Age, hearing loss and cognition: susceptibility to hearing aid distortion

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Background

Response to hearing aids continues to be quite variable, with some individuals reporting more benefit than others. This variability is particularly evident among older listeners. Recent work suggests that variable response to complex signal processing may be related to patient factors, including cognitive abilities. For example, older adults with good cognition benefit from fast-acting wide dynamic range compression (WDRC), while those with lower cognition do not[1,2]. We propose that the relationship between patient factors (including cognition) and benefit will also apply to other signal processing algorithms (e.g., frequency compression) that cause significant manipulations to the speech signal.

Purpose

This study investigated the contributions of age, cognition and hearing loss to intelligibility and quality of frequency-compressed speech.

Participants

40 older listeners classified as normal hearing through 4 kHz (n=14, 60-78 yrs) or hearing loss (n=26, 62-92 yrs).

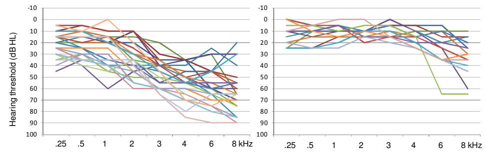


Fig. 1. Test ear audiograms for hearing-impaired (left) and normal hearing (right) participants.

Tests

1. Working memory (Reading Span Test, RST[3,4]): The participant is asked to recall – in correct serial order - either the first or the last words of a sequence of sentences shown on a computer screen.
2. Intelligibility of low-context sentences spoken by a female talker. After practice, listeners responded to 10 sentences for each of 60 conditions.
3. Quality ratings of a pair of sentences spoken by a female talker using a 11-point rating scale, with 0 representing minimum quality and 10 representing maximum quality. After practice, listeners rated each of the 60 conditions two times each.
4. The stimulus was 65 dB SPL, plus individualized NAL-R[5].

Frequency Compression

Cutoff frequency (CF): Linear below, compressed above at specified frequency compression ratio (CR)

Two-band system is unmodified at low frequencies with sinusoidal modeling at high frequencies; 10 highest peaks are selected and reproduced as sinusoids at shifted frequencies

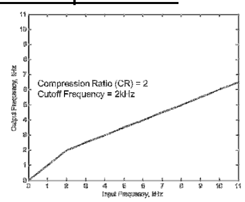


Fig. 2. Example of frequency compression parameters (CR=2; CF= 2 kHz)

Noise and distortion

No Processing	CR=1.5			CR=2.0			CR = 3.0		
	1.0 kHz	1.5 kHz	2.0 kHz	1.0 kHz	1.5 kHz	2.0 kHz	1.0 kHz	1.5 kHz	2.0 kHz
Condition 1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
-10 dB SNR -5 dB SNR 0 dB SNR +5 dB SNR +10 dB SNR Clean Speech	-10 dB SNR -5 dB SNR 0 dB SNR +5 dB SNR +10 dB SNR Clean Speech			-10 dB SNR -5 dB SNR 0 dB SNR +5 dB SNR +10 dB SNR Clean Speech			-10 dB SNR -5 dB SNR 0 dB SNR +5 dB SNR +10 dB SNR Clean Speech		

Table 1. 60 conditions (10 processing x 6 signal-to-noise ratios (SNR)).

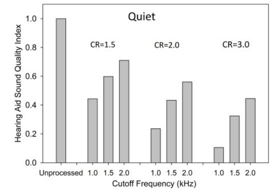
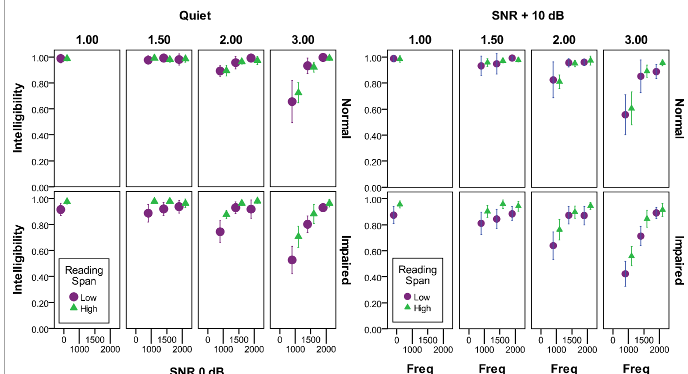
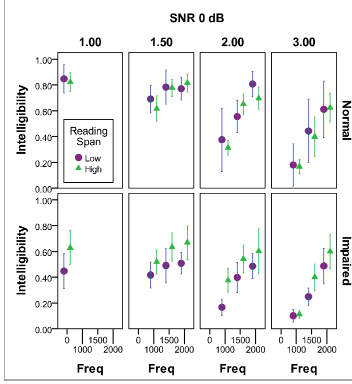


Fig. 3. HASQI[6] (indicating amount of signal modification) for the 10 processing conditions for quiet speech. HASQI values decrease with increasing CR & decreasing CF.

Intelligibility

In quiet and low noise levels, participants with hearing loss and/or low RST scores perform poorly, especially in highly processed conditions. At higher noise levels, noise and distortion (rather than cognition) affect performance.



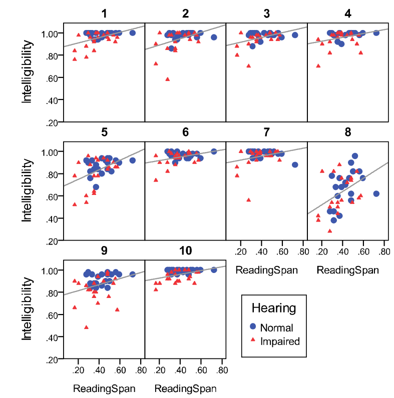


Figs. 4-6. Intelligibility as a function of CR and CF. In each panel, low and high (re: median) RSTs are compared. Top panels show normal hearing, bottom panels show impaired hearing.

Table 2. p values for intelligibility

	Quiet	10 dB SNR	0 dB SNR
HASQI (distortion)	<.001	.001	.001
Reading Span	.042	.04	.218
Hearing Group	.013	.005	.001
RST x Hearing	.07	.175	.102
HASQI x Hearing	.284	.332	.009
RST x HASQI	.048	.341	.305
3-way interaction	.573	.436	.584

Cognition and hearing



The plots at left illustrate the relationship between RST and intelligibility. Participants with high RST scores also had higher intelligibility scores. This is most evident in high-distortion conditions for listeners with hearing loss. Consider the data shown in panels 5 and 8, which represent the conditions with the greatest distortion (i.e., lowest HASQI values). In both cases, Pearson r=.49 (p=.005). The effect disappears at high SNRs (data not shown).

Fig. 7. Intelligibility as a function of RST for speech in quiet. Each panel shows a different CR/FC combination (see Table 1).

Consistent with trends shown in Fig. 7, multiple regression models indicate that RST and hearing explain a significant proportion of the variance, accounting for up to 20% of the variance in quiet, and up to 50% of the variance in noise. In general, adding age did not significantly improve the model fit.

Quality

Quality ratings show similar patterns to intelligibility; hearing loss, RST and signal distortion all play a role.

Table 3. p values for quality

	Quiet	10 dB SNR	0 dB SNR
HASQI (distortion)	.001	.001	.001
Reading Span	.151	.019	.042
Hearing Group	.076	.007	.065
RST x Hearing	.291	.601	.780
HASQI x Hearing	.197	.896	.666
RST x HASQI	.292	.796	.565
3-way interaction	.543	.494	.867

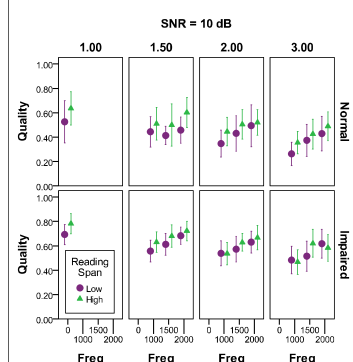


Fig. 8. Quality as a function of CR and CF. In each panel, low and high (re: median) RSTs are compared. Top panels show normal hearing, bottom panels show impaired hearing.

Summary

Listeners with hearing loss had poorer intelligibility scores, and higher quality ratings, than listeners with normal hearing. Listeners with poorer cognition (low Reading Span scores) had more difficulty understanding speech in quiet and in moderate levels of noise. In quiet, increased distortion (from frequency compression) had a greater effect for listeners with poorer cognition.

Acknowledgments

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Notes: Error bars are 95% confidence intervale.