

Abstract

This study examined listening effort for speech recognition in adults with a history of traumatic brain injury (TBI) and self-perceived hearing difficulties (HD). Listening effort was measured after a speech-in-noise and a dichotic word recognition task. Results demonstrated significantly greater perceived listening effort for adults with TBI compared to a control group for both speech tasks, despite similar performance. Greater listening effort for adults with TBI suggests that greater cognitive resources are necessary to achieve similar levels of understanding.

Introduction

- A portion of adults with **traumatic brain injury** (TBI) and clinically normal pure-tone sensitivity often complain of **'hearing difficulties'** (HD) and suprathreshold auditory deficits.
 - In particular, acoustically complex listening scenarios pose significant difficulty for those with TBI.^{1,2,3}
- HD after TBI has been attributed to decreased cognitive resources and increased effort for challenging tasks^{4,5,6}
 - Despite patients frequently reporting that listening is effortful, tiring, or even stressful, clinical measures of listening effort are not widely used or readily available to audiologists.
- The **purpose** of the present study, therefore, was to explore perceived listening effort of TBI subjects with HD (TBI HD) during acoustically complex listening scenarios.

Methods

SUBJECTS

- Control:** 20 adults 18-24 years of age (mean = 21.9 years) without a history of TBI and subjective HD
- Age-Matched Control:** 11 adults 42-57 years of age (mean = 48.45 years) without a history of TBI and subjective HD
- TBI:** 10 adults 21-33 years of age (mean = 24.8 years) with a history of TBI
- TBI HD:** 10 adults 25-63 years of age (mean = 47.8 years) with a history of TBI and subjective HD
 - Hearing Handicap Inventory for Adults (HHIA)⁷ used to classify subjects as having HD (scores of ≥ 35)
- Inclusion criteria included:
 - 1) normal otoscopy and tympanometry; 2) native speakers of English; 3) normal peripheral hearing (thresholds ≤ 20 dB at 250-8000Hz); 4) no middle ear pathology

MATERIALS

- Revised Speech Perception in Noise (R-SPIN)⁸**
 - Monaural right, left, and binaural at -4, 0 and +4 dB SNRs
- Unfiltered and Filtered Dichotic Words⁹**
 - 100-pairs of monosyllabic words in three conditions: free recall, directed-right, and directed-left
- National Aeronautics and Space Administration Task Load Index (NASA-TLX)¹⁰**
 - Visual-analog rating scale that assesses the perception of task demand. Ratings converted to a 20-point scale with 0 indicating low demand and 20 indicating high demand.
 - Effort:** How hard did you have to work (mentally or physically) to accomplish your level of performance?
 - Mental Demand:** How much mental and perceptual activity was required (e.g. thinking deciding, calculating, etc)? Was the task simple or complex?
 - Frustration:** How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

PROCEDURES

- NASA-TLX was given after each speech recognition measure (R-SPIN and Dichotic Words) condition
- 60 dB HL presentation level via insert earphones



R-SPIN Performance & Dichotic Word Recognition

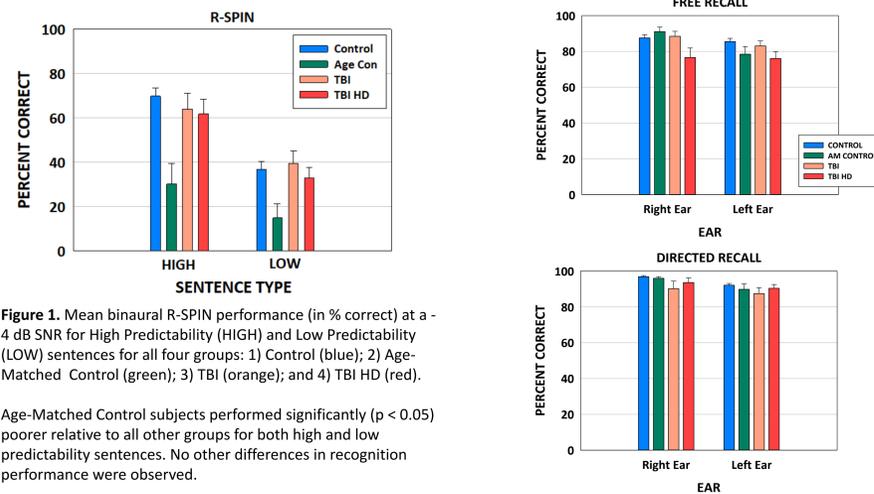


Figure 1. Mean binaural R-SPIN performance (in % correct) at a -4 dB SNR for High Predictability (HIGH) and Low Predictability (LOW) sentences for all four groups: 1) Control (blue); 2) Age-Matched Control (green); 3) TBI (orange); and 4) TBI HD (red).

Age-Matched Control subjects performed significantly ($p < 0.05$) poorer relative to all other groups for both high and low predictability sentences. No other differences in recognition performance were observed.

R-SPIN Performance & Listening Effort

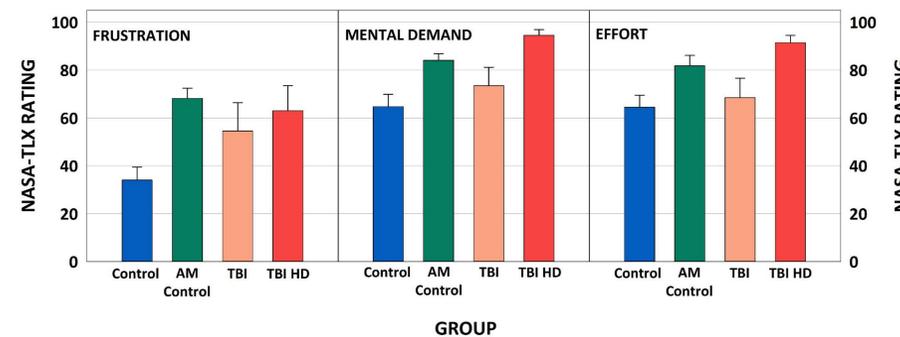


Figure 4. Mean NASA-TLX rating after completion of nine R-SPIN conditions (monaural right, left, and binaural at -4, 0 and +4 dB SNRs) for all four groups: 1) Control (blue); 2) Age-Matched Control (green); 3) TBI (orange); and 4) TBI HD (red). Significant differences between groups ($p < 0.05$) in listening effort were found. Both Age-Matched controls and TBI HD exhibited significantly greater frustration, mental demand, and effort than the control group.

Dichotic Word Recognition & Listening Effort

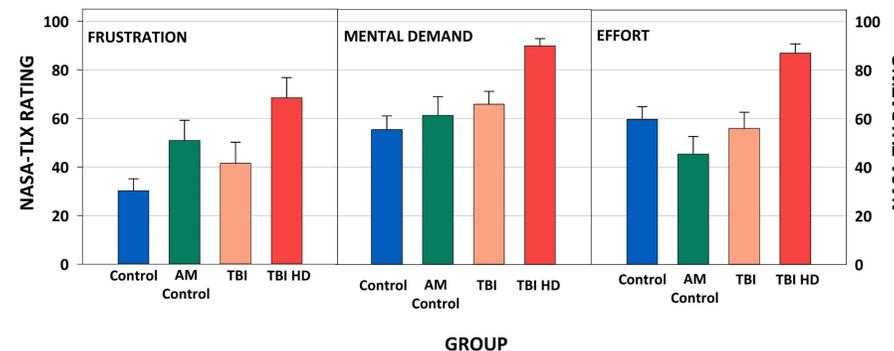
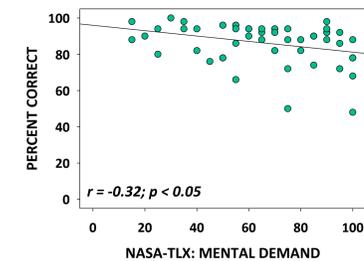


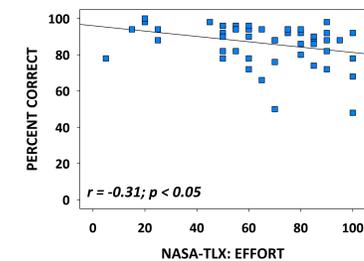
Figure 5. Mean NASA-TLX rating after the completion of unfiltered and filtered Dichotic Word Recognition under three conditions (free recall, directed-right, and directed-left) for all four groups: 1) Control (blue); 2) Age-Matched Control (green); 3) TBI (orange); and 4) TBI HD (red). Significant differences in listening effort were found between groups. TBI HD exhibited significantly greater frustration, mental demand, and effort than the Control, Age-Matched Control, and TBI groups.

Correlations

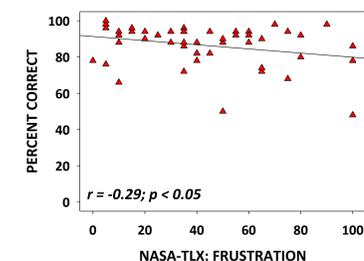
DWR Free Recall and the NASA-TLX



Figures 6, 7, & 8. Individual data presented as bivariate plots with post-dichotic listening NASA-TLX responses on the abscissa and dichotic word recognition performance for the right ear in the free recall condition on the ordinate. The line represents the regression from the mean.



Data are presented as a function of NASA-TLX category: mental demand (top panel), effort (middle panel), and frustration (bottom panel).



Significant negative correlations were observed between recognition performance on dichotic words presented to the right ear and measures of listening effort (e.g., mental demand, effort, and frustration).

Conclusions

- Listening effort, as measured by the NASA-TLX (mental demand, effort, & frustration), differentiated the TBI HD group:
 - Speech-in-Noise (**Figure 4**): greater listening effort was exhibited by Age-Matched Controls and TBI HD groups
 - Dichotic Listening (**Figure 5**): greater listening effort was exhibited by the TBI HD group
- A subjective listening effort task like the NASA-TLX may prove useful in detecting subtle HD in TBI patients with normal pure-tone sensitivity.
 - The significant correlations between DWR and listening effort emphasizes the importance of utilizing a complex auditory processing test battery when assessing adult TBI patients (**Figures 6-8**).
- The ability to measure greater perceived listening effort as part of an auditory processing test battery supports patient self-perception (e.g., HD) and provides a basis for the provision of treatment recommendations:
 - Counseling on the use of communication strategies;
 - Computerized auditory training programs;
 - Mild-gain amplification or assistive listening devices

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