Published in final edited form as:

Otol Neurotol. 2020 February ; 41(2): e227–e231. doi:10.1097/MAO.0000000000002477.

Duration of processor use per day is significantly correlated with speech recognition abilities in adults with cochlear implants

Jourdan T. Holder, AuD, Nichole C. Dwyer, BS, René H. Gifford, PhD

Department of Hearing and Speech Sciences, Vanderbilt University Medical Center, Nashville, TN

Abstract

Objective: Quantify the relationship between average hours of processor use per day and measures of speech recognition in postlingually deafened adults with cochlear implants.

Setting: Cochlear implant (CI) program at a tertiary medical center

Patients: Three hundred adult (mean age = 64, 130 females) CI users were included.

Main Outcome Measures: Correlation analyses were completed for CI-aided speech recognition [Consonant-Nucleus-Consonant (CNC) monosyllables and AzBio sentences] at approximately 12 months post-implantation and average hours of processor use per day, which was extracted from the CI programming software.

Results: Average processor use was 10.2 hours per day (range: 0.1 to 22.7), and average speech recognition scores were 49.9% and 61.7% for CNC and AzBio sentence recognition, respectively. We found a strong, significant correlation between hours of processor use per day and CNC word recognition ($r_s = 0.61$, $p < 0.0001$) and AzBio sentence recognition ($r_s = 0.56$, $p < 0.0001$).

Conclusions: Results suggest that highest speech recognition outcomes are correlated with greater than 10 hours of CI use per day. Further research is needed to assess the causal link between daily CI use and speech recognition abilities.

Keywords

cochlear implant; audiology; outcomes; datalogging; speech perception

INTRODUCTION

Cochlear implant (CI) technology is used to restore audibility and improve speech understanding for individuals with sensorineural hearing loss (SNHL). The majority of patients receive significant improvement in speech understanding with device use; however, considerable variability remains amongst adult recipients for which the range of postoperative speech recognition scores is from 0 to 100%^{1–5}. Understanding this variability

CORRESPONDING AUTHOR: Jourdan Holder, AuD, Department of Hearing and Speech Sciences, 1215 21st Avenue South, Medical Center East, South Tower, #9302, Nashville, Tennessee 37232-8605, Telephone: 615-936-5080, Fax: 615-875-1410, jourdan.t.holder@vumc.org.

CONFLICT(S) OF INTEREST TO DECLARE:

René Gifford: Advisory board for Advanced Bionics, Cochlear, and Frequency Therapeutics

in CI outcomes has become a hot topic of research because predicting postoperative performance for a given patient remains challenging. Over a thousand articles have been published in the last five years seeking to understand how several factors potentially affect outcomes. These factors include etiology, duration of deafness, spiral ganglion cell count, age, electrode position, manufacturer, electrode type, programming, surgical technique, etc. Many of these variables are either outside of clinician control (e.g., etiology, duration of deafness, spiral ganglion cell count, age) or completely unknown. One potentially important and malleable factor sparsely reported in the adult CI literature is the average number of hours of processor use per day, also reported as datalogging.

The ability to track a CI recipient's average usage of their CI processor per day automatically within the programming software is a relatively new feature. This feature was immediately beneficial in children for tracking consistency of wear time at home, school, and daycare. It also allows clinicians to become aware of persistent device problems when a child is unable to accurately report issues. Exposure to spoken language is vital for typical speech and language development in children (e.g.,^{6,7}), so it is not surprising that the current literature has focused on the correlation between CI use and auditory outcome measures in the pediatric population. Easwar and colleagues⁸ found that average CI use per day was significantly correlated with higher speech recognition scores in a group of 85 children. Guerzoni and Cuda's data⁹ showing a positive correlation between hours of device use per day and lexical quotient corroborated this finding. Only one previous study has evaluated a similar correlation in the adult population. Schwartz-Leyzac and colleagues¹⁰ found a moderate correlation between average duration of CI use per day and speech recognition measures in a sample of 177 adults. Based on these data, one could hypothesize that average duration of CI use per day may account for a significant portion of the variability in speech recognition outcomes.

It is reasonable to assume that all CI recipients need experience and practice to learn to listen via electrical stimulation. Studies showing that CI recipients require approximately six months of listening prior to reaching asymptotic performance^{11,12} point to the importance of adults wearing their processor as often as possible. However, we are unable to make a data driven recommendation regarding how many hours per day a patient should use their processor for optimal performance. In 2017, Busch and colleagues¹³ analyzed CI use for 1,501 CI recipients of all ages and found daily average wear time to be 10.7 hours with the 95% confidence interval ranging from 4.3 to 15.2 hours per day. This finding indicates considerable variability in average wear time for all recipients across the lifespan.

In the current study, we aimed to quantify the relationship between average daily processor use and measures of speech recognition in postlingually deafened adults. We hypothesized that higher daily wear time would be positively correlated with CI-only speech recognition scores.

MATERIALS AND METHODS

A retrospective review of CI programming software and clinical reports was conducted for 300 postlingually deafened adult CI recipients (130 female) with an average age of 64 years

(range: 18–96 years) at the time of implantation. All patients were implanted between 2012 and 2018. Recipients of three CI manufacturers were included as follows: 132 Advanced Bionics, 128 Cochlear, and 40 MED-EL. Exclusion criteria included prelingual onset of deafness and revision surgery. The following data points were recorded for each participant as available: age at implantation, gender, surgery date, hours of CI use per day, CI-only speech recognition [consonant-nucleus-consonant (CNC) word recognition, AzBio sentence recognition in quiet, and AzBio sentence recognition at +5 dB signal-to-noise ratio (SNR)], and Speech Spatial Qualities (SSQ) questionnaire.

Hours of CI Use per Day

The average number of hours of processor use per day was extracted from each individual participant's datalogging information housed in the CI programming software. The datalogging value closest to the one-year post-implantation time point (Mean = 12.5 months) was recorded for each recipient. Audiologic reports were also reviewed. If the patient used more than one processor per ear, datalogging from each processor over identical time periods was summed. Patients using equipment that did not support datalogging were not included; this group included bilaterally initialized Advanced Bionics Naida CI users, Advanced Bionics Harmony and Neptune users, MED-EL Rondo & Opus 2 users, and Cochlear Nucleus 5 users.

Speech Recognition

Speech recognition testing was conducted as previously reported in Holder et al. (2018)¹⁴. Speech recognition results reported herein follow the revised Minimum Speech Test Battery (MSTB) for adult CI recipients¹⁵. Speech recognition testing was completed in a sound treated booth with a presentation level of 60 dB SPL through a single loud speaker positioned at zero degrees azimuth approximately 1 meter from the listener. Larson Davis LxT sound level meters were present in the test booths allowing for calibration prior to assessment for every patient. Participants completed CNC word recognition (50-word list)¹⁶ and AzBio sentence recognition (20-sentence list)¹⁷. Sentences were presented in quiet and +5 dB SNR multi-talker babble. Patients also completed the SSQ questionnaire, which assesses subjective hearing abilities across three listening domains: speech understanding, spatial hearing, and overall quality of speech using a visual analog scale ranging from 1 (poor) to 10 (perfect)¹⁸.

Statistical Analyses

The primary correlation of interest was the correlation between the average number of hours of CI use per day and CNC word recognition. Correlation analyses were completed using Spearman's rank-order correlations, as the hours of CI use were not normally distributed.

RESULTS

Average CI use was 10.2 hours per day (SD = 4.2 hours) and ranged from 0.1 to 22.7 hours per day. Males wore their processor an average of 11.1 hours per day compared to 9.0 hours per day for females; a Mann-Whitney test indicated that this 2-hour difference per day across gender was statistically significant ($U = 7604$, $p < 0.001$). There was no effect of

manufacturer. Advanced Bionics users' mean use was 10.1 hours, Cochlear users' mean was 10.6 hours, and MED-EL users' mean was 9.3 hours; these differences were not found to be statistically significant. A Spearman's rank-order correlation was run to determine the relationship between age at implantation and hours of CI use per day as well as age at implantation and CNC word score. There was a negative correlation between hours of CI use and age at implantation ($r_s = -0.13$, $p = 0.024$), which was statistically significant but weak¹⁹. There was also a negative correlation between CNC word score and age at implantation ($r_s = -0.21$, $p < 0.001$), which was also statistically significant but a small effect size¹⁹.

Speech recognition measures were collected at an average of 12.5 months post-implantation (range: 5 to 76 months). The mean scores for CNC words, AzBio sentences in quiet, and AzBio sentences at +5 dB SNR across all CI users were 49.9%, 61.7%, and 24.3%, respectively. Spearman's rank-order correlations were completed to assess the relationship between hours of use per day and scores for CNC, AzBio, and AzBio at +5 dB SNR. The main finding of this study was the statistically significant and strong correlation between speech recognition and hours of CI use per day for CNC word recognition ($r_s = 0.61$, $p < 0.0001$, 95% Confidence Interval [0.54, 0.69]) and AzBio sentence recognition in quiet ($r_s = 0.56$, $p < 0.0001$, 95% Confidence Interval [0.46, 0.64]). We found a statistically significant and moderate positive correlation between hours of CI use per day and AzBio sentences at +5 dB SNR ($r_s = 0.41$, $p < 0.0001$, 95% Confidence Interval [0.27, 0.54]). However, there was no significant correlation with SSQ ($r_s = 0.15$, $p = 0.121$, 95% Confidence Interval [-0.04, 0.32]).

DISCUSSION

The objective of the current study was to quantify the relationship between average hours of CI use per day (data logging) and speech recognition scores. Results showed a strong positive correlation between average hours of CI use per day and both CNC word and AzBio sentence recognition. This correlation suggests that CI users who wear their processor for a greater number of hours per day demonstrate better speech recognition skills or that CI users with better speech recognition skills tend to wear their processor for more hours per day on average.

CI users in our group used their devices 10.2 hours per day, which is consistent with Busch and colleagues' report of 10.7 hours per day¹³ and slightly lower than Schwartz-Leyzac and colleagues' report of 12.1 hours per day¹⁰. Average CNC word recognition for our group was 50%, which is approximately 10-percentage points higher than a recent report by Fabie and colleagues²⁰, but relatively consistent with other reports of large clinical populations^{2,21,22}. We found a statistically significant and strong correlation between these measures (CI use vs. CNC: $r_s = 0.61$), which is slightly higher than a recent report by Schwartz-Leyzac and colleagues with a smaller sample size ($r = 0.43$)¹⁰.

The results of the current study show that greater daily processor use is associated with higher, less variable speech recognition scores. The correlation between average hours of CI use per day and speech recognition was found to be 0.6, which is higher than other

commonly referenced factors such as age at implantation^{23,24}, duration of deafness^{23–26}, length of CI use^{5,23,27,28}, or electrode position^{4,5,29}. This finding is promising for CI users and clinicians because it is a factor that can be readily manipulated by the CI recipient and is likely malleable, though further investigation is required to determine whether increased daily CI use will result in improved outcomes for longer term CI users. Our data suggest that 10.2 hours of processor use per day is associated with average (50%) speech recognition performance. Greater than 10 hours of daily processor use is associated with above average speech recognition and lower variability in outcomes for all measures. For example, the participants in our group wearing their processor ~10 hours per day, ranged in performance from 24 to 82% correct for CNC word recognition, whereas participants wearing their processor 15 hours per day ranged from 40 to 92% correct on the same measure. Based on these findings, audiologists may wish to be more specific in their recommendation of daily processor use. Currently, audiologists report recommending “full-time” use or “all waking hours,” but this recommendation may be ambiguous for some users. Although this study does not assess causation, it is reasonable for clinicians to use 10 hours of CI use per day as a minimum recommendation, as 10 hours was associated with average performance. Our correlational data suggest that greater than 10 hours of CI use per day is associated with higher performance, so clinicians may wish to implement higher daily use goals to improve speech recognition performance as we continue to investigate the causal link between these two measures.

These results also have implications for future CI research studies. Going forward, CI use habits should be accounted for in CI outcome studies, and some researchers may wish to consider implementing a minimum number of hours of daily use prior to enrolling participants in CI-based intervention research.

Limitations

Although we found a strong association between average hours of CI use per day and speech recognition scores, causality cannot be assumed. A reasonable, alternate interpretation could be that CI users are wearing their processor more because they are performing better. One reason we feel that this is unlikely is due to the lack of correlation between CI use and SSQ scores. Patients who wear their device more, do not self-report better performance or sound quality. Future research is needed to confirm causation as well as to further investigate whether there is a dose dependent response for auditory outcomes in long-term CI recipients. In other words, can we drive higher performance for existing CI users who are scoring below average by simply enforcing longer daily wear times?

CONCLUSION

In summary, the current study assessed the correlation between measures of speech recognition and average daily processor use in adult CI recipients. Results showed a strong, positive correlation between daily processor use and speech recognition scores (CNC and AzBio). We found that on average 10 hours of processor use per day was associated with average speech recognition (CNC = 50%). These results support current recommendation for “full-time” use of the CI processor to achieve maximal performance, but more specifically

clinicians may elect to use 10 hours per day as a minimum goal and 15 hours per day as a higher recommended target to increase the likelihood of above average speech recognition performance while we continue to investigate whether or not there is a causal link between these two measures.

Acknowledgments

FINANCIAL MATERIAL & SUPPORT:

NIH R01 DC13117; PI: RenéH. Gifford, PhD

References

1. Buss E, Pillsbury HC, Buchman CA, et al. Multicenter U.S. bilateral MED-EL cochlear implantation study: Speech perception over the first year of use. *Ear Hear.* 2008;29(1):20–32. doi:10.1097/AUD.0b013e31815d7467 [PubMed: 18091099]
2. Gifford RH, Shalloo JK, Peterson AM. Speech recognition materials and ceiling effects: Considerations for cochlear implant programs. *Audiol Neurotol.* 2008;13(3):193–205. doi:10.1159/000113510
3. Litovsky R, Parkinson A, Arcaroli J, Sammeth C. Simultaneous bilateral cochlear implantation in adults: A multicenter clinical study. *Ear Hear.* 2006;27(6):714–731. doi:10.1097/01.aud.0000246816.50820.42 [PubMed: 17086081]
4. Holden LK, Finley CC, Firszt JB, et al. Factors affecting open-set word recognition in adults with cochlear implants. *Ear Hear.* 2013;34(3):342–360. doi:10.1097/AUD.0b013e3182741aa7 [PubMed: 23348845]
5. Chakravorti S, Noble JH, Gifford RH, et al. Further Evidence of the Relationship Between Cochlear Implant Electrode Positioning and Hearing Outcomes. *Otol Neurotol.* 2019. doi:10.1097/MAO.0000000000002204
6. Vohr BR, Topol D, Watson V, St Pierre L, Tucker R. The importance of language in the home for school-age children with permanent hearing loss. *Acta Paediatr Int J Paediatr.* 2014. doi:10.1111/apa.12441
7. Weisleder A, Fernald A. Talking to children matters: early language experience strengthens processing and builds vocabulary. *Psychol Sci.* 2013. doi:10.1177/0956797613488145
8. Easwar V, Sanfilippo J, Papsin B, Gordon K. Impact of Consistency in Daily Device Use on Speech Perception Abilities in Children with Cochlear Implants: Datalogging Evidence. *J Am Acad Audiol.* 2017. doi:10.3766/jaaa.17051
9. Guerzoni L, Cuda D. Speech processor data logging helps in predicting early linguistic outcomes in implanted children. *Int J Pediatr Otorhinolaryngol.* 2017;101:81–86. doi:10.1016/j.ijporl.2017.07.026 [PubMed: 28964316]
10. Schvartz-Leyzac KC, Conrad CA, Zwolan TA. Datalogging Statistics and Speech Recognition During the First Year of Use in Adult Cochlear Implant Recipients. *Otol Neurotol.* 5 2019. doi:10.1097/MAO.0000000000002248
11. Massa ST, Ruckenstein MJ. Comparing the performance plateau in adult cochlear implant patients using HINT and AzBio. *Otol Neurotol.* 2014;35(4):598–604. doi:10.1097/MAO.0000000000000264 [PubMed: 24557031]
12. Lenarz M, Sönmez H, Joseph G, Büchner A, Lenarz T. Long-term performance of cochlear implants in postlingually deafened adults. *Otolaryngol - Head Neck Surg (United States).* 2012. doi:10.1177/0194599812438041
13. Busch T, Vanpoucke F, van Wieringen A. Auditory Environment Across the Life Span of Cochlear Implant Users: Insights From Data Logging. *J Speech Lang Hear Res.* 2017;60(5):1362. doi:10.1044/2016_JSLHR-H-16-0162 [PubMed: 28418532]

14. Holder JT, Levin LM, Gifford RH. Speech Recognition in Noise for Adults With Normal Hearing: Age-Normative Performance for AzBio, BKB-SIN, and QuickSIN. *Otol Neurotol.* 9 2018. doi: 10.1097/MAO.0000000000002003
15. MSTB. Minimum Speech Test Battery For Adult Cochlear Implant Users. <http://auditorypotential.com/MSTBfiles/MSTBManual2011-06-20.pdf>. Published 2011. Accessed January 5, 2018.
16. Peterson GE, Lehiste I. Revised CNC Lists for Auditory Tests. *J Speech Hear Disord.* 1962;27(1): 62. doi:10.1044/jshd.2701.62 [PubMed: 14485785]
17. Spahr AJ, Dorman MF, Litvak LM, et al. Development and validation of the AzBio sentence lists. *Ear Hear.* 2012;33(1):112–117. doi:10.1097/AUD.0b013e31822c2549 [PubMed: 21829134]
18. Gatehouse S, Noble W. The Speech, Spatial and Qualities of Hearing Scale (SSQ). *Int J Audiol.* 2004;43(2):85–99. doi:10.1080/14992020400050014 [PubMed: 15035561]
19. Cohen J Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
20. Fabie JE, Keller RG, Hatch JL, et al. Evaluation of Outcome Variability Associated With Lateral Wall, Mid-scalar, and Perimodiolar Electrode Arrays When Controlling for Preoperative Patient Characteristics. *Otol Neurotol.* 8 2018. doi:10.1097/MAO.0000000000001951
21. Cusumano C, Friedmann DR, Fang Y, Wang B, Roland JT, Waltzman SB. Performance Plateau in Prelingually and Postlingually Deafened Adult Cochlear Implant Recipients. *Otol Neurotol.* 2017. doi:10.1097/MAO.0000000000001322
22. Gifford RH, Noble JH, Camarata SM, et al. The relationship between spectral modulation detection and speech recognition: adult versus pediatric cochlear implant recipients. *Trends Hear.* 2018;22:1–14. doi:10.1177/2331216518771176
23. Blamey P, Arndt P, Brimacombe J, et al. Factors affecting auditory performance of postlinguistically deaf adults using cochlear implants. *Audiol Neuro-Otology.* 1996. doi: 10.1159/000259212
24. Leung J, Wang NY, Yeagle JD, et al. Predictive models for cochlear implantation in elderly candidates. *Arch Otolaryngol - Head Neck Surg.* 2005. doi:10.1001/archotol.131.12.1049
25. Green KMJ, Bhatt YM, Mawman DJ, et al. Predictors of audiological outcome following cochlear implantation in adults In: *Cochlear Implants International.* ; 2007. doi:10.1002/cii.326
26. Friedland DR, Venick HS, Niparko JK. Choice of ear for cochlear implantation: The effect of history and residual hearing on predicted postoperative performance. *Otol Neurotol.* 2003. doi: 10.1097/00129492-200307000-00009
27. Dorman MF, Hannley MT, Dankowski K, Smith L, McCandless G. Word recognition by 50 patients fitted with the symbion multichannel cochlear implant. *Ear Hear.* 1989. doi: 10.1097/00003446-198902000-00008
28. Dowell RC, Mecklenburg DJ, Clark GM. Speech Recognition for 40 Patients Receiving Multichannel Cochlear Implants. *Arch Otolaryngol Neck Surg.* 1986. doi:10.1001/archotol.1986.03780100042005
29. Wanna GB, Noble JH, Gifford RH, et al. Impact of Intrascalar Electrode Location, Electrode Type, and Angular Insertion Depth on Residual Hearing in Cochlear Implant Patients: Preliminary Results. *Otol Neurotol.* 2015;36(8):1343–1348. doi:10.1097/MAO.0000000000000829 [PubMed: 26176556]

Figure 1.

A) Correlation between average hours of cochlear implant (CI) use per day and consonant-nucleus-consonant (CNC) word scores, B) Correlation between average hours of CI use per day and AzBio sentence scores, C) Correlation between average hours of CI use per day use and AzBio sentence scores in +5 dB signal-to-noise ratio (SNR), D) Correlation between average hours of CI use per day and Speech Spatial Qualities (SSQ) scores.

Figure 2.

A) Correlation between age at implantation and average hours of cochlear implant (CI) use per day, B) Correlation between age at implantation and consonant-nucleus-consonant (CNC) word score.