Brain Changes in Mild to Moderate Hearing Loss after Hearing Aid Use

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BACKGROUND

Research suggests that hearing loss is associated with incident cognitive impairment, as well as faster rates of cognitive decline, with conflicting evidence regarding effects of hearing aid use.[1]

In this study, we examined EEG spectral bands in older adults with mild-moderate hearing loss before and after 6 months of hearing aid use.

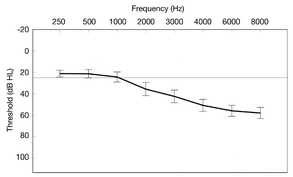
Results can give us insight into neurocognitive changes associated with age-related hearing loss (ARHL), and how intervention with hearing aids may improve outcomes.

METHODS

Participants

Retrospective analysis of data was analyzed from 21 participants with age-related hearing loss (mean age = 64.4 years), prior to hearing aid use (Pre-hearing aid), and 6 months after being fit with hearing aids (Post-hearing aid).

Average Audiogram



Subjects had normal hearing (defined as ≤ 25 dB HL) through 1000 Hz, sloping to moderate hearing loss (~60 dB HL)[2].

Methods:

The following tests were administered (see Glick and Sharma 2020 for details)

Speech in noise testing

Clinically used sentence-level measure, QuickSIN[3]

Cognitive Test Battery

- Reading Span Test (RST)[4] - visual working memory
- Behavioral Dyscontrol Scale II (BDS-2)[5] - executive function
- Symbol Digits Modalities Test (SDMT)[6] - processing speed
- Montreal Cognitive Assessment (MoCA)[7] - global cognition

High Density EEG Data Collection Protocol (Cortical Visual Evoked Potentials)

- Recorded from a 128-channel EGI cap
- Artifacts and noisy channels removed manually and through Independent Components Analysis
- Spectral analysis completed by:
  1. Spectral sum average calculated per subject per channel per spectral band
  2. For each spectral band, average spectral power calculated per electrode per subject and averaged across all subjects in each group
  3. Average spectral power plotted by electrode on a scalp map

RESULTS (PRE/POST HEARING AID USE)

SPECTRAL POWER AFTER HEARING AID USE

Spectral Band	Aspect of Cognition	ROI	Average Post-Pre change	P value
Alpha (8-12 Hz)	Listening Effort[8]	E33, E38	-0.36	0.170
Theta (4-8 Hz)	Working memory capacity[9]	E35, E36, E41	0.32	0.23
Gamma (30-79 Hz)	Learning[10]	E45, E46	0.044	**0.035***
Theta/Alpha Ratio	Cognitive capacity[11]	E35, E36, E41	0.23	**0.075****
Theta/Beta Ratio	Cognitive capacity[12]	E62, E72	1.59	0.096

Table 1. Spectral band definitions, aspect of cognition reflected, regions of interest (ROI) tested, average difference of spectral power measured post-hearing aid minus pre-hearing aid, and significance. *significant at p<0.05; ** trending towards significance.

THETA ALPHA RATIO (TAR) POWER:

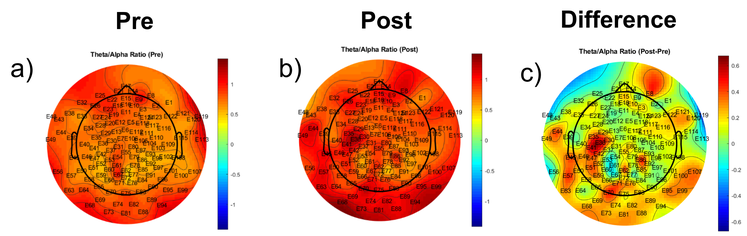


Figure 1. Scalp map of theta/alpha ratio power, averaged across all subjects a) pre hearing aid use b) post hearing aid use, and c) the difference result. As shown on the scale on the right, the more positive value (or increase in the diff map) is shown in red. TAR increase is considered a sign of healthy cognition.

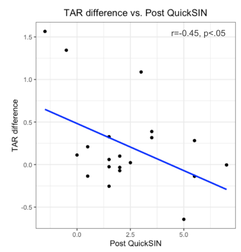


Figure 2. TAR versus post-hearing aid QuickSIN scores. TAR increase was significantly correlated with the improvement in speech perception in noise with hearing aids, suggesting that amplification results in both improved speech perception and neurocognition.

GAMMA POWER

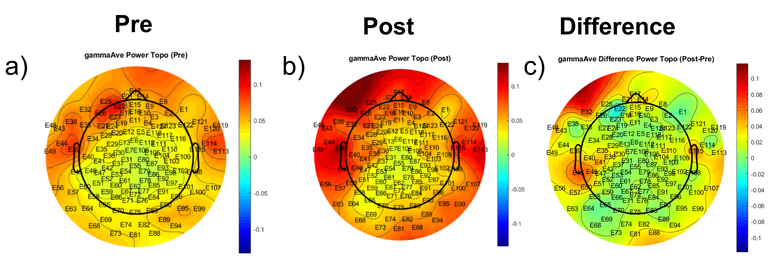


Figure 3. Scalp map of gamma power, averaged across all subjects a) pre hearing aid use b) post hearing aid use, and c) the difference result. As shown on the scale on the right, the more positive value (or increase in the diff map) is shown in red. Gamma increase is associated with learning.

Improvement in speech perception in noise

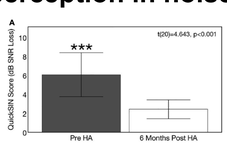


Figure 4. Improvement in QuickSIN Scores pre and post hearing aid use[2]

Improvement in cognitive function

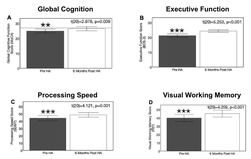


Figure 5. Improvement in scores pre and post hearing aid use for A) Global Cognition (MoCA); B) Executive Function (BDS-2); C) Processing Speed (SDMT); D) Visual Working Memory (Reading Span)[2]

Decrease in frontal activation (cognitive load)

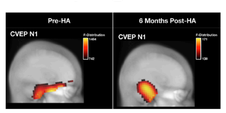


Figure 6. Source localization of activity pre and post hearing aids. Prior to hearing aid use, frontal cortex activation is seen in the left panel(Pre HA) suggestive of effortful listening. However, there is no frontal cortex activation in the right panel(post HA) suggestive of a reduction in cognitive load and effortful listening with hearing aid use. [2]

DISCUSSION and CONCLUSIONS

In this study we sought to identify neural correlates from EEG spectral bands analyses which may serve as a clinically relevant marker of early candidacy for hearing aid, and a marker of neurocognitive improvement after hearing aid use.

Overall, we find that adults with age-related hearing loss show an improvement in speech in noise perception (QuickSIN), global cognition (MOCA), executive functioning (BDS), visual working memory (Reading Span) and processing speed (SDMT) after 6 months of hearing aid use.[2]

In addition, we have identified two possible EEG spectral markers of neurocognitive outcome.

1. The Theta-Alpha ratio (TAR) showed an increase after 6 months of hearing aid use and this increase was significantly positively correlated with improvement in speech in noise perception ($p<.05$). Changes seen in TAR may be a sign of healthy cognition[11], and may increase the likelihood of better performance in speech in noise.
2. We saw a significant increase in gamma power post-hearing aid use ($p<.05$), which may reflect enhanced ability for learning to process restored auditory information with hearing aids[10]

These results provide overall evidence of improved neurocognitive functioning with hearing aid use in individuals with mild to moderate age-related hearing loss.

Future Directions

In future research our aim is to further understand TAR, Gamma and other clinically relevant and feasible markers of improved neurocognitive outcomes to help determine who should receive early intervention with hearing aids and to monitor outcomes after hearing aid use in adults with age-related hearing loss.

REFERENCES

1. Lin, F. R., Yaffe, K., Xia, J., Xue, Q.-L., Harris, T. B., Purchase-Helzner, E., Satterfield, S., Ayonayon, H. N., Ferrucci, L., Simonsick, E. M., & Health ABC Study Group, for the. (2013). Hearing loss and cognitive decline in older adults. *JAMA Internal Medicine*, *173*(4), 293. https://doi.org/10.1001/jamainternmed.2013.1868
2. Glick, H. A., & Sharma, A. (2020). Cortical neuroplasticity and cognitive function in early-stage, mild-moderate hearing loss: Evidence of neurocognitive benefit from hearing aid use. *Frontiers in Neuroscience*, *14*, 93. https://doi.org/10.3389/fnins.2020.00093
3. Killion, M. C., Niquette, P. A., Gudmundsen, G. I., Revit, L. J., & Banerjee, S. (2004). Development of a quick speech-in-noise test for measuring signal-to-noise ratio loss in normal-hearing and hearing-impaired listeners. *The Journal of the Acoustical Society of America*, *116*(4), 2395–2405. https://doi.org/10.1121/1.1784440
4. Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*(4), 450–466. https://doi.org/10.1016/S0022-5371(80)90312-6
5. Grigsby, J., and Kaye, K. (1996). The Behavioral Dyscontrol Scale: Manual, 2nd Ed. Denver, CO: Authors.
6. Smith, A. (1982). Symbol Digits Modalities Test. Los Angeles: Western Psychological Services.
7. Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., et al. (2005). The Montreal cognitive assessment, MoCA: a brief screening tool for mild cognitive impairment. *J. Am. Geriatr. Soc.* *53*, 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x
8. Wisniewski, M. G. (2017). Indices of effortful listening can be mined from existing electroencephalographic data: *Ear and Hearing*, *38*(1), e69–e73. https://doi.org/10.1097/AUD.0000000000000354
9. Sauseng, P., Griesmayr, B., Freunberger, R., & Klimesch, W. (2010). Control mechanisms in working memory: A possible function of EEG theta oscillations. *Neuroscience & Biobehavioral Reviews*, *34*(7), 1015–1022. https://doi.org/10.1016/j.neubiorev.2009.12.006
10. Fitzgibbon, S. P., Pope, K. J., Mackenzie, L., Clark, C. R., & Willoughby, J. O. (2004). Cognitive tasks augment gamma EEG power. *Clinical Neurophysiology*, *115*(8), 1802–1809. https://doi.org/10.1016/j.clinph.2004.03.009
11. Trammell, J. P., MacRae, P. G., Davis, G., Bergstedt, D., & Anderson, A. E. (2017). The relationship of cognitive performance and the theta-alpha power ratio is age-dependent: An EEG study of short term memory and reasoning during task and resting-state in healthy young and old adults. *Frontiers in Aging Neuroscience*, *9*, 364. https://doi.org/10.3389/fnagi.2017.00364
12. Clarke, A. R., Barry, R. J., Karamacoska, D., & Johnstone, S. J. (2019). The eeg theta/beta ratio: A marker of arousal or cognitive processing capacity? *Applied Psychophysiology and Biofeedback*, *44*(2), 123–129. https://doi.org/10.1007/s10484-018-09428-6

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