© J Hear Sci, 2018; 8(2): 16–21
DOI: 10.17430/904267

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

AUDIOMETRIC THRESHOLD MEASUREMENT IN CHILDREN WITH INTELLECTUAL DISABILITY: PREFERRED RESPONSE MODE

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Abstract

Background: The accuracy of pure tone audiometry is important for the success of auditory assessments and in monitoring rehabilitation programs for auditory disorders. Studies have reported that pushing a button as a response mode has a significant effect on pure tone thresholds in subjects with normal and impaired hearing. We therefore assumed that a push-button response mode may negatively impact pure tone threshold measurement in subjects with intellectual disability (ID) owing to their impaired cognition and poor motor coordination. The current study compares in persons with ID the number of presentations, number of false alarms, test duration, and participant preference across three response modes during audiometry.

Materials and methods: Air-conduction thresholds were measured for each response mode – push button, hand raise, and verbal – at octave intervals between 500 and 2000 Hz in the right ear of 14 children with intellectual disability. The order of the response mode was randomly assigned to three subgroups.

Results: The results indicated that among ID subjects a verbal response yielded a threshold in significantly less time. There was a significant preference for using the verbal response. Children who were assigned a push button or hand raise also responded with a verbal response. For push button participants, this occurred before the button was pushed and for the hand raising participants, a verbal response occurred before the button push.

Conclusions: The study finds verbal responses more beneficial in measuring auditory thresholds in children with ID.

Keywords: Pure tone audiometry • auditory threshold • response mode • intellectual disability • listener's preference

MEDICIÓN DE LOS UMBRALES AUDIOMÉTRICOS EN NIÑOS CON DISCAPACIDAD INTELECTUAL: LA FORMA PREFERIDA DE REACCIONAR

Resumen

Introducción: La exactitud de la audiometría de tonos puros es importante para el éxito de la evaluación de la audición y para el seguimiento de los programas de rehabilitación de los trastornos auditivos.

Los estudios han revelado que la forma de responder mediante pulsación del botón influye de manera importante en los umbrales de la audiometría de tonos puros en personas con audición normal y en personas con trastornos auditivos. Por eso, hemos supuesto que la reacción mediante pulsación del botón puede tener un impacto negativo en la medición de la audiometría tonal en personas con deficiencia intelectual debido a sus dificultadas con las funciones cognitivas y su mala coordinación física. El estudio presentado a continuación compara, en caso de personas con discapacidad intelectual, el número de presentaciones, el número de falsas alarmas, el tiempo de duración de la prueba y las preferencias de los participantes con respecto a tres modos de respuesta durante la audiometría.

Material y métodos: Se han medido los umbrales de conducción aérea para cada forma de reacción: mediante pulsación del botón, la mano alzada y reacción verbal, a intervalos de octava de 500 a 2000 Hz en el oído derecho en niños con discapacidad intelectual. La secuencia de la forma de reaccionar se ha asignado a los tres subgrupos al azar.

Resultados: Los resultados indican que entre las personas con discapacidad intelectual la respuesta verbal indicaba el umbral en un tiempo mucho más breve. Se observó una considerable preferencia a responder verbalmente. Los niños a los que se asignó la pulsación del botón de respuesta o la reacción mediante la mano alzada, daban también una respuesta verbal. En caso de los participantes que utilizaban el pulsador de respuesta o que reaccionaban levantando la mano, la respuesta verbal se daba respectivamente antes de pulsar el botón.

Conclusiones: Los presentes análisis indican que las respuestas verbales son más favorables para la medición de los umbrales auditivos en niños con discapacidad intelectual.

Palabras clave: audiometría de tonos puros • umbral auditivo • modo de respuesta • discapacidad intelectual • preferencias del oyente.

ИЗМЕРЕНИЕ АУДИОМЕТРИЧЕСКИХ ПОРОГОВ У ДЕТЕЙ С УМСТВЕННОЙ ОТСТАЛОСТЬЮ: ПРЕДПОЧТИТЕЛЬНЫЙ СПОСОБ РЕАГИРОВАНИЯ

Абстракт

Введение: точность тональной аудиометрии важна для успешной оценки слуха и мониторинга программ реабилитации нарушений слуха. Исследования показали, что способ ответа путём нажатия кнопки имеет значительное влияние на пороги тональной аудиометрии у лиц с правильным слухом и у людей с нарушениями слуха. Поэтому мы предположили, что реагирование с использованием кнопки ответа может отрицательно влиять на измерения тональной аудиометрии у людей с нарушениями умственной отсталостью по причине когнитивных сложностей и низкой двигательной координации.

Нижеуказанные исследования сравнивает у лиц с умственной отсталостью количество презентаций, количество фальшивых тревог, длительность теста и предпочтения участников в трёх режимах ответа во время аудиометрии.

Материал и методы: Пороги воздушной проводимости были измерены для каждого способа реакции – с использованием кнопки, путём поднятия руки и словесной реакции – в октавных промежутках от 500 до 2000 Гц в правом ухе у 14 детей с умственной отсталостью. Последовательность способа реакции была случайно приписана трём группам.

Результаты: Результаты показали, что среди лиц с умственной отсталостью устный ответ показывал порог за намного более короткое время. Было замечено значительное предпочтение к использованию вербального ответа. Дети, которым приписали нажатие кнопки ответа или реагирование путём поднятия руки, также давали устный ответ. В случае участников, пользующихся кнопкой ответа и реагирующих путём поднятия руки, устный ответ давался перед нажатием кнопки.

Выводы: Настоящие исследования показали, что устные ответы оптимальнее при измерении слуховых порогов у детей с умственной отсталостью.

Ключевые слова: тональная аудиометрия • слуховой порог • режим ответа • умственная отсталость • предпочтения слушателя

POMIAR PROGÓW AUDIOMETRYCZNYCH U DZIECI Z NIEPEŁNOSPRAWNOŚCIĄ INTELEKTUALNĄ: PREFEROWANY SPOSÓB REAGOWANIA

Streszczenie

Wprowadzenie: Dokładność audiometrii tonalnej jest istotna dla powodzenia oceny słuchu oraz monitorowania programów rehabilitacji zaburzeń słuchowych.

Badania wykazały, że sposób odpowiedzi poprzez naciśnięcie przycisku ma znaczący wpływ na progi audiometrii tonalnej u osób z prawidłowym słuchem oraz u osób z zaburzeniami słuchu. Dlatego założyliśmy, że reagowanie przy użyciu przycisku odpowiedzi może negatywnie wpływać na pomiary audiometrii tonalnej u osób z niepełnosprawnością intelektualną z powodu ich utrudnionych czynności poznawczych i słabej koordynacji ruchowej. Poniższe badanie porównuje u osób z niepełnosprawnością intelektualną liczbę prezentacji, liczbę fałszywych alarmów, czas trwania testu oraz preferencje uczestników w trzech trybach odpowiedzi podczas audiometrii.

Materiał i metody: Progi przewodnictwa powietrznego zostały zmierzone dla każdego sposobu reakcji – z wykorzystaniem przycisku, podniesienia ręki i reakcji mówionej - w odstępach oktawowych od 500 do 2000 Hz w prawym uchu u 14 dzieci z niepełnosprawnością intelektualną. Kolejność sposobu reakcji została losowo przypisana do trzech podgrup.

Wyniki: Wyniki wskazują, że wśród osób z niepełnosprawnością intelektualną odpowiedź ustna wskazywała próg w znacznie krótszym czasie. Zauważono znaczną preferencję do korzystania z odpowiedzi werbalnej. Dzieci, którym przypisano naciskanie przycisku odpowiedzi lub reagowanie przez podniesienie ręki, również udzielały odpowiedzi ustnej. W przypadku uczestników korzystających z przycisku odpowiedzi oraz reagujących przez podniesienie ręki, odpowiedź ustna była udzielana odpowiednio przed naciśnięciem przycisku.

Wnioski: Niniejsze badania pokazują, że odpowiedzi werbalne są bardziej korzystne w pomiarze progów słuchowych u dzieci z niepełnosprawnością intelektualną.

Słowa kluczowe: audiometria tonalna • próg słuchowy • tryb odpowiedzi • niepełnosprawność intelektualna • preferencje słuchacza

INTRODUCTION

Pure tone audiometry is a fundamental clinical procedure for determining hearing sensitivity, categorizing hearing loss/disorders, and setting hearing aid parameters in aural rehabilitation programs [1-4]. The widespread clinical realization of pure tone audiometry is based on the intrinsic assumption that persons provide an appropriate response when a stimulus is audible and that responses are consistent upon retesting. Numerous analytical and comparative studies on test procedures and stimuli parameters, sometimes including participant's response preferences, have led to the formation of guidelines from the American Speech Language Hearing Association (ASHA, 2005) for obtaining repeatable and valid pure tone thresholds [5].

The ASHA (2005) guidelines include information on (a) how to instruct the participant on the task, (b) how to interpret the response behavior, (c) stimulus parameters, and (d) the recommended procedure for threshold determination [5]. The literature reports no significant difference in pure tone threshold among the three procedures, the number of false positives, or participant preference [6-8]. However, persons with normal hearing have shown a significant difference in threshold with pulsed tones [7-9]. Further, patients with sensorineural hearing loss and tinnitus showed a larger number of presentations and more false positives to continuous than to pulsed tones [10-11]. Hence, these reports recommend using pulsed tones to measure pure tone thresholds.

DOI: 10.17430/904267

With respect to response modes, DiGiovanni & Repka (2007) reported that typical persons with normal hearing have a general preference for the push button response mode. This response mode requires a shorter test time to achieve pure tone threshold compared to hand raising and verbal responses [12]. They concluded that the push button was preferred owing to easier motor function requirements (the thumb pressing a button) than response modes involving more complex actions like raising a hand or a verbal response. They therefore recommended use of a push button as a response mode in obtaining pure tone threshold.

Individuals with intellectual disability have impaired linguistic skills and oral communication, difficulties in motor coordination, and reduced attention span compared to typical persons. The behavioral variables of persons with intellectual disability include the effect of physical discomfort, antagonism toward the task [13], and difficulty in attending to the required task, making them a "difficult to test population" for pure tone audiometry [14]. Mauer & Rupp (1979) recommended that standard audiometric test procedures be modified to ensure accurate and valid measurement of auditory thresholds in "difficult to test" populations [15].

Each response mode requires considerable cognitive skills involving understanding of instructions and motor coordination of the response task [16-18]. We assumed that persons with cognitive deficits may have a response preference different to the typical population. Hence, we aimed to find the effect of common response modes on the number of presentations, test duration, false alarm rate, and response mode preference during pure tone threshold measurement. The effect of response mode on pure tone threshold has not been studied in persons with intellectual disability, so far as a literature search could determine.

This gap warrants an investigation into response modes as a factor in threshold determination and for determining the best response mode that provides the most accurate and reliable thresholds in individuals with ID. The study results could therefore be helpful in choosing the most accurate and effective audiological assessment technique, which in turn might help in aural rehabilitation programs, including the selection of appropriate hearing aids. Successful audiological intervention is likely to reduce complications due to hearing impairment in population with cognitive challenges [19-20].

OBJECTIVE

The purpose of the study was to determine the impact of common response modes – verbal response, push button, and hand raising – on test duration, false alarm rate, and preferred response mode during audiometric threshold measurements in individuals with intellectual disability.

METHOD

Research design

This exploratory survey research consisted mainly of pure tone audiometric testing and a brief, three-question interview in individuals with intellectual disability. Since not all variables could be controlled in the research [21], qualitative comparative analysis (QCA) was performed to study the effect of response mode on pure tone threshold.

Sampling procedures

Subjects fulfilling the requirements of the study were purposefully selected from our audiology clinic who either visited themselves or were referred for routine audiological checkup from special schools for children with intellectual disabilities within the Mumbai Metropolitan Regions, to audiology clinic, Ali Yavar Jung National Institute of Speech & Hearing Disabilities (Divyangjan), Mumbai.

Ethical considerations

The necessary ethical clearance for the study was obtained. All participants/guardians signed written informed consent, their identifying participant information was kept confidential, and test findings were shared with them.

Participants

Fourteen participants (8 males and 6 females; mean age = 13.3 years, SD± 4.5; range 9–16 years) having Intelligence Quotient (IQ) 50–60 on intelligence test and were classified as having intellectual disability (educable group). All participants were enrolled in a special educational program and had pure-tone thresholds ≤20 dBHL for octave frequencies from 250 to 8000 Hz. Immittance audiometry was conducted to rule out middle ear pathology. Participants exhibited 'A' type tympanogram at the time of pure tone testing at each session. The development of speech and language skills were informally assessed on the Receptive & Expressive Emergent Language Scale (REELS) to ensure that all participants had a receptive and expressive language age of 5 years or above.

Instrumentation

For testing, a calibrated GSI-61 clinical audiometer with earphones (Telephonics TDH-50P mounted in MX-51/AR supra-aural cushions) meeting ANSI (2004) guidelines was used in a double-walled, two-room sound booth [22].

Procedure

Participants fulfilling the selection criteria were arbitrarily divided into three subgroups, one of 4 subjects and the other two of 5 subjects. The participants were tutored to respond to test signals with a push-button, hand-raise, or verbal sound whenever a tone was audible.

The participants were instructed to verbally say hai (meaning *yes*) whenever a tone was audible or nahi (meaning *no*) whenever a tone was inaudible.

The participants were asked to push the button when the stimulus was audible and release the button when the stimulus was no longer audible.

The participants were instructed to raise their hands whenever a tone was audible and put their hand down when the tone was no longer audible.

DOI: 10.17430/904267

The response modes were explained to each participant verbally in the language they used for communication as well as through demonstrations. To ascertain proper understanding of the task, response modes were presented in pictorial form on a card given to each participant. In essence, all possible efforts were made to ensure that all participants understood the task correctly. They were asked to use their right hand when raising a hand or pushing a button. Use of their right hand was based on observing that all participants used their right hand for routine work, writing, and drawing. The participant's right-handedness was also confirmed through parental and teacher inquiry before the start of testing.

Air-conduction thresholds for the right ear only were measured twice for each response mode at octave intervals between 500 and 2000 Hz using stimulus parameters and test procedure recommended by ASHA (2005). The second threshold measurements were performed to determine the consistency and reliability of the threshold. The ascending/descending method developed by Carhart and Jerger (1959) was used to obtain thresholds unilaterally (right ear only) at octave frequencies of 500, 1000, and 2000 Hz [23]. Stimuli were manually presented as two short pulses (rise-fall time of 35 ms with duration of 200 ms onset to offset automatically generated by the audiometer) over a time of 1 to 2 seconds.

Subjects responded to pure tones with all three response modes for both test sessions. To eliminate the order effect of presentation on pure tone findings, response modes were not assigned in the same order to the groups. Instead, the order of the response mode was randomly chosen. Thus, if push button was assigned to one group, a hand raise or push button was allotted to the second group, and a push button or hand raise was allocated to the third group. In this way, pure tone thresholds were recorded from each participant in three response mode sequences: verbal response, push button, and hand raise; push button, verbal response, and hand raise; and push button, hand raise, and verbal response. After testing in each response mode, a rest period of about 30 minutes was provided to participants.

Threshold was determined as the lowest level obtained on at least two responses out of three presentations on an ascending/descending run. Participants were familiarized with a 40 dBHL pulsed tone presentation at each frequency. If a response was obtained, threshold measurement commenced. The first presentation was given 20 dB below the familiarization level. Thereafter, down 10 / up 5 dB steps were used to achieve threshold levels. The order of the test frequencies was always 1000 Hz, 2000 Hz, and 500 Hz. The interval between tone presentations varied but was not shorter than the test stimulus duration.

The study yielded three sets of thresholds to each response mode consisting of the total number of false alarms, tone presentations, and test time. A response occurring more than 1 sec after tone presentation was considered as a false positive. The number of tone presentations for threshold level to be reached was counted starting with the 40 dBHL familiarization tone. The test time was computed with the first familiarization tone of 1000 Hz at 40 dBHL and ended with the final presentation for threshold at 500 Hz. The order of the response modes was determined by which group they belonged to. Participants were asked to report again within 3–4 weeks for the second threshold measurement.

Table 1. Participants' mean thresholds and standard deviations (in parentheses) for each response mode at 3 test frequencies in the right ear. There is no significant differences in threshold of participants across response modes.

Response mode	Mean (SD) thresholds in dBHL		
	500 Hz	1000 Hz	2000 Hz
Verbal response	18.3 (3.9)	17.6 (5.0)	15.7 (5.4)
Push button	19.1 (4.2)	16.5 (4.6)	18.3 (4.7)
Hand raise	20.6 (3.5)	16.7 (5.1)	15.6 (6.3)

The second session was conducted to show that the threshold measures could be replicated. Therefore, the same procedure, including instructions, threshold measurement procedure, and response mode order was used. On completion of the second session, a brief three-question interview was conducted with each participant to determine their preferred response mode. Participants were asked to provide the answer orally as well as by pointing to the pictorial card depicting the response modes to ensure the the participant's response was correct. The participant's preferred response mode was recorded.

RESULTS

All the subjects responded to tones in the right ear and thresholds for each response mode at octave intervals from 500 to 2000 Hz were determined. The computed mean thresholds and standard deviations (in parentheses) for each response mode at each test frequency are shown in Table 1.

The mean audiometric thresholds in Table 1 indicate no significant differences across response modes. To understand the effect of response mode on threshold, a two-way analysis of variance (two-way ANOVA) was performed using threshold as the dependent variable with response mode and order as factors. Response mode did not affect the threshold level, $F(2, 234) = 0.57$, $p = 0.49$. Furthermore, the thresholds remained the same for the first and second tests, suggesting that the threshold was reliable $F(1,234) = 0.043$, $p = 0.92$. Moreover, there was no interaction between the order in which response modes were tested and the results obtained by each response mode, $F(2,234) = 0.031$, $p = 0.86$.

The preferred response mode for responding to pure tones was recorded from all 14 participants as described earlier. In total, 8 of 14 (57%) participants preferred the verbal response mode; for the push button and hand raise mode, each was preferred by 3 (21%) of the participants. The number of presentations, number of false alarms, and test duration for each response mode in order to reach threshold levels are shown in Table 2. The frequency and percentage of preferred response mode are also shown.

A chi-square analysis of Table 2 showed a significant difference for participant's preference for using the verbal

DOI: 10.17430/904267

Table 2. Number and percentage of participant's preferred response mode, means and SD of tone presentations, number of false alarms, as well test duration to achieve threshold

Response mode	participant's preference		Number of presentations		Number of false alarms		Test duration (min)	
	n	%	mean	SD	mean	SD	mean	SD
Verbal response	8	57.1	21.5	4.6	0.84	0.9	8.3	1.2
Push Button	3	21.4	26.3	4.1	1.12	1.5	10.1	1.3
Hand raise	3	21.4	23.7	3.8	0.91	0.8	9.1	1.7

response, $\chi^2(1, N = 14) = 7.24$, $p < 0.05$, compared to other response modes. A multivariate analysis of variance (MANOVA) of Table 2 indicated that there was no significant difference in the number of presentations, $F(2,39) = 2.34$, $p = 0.233$, or number of false alarms, $F(2,39) = 1.19$, $p = 0.17$, as a factor in pure tone threshold measurement among the response modes.

However, test duration to achieve threshold differed significantly across groups, $F(2,39) = 5.54$, $p<0.05$. Tukey's post hoc comparisons showed that verbal response (8.3 min) and hand raise (9.1 min) required statistically significant less time than the push button (10.1 min) to attain the threshold level (Figure 1).

DISCUSSION

The study was conducted under the assumption that the preferred response mode to pure tones in individuals with an intellectual disability may be different due to impaired communication, linguistic skills, or motor coordination, factors which may have an impact on pure tone threshold measurement. To test the assumption, audiometric pure tone thresholds using a verbal response mode, a hand raise, and a push button were obtained from the right ears of 14 participants with intellectual disability.

The results indicated that the response mode does not have a statistically significant effect in terms of pure tone threshold levels, number of tone presentations, and number of false alarms at a significance level of <0.05 in persons with intellectual disability. These findings can be connected with data reported by DiGiovanni & Repka (2007), who obtained comparable and statistically insignificant different threshold levels across response modes at audiometric test frequencies in a typical population [12]. The comparable results of the current study are expected since audiometric procedures involve simple tasks that can be successfully and reliably performed by individuals having a mental age over 2½ years [18, 24-25].

However, the total test duration required to attain threshold differed significantly across response modes. Tukey's post hoc comparisons showed that verbal response and hand raise required a statistically significant shorter time (by a minute or more) than the push button. This was in contrast to the finding by DiGiovanni & Repka (2007), who reported that a push button required less time to accomplish pure tone testing [12]. They suggested that the time saving might be due to the use of a minor motor function (thumb pressing a button) as a response rather than a more complex motor function (raising one's own arm) or a more complex motor-speech function (verbalizing a word).

Thus, it can be seen that the response pattern in individuals with ID is different than that seen more commonly. Table 2 shows that the verbal response mode required fewer tone presentations (21.5) than hand raise (22.7) or push button (26.2). Further, there were fewer false positives with the verbal mode compared to push button or hand raise. Collectively these two factors contributed to a reduced test time to reach threshold in persons with ID. Further, a majority (57%) of participants preferred a verbal response over the other two response modes. It can therefore be concluded that the verbal response mode is better for threshold determination in individuals with ID.

This conclusion can be supported by considering that the natural function of hearing is to bring about behavioral change in the form of speech. A verbal response appears to be a natural reflex to an acoustic stimulus. This could be why participants who were assigned a push button or a hand raise also often responded verbally. Speech is interwoven with hearing in a complex way and the feedback mechanism might have helped subjects maintain attention during the test and facilitated quicker responses, resulting in fewer tone presentations and shorter test durations to reach threshold.

The preference against a push button or hand raise might be because these are not natural responses to auditory stimuli in real world settings. Moreover, a push button or hand raise does not provide a hearing-linked feedback to assist monitoring, perhaps important for the intellectually disabled population. However, the study did find that a hand raise was the second-best mode in terms of number of tone presentations and test duration. This observation might relate to the participants being of school age, and so verbal and hand raise responses might be familiar to them, as when responding to a teacher's roll call in class.

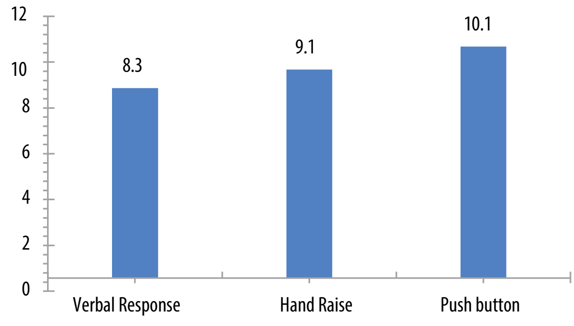

Figure 1. Test duration (minutes) to achieve threshold. Values increase from verbal response to hand raise to push button.

DOI: 10.17430/904267

On the basis of the above, we infer that verbal responses are particularly effective in achieving an auditory threshold in persons with intellectual disability. However, other response modes, hand-raising and button pushing, can also yield a similar threshold although it may take little longer. The current study has not examined the effects of factors such as hearing status, oral communication ability, tinnitus, or category of intellectual disability. Further research is needed to explore these complexities.

SUMMARY

The benefits of using a push button response mode over a verbal response or hand raising have been documented in literature. However, this exploratory study revealed that a verbal response was preferred by the participants. It required fewer presentations, involved fewer false alarms, and minimised the time needed to determine audiometric threshold in persons with intellectual disability. Hence, in such a situation, a verbal response may be better in reducing test time.

It is recommended that audiologists ask their clients which response mode they prefer. This may improve attention and help the clinician as well, although threshold levels will be about the same. Especially for clients with intellectual disability, taking their preference into account is likely to improve cooperation and make the testing experience less arduous.

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DOI: 10.17430/904267