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Study on Audiometry for Preschool Children by Use of Telephone Set

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The establishment of welfare measures for preschool children with speech impediments caused by hearing disorders has now become one of the most important of social questions in this country. In order to effect an early and timely discovery of preschool children with such physical handicaps, there is no choice for it but to resort to child audiometry.

Getting hint from the fact that little children are found of playing with the toy telephone, the author has contrived a new apparatus for their audiometric examination, putting some improvements into the toy telephone set, and studied on clinical application of this apparatus. The objects were 25 normal adults, 100 normed children, 5 or 6 year old, and 10 children hard of hearing. The method employed in this study consisted of the comparative study on results of hearing test for normal adult through standard audiometer and those obtained through new apparatus, examination of liminal threshold of audibility and auditory responses through hearing test for normal preschool children and experimental application of the apparatus to hearing test of preschool children hard of hearing. What can be said from results of these studies are that this is a method of child audiometry midway between Startle Response Audiometry and Play Audiometry, and this will also be applicable for screening purposes of small children.

The establishment of welfare measures for preschool children with speech impediments caused by hearing disorders has now become one of the most important of social questions in this country. The essential factors, for the measure are considered to lie in early discovery and early therapy of preschool children with such physical handicaps. In order, therefore, to effect an early and timely discovery, there is no choice for it but to resort to child audiometry.

In recent years, due to progress in the methodology of audiometry, audiometric study of preschool children has been extensively carried on, such tests as E. E. G. Audiometry, Play Audiometry, Startle Response Audiometry, C. O. R. Audiometry being clinically employed. However, these methods are not so simple to operate as are generally

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supposed.

Getting hint from the fact that little children are fond of playing with the toy telephone, the author has contrived a new apparatus for their audiometric examination, putting some improvements into the toy telephone set. The result of clinical study obtained through this apparatus is here shown as follows:

THE APPARATUS

As illustrated in the picture, the apparatus consists of 3 parts, i.e. microphone, amplifier, receiver. It is of small size and of light weight, and naturally easy to move.

Fig (1) shows the block diagram of the apparatus.

Fig. 1. Block Diagram & Telephone Set
For test sound, use is possible of the natural voice of the subject's mother besides pure tone, speech sound, social sound.

Performance of audiometric examination of a little child through the medium of his or her mother's voice would bring about a great advantage to the tester in the point that the subject child would be free from fear during performance. In this case, input is made by means of microphone, but in case of pure tone, speech sound, social sound, it is done by sounds picked up from record-player or tape-recorder. The test sound for input should be regulated so that the tip of the V. U. meter needle of the amplifier may come as near to O mark of the gradations as possible, and transmitted to the receiver on amplification by the db meter. The responses from the subject child will be caught by the receiver, and, amplified, informed to the subject through the response speaker.

Another feature of this device is that it is so constructed that, in case of test sound 1000 cps, the sound pressure emanating from the receiver will agree with the gradation of the db meter, if input is made so that the V. U. meter needle may point to O mark of the gradations. Therefore, in case of another test sound than pure tone, the sound should be considered to be laden with a sound pressure of about the same gradation mark as that of the db meter.

**TECHNIQUE**

The call bell fixed to the amplifier causes the telephone bell ring when pressed down. The action of the subject child to turn his or her head to the bell at the sound and take the receiver in hand would be evidence enough to testify to the presence of auditory sense in the child. On regulating the sound pressure emanating from the receiver, the tester will cause the child to listen to his or her mother's voice or social sound, etc. for test sound, and give judgment as to the presence and degree of audition in the child on close observation of the responses or auditory reflexes the child would make.

**OBJECT AND METHOD OF STUDY**

With a view to reliability on the test results obtained by use of the apparatus of the author's own invention, the following observations have been carried out.

A comparative study has first been made of the results of the hearing test of 25 adult Japanese with normal hearing acuity conducted by use of the standard audiometer, and those of the test for the same person through the telephone set, the Japanese Monosyllable Test List for Speech Audiometry designated by the Audiological Society of Japan.
As regards preschool children, hearing test by the telephone set has been executed for 100 children of the age of 5 or 6 who were free from any otological disorders. In the test, children's responses to the sound of the bell were ascertained; the value of liminal threshold of audibility was determined during conversation between tester and subject; and confirmation was also made of auditory reflexes the small children were expected to give at the sound of animal cries.

With regard to children hard of hearing, a comparative study has also been carried out on the results obtained from another hearing test carried out for 10 preschool children hard of hearing and those given by the same children tested through the present apparatus.

Lastly, an analytical study has been made on the sound pressure and frequency of the telephone bell as well as on the sound of animal cries, the outcome and extent of audibility of the latter being treated under 'Discussion'.

![Graph](image-url)

**Fig. 2.** The mean value of points for the 25 cases
Table 1. The results given by each of the 25 subjects tested by the standard audiometry and those given by the same subjects tested through the telephone.

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<th>Audio. Tel. ±</th>
<th>30db ±</th>
<th>Audio. Tel. ±</th>
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Average 42.9 43.1 0.2 80.1 78.5 2.8 95.8 91.24.64 91.2 90.6 2.6 97.0 95.51.44 98.2 98.11.44

Fig. 3. The numerical differences in the points of two method of hearing test being as exhibited in the distribution diagram.
mission to the listening child of the test sound. In his attempt, therefore, to secure reliability on the results of hearing test conducted through this apparatus, the author has carried out a comparative study on the results of test obtained from 25 normal adult Japanese who had undergone hearing test by standard audiometer and those gathered from the same subjects tested through the telephone set with the Japanese Monosyllable Test List for Speech Audiometry designated by the Audiological Society of Japan as test material in both cases.

The result given by each of the 25 subjects tested by the standard audiometer and those given by the same subjects tested through the telephone, together with the numerical differences in their points are displayed in Table (1). What is drawn from these results is that, each time the test sound pressure was applied to the case, points given to the regular audiometric test were greater than those allowed to test by the telephone. The mean value of points for the 25 cases being as displayed in Fig. (2), the difference was biggest at sound pressure 40db, showing 4.64%. smallest at 20db. giving 0.2%. Again, in each of the 25 cases to which the test sound pressure was applied, the numerical differences in the points of the two methods of hearing test being as exhibited in the distribution diagram Fig. (3). the fact is noted that fluctuation of the numerical differences in the two series of cases were greater at 20db. and 30db. that the stronger the test sound pressure was, the smaller the numerical differences grew. Of the

Fig. 4 Audiogram of the case showing sharpest fluctuation
Fig. 5. Audiogram of the least fluctuation

![Audiogram of the least fluctuation](image1)

Fig. 6. Audiogram of the mean value of all the cases

![Audiogram of the mean value of all the cases](image2)
results mentioned above, the audiogram of the case showing the sharpest fluctuation is displayed in Fig. (4); that presenting the least in Fig. (5); and that of the mean value of all the cases in Fig. (6).

RESULTS OF HEARING TEST FOR NORMAL PRESCHOOL CHILDREN

a) Liminal threshold of audibility

For the purpose of obtaining the liminal threshold of audibility of children through the apparatus, hearing test has been carried out for 100 preschool children of the age of 5 or 6 with no otological disorders. The threshold has been gained through experiments at different sound pressures performed during conversation between tester and child as the child was playing with the telephone set. The composition of the subject group of children is as shown in Table (2). i.e. 27 (aged 5), 73 (aged 6); 48 male, 52 female.

The results obtained being as exhibited in Fig. (7), 26 (26%) gave the threshold 20db; 48 (48%) 25db; 26 (26%) 30db upwards.

Table 2. The composition of the subject group of children

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<tr>
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<th>5 year old</th>
<th>6 year old</th>
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<td>Male</td>
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<td>32</td>
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</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>41</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
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</table>

Fig. 7. Liminal threshold of audibility obtained for 100 preschool children
b) Auditory responses

Hearing test of preschool children should be carried out objectively. The tester has therefore to be on the alert not to miss their possible responses to the test sound. In the experiment, the subject children were so guided as to hear the test sound during their play with the telephone, observation being kept all the while on the responses they might make to hearing stimulation. Observation revealed, besides the liminal threshold of audibility, facial expressions, actions, etc. of the subject child manifested in response to the reproduced sound of the animal cries which had been taken in record at the sound pressure of minimum audibility. These auditory responses and their incidence are displayed in Table (3).

Table 3. Auditory responses and their incidence

1) turn to the telephone
2) turn round
3) take and apply the reciver to the ear
4) respond, saying "Moshi Moshi"

1) winking ................................ 34 cases
2) move the eyes, turn towards the ear under test: stop moving the eyes .... 83
3) stop breathing ........................... 7
4) be intent on listening ...................... 50
5) being smiling ........................ 37
6) make looks of relief ...................... 34
7) move the lip ........................... 31
8) no expression ........................... 1

ON SOUNDS OF BELL AND ANIMEL CRIES

The measurement of sound pressure of the telephone bell employed in the test was effected at a distance of 30cm from the telephone set, with the result that the pressure was ascertained to be of approximately 60db. As for the sound itself of the telephone bell it had been put in a tape-recorder, from which the sound spectrogram was reproduced as exhibited in Fig. (8). The test also revealed that the main cycle range lay somewhere around 800 cycle and 3200 cycle. Besides, commercial records were used in order to verify the children’s responses to animal cries. The sounds of animal cries tested being those of bush-warbler, owl, cock, cow,
Fig. 9. Sonagram of animal cries

duck

cook

owl

cow

bush-warbler
duck, their sonagram is demonstrated in Fig. (9).

EXPERIMENTAL APPLICATION OF THE APPARATUS TO HEARING TEST OF PRESCHOOL CHILDREN HARD OF HEARING

Application was made of the apparatus to the hearing test of preschool children hard of hearing who had been attending for treatment the Hearing and Speech Disorders Clinic, Department of Oto-Rhinolaryngology, Nagasaki University School of Medicine. The subject children counted 10 in all, (3 male; 7 female) of whom 3 were aged 4 years; 4, 5 years; 3, 6 years, as exhibited in Table (4).

<table>
<thead>
<tr>
<th>Case</th>
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<th>Tele. Audio.</th>
<th>Auditory Response</th>
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<td>r. 61. 5</td>
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<td>being smiling</td>
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No remarkable difference was noted between the results obtained by application of this telephone method and those gained through other methods; 5 worse cases, 3 better cases, 2 similar cases being observed in the former method.

DISCUSSION

Difficulty that impedes the smooth performance of audiometric examination for preschool children lying in their incooperative attitude
towards the work, objective audiometry may be the only way practicable in such cases. The most prevalent of objective audiometries at present time comprize those with indications either for physiological phenomena caused by hearing stimulation, or for physical reactions or conditioned reflexes to the same. Execution of these methods needing specialists and massive installations, employment of the methods in actual cases would incur a great difficulty. (11-34)

For clinicians, screening of preschool children hard of hearing is of prime importance. As for disordered children found out during performance, it would be enough for them to undergo precise examination afterwards taking ample time for it.

At present, methods such as the following are in use for screening purposes for preschool children hard of hearing:

- Whispered and Spoken Voice Tests,
- Tuning Fork Tests,
- Watch Tick and Coin Click Tests

The present apparatus of the author's invention being considered to possess potential enough for screening purposes, the author wishes to discuss and debate, in the following lines, on the outcome of the experiment undertaken for clinical application of the apparatus as well as on the result of actual clinical application thereof.

PLAY AUDIOMETRY

There is a multitude of studies available on the hearing test of preschool children. These studies can be roughly divided into two groups. One is that to which such methods belong as E. E. C. Test, P. G. S. R. Test, etc., all of which present as indicators specific physiological phenomena in response to sound stimulus; (4, 5, 15, 23, 24, 29, 32, 33) the other is that which makes a thorough examination for presence of hearing acuity in the subject child through his or her responsive attitude towards sound stimulus. (1, 2, 3, 6, 7, 8, 9, 10, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 30, 31) The latter group comprizes methods such as Play Audiometry, C. O. R. Test, Startle Response Audiometry, all of which are gradually finding employment in clinic also.

Regarding Play Audiometry, Bloomer (3) reported in 1942 on Picture Gard Test, but it is only after the introduction of Peep Show Test by Dix & Hallpike (5, 7) in 1947 that Play Audiometry has grown to secure general recognition as an audiometrical method for preschool children.

There are two methods in which the principle of Play Audiometry is exemplified. One is that in which condition is to be made between sound stimulus and light stimulus, the latter being used for nonconditioned stimulus (Peep Show Test); (6, 7) the other is that in which condition is to be made after the subject child has undergone training by sound...
stimulus and play combined (Barr's Series Game).\textsuperscript{1,2} Recently, however, Suzuki-Hagiya\textsuperscript{16,17,28} have introduced C. O. R. Test which is a method midway between Startle Response Audiometry and Play Audiometry, and say that their new device can also be applicable to the hearing test of children under 3 years of age. It is generally accepted that a 6 month-old child of fast mental growth will take interest in the ringing sound of telephone bell, and amuse itself playing with the telephone for a toy. In 2 years, the child will grow to be very fond of speaking with its parents on the telephone.

Getting hint from the fact, the author has made use of this wont of small children in his new method.

The technique of the method is in the first place to pass judgment as to the presence of hearing acuity in the subject based on his or her possible reactions to the bell sound; i.e., judgment can be given on the presence of hearing acuity for test sound 60db, for the bell sound is of sound pressure 60db. Furthermore, audiometry can be performed during conversation between the subject and his or her mother’s voice, or by watching the change of looks the child would make at the sound of toy bell or animal cries. The most distinctive of characteristics that separates this from other child audiometries lying in the former’s being of Talk Back Style in which the child’s most beloved mother’s voice is employed, as well as in its ability for hearing test by use of human voice, it is considered that this will prove an adequate method for early discovery and resultant early speech therapy of children hard of hearing.

By all accounts, this is to be regarded as a combined method of Startle Response Audiometry and Play Audiometry, of which the ruling factor will be the latter.

RELIABILITY ON RESULTS OBTAINED THROUGH THE PRESENT APPARATUS

As previously stated, this apparatus is of exceedingly simple mechanism, so that it becomes strictly necessary to ascertain the correct transmission to the subject child of the test sound employed. In the audiometry of adult persons, which is of different meaning from mere sensory reception of sound stimulus, judgment on the audibility of speech sounds should be given according to the degree of meaning the sounds convey, because the adult audiometry is essentially a speech one, in which speech sounds transmitted via the receiver are not felt as mere sounds, but sounds implying meaning. In case, therefore, speech sounds are to be heard through the receiver, those of low audibility will become of little practicability. Thus the speech audiometry proves of great significance.
With regard to the relationship between the standard speech audibility and the speech audibility through the telephone, investigation reveals that, in case of low sound pressure, there occurs a great change in the difference in their points, but so little change in that of the mean value of all cases that they make an approximate value. This is demonstrative of the fact that, in case of low sound pressure, degree of speech audibility through the telephone is better or worse as the case may be. This thing also testifies to the fact that no absolute stability is established in the speech audibility through the telephone. On the contrary, the phenomena that the higher the sound pressure, the less the change in points, and that, in the mean value of all the cases, too, the difference in points of both tests is slight, bear evidence enough to the speech audibility not being seriously affected by use of the telephone. However, the fact that, in case of speech sound with sound pressure 40db, points gained through the telephone were decidedly little as compared with those obtained by use of standard audiometer, and the difference in the mean values of results of both tests gave 4.64%, is considered attributable to a similar cause to what brought about, as stated above, the big change in the results of test at low sound pressure, as well as to the sound characteristics of the receiver. This is a question susceptible of solution on future improvement of the apparatus.

THE LIMINAL THRESHOLD OF HEARING

It may well be presumed that a fair degree of audiometrical error is to be expected in the results obtained from the child audiometry, because the subject children are of preschool age. As regards the relationship between age and error, it is reported that the less the age, the bigger the error; f. i. in case of 3-year-old children, an error exceeding ±10db is given by over 45% of the subjects; whereas, in case of 6-year-old children, only 18% has presented an error ±10db. With regard to the relation of the test sound to the result, in case of pure tone test, the subject does not give any valid result in one single test; especially, in case of children hard of hearing, determination of the liminal value of hearing in one single test would be dangerous. As for the liminal threshold of hearing of preschool children, report has it that that of 3-6-year-old children stands at 5-20db above that of adult persons.\(^8,18,19,20,23,27,31\)

The aim of this new device lying in early discovery of hearing disorders in small children by making screening test, the method proves of great significance in its ability for test by speech sound. Hearing of speech sound has a different meaning from mere sound sensation of pure tone; the meaning which the speech sound conveys should be
understood. This proves of great importance in the speech training of children hard of hearing.

With regard to the relation between hearing acuity for pure tone and that for speech sound in normal children, in case of test conducted at sound pressure 40db above the liminal threshold of hearing obtained in pure tone audiometry, discrimination of speech sound is said to prove 100%. As for the liminal threshold of hearing of speech sound, as it is of value approximate to the sound pressure to be produced in case of audibility showing 50%, the sound pressure of speech sound during conversation, when such is possible on the telephone, is considered to be the liminal threshold of hearing of speech sound.

The fact that, of 100 normal children subjected to the test, 70 (70%) gave the liminal threshold of hearing of speech sound 20db; 25 (25%), 25db; 5 (5%), 30db upwards, is to be taken to show that the liminal threshold of hearing of speech sound in normal children tested with this apparatus is set at 20db. This means that the outcome minus 20db of test performed for children hard of hearing is considered to be the liminal auditory threshold of speech sound in the subject children.

AUDITORY RESPONSES

Child audiometry should be carried out in such a way that objective judgment be passed as to whether or not the subject child has caught the test sound. Indications for judgment on the presence of audition comprize E. E. G., G. S. R., pupilary reflex, wink reflex, respiratory and cardiac change, all or which are based on physiological reactions of the body to sound stimulus.

As against these, there are Startle Response Audiometry, C. O. R. Test, Play Audiometry for determining the presence of audition based on the reactions, facial expressions or movements the child would make in response to the sound stimulus.

The following reactions are enumerated as indications in Startle Response Audiometry:
1) move the pupils, or turn to the sound source
2) turn round
3) stop moving
4) wake up
5) begin smiling
6) start crying
7) make startled looks
8) utter voice, or respond (after SUZUKI)

The mechanism of C. O. R. Test (SUZUKI) is that a thing which is
sure to please the child’s fancy appears in the direction of the source of test sound. On hearing the sound, the child will unconsciously and reflexively turn his eyes towards the sound source. This action of the child’s makes an indicator in this test.\textsuperscript{10,17,28,30}

A variety of ways for Play Audiometry has been reported, each of which is so contrived that, on hearing the sound, the child is tempted to play with some thing, the child’s curiosity for play being made good use of. It is characteristic of this method that it demands a fairly positive cooperation on the subject’s part, but gives no pain to him.\textsuperscript{2,3,6,7,8,11,12,13,18,23,26,27,31}

In the author’s apparatus, what makes indication to the auditory response is the reactions and movements the child makes at the sound of the telephone bell as well as the change of facial expressions and actions the subject demonstrates the moment he catches the test sound through the receiver when applied to the ear. In the former case, the following reactions are observed to happen:

1) turn to the telephone
2) turn round
3) take and apply the receiver to the ear
4) respond, saying “Moshi Moshi”

These reactions bear a similarity to the auditory responses developed in Startle Response Audiometry, and, accordingly, the author’s apparatus is capable of use as Startle Response Audiometry also. In the latter case, the apparatus is so made as to cause the child to catch the test sound produced with a sound pressure controlled during application to the ear of the receiver, so that such facial expressions as the following which the child would make at the sound may well serve as indications:

1) winking
2) move the eyes; turn towards the ear under test; stop moving the eyes
3) stop breathing
4) be intent on listening
5) begin smiling
6) make looks of relief

These physical expressions are unconsciously made during play with the telephone set, so that, although the way of execution itself follows that of Play Audiometry, indications for judgment on auditory responses include the intrinsic elements of Startle Response Audiometry.

In fine, the present method may be regarded as a combination of the essential factors (characteristics) of both Startle Response Audiometry and Play Audiometry. Accordingly, of all the preschool children for whom audiometric examination is possible, 2-year-old children are considered able to produce fairly accurate data.
CLINICAL APPLICATION OF THE APPARATUS
TO AUDIOMETRY OF PRESCHOOL CHILDREN
HARD OF HEARING

Some reports on audiometric examinations for preschool children hard of hearing state that Startle Response Audiometry gives better results than those of any other audiometry for preschool children. The only drawbacks of this method, however, lie in the difficulty it offers in making not only pure tone test, but individual test of the right and left ears also (SUZUKI). On the other hand, there are reports on C. O. R. Test, which say that this method is capable of making accurate pure tone test even by use of an apparatus of simple mechanism, but incapable of making individual test of the right and left ears.

Regarding Play Audiometry, reports say that results obtained present different achievement percentages according to the age of subjects. For instance, in case of children over 3 years of age, results obtained give an achievement percentage of over 80%. Comparing the results of test given by children hard of hearing with those obtained from normal children, it is noted that the former offers a worse achievement percentage than the latter. As for the degree of accuracy of test, WESTLAKE says that, in case of children under 5 years of age, an error of over 5db is given, whereas WATANABE maintains that, generally, an error of 10-15db occurs.

Actual application in clinic of the author's method to children hard of hearing has given worse results in 4 cases, better results in 3 cases, similar results in 3 cases, as compared with those obtained from the other audiometric methods employed, which is considered to demonstrate the fact that no distinctive difference exists between the two results. Besides, in a multitude of cases, judgment on the existence of hearing acuity in the children has been passed on the basis of the change of facial expressions they made. In this meaning, also, the present method is considered to have verified its ability to obtain accurate results in a fairly objective manner.

Another merit of this system is that it makes it possible to undertake individual test of the right and left ears, that such sounds as pure tone, social sound, mother's voice (live-voice audiometry) can be made use of as test sounds, and that the fact is made known that, through it, comparatively accurate examination is possible of small children and children hard of hearing who are ignorant of speech. These things meaning that this is possessed of a singular merit, it is evident that audiometric test even of children 1-2 years of age will be carried out by this instrument with fair accuracy provided that this merit is made good use of. To conclude, all what is stated above comes to this that the author's new
device is fit for use in screening test of hearing acuity in children at their infantile stage.

CONCLUSION

Clinical application has been tried of the new apparatus for child audiometry invented by the author by use of toy telephone set.
1. The conception of the method was formed on the fact that small children are fond of playing with the telephone set.
2. For test sounds, pure tone can be used besides mother’s voice and animal cries. This is a method of Talk Back Style.
3. No substantial difference is observable between the result of the test made on normal adults by use of the standard audiometer and that obtained by use of this apparatus, but, in case of low sound pressure, a sizable difference is discernible between the two results. However, this latter phenomenon being considered due to the sound characteristic of the receiver, this will be subject to correction on future improvement of the apparatus.
4. As for the liminal threshold of hearing, 26 (26%) subject gave 20db; 48 (48%), 25db; 26 (26%), 30db upwards.
5. As regards auditory responses, the following reactions were observed.
   At the ringing of the bell:
   Turn to the telephone
   Turn round
   Take and apply the receiver to the ear
   Say "Moshi, Moshi"
   During the course of test:
   Move the eyes
   Turn in the direction of the ear under test
   Stop moving the eyes
   Stop breathing
   Become intent on listening
   Start smiling
   Make looks of relief
6. In case of children hard of hearing, no material difference is noted between the results of test obtained through this apparatus and those gained by use of other child audiometries.
7. This is a method of child audiometry midway between Startle Response Audiometry and Play Audiometry. This will also be applicable for screening purposes of small children under 2 years of age.
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