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Assessment of Central Auditory Processing in Children using a Novel Tablet-based Platform: Application for Low- and Middle-Income Countries

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Abstract

Objective—Evaluate whether a portable, tablet-based central auditory processing (CAP) test system using native language training videos and administered by minimally trained community health workers (CHW) can produce CAP results comparable to previously published norms. Our secondary aim is to determine subject parameters that influence test results.

Study Design—Cross-sectional study.

Setting—Community-based settings in Chontales, Nicaragua, New Hampshire, and Florida.

Patients—English and/or Spanish-speaking children and adolescents (n=245, average age: 12.20 years old (y.o.), range 6–18 y.o.)

Main Outcome Measures—Completion of the following tests with responses comparable to published norms: Pure tone average (PTA), Gap Detection Threshold, Fixed Level Frequency

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Threshold (FLFT), Masking Level Difference (MLD), Hearing in Noise Test (HINT), Dichotic Digits Test (DDT), and Frequency Pattern Recognition Test (FPR).

Results—GDT, HINT, and DDT had comparable results to previously published normative values. MLD and FPR results differed compared to previously published normative values. Most CAP tests (MLD, GDT, HINT) results were independent of age and PTA (p=0.1–0.9). However, DDT was associated with age and PTA (p<.0001)

Conclusions—Pediatric CAP testing can be successfully completed in remote LMIC environments using a tablet-based platform without the presence of an audiologist. Performance on DDT improved with age but deteriorated with hearing loss. Further investigation is warranted to assess the variability of FPR.

Introduction

Assessing for central auditory processing deficits (CAPD) is critical when neurological diseases, trauma, or toxicity may affect brain function[1]. CAPD reflect impairments in the central nervous system's ability to process and use auditory information[2]. Individuals with CAPD often have normal hearing thresholds, but have trouble interpreting complex sounds, such as speech in background noise[2]. In school-age children, CAPD may present with problems related to listening, learning, and communication[2]. In addition, CAPD may be an early sign of central nervous system (CNS) dysfunction or early cognitive decline[3]. Previous studies have demonstrated a relationship between specific central auditory processing (CAP) tests and CNS dysfunction in patients living with HIV and in other conditions[3].

Trauma, neurologic disease, and neurotoxic substance exposure can produce CAPD[1]. One important set of neurotoxic substances are heavy metals (e.g., acute mercury toxicity)[4]. Heavy metal exposure disproportionately affects individuals in low- and middle- income countries (LMIC). One potential source of heavy metal exposure in these countries is artisanal scale gold mining (ASGM). ASGM often takes place in rural communities with limited access to audiologic or otolaryngologic care. Performing CAP testing in these exposed individuals requires a portable testing platform, ideally used by technicians without specialized training in audiology. Many researchers have explored the use of portable audiometric systems for pure tone audiometry, but no previous studies have extended this point-of-care approach to CAP testing.

CAP testing uses a battery of behavioral tests that assesses speech perception, auditory pattern recognition, temporal processing, frequency resolution, and auditory performance with competing and/or degraded acoustic signals[5]. Our research team has developed a tablet-based CAP test battery in English and Spanish. These protocols were incorporated into an established and validated platform for pure-tone audiometry that combined a highly attenuating headset (the Wireless Automated Hearing Test System (WAHTS))[6–7] and a highly-portable, tablet-based user interface and data management application (TabSINT)[8]. Such a tablet-based system is ideal for use in remote locations because it is portable, light weight, and rechargeable.

For use in the developing world, we needed a system that could be used by minimally trained personnel and would provide reliable results. To achieve this, we used a three-step process. Initially, the system was tested with a US English speaking group with the tests administered by a trained audiologist or medical student trained to use the system. Next, the system was tested in a bilingual Spanish and English-speaking group where the tests were administered by a medical student. Lastly, the system was deployed to Nicaragua and used by community health workers (CHWs) in Nicaragua. We compared results with normative values and test outcomes between the groups and hypothesized that CWH in Nicaragua would be able to administer the battery of tests and obtain reliable test results.

Methods

Equipment and User Training

The Wireless Automated Hearing Test System (Edare LLC, Lebanon NH) is a wireless headset with highly attenuating earcups that attenuate ambient noise and allow for audiometric threshold tests outside a sound booth. Electronics mounted in the headset control the stimulus levels for the automated hearing tests and transmit test results wirelessly to a smartphone, tablet, or laptop[7]. The TabSINT software[8–9] running on the mobile device, sends commands to the WAHTS through a Bluetooth connection to begin or end a test, and acts as a user interface, either for the subject or for the test administrator. TabSINT also handles the data and saves it to a cloud-based repository for later analysis. The WAHTS, along with TabSINT, is registered with the FDA as a medical device, when used for audiometry. Other tests reported here have been used for research only. Engineers at Creare LLC (Hanover, NH) implemented existing or adapted versions of the CAP tests in Spanish and English onto the WAHTS/TabSINT platform.

Medical students from the United States and CHWs in Nicaragua were locally trained to administer standard audiometric PTA testing, Fixed-Level Frequency Threshold (FLFT) tests, and the CAP test battery using the WAHTS headset and TabSINT platform. Training to perform tympanometry and otoscopy was also completed.

Study Subjects and Recruitment

All test procedures were completed under the approval of the Nicaraguan Minister of Health, the National Autonomous University of Nicaragua at Leon institutional review board, and Dartmouth College Committee for the Protection of Human Subjects. Children and adolescents ages 6–18 years old participating in the study were recruited from community-based settings in Chontales, Nicaragua, and a small United States based group from an English-speaking population in New Hampshire (ESUS) and a bilingual Spanish-speaking community in Florida (SSUS) through local school systems and by word-of-mouth. Exclusion criteria included active ear infections or known middle ear pathology, and severe cognitive impairment that would preclude completion of the test.

Test Procedures

Otoscopy and tympanometry were performed on all subjects. Subjects were presented with a training video and audio instructions prior to partaking in the majority CAP tests (Masking

Level Difference (MLD), Gap Detection Threshold (GDT), Dichotic Digits Test (DDT), and Frequency Pattern Recognition (FPR)). Administrators verbally instructed children how to perform the HINT, followed by a supervised practice training session. For all CAP tests, the presentation level (dB HL) was adjusted based on the participant's Pure Tone Average (PTA). In addition, high frequency hearing acuity was assessed using FLFT. Each test is described below with the workflow of the battery depicted in Figure 1. Instructions and test stimuli were presented in English to the ESUS group and in Spanish to the SSUS and Nicaraguan groups.

Pure Tone Audiometry

Pure tone audiometry was administered manually using a modified Hughson-Westlake method. Thresholds were determined for 6 tones (octave frequencies 0.5 – 8.0 kHz) and a 6-frequency PTA was calculated using results of both ears and used to adjust the presentation levels for the CAP test battery. Normal hearing was accepted as a PTA ≤ 20 dB in both ears[10].

Fixed-Level Frequency Threshold (FLFT)

A von Békésy method was used to determine the highest perceived frequency in each ear at a fixed presentation level of ((PTA of better hearing ear) + 40 dB HL). Subjects were instructed to hold down a button on the tablet when a tone was heard. Two training videos were presented to the child being tested: 1) a child demonstrating how to hold the button down on the tablet and 2) colored bars acting as a visual representation of the tone getting higher in pitch. Pure tones started at 0.5 kHz and increased to a maximum of 20 kHz or until a threshold was obtained in both ears. Threshold was determined by averaging the 5 lowest and 5 highest excursions, corresponding to when the subject let go and pressed the button on the tablet, respectively.

Masking Level Difference (MLD)

MLD was adapted from a previously established test to assess binaural release from masking[11–12]. Children watched a short video that instructed them to hold down a button on the tablet when a tone was heard over a static masking white noise. A 0.5 kHz pure tone signal and Schroeder-Phase masking noise were presented binaurally. The pure tone was initially presented at 70 dB SPL and reduced to 0 dB SPL in 1 – 2 dB steps. The signal started at 70 dB SPL with initial signal-to-noise ratio (SNR) at 0. Masking noise was presented either in phase (S_0N_0) or 180 degrees out of phase with the pure tone signal (S_0N_π). The normal response is a reduction of the signal threshold in the S_0N_π condition (a release of masking). MLD is the difference in signal threshold between these two masking conditions. Because this test uses a von Békésy methodology, it is possible to drive the response to an inaudible presentation level. Therefore, a test response of 0 dB SPL for either condition (S_0N_0 or S_0N_π) was considered an invalid response.

Gap Detection Threshold (GDT)

GDT was adapted from a test as described elsewhere to assess temporal resolution[13–15]. The children received training on the GDT task with a training video and a screen that provided both auditory and visual reinforcement of correct responses. Children were instructed to press a button when a short break (i.e., gap) in continuous white noise was identified. Administrators trained the participants until they comprehended the task. The GDT test was presented monaurally to each ear at a suprathreshold presentation (40 dB HL above the tested ear PTA). Gaps were randomly presented within a central 2 second window of a 4 second white noise burst through a wide band pass filter. Gap duration (in milliseconds-ms) decreased in steps until children incorrectly identified 2 gaps in a row or 3 gaps overall, at which point the gap duration increased until it was detected again (i.e., an excursion). Through a series of 10 excursions in gap length, a threshold of gap duration (i.e., shortest detectable gap length) was obtained. The test started with the longest gap of 20 ms and continued until the subject completed 10 excursions or a total of 120 presentations.

After the GDT was completed, a plot of the percentage of time a gap was correctly detected vs. gap duration was produced. If gap length convergence was inconsistent and a clear threshold was not apparent, participants were asked to retake the test. If gap thresholds convergence was inconsistent after the second attempt, the test results were recorded, and the child moved on to the next protocol. The results of all GDT convergence patterns were subsequently reviewed. If the best GDT result did not achieve a consistent convergence upon a threshold, the GDT test result was considered invalid and, therefore, not successfully completed.

Hearing in Noise Test (HINT)

A validated pediatric HINT test in English and Spanish was adapted for the tablet-based platform to assess ability to discriminate speech in quiet and noise (Hearing Systems, LLC) [16–19]. Children listened to sentences through the headset and were asked to repeat what they heard and to guess if they were unsure. Five practice sentences were presented prior to the start of the test to ensure that children understood instructions. The sentences were presented at 40 dB HL above the PTA of the best hearing ear in a variety of background noise conditions: quiet, front (speech and noise presented in front of the participant), left ear (speech presented in front and noise presented in the left ear), and right ear (speech presented in front and noise presented in the right ear). The signal intensity of the speech was maintained while the speech spectrum noise signal intensity varied to determine SNR with 50% discrimination for each condition. A composite score was calculated as ((2 x front SNR) + right ear SNR + left ear SNR)/4[20]. This score was adjusted to provide a single index of overall speech recognition in background noise[18, 20–21]. The higher the SNR, the more difficulty the subject had with differentiating words.

Dichotic Digits Test (DDT)

The DDT was adapted from an established and validated test protocol to assess binaural integration[22]. In this test, children were instructed to listen for two numbers presented in each ear simultaneously (4 in total) and press the corresponding numbers shown on the tablet, without paying attention to the specific order of presentation (free recall). A visual and audiometric demonstration was provided prior to administering the scored test. DDT was scored as the percentage of numbers correctly selected out of 20 presentations of 2 pairs of dichotic digits (80 digits total) for ears. The correct responses for those digits presented to either ear was also analyzed to explore any asymmetry or "ear advantage" in responses. Subjects with PTA asymmetry of 10 dB or higher were excluded from the analysis (n=7).

Frequency Pattern Recognition (FPR)

FPR was adapted from an established test to assess temporal ordering[23–24]. Three 500 ms tones were presented binaurally consecutively with a 300 ms interstimulus interval between the tones. Tones were either high (1430 Hz) or low (880 Hz) frequency and the presentation order (i.e., high-low-high, low-high-low, low-low-high, high-high-low, high-low-low, low-high-high) was randomly assigned for each child. Children were asked to associate the low-frequency tone with a picture of a frog and the high-frequency tone with a picture of a bird. Children were instructed to press the bird for high-frequency tones and the frog for low-frequency tones. A visual and audio demonstration was presented prior to the scored test administration. FPR was scored as a percentage of correctly identified 3-tone presentations (20 presentations total). Responses that were in the proper order but reversed with the opposite frequency (e.g., high-low-high instead of low-high-low) were recorded as "reversals". According to recommended scoring procedures, both raw scores (assigning reversals as incorrect) and scores with reversals (reversals as correct) were collected for comparison[26].

Statistical Analysis

Statistical analysis for this study was completed using R (R core team 2021) and Microsoft Excel (2018). Our data set contains categorical (group) and continuous (CAP, age, PTA) variables, making generalized linear models (GLM) the preferred analysis method. We used a generalized linear model to examine whether age, PTA, and group can predict CAP test battery (FLFT, MLD, GDT, HINT, DDT, FPR) results (glm (CAP ~ Age + PTA + group)), ((GLM,*glm* in the *glm2* R package, R Core Team 2021). In addition, we used a generalized linear model to examine the relationship between PTA, age, and group (PTA ~ Age + group). Post hoc comparisons using Tukey's method were performed to assess significance in the relationship between CAP test, age, PTA, and group, as well as between PTA, age, and group (*emmeans* R package). For continuous variables (PTA, age) post hoc comparisons were performed on pre-established groups of interest (PTA: 0, 10, 20, 30 dB; age: 9, 12, 15, 18 years old). Paired T-tests were completed to compare non-reversal FPR scores (%) with reversal FPR scores (%).

Results

This study included a total of 245 children ages 6–18 (mean (M) age ± standard deviation (SD): 12.20 ± 2.99 y.o.) from ESUS (n = 19), SSUS (n = 17), and Nicaragua (n = 209) groups. Average completion time was 34.43 ± 8.12 minutes (min) in the ESUS group, 47.54 ± 9.00 min in the SSUS group, and 60.82 ± 24.18 min in Nicaragua. Demographic data and PTA thresholds for each group are provided and in Table 1. Ability of children to complete the CAP battery, comparisons between each group, and subject parameters that influence CAP results are presented in the following results sections. Using an alpha of 0.05, the post-hoc power analysis of each group for individual CAP tests ranged between 0.05–1.0.

Power analyses revealed a post-hoc value less than 0.8 in the ESUS (GDT, DDT, FPR) and SSUS (DDT, FPR) cohorts.

Pure Tone Average (PTA)

Subjects who had recorded PTAs across all frequencies were included in this analysis (n = 243). PTAs were significantly higher in the Nicaragua group (11.03 ± 4.38 dB HL, n = 207) compared to both the ESUS (4.54 ± 5.45 dB HL, n =19) ($\beta = 9.31$, $p < 0.0001$) and SSUS (1.77 ± 3.34 dB HL, n = 17) ($\beta = 2.94$, $p = 0.0466$) groups. There were no significant differences between SSUS and ESUS group thresholds ($p = 0.11$). We observed no significant age effect on PTA thresholds ($p = 0.42$).

Fixed Level Frequency Threshold (FLFT)

Thresholds were obtained from 19 (100%) ESUS, 17 (100%) SSUS, and 202 (97%) Nicaragua subjects. PTA ($\beta = -130.27$, $p < 0.0001$) was a significant predictor of performance on FLFT. Post hoc analyses revealed significant differences across predefined categories of PTA (0 dB (1.86 ± 0.42 kHz; n = 8), 10 dB (17.41 ± 1.39 kHz, n = 121), 20 dB (17.08 ± 1.48 kHz, n = 102), 30 dB (13.83 ± 3.80 kHz, n = 7), such that performance improved significantly with better (i.e. lower) PTA thresholds ($p < 0.0001$). Age and group did not significantly affect threshold results (age: $p = 0.07$, group: $p = 0.09$).

Masking Level Difference (MLD)

MLD responses were recorded in 19 (100%) ESUS, 17 (100%) SSUS, and 207 (99%) of Nicaragua subjects. Six (35%) subjects in the SSUS and 35 (17%) in the Nicaragua groups had responses at inaudible levels (0 dB SPL) in either condition (S_0N_0 or S_0S_π), indicating an invalid response. These tests were not considered to be successfully completed and were excluded from the analysis. There were no significant differences in MLDs between the ESUS (8.68 ± 4.37), SSUS (7.64 ± 3.11), and Nicaragua groups (7.53 ± 5.49, $p = 0.69$ – 0.71). Age ($p = 0.89$) and PTA ($p = 0.50$) were not significantly associated with MLD results. Average SNRs for each group were smaller than previously published normative data (13.7 ± 2.2) by more than two standard deviations[11].

Gap Detection Threshold (GDT)

Thresholds were obtained in 19 (100%) children in ESUS, 6 children (35%) in SSUS, and 207 children (99%) in Nicaragua groups. In addition, 19 children in the Nicaragua group had a threshold in at least one ear that was considered invalid after the threshold convergence patterns were reviewed for a valid response rate of 91% in that group (395 out of 414 ears). We found a significant main effect of group for the right ear ($\beta = -3.46$, $p = 0.008$; $\beta = -2.53$, $p = 0.039$). The GDT thresholds were significantly lower for ESUS (5.24 ± 1.45 ms, n = 18) than SSUS (8.60 ± 6.07 ms, $p = 0.02$, n = 6) group, although these differences may have been driven by small sample sizes. The Nicaragua group (6.25 ± 2.62 ms, n = 192) was not significantly different from other groups ($p = 0.10$ – 0.40). There were no significant differences in GDT between ESUS (5.87 ± 2.67 ms, n = 19), SSUS (5.27 ± 1.09 ms, n = 6), and Nicaragua groups (6.26 ± 2.77, n = 195) ($p = 0.50$ – 0.69) for the left ear. Average thresholds in all groups were within 2 standard deviations of previously published normative data[11, 31]. Age and PTA were not significant predictors of GDT performance (age: $p = 0.88$, PTA: $p = 0.72$).

Hearing in Noise Test (HINT)

The HINT was completed by 19 (100%) ESUS, 16 SSUS (94%), and 207 (99%) Nicaragua subjects. There was a significant effect of group on performance ($\beta = -2.10$, $p = 0.007$). Post hoc analysis revealed that the Nicaragua group (−7.38 ± 2.84 dB SNR) performed significantly better compared to both the ESUS (−3.97 ± 1.10 dB SNR, $p < 0.0001$) and SSUS (−5.54 ± 1.17 dB SNR, $p = 0.02$) groups (Figure 2). There were no significant differences between the ESUS and SSUS groups ($p = 0.23$). Average SNRs in the SSUS and Nicaragua groups were within 2 standard deviations of previously published normative data (−6.2 ± 0.9), while the ESUS group revealed an average SNR slightly higher than normative data. Age and PTA were not significantly associated with HINT composite results (age: $p = 0.11$, PTA: $p = 0.30$).

Dichotic Digits Test (DDT)

The DDT was recorded for 17 (90%) ESUS, 15 SSUS (88%), and 199 (94%) Nicaragua subjects. Both age (β = , $p < 0.0001$) and PTA (β =, $p = 0.002$) were significant predictors of performance for DDT. There were no significant differences in scores between groups (ESUS 91.84 ± 8.42%; SSUS 88.92 ± 9.42%; Nicaragua 81.90 ± 10.94%; p = 0.08 – 0.16). Average scores (%) were within two standard deviations of previously published normative values in all groups (88 ± 8.4%)[31]. Post hoc analysis revealed significant differences across predefined categories of age (9 yrs. (74.53 ± 9.17%, n = 40), 12 yrs. (80.35 ± 11.02%, n = 93), 15 yrs. (89.31 ± 7.37%, n = 63), 18 (88.96 ± 9.51%, n = 35) yrs.) and PTA (0 (91.67 ± 8.16%, n = 6), 10 (85.00 ± 10.42%, n = 121), 20 (80.82 ± 11.20%, n = 98), 30 (73.13 ± 11.37, n = 6) dB) such that performance improved significantly with increased age ($p < 0.0001$) and decreased PTA ($p = 0.0091$) (Figure 3).

Frequency Pattern Recognition (FPR)

The FPR test was completed by 19 (100%) children in the ESUS, 15 (88%) SSUS, and 206 (99%) in Nicaragua groups. Age ($\beta = 2.36$, $p = 0.0001$) and group ($\beta = -39.54$, $p < 0.0001$) were significant predictors of performance on FPR. PTA was not a significant predictor of FPR performance ($p = 0.47$). Post hoc analyses of the entire cohort (240 children) revealed significant differences of performance across predefined categories of age [9 yrs. (40.49 ± 31.57%, n = 41), 12 yrs. (49.55 ± 30.91%, n = 99), 15 yrs. (61.43 ± 30.98%, n = 63), and 18 yrs. (55.41 ± 28.46%, n = 37)], such that performance improved significantly with age ($p = 0.0006$). The ESUS (94.74 ± 10.20%) and SSUS (85.00 ± 24.86%) groups had significantly higher scores compared with the Nicaraguan group (45.68 ± 28.33%; p = < 0.0001), but not from one another ($p = 0.55$) (Figure 4). These differences are not entirely explained by variable difficulty of the randomly assigned sequences as there was no difference in the difficulty level between groups. Average scores (%) in the ESUS and SSUS groups were within 2 standard deviations of previously published normative data – the Nicaragua group had a lower average percentage score.[11]

In the Nicaragua group, the average raw score (45.68 ± 28.33%) was significantly lower ($p < 0.0001$) when compared to the average score adjusted for pattern reversals (63.76 ± 24.64%).

Discussion

In this study, we show that a portable, tablet-based system combined with native-language video instruction can collect CAP test results within range of previously published normative data using minimally trained CHW (Table 1). In addition to completing the CAP test battery, identifying and understanding parameters that influence results of each test (e.g., age, PTA, and group) are important for establishing normative values for given subjects or populations. Although we saw no differences between our groups on most of the tests, we found that age, PTA, and language background affect domain-specific performance.

The age of participants was linked to their performance on certain tests (i.e., DDT, FPR) within the test battery. We did not observe an age effect in tests that focus on auditory processing in the subcortical areas (MLD and GDT), which are fully developed early in life[11, 26–28]. This contrasts with tests using higher-level cortical areas (DDT, FPR) which do have an observed age effect, suggesting that incomplete maturation of cortical structures at younger ages contributes to poorer subject performance[29–30]. PTA was also significantly associated with performance on DDT. Because presentation levels in this protocol were set according to the PTA of the better-hearing ear, PTA asymmetry may influence DDT. However, our results demonstrated a relationship between PTA and DDT performance that remained even after subjects with asymmetric PTA > 10 dB were excluded. Indeed, adults with sensorineural hearing loss also exhibit a diminished recall of DDT with an increase in hearing loss (Fischer et al., 2017; Roeser et al., 1976)[29].

The effect of language on performance was most markedly observed in the HINT results. Both of our Spanish groups performed better on the HINT (in Spanish) than their English-speaking counterparts, and there was a significant difference between the Nicaraguan group and the ESUS group. These results are consistent with previous studies showing that differences in sentence structure led to better performance on the Spanish HINT compared to English HINT[18]. This should be a consideration when determining normative values for HINT SNRs in Spanish vs. English-speaking populations.

Studies have debated whether including the “reversals” of FPR responses (e.g., high-low-high instead of low-high-low) provides more consistent data.[25] These “reversed” responses may reflect a problem with working memory rather than auditory perception. The sensitivity and specificity of these different scoring methodologies have not been determined. In our study, assessing the Nicaragua group with reversed responses did increase the consistency and improve the performance means of test results. In our test protocol, children were not administered a practice session to ensure that they were able to discriminate between the two tones and understood the task. This may help explain score inconsistency in the Nicaragua group. Furthermore, our protocol delivered randomly presented tonal sequences with each child receiving a different list of triads. Others have shown that the difficulty of distinguishing the frequency pattern is not uniform between different triads.[25] However, our post hoc analysis did not find a difference in test difficulty between groups. Future investigation is warranted to better understand score variation in FPR.

Limitations of this study include small groups from the United States that were used for test development and evaluation of the test battery. Variability of test administrators' knowledge of each test as well as educational backround of subjects may have also contributed to inconsistency in results. The time to completion for children in the ESUS and SSUS groups were shorter than the Nicaragua group which may reflect a familiarity with technology in this cohort. We found lower completion rates in the SSUS cohort for the GDT (35%), DDT (88%), and FPR (88%) that was attributed to a transient technical difficulty uploading initial test results into the TabSint system. Because the SSUS cohort was small, incomplete test submissions had a greater impact on the overall completion rate. Post-hoc power analysis revealed a low power for multiple tests in the ESUS and SSUS cohorts, which is attributed to the low sample size in these cohorts. Future modifications in our test battery will include 1) adding practice sessions before the scored exams for MLD and FPR tests to ensure understanding of instructions, 2) uniform difficulty of FPR sequence lists, and 2) ear specific adjustment of the presentation level based upon the PTA of that ear. Despite these limitations, this study demonstrates the potential for successful administration of tablet-based CAP testing administered by minimally trained CHW in low resource environments.

Conclusion

A portable tablet-based CAP test battery using native-language video training can be administered successfully by CHWs in both Spanish and English. For GDT, HINT and DDT this system yielded results similar to published normative data in all groups. FPR revealed significant variability in the Nicaragua group. Significant differences in the HINT scores between groups is consistent with differences in sentence structure and phonological repertoire between Spanish and English languages. Older subjects perform better on DDT and FPR tests.

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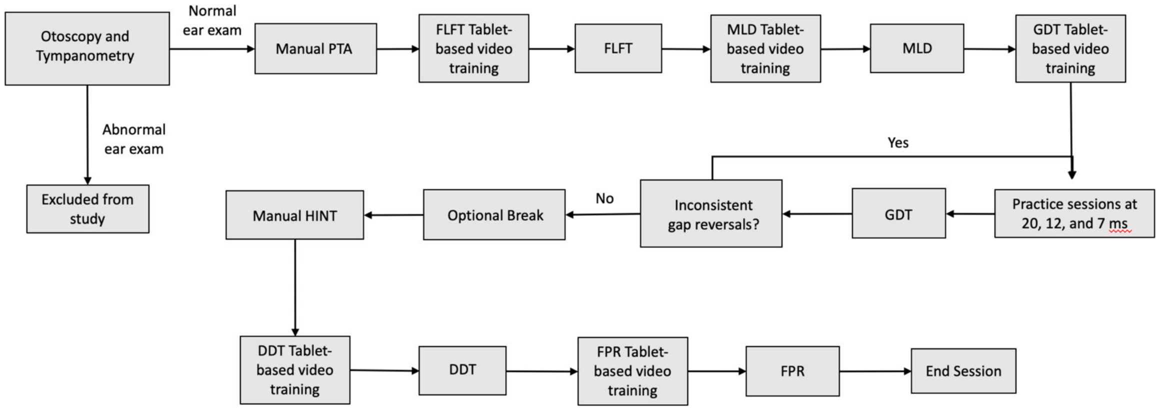

Figure 1.
Test battery workflow

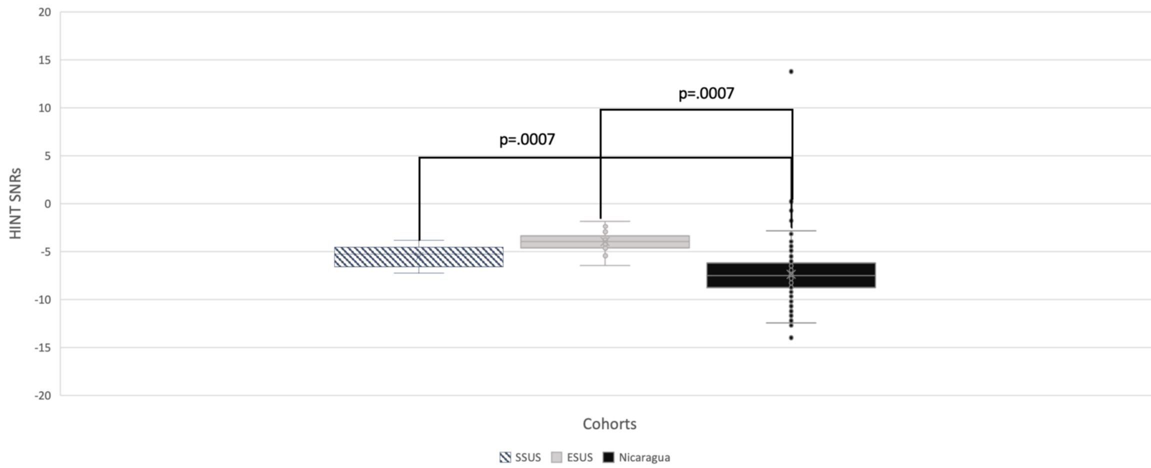

Figure 2.
HINT SNR Comparison Between Groups

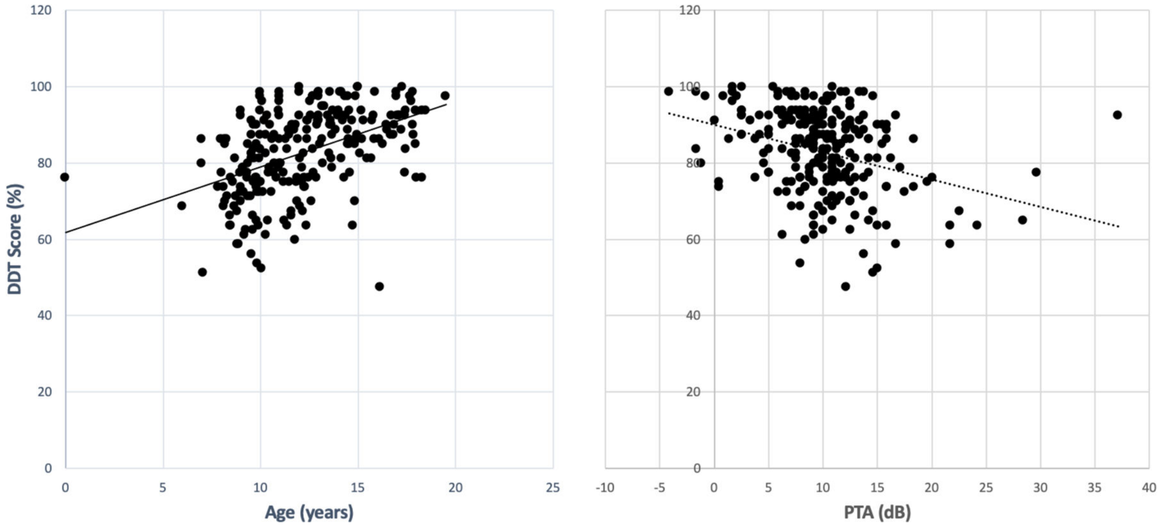

Figure 3.
DDT Associations with Age and PTA

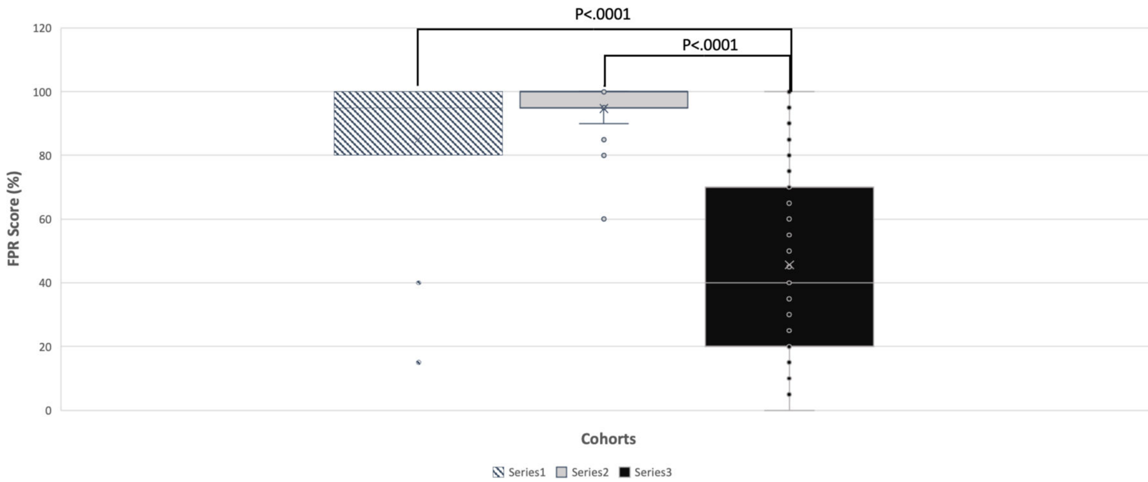

Figure 4.
FPR % Comparison Between Groups

Table 1.

Demographic Characteristics and CAP Test Battery Results

		English Speaking US (ESUS)	Spanish Speaking US (SSUS)	Nicaragua (Spanish-Speaking)	CAP Test Reference Values
Cohort (n)		19	17	209	-
Gender	Male	11 (58%)	10 (59%)	124 (59%)	-
	Female	8 (42%)	7 (41%)	85 (41%)	-
Age (years)		11.6, SD 3.0	11.6, SD 2.8	12, SD 2.8	-
PTA Average (dB)		4.5, SD 5.5	1.8, SD 3.3	11.0, SD 4.4	-
FLFT (kHz)		18.4, SD 0.6	17.9, SD 1.0	17.0, SD 1.7	-
MLD (SNR)		8.7, SD 4.4	7.6, SD 3.1	7.5, SD 5.5	13.7, SD 2.2[11]
GDT (ms)		5.2, SD 2.4	8.6, SD 6.0	6.3, SD 2.6	5.4, SD 2.8[11] 6.6, SD 5.2[31]
HINT (SNR)		−4.0, SD 1.1	−5.5, SD 1.1	−7.4, SD 2.8	−6.2, SD 0.9 [32]
DDT (%)		91.8, SD 8.4	89.9, SD 9.4	81.9, SD 10.9	92.5, SD 7.1[11] 88.0, SD 8.4[31]
FPR (%)		94.7, SD 10	85.0, SD 24.9	45.7, SD 28.3	87.5, SD 17.1[11]