Hearing Assessment of Children

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Abstract

The primary value of OAEs (otoacoustic emissions) is that their presence indicates that a preneural cochlear receptor mechanism is able to respond to sound normally. Emissions are frequency specific and frequency selective, so that it is possible to gain information about different parts of the cochlea simultaneously. This is a study of 100 suspected children (neonatal hyberbilirubinemia, convulsion, neonatal intensive care unit (NICU) admission, ototoxic drug exposure and other predisposing factors) which were referred from a Pediatric Outdoor Patient Department and Neonatal Intensive Care Unit (NICU). OAEs were performed in all of the above mentioned children. The data was analyzed and results were compiled. These results were compared with other studies to identify the most likely risk factor associated with childhood hearing impairment. OAEs can be used as a neonatal screening tool as well as for the evaluation of a suspected pediatric population to help diagnose childhood hearing impairment at a very early stage, allowing for the rehabilitation the child within the critical period for speech and language development.

Introduction:

OAEs (otoacoustic emissions) were first reported by Kemp in 1978. OAEs testing is the recording of sounds that are produced by the ear itself. They appear to be generated by motile elements in the cochlear outer hair cells. The sounds generated by the cochlear outer hair cells are small but potentially audible, and detected by microphones instead of electrodes. There are two types of OAEs:[1]

1. Spontaneous OAEs are sounds emitted from the non-linear outer hair cells' activity without acoustic stimulation. They are emitted spontaneously. Spontaneous Otoacoustic emissions are found only in 50% of normal hearing adults and children.

2. Evoked OAEs are in response to acoustic stimulation. Evoked OAEs are further subdivided into three categories:

a) Transient evoked otoacoustic emissions (TEOAEs): Sounds emitted in response to an acoustic stimulus of very short duration usually clicks but it can be a tone burst. TEOAEs are evaluated in terms of amplitude (dB SPL), percentage reproducibility, and amplitude/noise (SNR). Most commonly, 80-85dB SPL stimuli are used clinically.

b) Distortion product Otoacoustic emissions (DPOAEs): Sounds emitted in response to two simultaneous tones of different frequencies. The frequencies of the two sinusoidal signals are designated as f1 and f2 (f2>f1) and corresponding intensity levels are L1 and L2. When f1 and f2 are close in frequency, interaction of the two sinusoidal signals result in inter-modulation distortion that undergo reverse transduction through the middle ear and are converted to an acoustic that can be measured in the ear canal. The level of stimuli is approximately 75dB SPL with a frequency ratio (f2/f1) = 1.21.2. DPOAEs allow greater frequency specificity. Any external, middle and inner ear pathology can lead to absence of Otoacoustic emissions.

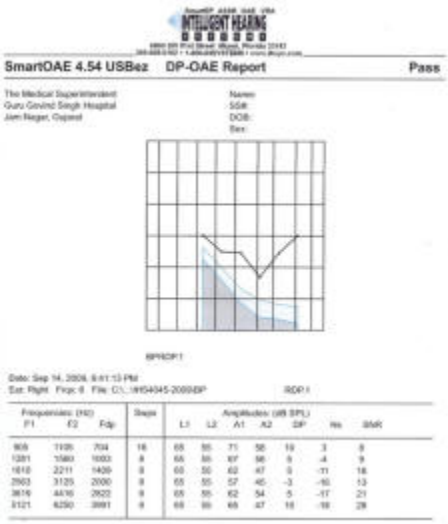
C) Sustained-frequency Otoacoustic emission (SPOAEs): Sounds emitted in response to a continuous tone. This is the most frequency-specific OAEs.

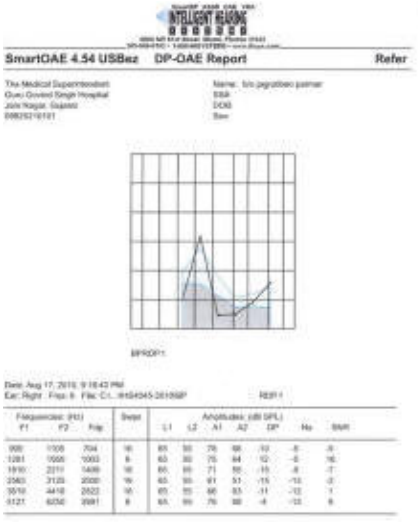
Mechanism for the generation of otoacoustic emission:[3] The basilar membrane receives sound energy delivered to the cochlear fluid from the middle ear. Sounds entering the cochlea result in a ripple wave along the basilar membrane which travels from the base to the apex. Low frequencies are focused at the apex while high frequencies are focused at the base. Sound image quality depends upon the health of the three rows of outer hair cells. Outer hair cells are responsible for amplification of the travelling waves, resulting in higher and sharper peaks of excitation to the inner hair cells.

An OAE machine is shown below.

Most of the sound vibration generated by the outer hair cells becomes part of the forward travelling waves, but a fraction escapes. It then travels back out of the cochlea to cause secondary vibrations of the middle ear and eardrum. The whole process can take 3 to 15 milliseconds. These cochlear-driven vibrations are the source of Otoacoustic emissions. Most cochlear pathologies involve the outer hair cells , making OAEs an ideal frequency-specific screening test for cochlear functions.

Below are examples of OAE Reports: **Enlarged Reports at End of Manuscript**





The pathologic conditions[3] that can cause absence of OAEs are:

- External ear pathology- stenosis of external auditory canal, wax, otitis-externa.
- Middle ear pathology-otitis media, serous otitis media, tympanic membrane perforation.
- Inner ear pathology – otosclerosis, ototoxicity, noise-induced hearing impairment and other cochlear pathology.
  The conditions like vestibulocochlear nerve pathology (if cochlear blood supply is not interrupted) and central auditory disorder do not affect OAEs.

Importance of Otoacoustic emissions:[3] OAEs (otoacoustic emissions) indicate that the pre-neural cochlear receptor mechanism (and the middle ear mechanism as well) is able to respond to sound in a normal way. Emissions are frequency specific and frequency selective, so that it is possible to gain information about different parts of the cochlea, simultaneously. No other clinical test specifically tests the cochlear biomechanics or combines the operational speed, non-invasivity, objectivity, sensitivity, frequency selectivity, and noise immunity as otoacoustic emission testing. The otoacoustic data does not translate into threshold data. It does not replace audiometric data and is quite unique to cochlear biomechanics. The typical 100dB hearing loss gives no response in the same manner as a typical 35dB hearing loss in otoacoustic emission testing.

Permanent childhood hearing impairment (PCHI):[4] Hearing impairment is considered to be present when it exceeds 40dB. The causes of childhood hearing loss may be congenital or acquired. Congenital hearing loss may be genetic (autosomal dominant, recessive, x-linked or mitochondrial) or non-genetic (infectious, radiation or drug induced). The acquired hearing loss may be due to hypoxia, hyperbilirubinemia, low-birth weight, meningitis, convulsions, ototoxic drugs trauma, and idiopathic.

The early diagnosis of childhood hearing loss and early intervention is very important for speech and language development of children. Otoacoustic emission testing is an objective test that can be done at any age and it permits early detection of inner ear abnormalities associated with a wide variety of diseases and disorders, including non-pathologic etiologies like metabolic dysfunction. It is a screening test and not a confirmatory test. It does not provide the hearing threshold, but rapidly screens the child. OAE testing helps to decide whether the child will require further assessment by BERA.

Methods

This is the prospective study of 100 patients that was carried out at the Department of Otolaryngology and Head and Neck Surgery at M.P. Shah Medical College, Jamnagar, India. A total of 100 children (0 to 5 years) were included in this study. They were referred from the Pediatric Outdoor Patient Department or admitted in the newborn baby ward and other pediatric wards. These children were suspected by pediatricians on the basis of their antenatal, intra-natal and postnatal history and suspected to have some hearing impairment and were sent to the ENT Department for further hearing assessment, especially for OAEs testing. Only those children having intact tympanic membranes were included in this study. Parents of suspected children which were included in this study were explained the purpose and use of the OAEs. A detailed procedure was explained after their consent was obtained. A detailed history including perinatal history was elicited from the parents preferably from the mother. This was followed by a complete ENT examination[5] including otoscopic examination of the ears. If any wax, debris, or foreign bodies were found

in the ear canal, they were removed. Tympanometry was done in every case to rule out middle ear abnormality.

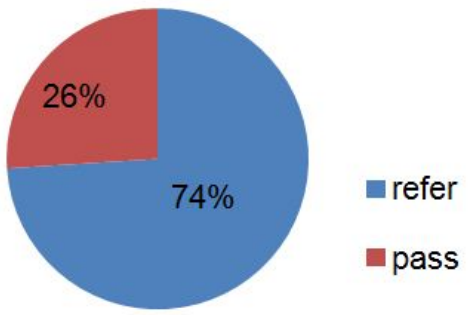
All OAEs were analyzed relative to the environmental noise-floor level. Ambient noise was compensated for during OAE testing, therefore, reducing the physiological and acoustic ambient noise which is very critical for good recordings. For quiet and co-operative patients, recordings usually required less than 5 minutes. If the results were "Pass" [6] then no follow up OAE was required. If results were "Refer" then children were called after one month for repeat OAEs testing. If results still remained "REFER" [6] then candidates were referred for BERA study. The "Pass" test results means OAEs are present, and one can assume the individual's hearing is at least 30 dB or better. If there is damage to the outer hair cells producing a mild hearing loss, then OAEs may not present. If the test result is "Refer", the child may be at risk for possible communication handicaps and can benefit from further diagnostic assessment and possible rehabilitation.

Exclusion criteria were:
1. Newborns and children with purulent ear discharge, external and middle ear abnormalities.
2. Refusal by parents or guardian for OAE.
3. Tympanic membrane perforation.

Testing procedure: It is best carried out in a lying down position and when the child is quiet. Sometimes sedation with syrup pedirest (trichloflous) in a dose of 20 mg/kg (250-500 mg) or (2.5-5ml)[7] was given to the child to make them quiet and calm. Position of a probe was kept stable by securing a probe's cable to the patient's clothing throughout the recording to ensure proper testing. Click stimuli was used at an 85 dB sound pressure level (SPL). The "Start" frequency (lowest test frequency) is 500 Hz and the "End" frequency (highest test frequency) is 8000 Hz, which is the default procedure that the OAE machine executes. The passing criteria was determined on the basis of:

a) Dp (distortion product) minus Ns (noise floor) is equal to SNR (signal-to-noise ratio) which is the dB sound pressure level (SPL) and is the absolute signal-to-noise difference. This allows the user to set the passing criteria to a specific signal-to-noise ratio (SNR). The specified SNR is the difference between Dp (distortion product) and noise-level mean. Results are considered "pass" at a specific frequency when a difference is greater than the specified level.

b) Dp (distortion product) minus Ns(noise floor) (in units of standard deviation) is equal to relative signal-to-noise difference. This option allows the user to set the passing criteria to a specific number of standard deviations above the mean of the noise floor (Ns). Results are considered "pass" at a given frequency when the difference between the distortion product amplitude and the noise level is greater than the user-specified number. Patients are considered to have passed a test when the percentage of frequency across the entire testing range is greater than or equal to the percentage entered. For example, if 80% is entered and the patient passed 9 out of 10 frequencies tested, then the patient is considered to have passed the test.



Results & Discussion

In this present study:

1) 74 (74%) of the cases had “refer” results and 26 (26%) of the cases had “pass” results out of 100 cases. (Figure 1 -- To the right.)

Figure 1: Pass/Fail rates in test subjects.

2) The maximum patients were in the age group of 0-6 months (40%). Out of 100 cases, 53 were females and 47 were males. Female:male ratio=1.12. (Figure 2, Table 1) **Click on Figures and Tables to Enlarge**

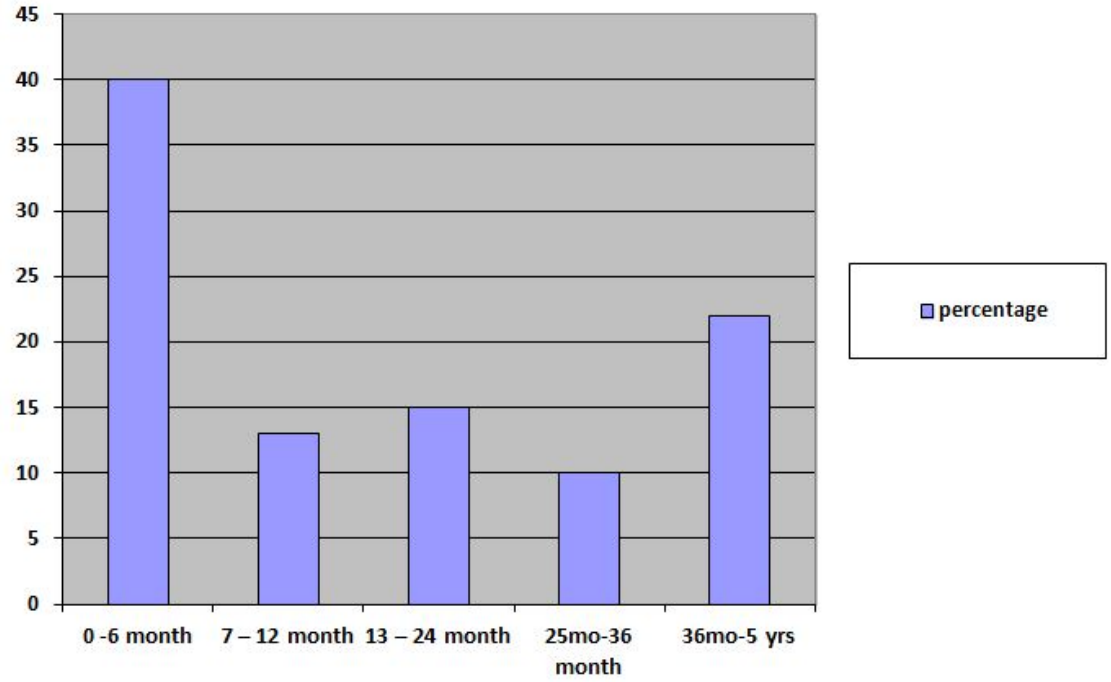


Figure 2. Age distribution of subjects

Table 1. Age distribution of subjects

Table: 1

Age	No. of candidates	Percentage (%)
0 -6 month	40	40
7 – 12 month	13	13
13 – 24 month	15	15
25mo-36 month	10	10
36mo-5 yrs	22	22

3) There were 22 preterm deliveries (including low-birth weight, neonatal intensive care unit (N.I.C.U) admission,[8,9] birth asphyxia) out of which 15 children (68%) had a “refer” result. (Figure 3, Table 2a and 2b)

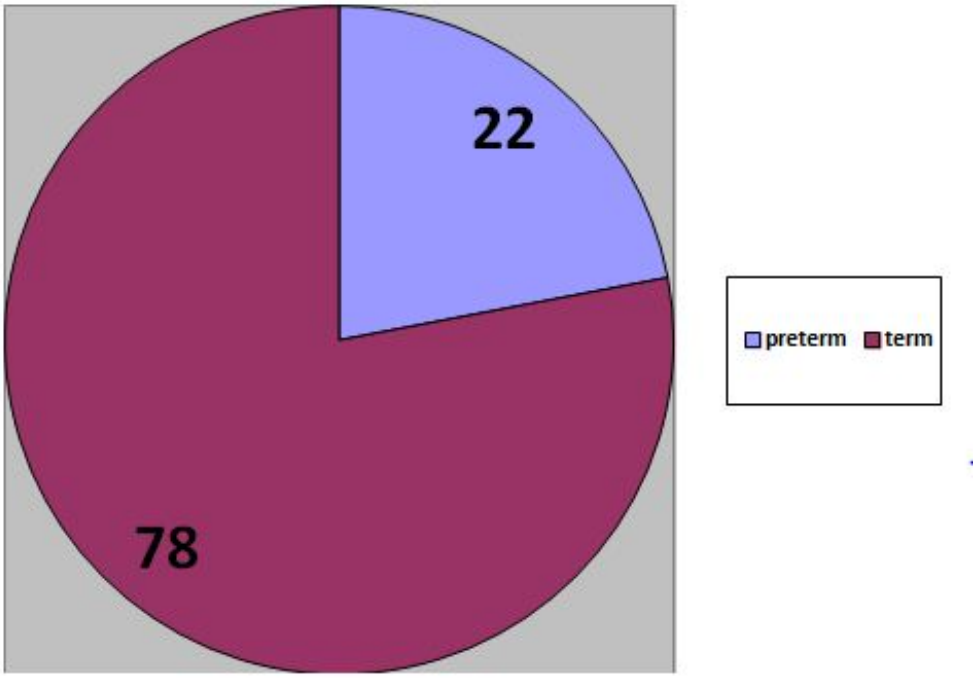


Figure 3. Preterm vs. Term Delivery

Table 2a. Preterm vs. Term Delivery

Table: 2a

	No. of Candidates	Percentage
Pre-term delivery	22	22%
Term-delivery	78	78%

Table 2b. High Risk for Hearing Loss

Table: 2b

Result of OAE	Preterm/LBW/NICU/Birth asphyxia (total=22)	Percentage(%)
Refer	15	68%
Pass	7	32%

4) Seven children (7%) with jaundice (icterus neonatorum),[8] seven (7%) children with meningitis and five (5%) children were those children who were exposed to ototoxic drugs during early life. Ten (10%) children had febrile convulsions during early life and all had "refer" results. In the study of Pelagia-Stavroulakil,[10] there were 24 children on aminoglycoside therapy out of which 11 were for seven days and 13 were for greater then eight days and were found to have referred OAEs. (Figure 4, Table 3)

Figure 4. High-Risk Diagnosis

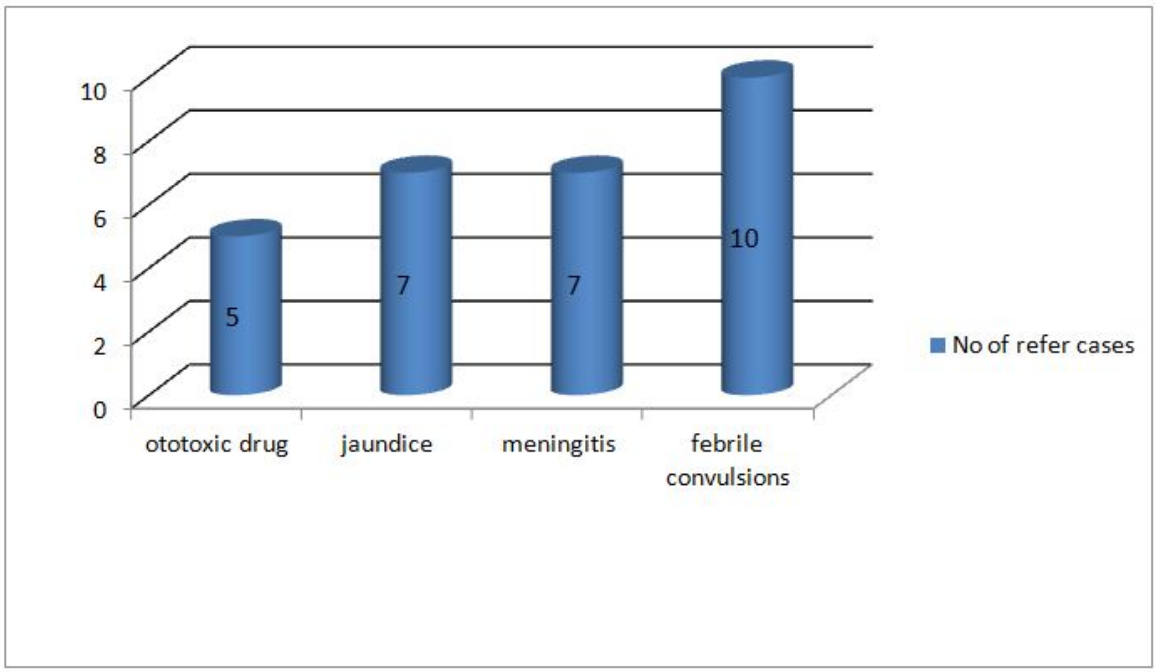


Table 3. High-Risk Diagnosis

Table: 3

	No. of Candidates	Percentage
Ototoxic drug exposure	5	5%
Jaundice	7	7%
Meningitis	7	7%
Febrile convulsions	10	10%

5) Two children with congenital rubella syndrome and five children with cerebral palsy had "refer" results. Morales Angulo[11] in their retrospective study of 64 confirmed cases of cerebral palsy, audiological testing for hearing impairment was done in 30 (47%) patients and out of them 18 (60%) patients had sensorineural hearing loss. (Figure 5, Table 4)

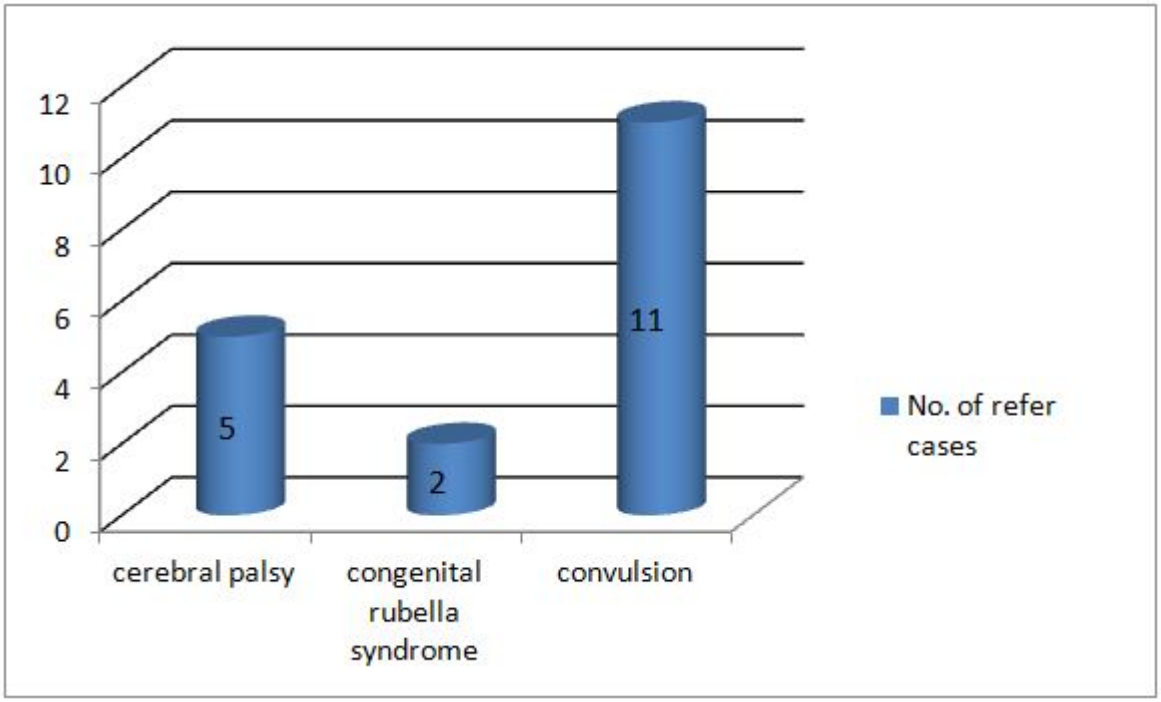


Figure 5. High-Risk Diagnosis

Table 4. High-Risk Diagnosis

Table: 4

	No. of candidates	Percentage
Cerebral palsy	5	5%
Congenital rubella syndrome	2	2%
Convulsions(epilepsy)	11	11%

6) Five children (5%) who had "refer" results in the present study were the post-lingual hearing loss cases. Out of these five children, two children had bilateral severe pneumonia and were treated with Amikacin for 21 days and Gentamicin[8,10] for 14 days, respectively. One child had a head injury at the age of three years, one child had meningitis at the age of three years and one child had measles at the age of two and half years.

Conclusion

In this present study, “Hearing assessment in children", 100 children (0-5 yrs) were referred from the Pediatric Department over a two-year period for testing with OAEs (otoacoustic emissions). Seventy-four cases (74%) had “refer” results and 26 cases (26%) had “pass” results. All the “refer” cases were advised for BERA (brainstem evoked response audiometry) testing. Of the 74 cases, only eight cases had undergone BERA examination and all were found to have a profound degree of sensorineural hearing impairment. The main aim of the study was to demonstrate the utility of OAES to be used as a rapid screening test for hearing impairment in suspected cases of jaundice, convulsions, fever, meningitis, ototoxic drugs, low-birth weight/neonatal intensive care unit (NICU) admission, etc. The OAE examination is a very rapid, highly sensitive, specific and objective test for the inner ear, especially the outer hair cells of the cochlea and form the basis of screening of newborns for early identification of childhood hearing impairment. Once a suspected impairment has been identified on screening further testing is done to confirm the suspected diagnosis so early intervention can be carried out for speech and language development of children.

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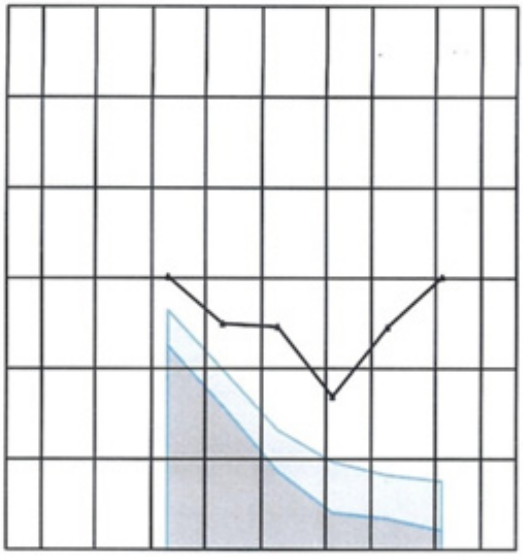

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1281	1560	1003	8	65	55	67	56	5	-4	9
1810	2211	1409	8	65	55	62	47	5	-11	16
2563	3125	2000	8	65	55	57	45	-3	-16	13
3619	4416	2822	8	65	55	62	54	5	-17	21
5121	6250	3991	8	65	55	65	47	10	-18	28

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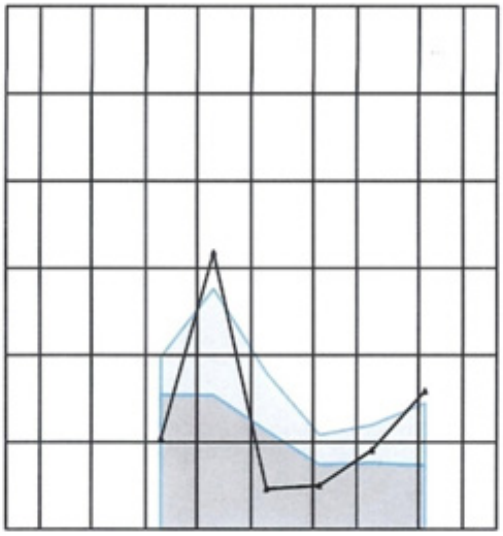

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905	1105	704	16	65	55	78	66	-10	-5	-5
1281	1560	1003	8	65	55	75	64	12	-5	16
1810	2211	1409	16	65	55	71	55	-15	-9	-7
2563	3125	2000	16	65	55	61	51	-15	-13	-2
3619	4416	2822	16	65	55	66	63	-11	-12	1
5121	6250	3991	8	65	55	76	68	-4	-13	9