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Original Article

Evaluating the Impact of Hearing Conditioning App on Clinician Task Load and Hearing Test Efficiency in Children

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BACKGROUND: Clinicians recommend that parents use noise-making toys for hearing conditioning, but these differ from formal testing stimuli, resulting in longer test times and more sessions to complete the hearing evaluation. The app-based (AB) conditioning method, having similar stimuli used in actual hearing evaluation with structured parental guidance, could reduce the clinician's task load and the number of sessions needed for pure tone audiometry (PTA) testing among children compared to the conventional conditioning method.

METHODS: A comparative research design assessed the effectiveness of 2 conditioning methods for hearing in 30 participants aged 2 to 3.6 years, randomly assigned to conventional (n = 15) or AB methods (n = 15). The clinician was blinded to the method used. The clinician's workload during PTA testing was evaluated using the National Aeronautics and Space Administration (NASA) task load tool, and the number of sessions needed to complete PTA testing was recorded for each method.

RESULTS: Children conditioned using the AB method required significantly less clinician task load and fewer PTA testing sessions than the conventional method (CM). Additionally, clinician task load decreased after conditioning, regardless of the method, with no correlation between task load before and after.

CONCLUSION: App-based conditioning creates a strong stimulus-response link in children and reduces clinician task load compared to the CM.

KEYWORDS: Children, hearing test, operant conditioning, workload

INTRODUCTION

According to the National Sample Survey Organization (NSSO), 291 individuals per 100 000 suffer from severe to profound hearing loss in India,[1] compared to 200 per 100 000 in developed countries.[2] Congenital hearing loss is prevalent among newborns.[2] However, it is often identified in developing countries only when children are between 1.4 and 4 years old, resulting in irreversible damage.[3] There is a shortage of audiologists in India, with an average of 1200 professionals serving 950 000 people in urban areas.[4] Rural areas lack audiologists and tele-practice programs,[5] while services at health centers are limited to the 350 diagnostic centers, only 120 are appropriately equipped.[6] Leading to increased referrals and long patient waits due to the inadequate number of qualified audiologists. [4]

The objective test accurately assesses hearing ability;[7] however, the gold standard is the behavioral hearing test, which requires children's active participation.[8] Temper tantrums and fear of the clinical environment can prolong hearing tests.[7] It can also be challenging to track a child's hearing threshold in 1 session, leading to parents being advised to 'condition' the child before the next visit.

Many hearing test applications work on Android [9] and iOS[10] for hearing screening.[11] However, some apps struggle with loudspeaker connectivity due to compatibility issues. Bluetooth generally allows only 1 audio stream, and wired connections may lack the necessary

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hardware, leading to signal distortion. Although a few hearing screening apps connect to the loudspeaker, they limit output to a maximum of 89 dBA (79.5 dB HL to 83 dB HL across frequencies). Even at full mobile volume, they are unable to condition the child to have profound hearing loss.[12] As a result, parents must engage their children with loud toys like drums to help them respond to sounds. Although children may become accustomed to high sounds, they often are not trained to recognize pure tones, warble tones, or native language speech materials, resulting in increased clinician workload and extended patient waiting times. It often requires multiple visits for a child's hearing evaluation, causing inconvenience for caregivers from remote areas due to travel expenses and lost wages.[7] There is currently no conditioning tool for hearing prior to tests, highlighting the need for a dedicated Android app. There are 67 million Android smartphone users in India, projected to reach 1.2 billion by 2026. Additionally, over 2600 village libraries have access to Android devices. With ongoing efforts in India (DO. No. N-11013/17/2022-PRI, Min of Panchayat Raj, GoI), an Android hearing conditioning app could significantly benefit users.

The developed application should include the following features: a) the ability to present stimuli similar to those used in clinical settings, b) a mechanism for delivering signal intensity in a controlled manner through loudspeakers, and c) an option to present test signals in a random order with controlled intensities to capture the child's attention and elicit responses to sounds. It is hypothesized that if the child is conditioned using the proposed application, clinicians will experience a reduced task load during pure tone audiometry (PTA), leading to fewer sessions to track the child's auditory threshold. Task load is the workload necessary to complete a task. [13] The NASA Task Load Index (TLX) is designed to assess and document subjective mental workload. The hearing conditioning Android application developed in this study has been validated using the NASA Task Load Index (TLX). The study aims to compare conventional and app-based (AB) hearing conditioning methods by assessing clinician task load (using the NASA-TLX) and session efficiency during PTA testing in children.

METHODS

A comparative research design evaluated clinicians' task load and session number for PTA among children trained with AB versus conventional methods.

MAIN POINTS

- Clinicians face challenges with longer test times and multiple sessions in hearing evaluations for children due to the mismatch between noise-making toy stimuli and formal testing stimuli.
- An app-based (AB) conditioning method with stimuli similar to formal hearing tests and structured parental guidance aims to address these challenges.
- A study with 30 children aged 2-3.6 years compared AB and conventional methods, assessing clinician task load and session requirements.
- Results showed that the AB method significantly reduced clinician task load and the number of sessions needed for Pure Tone Audiometry testing.
- App-based conditioning strengthens the stimulus-response link in children, offering greater efficiency and a reduced workload compared to conventional methods.

Participants

A total of 30 children aged 2 to 3.6 years with normal hearing were recruited. Auditory brainstem response confirmed normal hearing. Children who had passed newborn screening with a developmental listening age that matched the developmental listening age at the time of data collection were recruited. They were randomly assigned to 2 groups: Group 1 (n = 15, mean = 2.79, SD = 0.56) used an AB method for hearing conditioning, while Group 2 (n = 15, mean = 2.61, SD = 0.32) used a conventional method (CM). The tester was unaware of the conditioning method. Inclusion criteria included those children who demonstrated constructive play[14] and normal tympanometry throughout the study period (conditioning and testing). Children in each group had age-adequate speech, language, cognitive, and motor milestones. [12,15]

Ethical approval was secured from the AIISH (All India Institute of Speech and Hearing)) ethics committee (Approval No: SH/RCS/ARF-AUD-1/2020-21) dated January 4, 2021, and informed consent was obtained from parents/guardians.

Mobile Application for Hearing Conditioning

Stimuli Preparation

The recorded stimuli, such as pure tones (500 to 4000 Hz in octaves), narrow band noise (500 to 4000 Hz in octaves), standardized Kannada phonetically balanced words,[16] and Ling's 6 sounds,[17] were used. In addition, an option is provided to record the live voice and play at the desired set volume on the mobile. Figure 1 shows the waveform and spectrogram of the stimuli.

Pure Tones

Praat software (version 6.3.03) was used to generate pure tone of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. The formula [amp * sin(2 * pi * f)] generated a pure tone signal in the mono channel. The 'f' is the sampling frequency set at 44 100 Hz. The rise/fall time was set at 30 ms. The start and end times were kept at 0 ms and 300 ms, respectively, with an arbitrary amplitude of 1.

Narrow Band Noise

Narrow band noise with a central frequency of 500 Hz, 1 kHz, 2 kHz, and 4 kHz was generated using Aux viewer (version 3). Gaussian white noise was generated with the central frequency 'cf' with the sampling frequency 22 100 and bandwidth 'bw' in octave (0.25 kHz). The lower and upper limits of the frequency range were calculated using the equations below.

low_f1 = cf / 2 ^ (bw/2); Equation 1
high_f1 = cf * 2 ^ (bw/2); Equation 2

The generated Gaussian white noise is downsampled (0.6*fs) and then rounded off to 2 digits to the right of the decimal point. In addition, the number of samples is normally distributed, denoted by "x." The formula below gives the percentage of the bandpass, the Gaussian white noise, to get the narrow band noise.

y = bandpass (x, [low_f1 high_f1], fs);

[y= Narrow band noise; x= randomly distributed samples; low_f1 - low cut; high_f1 – high cut; fs – sampling frequency]

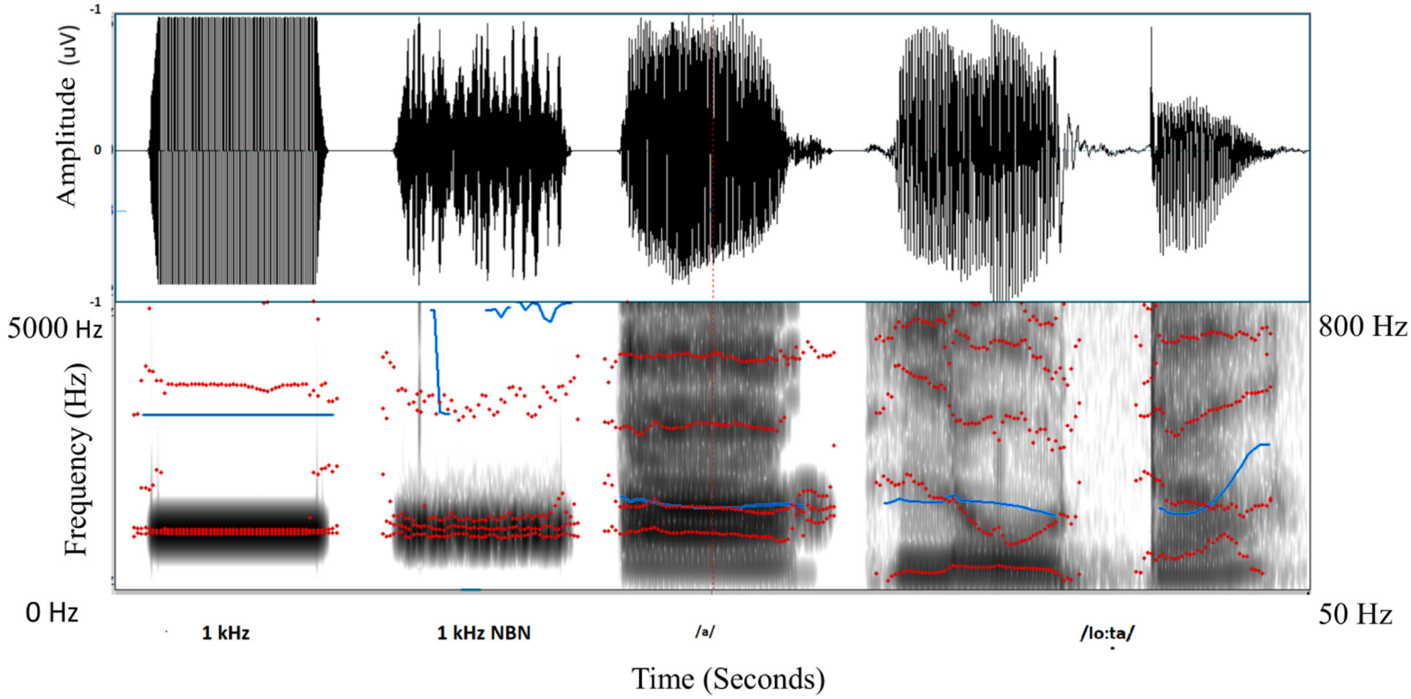

Figure 1. Shows the waveform and spectrogram of 1 kHz, narrow band noise, /a/ling's sound, and phonetically balanced word /lo: ta/.

Speech Stimuli

Ling's sounds (/a/, /i/, /u/, /m/, /s/, /ʃ/)[17] and 25 standardized phonetically balanced Kannada words[16] were recorded by the female adult speaker. The microphone (make) was placed 12 inches from the speaker's mouth. The speaker was instructed to utter these speech tokens in a regular vocal effort. Stimuli were digitized using a 16-bit analog-to-digital converter at a sampling frequency of 44 100 Hz. Stimuli were normalized using root mean squared.

Framework of Application

The recorded stimuli, such as pure tones, narrow band noise, and speech tokens (Ling's sounds and Phonetically Balaced (PB) words), were loaded into the application developed for the Android operating system. The flow chart of the mobile application for hearing conditioning is shown in Figure 2.

Upon clicking the app, users are directed to follow instructions for connecting and placing the loudspeakers, which include: a) ensure a quiet environment, b) pair the loudspeaker, c) position it 1 meter from each ear at ear level, and d) set the phone's volume to a preferred level. After clicking "Next," an alert prompt is displayed for the parents to take the appropriate action: "Are you sure the Bluetooth speaker is connected?" If the speaker is paired, click "Yes;" otherwise, pair it with the mobile device.

Users can select various stimulus categories, such as pure tones, narrow band noise (NBN), Ling sounds, PB words, and live voice. The user is instructed to select 1 stimulus category at a time, for example, "pure tone."

After choosing a category, a pure tone stimulus is delivered through a loudspeaker by pressing the Play button. The pure tones of different frequencies are played randomly and sequentially in the right or left speaker.

For PB words, 25 audio files are played in random order. Live voice stimuli are recorded and played back when the Play option is selected.

Conditioning for Hearing

The CM presented a stimulus through the squeaker (noise-making toys). In the AB method, the stimulus, such as either pure tones, NBN, or Ling's sounds (stimuli commonly used in the clinic), was delivered through the loudspeaker. A child was instructed to respond to sound through constructive play (e.g., drop the ball in the bucket) soon after the sound was delivered from a sound source (loudspeaker/squeaker). The sound source was placed at a distance of 1 meter at the child's ear level, who sat in their mother's lap.

An Illustration of an Activity Used for Conditioning

is described. In the practice session, a child and an informant were made to hold *a* ball at their ear level and instructed to "put it in a basket" after the sound was heard. The parent/informant was instructed to say "I hear sound" to the child and put the ball into a basket. If the child showed hesitation in the activity, then the parent clasped the child's hand holding *a* ball up to the child's ear and, when the sound was being presented, says, "We heard that" and encourages the child to drop "the ball into the basket." Later, the child was encouraged to respond by performing the activity soon after the sound was presented. The sound was initially paired with a token reinforcer (coins, marble stickers) to respond to the sound. The reinforcement was given intermittently to avoid rapid habituation and to increase the appropriate response; that is, the child performed constructive play (putting a ball in a basket) soon after the sound presentation. When the child showed a conditioned response to sound, the auditory stimulus was presented alone without any reinforcement. During conditioning, the stimuli (pure tone, NBN, Ling's) in the mobile application were randomly presented to hold attention and interest for longer. Similarly, a sound from different squeakers was presented randomly in the CM for hearing conditioning. After practice trials,

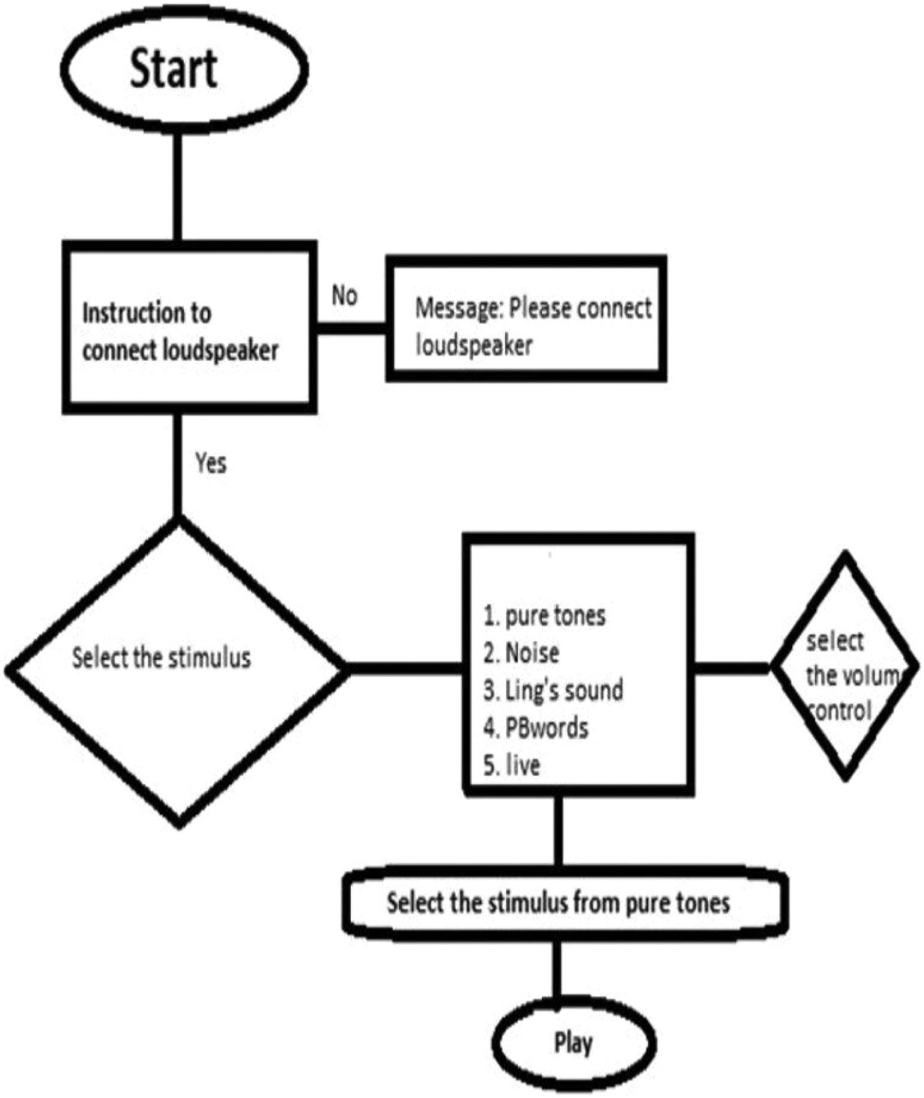

Figure 2. The flow chart for the hearing conditioning mobile application.

the parent was instructed not to respond to sound in any way during sound presentation.

Condition Play Audiometry to Assess the Hearing Threshold
Clinicians with 8 years of experience in clinical audiology were involved in tracking their hearing thresholds. The clinicians were blinded to the hearing conditioning method used (conventional/AB). Assessments occurred in a soundproof room, adhering to ANSI S3.1 (1999) ambient noise levels. A loudspeaker was positioned at 0-degree azimuth, 1 meter from the child seated in a parent's lap, with the speaker cone at the child's ear level. The condition*ing* process was illustrated in an accompanying activity. *The sound was t*ypically presented through a loudspeaker, conditioning the child to respond. The hearing threshold was estimated using earphones if the child responded correctly. The Ballpark Method was utilized to set the initial intensity level for threshold testing roughly. A systematic bracketing protocol of 10 dB down and 5 dB up was used to set the intensity of the tone based on the child's response to sound. Hearing thresholds for tonal stimuli of 500 Hz, 1 kHz, 2 kHz, and 4 kHz in each ear were obtained. The testing session was postponed if the child showed any of the following behaviors: crying, losing interest even with changing an activity, giving either a false negative or false positive (50% out of 10 presentations), being distracted or bored during conditioned play audiometry (CPA) testing even after frequent breaks. For every session postponement, the child underwent conditioning exercises for 1 week before the next appointment was provided for PTA testing. Hearing conditioning using constructive play activities was carried out daily for 30 minutes. A total duration in minutes was captured for the session in which PTA (4 frequencies) in both ears was obtained. The mean hearing threshold, measured from 500 Hz to 4000 Hz in octaves, was obtained using auditory brainstem response and subsequently converted to dB HL (baseline). Additionally, pure tone thresholds were measured at the same frequencies after conditioning for each ear among the children in each group. The results of the independent samples t-test are presented in Table 1.

NASA Task Load
The clinician task load was documented before conditioning the child and after conditioning for responding to sounds (a session where a child determined PTA) from 2 groups of children. The NASA task load [18,19] was performed using weights and ratings. Weight infers the contribution of each parameter (mental demand, physical

Table 1. The Hearing Threshold, Age Range, Gender, and Demographics of Group 1 and Group 2

	Group 1	Group 2			Group 1	Group 2		
	Right Ear				Left Ear			
	Mean (SD)	Mean (SD)	*t*-value	*P*	Mean (SD)	Mean (SD)	*t*-value	*P*
ABR (converted into dB HL)								
500 Hz	5.74 (3.2)	7.22 (3.51)	1.24	.22	5.30 (3.6)	4.60 (3.25)	1.15	.26
1KHz	7.22(2.80)	8.52 (3.01)	1.54	.13	8.36 (2.93)	6.46 (3.18)	1.66	.10
2 kHz	5.24(4.15)	6.65 (4.31)	0.92	.36	7.56 (3.82)	7.65 (4.01)	1.06	.38
4kHz	13.60 (3.61)	12.90 (3.8)	0.52	.60	11.84 (3.59)	13.25 (3.62)	1.09	.28
After Conditioning (Behavioral hearing threshold dB HL)								
500 Hz	15.26 (3.1)	16.78 (3.3)	0.20	.88	16.70 (3.2)	15.40 (3.3)	0.12	1.10
1KHz	13.78 (3.0)	12.15 (3.2)	0.15	1.10	15.36 (3.1)	13.54 (3.4)	0.15	1.38
2 kHz	15.24 (4.2)	16.65 (4.5)	1.32	.10	17.56 (40)	17.65 (4.2)	0.13	1.32
4kHz	18.60 (3.5)	17.40 (3.7)	0.14	.88	16.84 (3.8)	18.25 (4.1)	0.14	1.25
Age Range	2.76 (0.56)	2.61 (0.32)						
Gender	8M/7F	8M/7F						
Demographics	7U/8R	8R/7U						

F, female; M, male; R, rural; U, urban.

demand, temporal demand, performance, effort, and frustration) to the workload involved in PTA testing. Fifteen pairs were framed from the parameters that contributed to the task load. These pairs were presented sequentially to the clinician, who was instructed to select 1 parameter from each pair. The number of times each parameter was selected was noted, ranging from 0 (not relevant) to 5 (more important than any other parameter). With this, a different set of weights was obtained for each parameter. In addition, the magnitude of load (rating) was obtained from the clinician. After tracking the child's hearing threshold, the clinician was instructed to indicate each parameter's numerical ratings (0-100) that reflect the task load's magnitude. Each parameter is represented by 20 equal intervals. Each interval assigned a score of 5 marks, with a minimum score of zero and a maximum of 100. Furthermore, the overall workload score was computed by multiplying each rating by the weight of each workload parameter. The sum of the weighted ratings of each parameter was divided by 15.

The clinician's task load in tracking the threshold from children was assessed between sessions, with a gap of 3 hours between session 1 and session 2, using interclass correlation. The test-retest reliability for task load was 0.968, which infers high test-retest reliability. Furthermore, Cronbach's alpha method was used to assess inter-clinician differences in task load. The second clinician had clinical audiology experience similar to the first clinician in assessing pediatric cases. The task load for the second clinician while testing PTA was evaluated on the same child for whom the first clinician obtained the task load. The Cronbach's alpha result was $r = 0.892$, indicating a consistent task load reported by both clinicians.

RESULTS

To Develop a Mobile Application for Hearing Conditioning Before the Hearing Test

The mobile application is developed for the Android platform. Users can access a "How to Use?" option on the navigation page (Figure 3A), which plays a video to introduce the app. For instructions, users can click the "Conditioning" option (Figure 3B) and then press the "NEXT" button to proceed. In the conditioning settings, users can select a stimulus from a drop-down menu that includes Pure Tone, Noise, Ling's Sounds, Words, and Live Voice (Figure 3C). The selected stimulus can be delivered at the chosen volume through a connected transducer (Figure 3D) to help condition the child's hearing.

Validation of the Developed Mobile Application by Comparing the Task Load of the Clinician in Assessing the Hearing Ability of Children

The clinician's task load parameters were obtained before and after the PTA testing among children conditioned from either the CM or AB method, subjected to the Social Package for Social Science (SPSS version 21) to represent the data with the objectives mentioned earlier.

Comparison of Task Load of Clinician Between Groups of Children Conditioned for Hearing

From Table 2, it is observed that each parameter of the task load of clinicians in assessing the PTA remained similar (considering median, minimum, maximum, and range) before conditioning for hearing among 2 groups of children. A Mann–Whitney test was performed on the task load of clinicians between groups before conditioning for hearing. The results revealed no significant difference in the clinicians' task load parameters in assessing PTA between the 2 groups of children before being conditioned for hearing (Table 3). This indicates that the 2 groups of children are matched on each parameter of the clinicians' task load when assessing the PTA (Figure 4).

Furthermore, each of the parameters of the task load of the clinician in assessing PTA was compared between groups of children after being conditioned for hearing using the conventional and AB methods. Figure 4 shows that the median value of each of the parameters of the clinician's workload was reduced in assessing PTA testing in children conditioned using the AB method rather

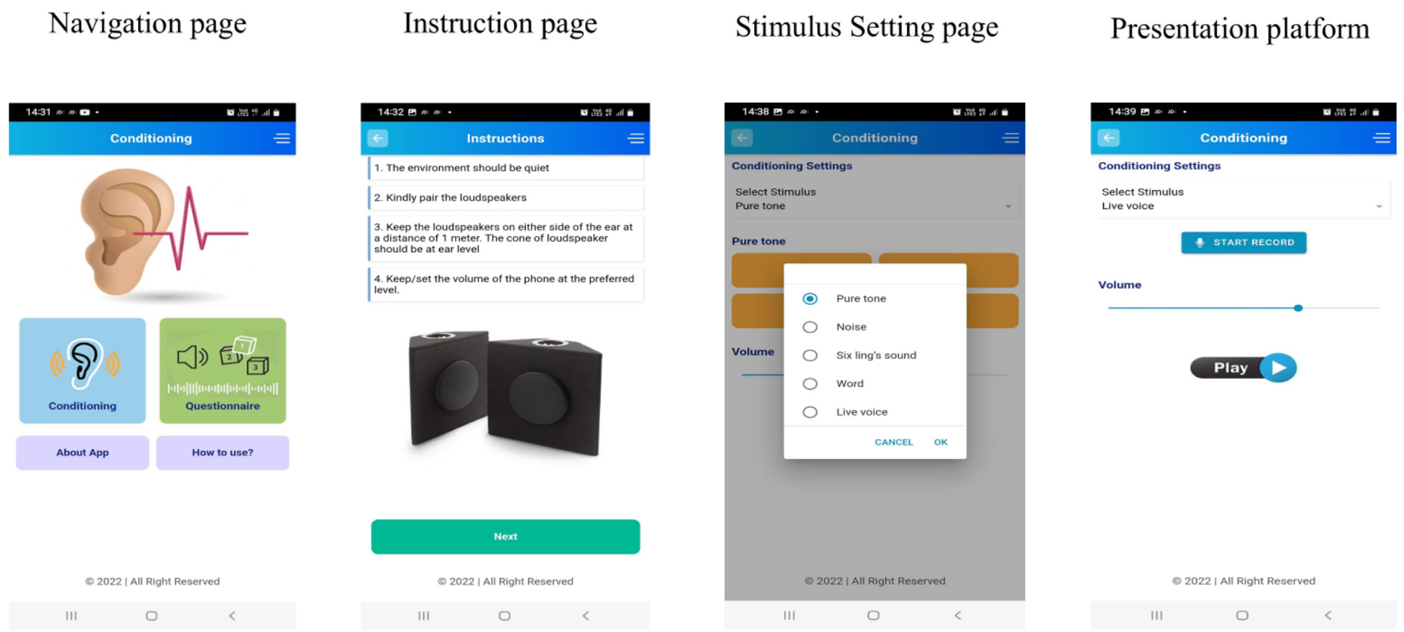

Figure 3. Android mobile application for hearing conditioning. A. Navigation page. B. Instruction page. C. Stimulus Setting page. D. Presentation platform.

than the CM. In addition, the clinician's performance was better in assessing PTA in children conditioned with the AB method than the CM. A Mann–Whitney *U* test was conducted on each of the parameters of the task load of clinicians between groups of children after being conditioned for hearing. Although the median value of physical demand and effort was lower in assessing PTA in children conditioned with the app-based method than in those children who were conditioned with the AB method than in those children who were conditioned with the CM, this difference failed to be statistically significant. Additionally, although the clinician's performance was better in assessing PTA in children conditioned for hearing using the AB method than the CM, the difference failed to reach significance. However, the mental demand, time pressure, frustration level, and overall workload of the clinician were significantly lower in performing the PTA testing among children conditioned with the AB method than the CM (Table 3).

Table 2. Summary of the Task Load Parameters Obtained from Clinicians After Pure Tone Audiometry Among Children Before and After Conditioned for Hearing Either with Conventional Method or App-Based Methods

Parameters	Conventional Method (CM)				App-Based (AB)			
	Median	Minimum	Maximum	Range	Median	Minimum	Maximum	Range
Before conditioning								
MD	80.00	65.00	95.00	30.00	75.00	65.00	90.00	25.00
PD	80.00	65.00	95.00	30.00	80.00	70.00	85.00	15.00
TD	80.00	65.00	95.00	30.00	75.00	60.00	100.00	40.00
P	75.00	50.00	100.00	50.00	70.00	55.00	100.00	45.00
E	70.00	60.00	95.00	35.00	80.00	60.00	90.00	30.00
F	80.00	60.00	100.00	40.00	80.00	60.00	90.00	30.00
WL	78.00	58.00	96.00	38.00	79.00	60.00	90.00	30.00
After conditioning								
MD	40.00	35.00	75.00	40.00	35.00	15.00	70.00	55.00
PD	55.00	40.00	75.00	35.00	40.00	30.00	75.00	45.00
TD	50.00	30.00	70.00	40.00	35.00	25.00	60.00	35.00
P	50.00	25.00	75.00	50.00	40.00	25.00	75.00	50.00
E	55.00	15.00	70.00	55.00	40.00	30.00	55.00	25.00
F	50.00	20.00	80.00	60.00	40.00	15.00	55.00	40.00
WL	50.00	35.00	62.00	27.00	39.00	30.00	53.00	23.00
Number of sessions	4.00	3.00	5.00	2.00	3.00	2.00	4.00	2.00

E, effort; F, frustration; MD, mental demand; P, performance; PD, physical demand; TD, temporal demand; WL, overall workload.

Table 3. *U* and *P*-Value of Mann–Whitney Test Results on Task Load Parameters of the Clinician in Assessing Pure Tone Audiometry Between Groups of Children Obtained Before and After Conditioned for Hearing

Parameters	Mann–Whitney *U*	Sig. (2-tailed)
Before Conditioning		
MD	62.000	0.033
PD	71.500	0.081
TD	76.000	0.804
P	89.000	0.325
E	56.000	0.151
F	78.500	0.151
WL	97.000	0.519
After Conditioning		
MD	56.500	**0.019***
PD	67.000	0.056
TD	34.500	**0.001*****
P	97.000	0.515
E	90.000	0.343
F	61.500	**0.033***
WL	46.500	**0.006****

E, effort; F, frustration; MD, mental demand; P, performance; PD, physical demand; TD, temporal demand; WL, overall workload($p < 0.05$, ** $p < 0.01$, *** $p < 0.001$): .

Task Load of the Clinician in Assessing PTA Before and After Conditioned for Hearing

Each parameter of the task load of the clinician in assessing PTA was lower after conditioning than before conditioning for hearing to sound. This was true in both groups of children, who were conditioned by conventional or AB methods. A Wilcoxon sign-rank test was performed on the clinician's task load parameters to assess the PTA before and after conditioning. Irrespective of the conditioning method, each of the parameters of the task load of the clinician was significantly lower in assessing PTA after conditioning than before conditioning (Table 4).

The overall workload of clinicians before and after being conditioned for hearing was subjected to Spearman's correlation coefficient. The results revealed no relationship between the clinicians' overall workload before and after conditioning. This is true in the CM (N = 15, r = −0.492, *P* = .062) and with the AB method (N = 15, r = 0.356, *P* = .192) (Figure 5A and B).

Number of Sessions Taken by the Clinician to Complete the Pure Tone Audiometry from Children Conditioned for Hearing

Figure 6 shows a histogram displaying the number of sessions the clinician requires to assess PTA from children conditioned using conventional and AB methods. The number of sessions needed to assess PTA in children conditioned for hearing using the AB method is fewer than the CM. The clinician requires a minimum of 2 and a maximum of 4 sessions to assess PTA in children conditioned for hearing using an AB method. However, in the CM of conditioning, a minimum of 3 and a maximum of 5 sessions are required to assess children's PTA.

In 3 sessions, a maximum of 9 children from 15 were tested for PTA when conditioned using the AB method. However, a maximum of 8 children from 15 were tested for PTA in 4 sessions when conditioned using the CM. A Mann–Whitney *U* test was performed to compare the number of sessions the clinician took to complete the

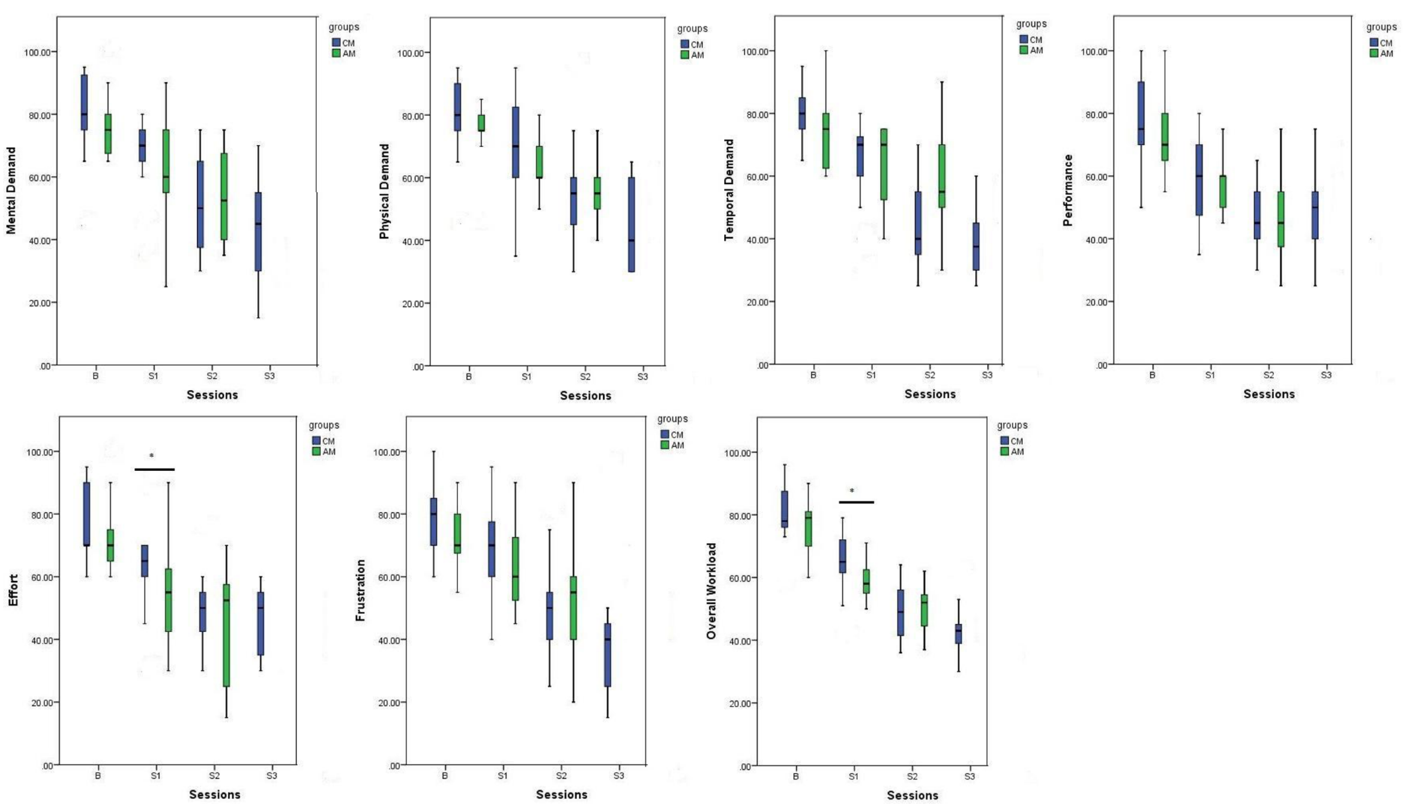

Figure 4. Box plot of each of the parameters of task load between groups of children obtained before and after conditioned for hearing.

Table 4. *Z* and *P*-Value of Wilcoxon Sign-Rank Test on Each Parameter of the Task Load of the Clinician in Assessing the Pure Tone Audiometry Before and After Conditioned for Hearing

		Parameters of Task Load						
Conditions	**Values**	$_{A}$MD - $_{B}$MD	$_{A}$PD - $_{B}$PD	$_{A}$TD - $_{B}$TD	$_{A}$P - $_{B}$P	$_{A}$E - $_{B}$E	$_{A}$F - $_{B}$F	$_{A}$WL - $_{B}$WL
Conventional Method	*Z*	−3.41	−3.37	−3.42	−3.11	−3.28	−3.20	−3.35
	P	0.001	0.001	0.001	0.002	0.001	0.001	0.001
App-based Method	*Z*	−3.35	−3.30	−3.42	−3.21	−3.42	−3.42	−3.41
	P	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Note that the subscript letter 'A' is after, and 'B' is before in the parameters of task load.
E, effort; F, frustration; MD, mental demand; P, performance; PD, physical demand; TD, temporal demand; WL, overall workload.

PTA in children conditioned with the conventional and AB methods. The results revealed that the median value of sessions required by the clinician to assess PTA in children who were conditioned using the AB method is significantly less than the CM (U = 49.50, *P* = .005). As expected, the AB method (median = 630, Min = 420, Max = 840, range = 420) requires less training time (in minutes) to condition the child for hearing before the actual testing than the CM (median = 840, Min = 630, Max = 1050, range = 420), and this difference was found to be significant (U = 169.50, *P* = .008) using the Mann–Whitney *U* test.

Furthermore, the total duration (in minutes) captured for the session in which PTA (4 frequencies) in both ears was obtained was compared between groups using the Mann–Whitney *U* test. Although the time required to obtain the threshold from children conditioned using the AB method was relatively less (median = 15, Min = 12, Max = 20, range = 8) than that of the CM (median = 16, Min = 10, Max = 20, range = 420), the results revealed no significant difference (U = 97.50, *P* = .539). In addition, the duration required for conditioning sessions and the session time required to complete PTA testing were correlated with each task load parameter using Spearman's correlation. Irrespective of the conditioning method, none of the parameters of the task load was correlated with the time metrics.

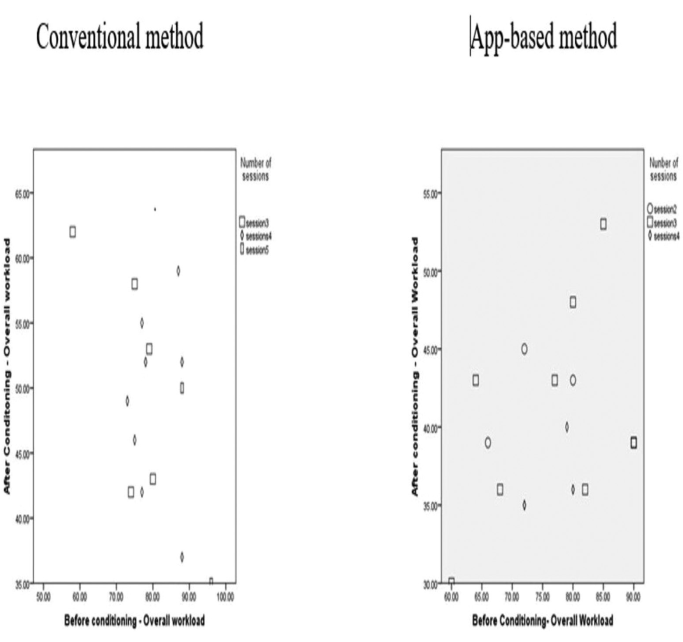

Figure 5. Overall workload relationship between before and after conditioning for hearing. A. Conventional method. B. App-based method.

DISCUSSION

The clinician failed to complete the PTA testing among children of both groups before conditioning for hearing. Children are disturbed in their regular schedule by new activities, such as hearing testing, a new environment, prolonged waiting time, and demands from the clinician, which are possible reasons for uncooperative behavior. Although the children were trained to respond to the sound in the clinic briefly (before the actual conditioning method), the chance of successful conditioning was less. Despite changing constructive play activities and providing frequent breaks to those children who displayed uncooperative and reluctant behavior, they could not complete the PTA testing. Because the stimulus (pure tone) and response (e.g., putting a ball into a basket) were not paired effectively, it resulted in confusion among children. Eventually, it increased clinicians' task load, leading to the postponement of the hearing evaluation session. This was true for both groups of children. Thus, the clinician's task load on each parameter was no different among children of both groups in the PTA testing before conditioning.

For incomplete PTA testing, the schedule for the hearing assessment was postponed to next week. The parents were instructed to condition their child daily for 30 minutes before the hearing testing. Hearing testing is delayed as the clinician's energy drains while tracking the threshold from a single case. This leads to a lack of energy and/or demotivation to continue testing the same case. Eventually, the non-tested successive cases pile up and must wait longer than scheduled. Thus, the clinician counseled the parents of the non-cooperative children to condition their children to respond to the sounds.

Although each of the parameters of the task load of the clinician was reduced after conditioning for hearing, the mental demand, temporal duration, frustration, and overall workload were decreased significantly in PTA testing among children conditioned with the AB method compared to children conditioned with the CM. In the AB method, the pure tone and the narrow band noise of different frequencies, the Ling's sound, and the speech sounds were delivered through the loudspeaker for hearing conditioning. The prior knowledge of these stimuli exposed during conditioning with the AB method led to an accurate response for the presented pure tone stimuli of different frequencies delivered in the clinic. The clinician required a lower task load to identify the hearing threshold in the PTA testing. The clinician reported a reduced false positive/negative response in children conditioned with the AB method. The consistency in responding to the pure tone increased. Due to this, the clinician could decide whether the response was genuine. The mental

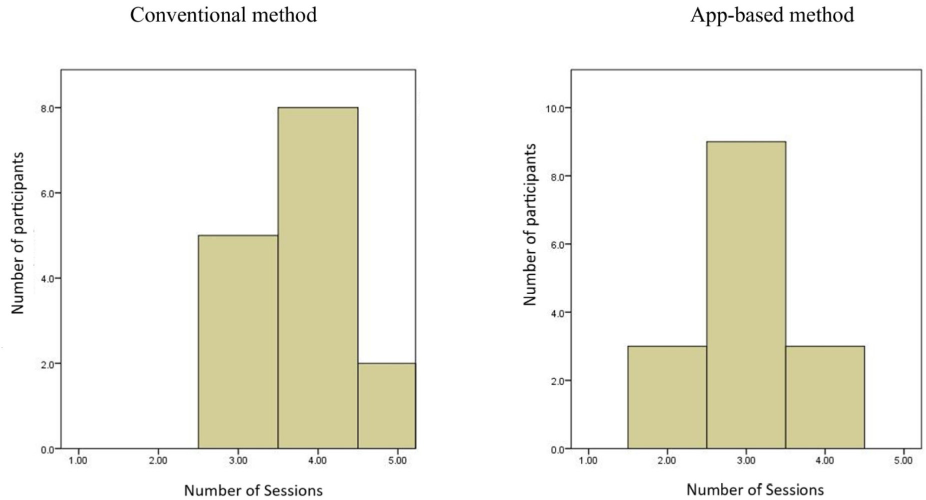

Figure 6. In several sessions, the clinician must assess pure tone audiometry from children conditioned for hearing. A. Conventional method. B. App-based method.

demand of the clinician was significantly reduced among children conditioned using the AB method compared to children conditioned using the CM. Additionally, the clinician felt more confident in the children's responses to the sounds, conditioned using the AB method. The clinician could estimate the thresholds for different frequencies of pure tones in less time. In addition, the PTA testing was completed significantly faster with fewer sessions for those children conditioned using the AB method than the CM. A minimum of 3 weeks of AB (3 sessions) conditioning was required to complete the PTA testing in a maximum number of 9 children.

In contrast, the CM of conditioning required 4 sessions to complete PTA testing for a maximum of 8 children. The PTA testing was completed for all 15 children within 4 sessions using the AB conditioning method and 5 sessions using the conventional conditioning method. Although the number of sessions differed by only by 1 session between the 2 conditioning methods, the overall clinician task load was significantly reduced when the AB method was used rather than the CM for hearing conditioning to complete the PTA testing.

Figure 5 indicates no relationship between the clinician's task load in each method's PTA testing before and after conditioning. However, the magnitude (after-before conditioning) of reduction in each of the parameters of the clinician task load was more significant when conditioned using the AB method than the CM (Figure 4).

The children conditioned using the AB method can be called after 3 weeks for PTA testing. There is a lower chance of postponing the PTA testing in successive sessions, which reduces the frequent visits to the clinic. The hearing threshold can be detected as early as possible, and a habilitation program is recommended to capitalize on the plasticity period for speech and language development.

Digital tools offer engaging pre-test training that reduces anxiety and streamlines audiometry processes. Gamified auditory activities help children develop listening skills, leading to more reliable test outcomes.[20] However, challenges like maintaining user engagement and tech barriers remain, and some caregivers may struggle with digital platforms due to limited tech experience.[21] A user-friendly interface and application help the caregiver condition the child before hearing testing. Such an application can improve test accuracy and reduce clinician workload while providing valuable insights into a child's auditory responses for early detection and intervention.[22] Using AB pre-training in pediatric audiology shows promise for enhancing timely hearing assessments.

In the future, applications and artificial intelligence (AI) technologies are expected to significantly improve pediatric hearing assessments, making them more accessible, efficient, and accurate. [23] These advancements leverage mobile platforms and machine learning to enhance hearing health. [24] They have the potential to overcome traditional challenges, such as the dependency on specialized equipment and expertise that is often missing in low-resource environments.[25]Integrating AI and mobile technology in hearing evaluation and management will facilitate more inclusive and effective hearing care.

CONCLUSION

This study highlights that using AB conditioning can significantly lessen the task load on clinicians and reduce the number of testing sessions when compared to traditional methods. However, it notes that younger children, particularly those under the age of 3, often struggle with PTA because they may not be ready for CPA. Future research should focus on children older than 3 who are better prepared for CPA. This could help clarify the differences between those groups receiving the AB method for conditioning for hearing and the CM while also strengthening the evidence for the benefits of digital training in pediatric audiology

Data Availability Statement: Data are available in the form of figures and tables within the article. The authors can provide additional information upon request.

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