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
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

Gatehouse, et al, 3 articles

(Gatehouse, et al, 2003)

(Gatehouse, et al, 2006a)

(Gatehouse, et al, 2006b)

Review of 13 previous studies

RT Tutorial (Moore, 2008)

RT + Cognition: 3 articles

(Foo, et al, 2007)

(Lunner & Sundewell – Thoren, 2007)

(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
    - 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

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

- **Loudspeaker**
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?
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.
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.

<table>
<thead>
<tr>
<th>SNR (dB)</th>
<th>Cohen’s $d$</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>0.351</td>
<td>Small</td>
</tr>
<tr>
<td>12</td>
<td>0.434</td>
<td>Approaching medium</td>
</tr>
<tr>
<td>8</td>
<td>0.541</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>0.389</td>
<td>Approaching medium</td>
</tr>
<tr>
<td>0</td>
<td>0.369</td>
<td>Small</td>
</tr>
</tbody>
</table>

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

![Graph showing Signal-to-Noise Ratio (dB) vs. Effect size (Cohen d)].

The graph displays the signal-to-noise ratio (dB) on the y-axis and the effect size (Cohen d) on the x-axis. The data points indicate different levels of signal-to-noise ratio across various effect sizes.
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 cannot 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 consider client’s subjective reports of hearing aid function, cognitive abilities, psychoacoustic characteristics, and auditory ecology.
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  - Also, thank you for attempting to answer my questions (no matter how absurd), for teaching me to look at findings with a novel perspective, and for encouraging me to think and articulate my thoughts through (instead of giving up on them).

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- Subjects

- AuD class 2011
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References


