different compression processing parameters?

Results

- YES! The PI function can provide information on the effects of intentional or unintentional changes to the distribution of speech information across the amplitude domain.

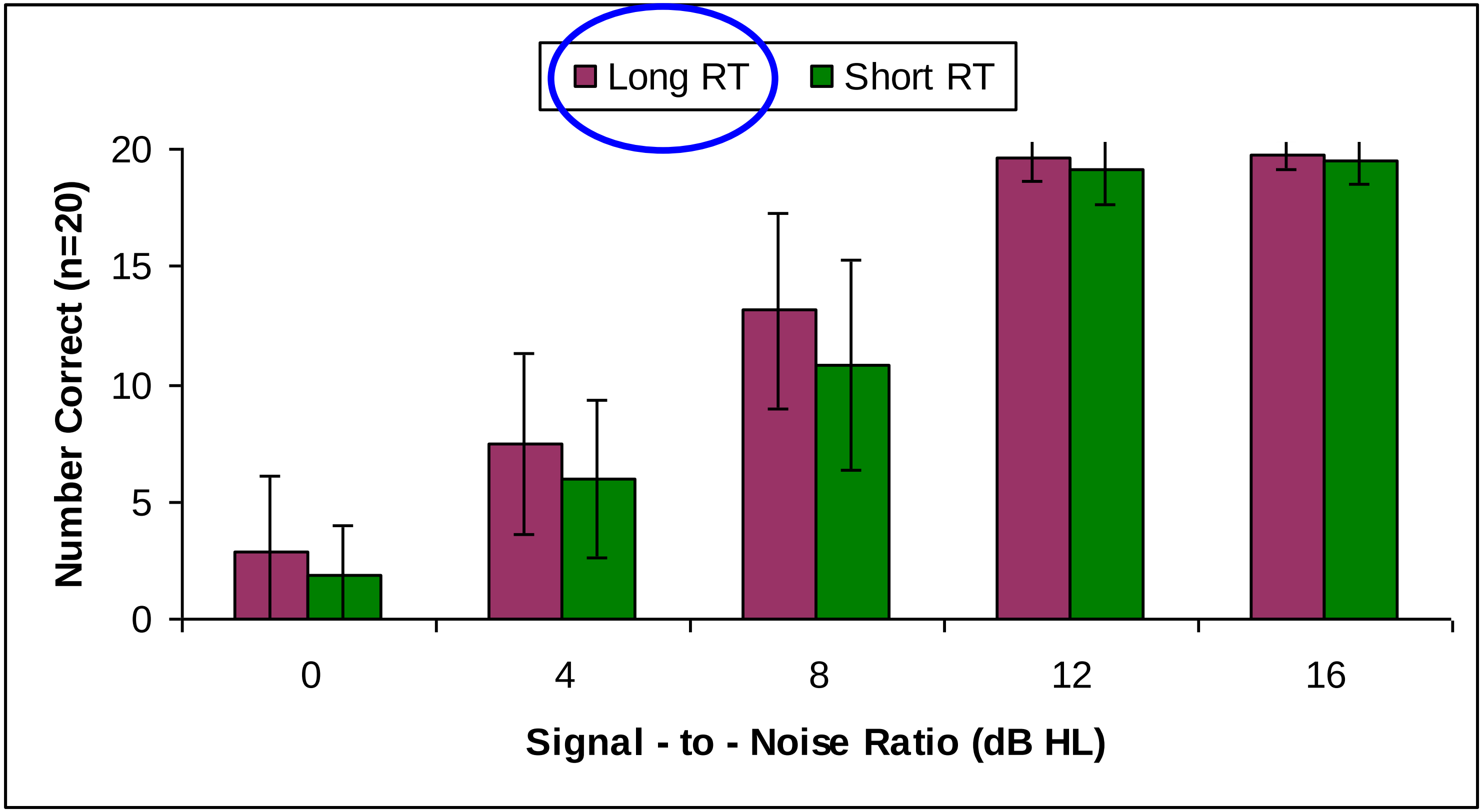


Results

- 2.) Do cognitively – high functioning listeners benefit more from fast – acting compression processing (short RT) than slow-acting compression processing (long RT) when listening to speech in noise?

Results

- Repeated measures ANOVA using Bonferroni post hoc adjustment showed a significant effect of release time on speech intelligibility on the WIN test.



Results

- Subjects performed significantly better on the WIN test using slow – acting compression, NOT fast – acting compression, $F(1, 29) = 9.742$, $p = 0.004$.
- However, no statistically significant interaction was found between release time and SNR, $F(2.813, 81.572) = 1.622$, $p = 0.193$.
- This suggested that the difference in performance between the short and long time constants was not influenced by SNR level.

Results

- A non-significant p-value may indicate that no significant interaction exists between release time and SNR.
- However, a non-significant p-value could reflect the fact that the study was under-powered to reveal an interaction.
- To further explore the data, effect size was calculated at each SNR level for the two time constant conditions.
  - Effect size indicates strength of relationship (magnitude of effect).
  - Unlike significance tests, these indices are independent of sample size.

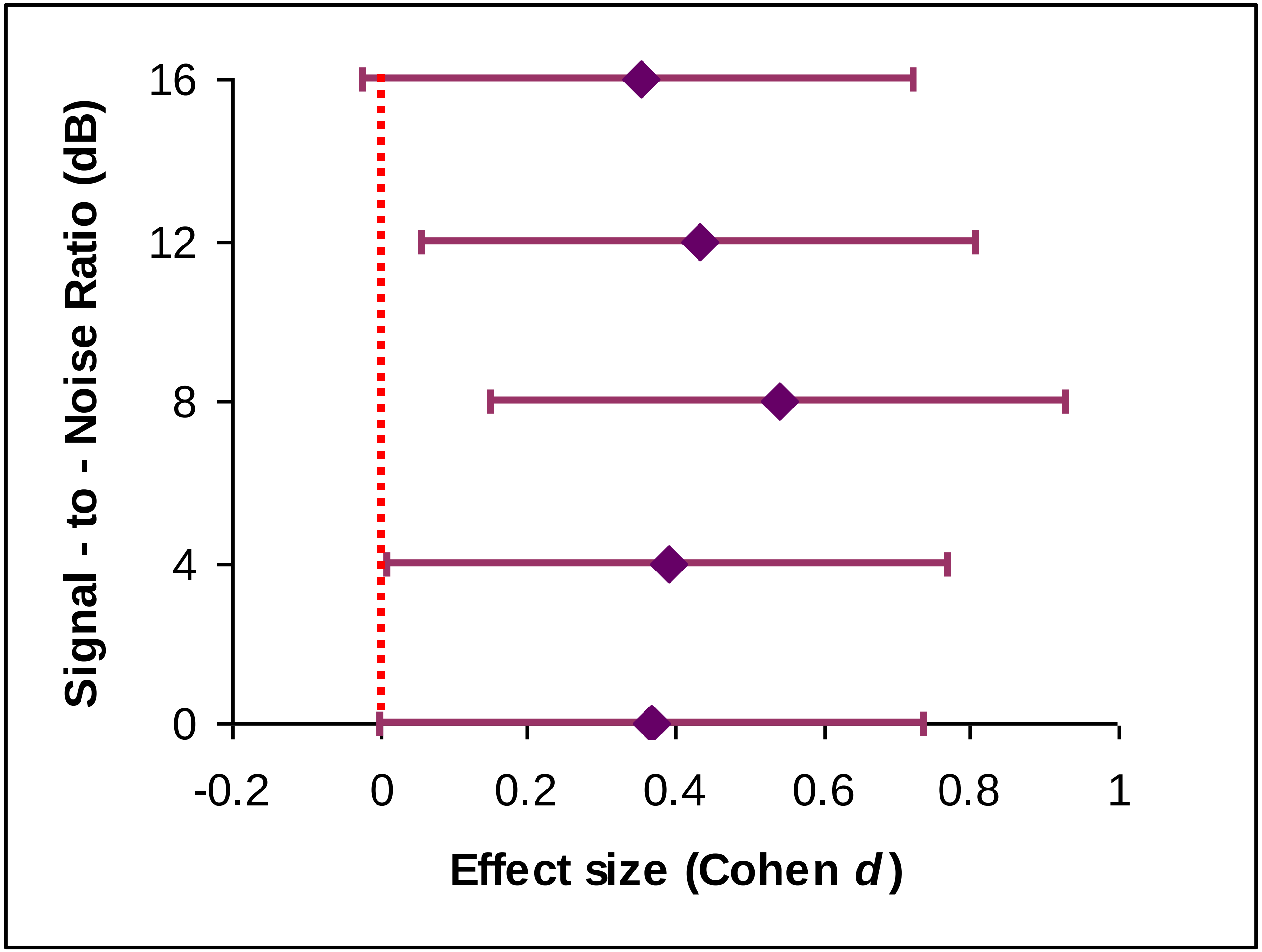
Results

- The results show that the difference in speech intelligibility between fast and slow RT was most pronounced at the SNR level of 8 dB.

SNR (dB)	Cohen's *d*	Strength
16	0.351	Small
12	0.434	Approaching medium
8	0.541	Medium
4	0.389	Approaching medium
0	0.369	Small

- The effect of release time on speech intelligibility at SNR levels of 4 dB and 12 dB is respectable.

Results



Signal - to - Noise Ratio (dB)
16
12
8
4
0
-0.2
0
0.2
0.4
0.6
0.8
1
Effect size (Cohen d)

Results

- Additionally, the confidence intervals at the SNR levels of 4, 8, and 12 dB do not cross 0.
  - This implies that the effect sizes would occur within the ranges determined by this study 95% of the time.

- Since confidence intervals are wide, there remains uncertainty about the exact effect sizes.

Discussion

- This study suggests fast – acting compression processing does not improve speech in noise performance over slow-acting compression processing for listeners of high cognitive function.
  - Not consistent with findings of Gatehouse, et. al. (2006b) or Lunner & Sundwell-Thoren (2007).

- This finding is consistent with Souza, Jenstad, & Boike (2006) that noted that fast – acting compression can actually degrade the speech signal.
  - Alteration of level - difference cues (degradation of the temporal envelope) may reduce the listener's ability to identify the syllable (Freyman, Nerbonne, & Cote, 1991) and lead to errors in perception of place of articulation (Hendrick & Rice, 2000).

Discussion

- Findings are more aligned with those of Cox & Xu (2010) and Foo and colleagues (2007) that showed no statistically significant differences for individuals of higher cognitive function.

- Measure of relationship between speech understanding and release time setting is dependent on speech tests used (Cox & Xu, 2010).
  - Subjects may do better with long release times when test material is of low-context (e.g. WIN corpus).
  - Release time may be less important when using more ecologically-valid (rich-context) test material.

- Relationship between release time processing, masker modulations, and cognitive abilities is complex (Cox & Xu, 2010).

Discussion

- The WIN test is low – context. What is the real-world utility of the results from such a test?
  - A speech-in-noise test, such as the WIN, could potentially aid an audiologist in selecting an optimal release time constant for a client.
  - A more ecologically – valid test (less clearly articulated, but rich in context), such as the BKB-SIN, may be a better predictor of a listener's ability to understand speech in their daily environment (i.e. allowing them to make use of top-down processing).

- Due to the exploratory nature of this study and the use of normal hearing listeners the results of this study <u>can not</u> be generalized to the hearing impaired population.

Limitations

- Attack time could not be controlled.
- Only one manufacturer and type of hearing aid was used.
- Only one configuration of hearing loss was simulated.
- Only two release times were selected (extremes of time constants) and programmed similarly across all hearing aid channels.
- Investigator was not blinded to test condition.
- Subject was seated outside sound – booth.
  - Occasional ambient noise and distracters present.

Final Comment

- Growing complexity of goals of audiological rehabilitation and the way hearing aid fittings can compromise or promote a client's progress.

- Therefore, it is important for clinicians to have access and understanding of as many hearing aid features and options, as possible, that may benefit the patient in meeting his/her unique goals.

- Also, clinicians should to consider client's subjective reports of hearing aid function, cognitive abilities, psychoacoustic characteristics, and auditory ecology.

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- Subjects
- AuD class 2011
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