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Computer-Assisted Speech Perception Assessment (CASPA) Data in Adults with and without HIV

Peter Torre III[1#], Gayle Springer[2], Christopher Cox[2], Howard J. Hoffman[3], Abigail Fellows[4], Jay Buckey Jr[4] and Michael Plankey[5]

[1]*School of Speech, Language, and Hearing Sciences, San Diego State University, San Diego, California, USA*
[2]*Department of Epidemiology, Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland, USA*
[3]*Epidemiology and Statistics Program, National Institute on Deafness and Other Communication Disorders (NIDCD), National Institutes of Health (NIH), Bethesda, Maryland, USA*
[4]*Geisel School of Medicine, Dartmouth University, Lebanon, New Hampshire, USA*
[5]*Georgetown University Medical Center, Washington D.C., USA*

Abstract

Objective: There is increasing literature on the association of HIV disease with hearing loss in adults, although only very limited research regarding communication, specifically in a background noise condition. The purpose of this study was to first, evaluate computer-assisted speech perception assessment (CASPA) data among adults living with HIV (ALHIV) and adults living without HIV (ALwoHIV). And second, to examine the association of HIV disease variables and HIV treatment with CASPA measures among ALHIV.

Methods: A sample of 101 ALHIV (n=57) and ALwoHIV (n=44) participants from the Baltimore-Washington DC site of the Multicenter AIDS Cohort Study (MACS) and the Washington DC site of the Women's Interagency HIV Study (WIHS) completed CASPA testing. Testing was performed in sound treated rooms using a speaker placed 3 ft away from the listener.

Results: ALHIV and ALwoHIV had similar mean thresholds for phoneme and consonant scoring. ALHIV had poorer phoneme and consonant thresholds despite better ear 4 kHz thresholds compared to the ALwoHIV, suggesting difficulty with detecting speech-in-noise not related to diminished pure-tone thresholds. In ALHIV only, after adjusting for age, sex, nadir CD4+ T-cell count, and better ear 4 kHz threshold, total time on protease inhibitors (PIs) was significantly negatively associated with both phoneme threshold and consonant threshold, while total time on non-nucleoside reverse transcriptase inhibitors (NNRTIs) was marginally associated with both threshold measures.

Conclusion: CASPA performance appeared to be poorer in ALHIV and these results suggest that HIV treatment (i.e., cumulative PI or NNRTI use) may preserve speech communication abilities in noise.

Keywords: HIV • Adults • Hearing • Computer-Assisted Speech Perception Assessment (CASPA)

Introduction

The hearing system includes both peripheral sensing of sound and central processing of the nerve signals to recognize and extract meaning from the sounds. Researchers have evaluated the effects of HIV on peripheral hearing in adults living with HIV (ALHIV) [1-4], although results of these studies are mixed; some researchers found an effect of HIV on peripheral hearing [1,4] while others have not [2,3]. Although identifying hearing loss in adults living with HIV (ALHIV) is important, so is understanding how this impacts communications.

There is a growing literature on speech communication measures in ALHIV. ALHIV on antiretroviral therapy (ART) had significantly more self-reported difficulty understanding speech compared to those ALHIV not taking ART [3]. Apart from the self-reported speech data from Maro et al. [3], word recognition data in a quiet background have only been collected as part of two studies [2,5]. Luque et al. [2] reported that late stage ALHIV had significantly poorer right ear only word recognition scores compared to both early stage ALHIV and control adults. There are two limitations in the significant results of Luque et al. [2]. First, word recognition scores in quiet were very good across all three groups (e.g., 97.2-98.5%). And second, the mean 1.3% difference between late stage ALHIV and control adults was not clinically meaningful. For a 25-word list, that means late stage ALHIV did not even miss one more word than controls in the 25-word list.

Torre et al. [5] also reported on word recognition data using recorded phonetically-balanced 25-word lists in quiet but those data were collected as part of the audiometric protocol [1]. Like Luque et al. [2], word recognition scores in Torre et al. [5] were also very good; 90% of both ALHIV and adults living without HIV (ALwoHIV) had 90% or greater word recognition scores. As a result, there was no statistically significant association between HIV status and word recognition scores. Further, in ALHIV only, there were no significant associations between HIV-related variables (i.e., current CD4+ cell count, HIV viral load, or ever having AIDS) and word recognition scores.

Recently, Zhan et al. [6] evaluated speech communication in the presence of a background noise in ALHIV using the hearing-in-noise test (HINT). Although all 166 ALHIV in the analyses had normal peripheral hearing, those adults with cognitive deficits had statistically significant poorer HINT scores than those adults without cognitive deficits. Zhan et al. [6] provided important data on speech-in-noise ability that was associated with cognitive function; and because the ALHIV in this study had normal hearing, these results might suggest damage to central auditory pathways, perhaps reflecting more general central nervous system damage.

***Address for Correspondence:** Peter Torre III, School of Speech, Language, and Hearing Sciences, San Diego State University, 5500 Campanile Dr., SLHS 237, San Diego, CA 92182-1518, USA, Tel: +(619) 594-4787; Fax: (619) 594-7109; E-mail: ptorre@sdsu.edu*

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Word recognition testing completed in quiet is easier for individuals compared to recognizing words in noise, even those with hearing loss, and might not be representative of a daily listening situation. Word recognition testing in background noise puts the listener in a more complex listening environment and can be used as a measure of central auditory processing, especially in ALHIV with normal hearing [6]. One such measure is the Computer-Assisted Speech Perception Assessment Test (CASPA) [7]. In this test, software installed on a computer presents consonant-vowel-consonant (CVC) stimuli that vary in presentation level but with a fixed background noise level. Once testing is complete, the examiner can assess separate scores words, phonemes, consonants, or vowels. Two advantages of CASPA testing are that testing is completed in background noise and there are multiple outcome data (i.e., word scores, phoneme scores, and consonant scores) to evaluate in an effort to determine the impact of hearing loss on word recognition ability. The purpose of this study was to extend the findings of Torre et al. [1,5], by recruiting ALHIV and ALwoHIV back to the clinics, and to collect CASPA data in these adults.

Materials and Methods

The Institutional Review Boards for San Diego State University, Johns Hopkins Bloomberg School of Public Health, Georgetown University, and Whitman-Walker Health approved this study. All participants provided signed informed consent.

Participants in the Multicenter AIDS Cohort Study (MACS) and Women's Interagency HIV Study (WIHS)

The MACS is multicenter prospective study of HIV infection among men who have sex with men in the United States whereas the WIHS is also a multicenter prospective cohort study to examine women with or at risk for HIV infection. Both studies are ongoing and specifics about the MACS have been described elsewhere [8,9] as well as the WIHS [10,11]. CASPA data were obtained from men recruited only from the Baltimore/Washington, DC MACS site while CASPA data were obtained from women from the Washington, DC site of the WIHS.

Procedures

As part of a previous research protocol, MACS/WIHS participants from the Baltimore/Washington DC sites had completed a standard clinical audiometric evaluation that included bilateral otoscopy, tympanometry, pure-tone air- and bone-conduction audiometry, and speech audiometry (i.e., speech recognition thresholds and word recognition scores in quiet) [1,5]. These audiometric evaluation data were collected in 2008 and 2010. But at the time of this initial testing, CASPA data were not collected. Because of this, participants were contacted and asked to participant in the current study. As a result, there was a mean of 7 years (minimum 5.5 years, maximum 8.0 years) between the time of audiometric testing and CASPA testing. No participant reported any speech or language problems at the time of testing. CASPA testing was completed in sound treated room and performed in sound field with a speaker set 3 ft. away from the listener and at 0° azimuth [7]. Ten CVC CASPA words were presented at each level from 45 to 75 decibels of sound pressure level (dB SPL) in 5-dB steps with a fixed 4-talker babble noise at 55 dB SPL. Participants repeated the words and the words were scored either using traditional spelling or any preferred phonetic system and entered in real time. Historical pure-tone data from MACS/WIHS participants were then merged with these prospectively collected CASPA data.

For ALHIV, both HIV treatment and disease severity data were obtained. ARTs were classified as nucleotide reverse transcriptase inhibitors (NRTIs), protease inhibitors (PIs), and non-nucleotide reverse transcriptase inhibitors (NNRTIs). Combination ART (cART) was determined by the DHHS Panel on Antiretroviral Guidelines for Adults and Adolescents [12] guidelines and defined as three or more ART drugs consisting of one or more PIs or one NNRTI or the NRTIs or an integrase inhibitor or an entry inhibitor (including fusion inhibitors). AIDS-defining conditions were obtained by self-report and determined according to the 1993 CDC definition of AIDS [13].

Disease severity, specifically HIV RNA (i.e., HIV viral load) was determined using COBAS TaqMan 2.0 (Roche Molecular Systems, Branchburg, NJ) with lower detection limit of 20 copies/mL. ALHIV with HIV RNA values less than that value were considered undetectable. HIV RNA values were subsequently logarithmically (log10) transformed for statistical analysis. CD4+ T-cell counts were obtained using standard flow cytometry [14] at study visits for ALHIV. Most lab results used in the statistical analyses were obtained within 6 months of hearing testing but all laboratory results were collected within one year prior to the hearing testing.

Statistical analyses

One outcome measure was obtained from performance-intensity curves (where percent correct is plotted for each presentation level) for both phoneme scoring and consonant only scoring. This measure was Threshold, in dB, defined as the 50% score. Multiple regression analyses were performed (SAS, Version 9.4). Independent variables (i.e., sex, age at test, in decades, and HIV serostatus) in these models were assessed at the time of testing. Nadir CD4+ T-cell counts, ever having had an AIDS-defining condition, and cumulative HIV-related medication use (e.g., PIs, NRTIs, and NNRTIs) were added to the models that included ALHIV. All statistical models were adjusted for sex and age (risk factors for hearing loss) and in ALHIV models only, models were adjusted for nadir CD4+ cell count, a global marker of HIV disease at its lowest point.

Results

One hundred one participants (57 ALHIV and 44 ALwoHIV) completed CASPA testing. Other demographic variables are shown in Table 1. Briefly, ALHIV were female, slightly younger, Black, with less self-reported non-occupational noise exposure compared to ALwoHIV. For ALHIV, mean nadir CD4+ T-cell counts are shown and all 57 ALHIV were virologically suppressed based on undetectable HIV RNA levels.

On average, ALHIV and ALwoHIV had similar mean thresholds for both phoneme and consonant scoring (Table 2). After adjusting for age, sex, there was a statistically significant interaction ($p < 0.05$) for HIV status and better ear (i.e., lower) 4 kHz thresholds for both phoneme thresholds (PTHRESH) and consonant thresholds (CTHRESH) (Table 3). These significant interactions are shown where ALHIV had poorer PTHRESH (Figure 1) and CTHRESH (Figure 2) with better 4 kHz thresholds suggesting more difficulty with speech-in-noise despite better pure-tone thresholds.

More than 75% of ALHIV had undetectable HIV RNA values, so this variable was not included in any further analyses. In ALHIV only, after adjusting for age, sex, nadir CD4+ cell count, and better ear 4 kHz threshold, there was statistically significant negative association between increasing time on PIs and both PTHRESH (estimate = -0.2, 95% confidence interval = -0.3, 0.0, p=0.02) and CTHRESH (estimate = -0.2, 95% confidence interval = -0.3, 0.0, p=0.01) (Table 3). Specifically, the longer the individual was taking a PI, the better (i.e., lower) the mean threshold. Increasing time on NNRTIs was marginally associated with PTHRESH (estimate = -0.2, 95% confidence interval = -0.4, 0.0, p=0.08) and CTHRESH (estimate = -0.2, 95% confidence interval = -0.4, 0.0, p=0.06) measures, but increasing time on NRTI was not associated with either PTHRESH or CTHRESH.

Discussion

On average, participants in this study correctly identified phonemes and consonants 50% of the time at a lower level than the background babble. Mean PTHRESH and CTHRESH for HIV status and sex were approximately 50 dB and, given that the background babble was fixed at 55 dB SPL, this would result in a negative signal-to-babble ratio (SBR). Despite better 4 kHz thresholds, ALHIV had poorer PTHRESH and CTHRESH outcomes, which might be indicative of more central auditory processing difficulties in ALHIV. Lastly, those ALHIV with longer total time use of PI had statistically significant better mean PTHRESH and CTHRESH, although total use of NNRTI was marginally associated with better mean PTHRESH and CTHRESH.

Table 1. Demographic characteristics of participants stratified by HIV status.

Variables	ALHIV (n=57)	ALwoHIV (n=44)
Sex (n, % female)	25 (43.9%)	6 (13.6%)
Age, mean (SD), yrs	58.0 (8.2)	64.5 (8.7)
Race, n (%)		
Non-black	22 (38.6)	37 (84.1)
Black	25 (61.4)	7 (15.9)
Occupational noise exposure, n (%)	15 (26.3)	12 (27.3)
Non-occupational noise exposure, n (%)	29 (50.9)	34 (77.3)
Nadir CD4+ cell count, mean (IQR), cells/μL	217 (88, 306)	
Current CD4+ cell count, mean (IQR), cells/μL	601 (470, 840)	
HIV RNA, median (IQR), copies/mL	<20 (<20, <20)[a]	

Abbreviations: ALHIV: Adults Living with HIV; ALwoHIV: Adults Living without HIV; SD: Standard Deviation; IQR: Interquartile Range.
[a] <20 denotes a plasma HIV RNA value as undetectable by the assay used.

Table 2. Outcome variables (means [SDs]), stratified by HIV status, then sex.

Variables	PTHRESH, in dB	CTHRESH, in dB
ALHIV	mean (SD)	mean (SD)
Women (n=25)	49.8 (3.6)	50.7 (3.8)
Men (n=32)	48.4 (3.4)	48.8 (3.3)
ALwoHIV		
Women (n=6)	47.8 (2.6)	48.7 (2.3)
Men (n=38)	48.8 (4.1)	49.5 (4.1)

Abbreviations: ALHIV: Adults Living with HIV; ALwoHIV: Adults Living without HIV; PTHRESH: Phoneme Threshold; CTHRESH: Consonant Threshold; SD: Standard Deviation.

Table 3. The estimates (and 95% confidence intervals) are shown for the final regression models for PTHRESH and CTHRESH outcome measures. The top portion presents models for all participants whereas the bottom portion presents models for ALHIV only.

ALL	PTHRESH	p-value	CTHRESH	p-value
Age (10-yr increase)	0.8 (-0.1, 1.6)	0.07	0.6 (-0.3, 1.4)	0.16
HIV status – ALHIV	3.1 (0.8, 5.4)	0.008	2.6 (0.3, 4.9)	0.03
Sex – Male	-2.2 (-3.7, -0.6)	0.007	-2.5 (-4.1, -1.0)	0.002
Better ear 4 kHz threshold	0.2 (0.1, 0.2)	<0.0001	0.2 (0.1, 0.2)	<0.0001
HIV status-by-better ear 4 kHz threshold	-0.1 (-0.2, 0)	0.02	-0.1 (-0.2, 0)	0.04
ALHIV only				
Age (10-yr increase)	1.0 (-0.2, 2.3)	0.09	0.8 (-0.4, 2.0)	0.17
Sex – Male	-3.4 (-5.6, -1.2)	0.003	-4.0 (-6.1, -1.9)	0.0005
Better ear 4 kHz threshold	0.1 (0.1, 0.2)	0.002	0.1 (0.1, 0.2)	0.0004
CD 4 Nadir (100 cell increase)	-0.6 (-1.3, 0)	0.06	-0.7 (-1.3, 0)	0.04
Increasing time on NRTI	0 (0, 0.1)	0.34	0 (0, 0.1)	0.29
Increasing time on NNRTI	-0.2 (-0.4, 0)	0.08	-0.2 (-0.4, 0)	0.06
Increasing time on PI	-0.2 (-0.3, 0)	0.02	-0.2 (-0.3, 0)	0.01
Ever AIDS	-1.9 (-4.2, 0.4)	0.09	-2.0 (-4.3, 0.2)	0.07

This current study is only the second, to date, that has evaluated the association between HIV infection and treatment and speech-in-noise in adults. Zhan et al. [6] collected HINT data in 166 Mandarin Chinese speaking ALHIV with normal hearing and reported that those with cognitive impairment had poorer HINT scores. There are no direct comparisons between the data from the current and those collected in Zhan et al. [6], but there is one consistency in the results between the two studies. In the Zhan et al. [6] participants with normal cognition (n=135), the mean signal-to-noise ratio (SNR) was approximately -6 dB whereas the participants in the current study would have had an estimated -5 dB SBR (calculated from the mean PTHRESH and CTHRESH of ~50 dB and a background babble of 55 dB). The participants in the current study, however, did not have cognitive function assessed, so it is not known whether or not any of the MACS/WIHS participants with CASPA data had cognitive deficits.

There are substantial differences, unfortunately, between the current study and Zhan et al. [6]. The HINT and the CASPA were administered differently; HINT was under earphones while the CASPA for the current study was completed in sound field. Further, the noise in the HINT was spectrally matched to the average long-term spectrum of speech (i.e., speech-shaped noise) and presented at a slightly higher level (65 dBA) than for the CASPA. For the CASPA, 4-talker babble at 55 dB SPL was used. The main difference between the two studies was participant characteristics. Zhan et al. [6] collected data in only ALHIV who were substantially younger (mean age = ~35 years) compared to participants in the current study (mean age = ~60 years). In the current study, the ALHIV were virologically suppressed at the time of CASPA whereas Zhan et al. [6] did not provide any HIV disease or treatment data in the ALHIV.

The participants in the current study were recruited directly from the MACS/WIHS groups that completed both pure-tone testing [1] and word recognition in quiet testing [5]. And although ALHIV had statistically significant poorer hearing, for both word recognition in quiet and now speech-in-noise, there was no effect of HIV on these measures. The sample size in the current study (n=101) is smaller, however, compared to the previous hearing MACS/WIHS studies [1,5,15]. In the current study, for ALHIV only, there was a statistically significant negative association between total time on PI and both phoneme and consonant thresholds. Torre et al. [1] reported that total time on any class of ART medication (NRTI, NNRTI, or PI) was not significantly

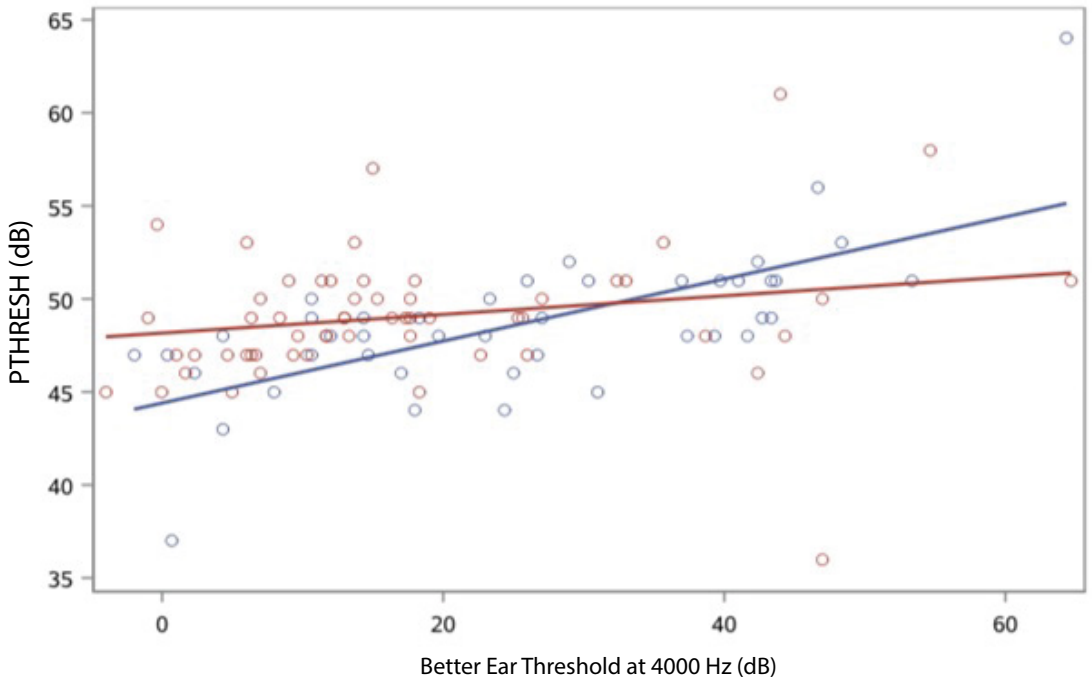

Figure 1. The scatter-plot for adults living with HIV (red data points, red regression line) and adults living without HIV (blue data points, blue regression line) presenting phoneme thresholds, in dB, (PTHRESH) as a function of better ear threshold, in dB, at 4000 Hz.

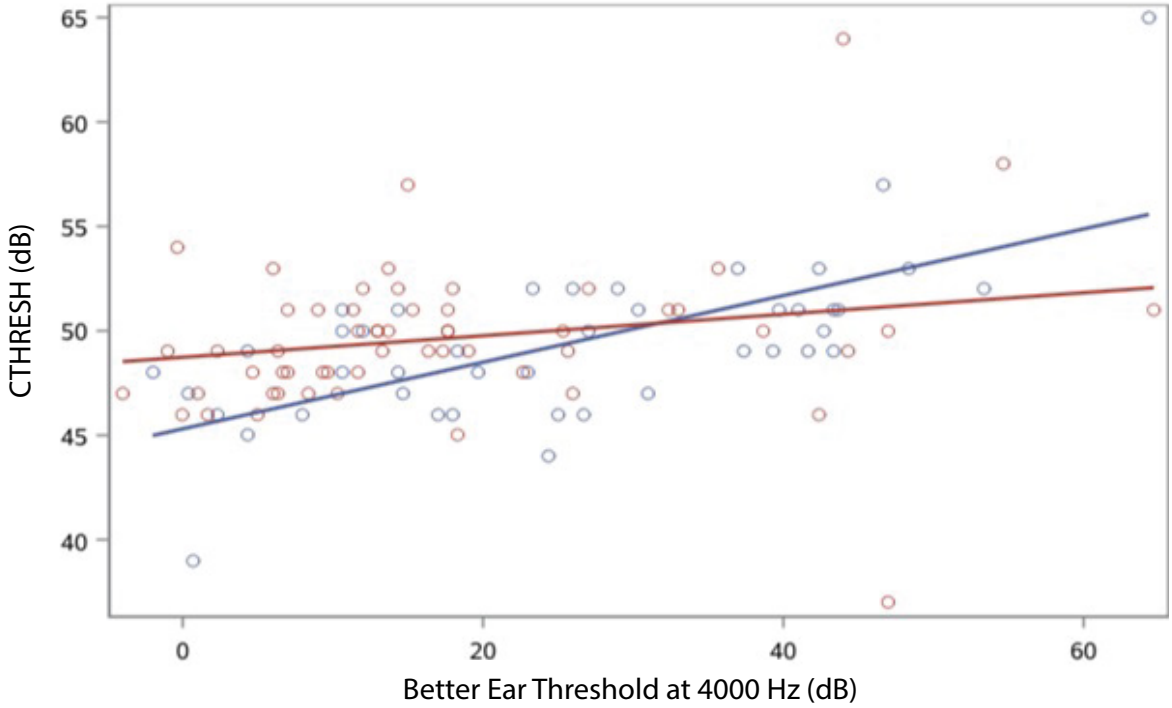

Figure 2. The scatter-plot for adults living with HIV (red data points, red regression line) and adults living without HIV (blue data points, blue regression line) presenting consonant thresholds, in dB, (CTHRESH) as a function of better ear threshold, in dB, at 4000 Hz.

associated with hearing sensitivity. Population differences could be the likely reason behind the lack of agreement between the two datasets, such that self-selection was likely higher in the current study since participants returned to the clinic sites for this additional measure. The participants in the current study may be more adherent with their medications and likely more aware of other health factors, such as hearing loss, and this could have led to the marginally and statistically significant negative associations between HIV medications and CASPA outcomes.

One limitation of the current study is smaller sample size compared with other MACS/WIHS hearing-related studies [1,5,15,16], especially female ALwoHIV (n=6). The CASPA procedure was added to the hearing protocol after all of the diagnostic audiometry had been collected; as a result, individuals had to return to the Baltimore/Washington DC sites to complete the CASPA. Although substantial measures were used to recruit equal numbers of participants among the four groups, similar sample sizes were not achieved. It is possible that this subset of MACS/WIHS participants with CASPA are not representative of the whole MACS/WIHS population or generalizable to other middle-aged ALHIV.

Conclusion

In conclusion, these speech-in-noise data, using the CASPA, in ALHIV and ALwoHIV add to a growing literature on the association of HIV disease on speech communication in adults. There was, however, a statistically significant interaction for HIV status and better ear 4 kHz thresholds for phoneme and consonant thresholds. ALHIV had poorer CASPA thresholds with lower 4 kHz thresholds than the HIV- adults, which might suggest a more central auditory processing problem in ALHIV. This would be consistent with the conclusions drawn by Zhan et al. [6] who found poorer speech-in-noise performance in ALHIV with cognitive deficits but normal hearing sensitivity. These data also suggest that treatment leads to improved CASPA performance, which is an area for further study within these established cohorts.

Conflict of Interest

All authors have no potential conflict of interest.

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