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Auditory brainstem response with alternative transducers: implications for newborn hearing screening

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AUDITORY BRAINSTEM RESPONSE WITH ALTERNATIVE TRANSDUCERS: IMPLICATIONS FOR NEWBORN HEARING SCREENING

by

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Introduction

The prevalence of hearing impairment in the newborn population varies depending upon the birth status of the newborn, primarily whether the infant is from the Neonatal Intensive Care Unit (NICU) or well baby nursery. Newborns in the NICU have a higher incidence of hearing loss when compared to that of the well baby population (Stein 1999). Hearing impairment among the newborns from the well baby nursery occurs in approximately 1 out 1,000 babies. Research in the late 80's and early 90's found that the prevalence in the NICU is between 2-4% higher than that of the well babies (Stein 1999). The discrepancy in the prevalence rates between nursery types can be attributed, at least in part, to the definition of hearing impairment that was used in the research. Some research only focused on a profound bilateral hearing loss while others included any degree and unilateral losses. The higher incidence in the NICU population can also be attributed to a combination of several other factors, including an illness or condition requiring 48 hours or greater stay in the NICU, stigmata or other finding(s) associated with a syndrome known to include a hearing loss, craniofacial anomalies, hyperbilirubinemia, and ototoxic medications (JCIH 2000). In addition to those babies with significant risk factors, it has been found that a 35-40% of children with a genetically based hearing loss do not have an obvious family history or any other signs of a hearing impairment (Mencher, G., and DeVoe, S. 2001). This evidence is compelling in its argument supporting universal screening.

The cost of a hearing screening program depends on the type of equipment used, supplies needed, personnel hired to screen, and follow up services. The cost of UNHS is 1/4 the amount of other newborn screening tests (Erenberg 1999, White & Maxon 1995, & NCHAM 2002). For example, the estimated cost of identifying one hearing impaired newborn is approximately $9,600 compared to $10,000 per case for hypothyroidism, $23,000 per case for

hemoglobinopathy, and $40,000 per case for phenylketonuria (Erenberg 1999). These previous figures are estimates based on the average cost to screen for the diseases divided by the incidences of the disease.

The need for earlier identification of hearing impairment is great. Prior to implementation of the universal newborn hearing screening the average age of identification of a profound hearing impairment was 2 ½ to 3 years of age with many congenitally hearing impaired children identified around 5 to 6 years of age (NCHAM 2002), while evidence suggests that the most critical time for speech and language development is in the first 6 months of life (Erenberg 1999, Thompson, D., McPhillips, H., Davis, R., Lieu, T., Homer, C., and Helfand, M., 2000, Downs, M., and Yoshinaga-Itano, C., 1999).

It has been found that earlier identification and earlier intervention lead to improved speech and language development (Erenberg 1999, Downs et al 1999). When children with hearing impairment who received intervention and amplification before 6 months of age were compared with children who received intervention and amplification after 6 months of age, a 1-2 years advantage was noted in language, cognitive, and social skills when compared to their counterparts (NCHAM 2002). Additionally, when hearing impairment is identified early and appropriate educational, medical, and audiological services are implemented, more than $400,000 can be saved on special education costs by the time the child graduates from high school (NCHAM 2002). Factors that play into the outcome of speech and language development include: age of identification, severity, type and stability of hearing loss, intervention, amplification, benefit from amplification, habilitation, and expectations and motivations of both the child and the parents.

The purpose of UNHS is to identify hearing loss by 3 months of age and intervene by 6 months of age (JCIH 2000). This hearing loss is defined by the Joint Committee on Infant Hearing as a permanent bilateral or unilateral, sensory or conductive hearing loss, averaging 30 to 40 dB or more in the frequency region important for speech recognition, which is between 500 and 4000 Hz (JCIH 2000).

The two main objective physiological measures used to screen hearing in the newborn population are otoacoustic emission (OEA) testing and auditory brainstem response (ABR) testing. Each measure can be used alone or in combination in a screening battery. The OAE test utilizes sound produced by the cochlea in response to an outside stimulus to assess hearing. The ABR utilizes an electrophysiologic response to an outside stimulus to assess the auditory status from the cochlea to the midbrain.

The sensitivity and specificity of each test have been scrutinized in numerous screening programs. Both OAE and ABR screening techniques have proven to be highly effective in sensitivity and specificity. Sensitivity of a test is the ability of the test to correctly identify the individuals with a hearing loss as disordered. The specificity of the test is the ability of the test to correctly identify the normal hearing individuals as normal. A false negative result occurs when the test identifies a hearing impaired individual as normal when in fact he/she is not. A false positive result occurs when the test identifies an individual as disordered when in fact he/she has normal hearing. A false positive result can occur when the stimulus encounters something that impedes its flow on the way to the cochlea. If a response is still obtainable despite this factor, the echo emitted back from the cochlea is also diminished. This often occurs when a transient middle ear pathology is the problem. The present mode of ABR testing is via an air conduction transducer. When testing the newborn population using this mode, results may

be confounded by several factors including transient middle ear disorders, pneumatization of the middle ear, and probe placement. More than one histopathologic study has shown that the temporal bones of neonates contain the presence of embryonic connective tissue, debris and/or residuals, aspirated amniotic fluid, and both serous and suppurative infectious materials (Stuart, A., Yang, E., and Green, W., 1994). Vernix has been documented to be present in the external auditory canal of all full-term neonates (Stuart et al 1994). Evidence shows that the presence of vernix can cause a transient outer ear disorder that can take up to 48-50 hours to resolve (Stuart et al 1993 and Stuart et al 1994). A transient outer or middle ear problem can influence the results of an OAE or ABR. When there is any extra substance within the ear canal or in the middle ear space, the system is unlikely to operate effectively. The resultant increase in stiffness and mass impacts the results of the screening tests by impeding the transduction of the stimulus going into the ear for both OAE and ABR and confounds the response to the stimulus that is reflected back from the inner ear for the OAE test. Transient outer and middle ear disorders due to vernix or other causes pose a problem for the well-baby neonates, who leave the hospital within an average of 48 hours of birth, and are screened prior to discharge. Because vernix may be present during the screening, false positive results can occur.

Studies have shown that the ABR thresholds for air conducted click stimuli are elevated in the presence of transient middle ear disorders in neonates (Stuart et al 1994). The false positive result can be eliminated if an alternative transducer is used, specifically one which will bypass the outer and middle ear and stimulate the cochlea directly. A bone conduction transducer could decrease the number of false positives by doing just that, bypassing the outer and middle ear and directly stimulating the cochlea. Bone conduction testing could possibly enhance thresholds if a transient middle ear problem is present due to the occlusion effect. As a

result fewer false positive results would occur with bone conduction stimulation. Another problem, which the bone conduction transducer could help to eliminate, is the false positive response obtained resulting from improper placement of the probe in the ear canal. Since neonates' ear canal walls are more flexible than in an adult, they can easily collapse around the end of the probe, which causes the sound to be directed toward the canal wall instead of being directed at the tympanic membrane.

The purpose of this study is to test the efficacy of a bone-conducted transducer for screening and relate these finding to the potential enhancement of the UNHS. This study was designed to determine if responses obtained by a bone conduction transducer were equal to those obtained by a traditional air conduction transducer for ABR screenings. Another questions that was evaluated was how closely the results of behavioral testing for both the air and bone conduction thresholds compared to the results of ABR threshold prediction, based on Fsp, from a screening device. To answer the questions of whether bone and air conduction responses to the AUDIOscreener were equal, and how closely the results for behavioral testing corresponded with the results obtained with the AUDIOscreener, this investigation measured the lowest level in dB at which a pass was obtained both behaviorally and with the use of the screener.

Methods and Materials

Subjects

Twenty normal hearing adults, an equal number of males and females, ranging in age from 23-36 years, were used in this study. The average age of the subjects was 27 years. All subjects underwent a basic comprehensive audiological evaluation including otoscopy, acoustic immittance measures, air conduction thresholds at octave intervals from 250-8000 Hz, speech

reception thresholds, speech recognition scores, bone conduction thresholds at octave intervals from 500-4000 Hz and distortion product otoacoustic emissions at 2000, 3000, 4000, and 5000 Hz. The following criteria determined eligibility to participate in the study; no obvious structural deformities apparent by otoscopy, type A tympanogram. AC and BC thresholds equal to or less then 20 dBHL, SRT in agreement with PTA (average thresholds at 500, 1000 and 2000 Hz), word recognition scores of 90% or better, and normal DPOAE.

Instrumentation

Hearing sensitivity measures were assessed via the GSI 61 Audiometer, and tympanograms were obtained using the GSI TympStar. The Everest Biomedical AUDIOscreener provided measurements for both distortion product otoacoustic emissions (DPOAE) and auditory brainstem response (ABR) testing. The otoacoustic emission testing utilized DPOAE at 2000, 3000, 4000, and 5000 Hz. The ratio of f2/f1 was set to 1.2/1 and presentation level of 65 dBSPL for f1 and 55 dBSPL for f2. To obtain a pass response the signal to noise ratio had to be a minimum of 6 dB at three out of the four frequencies. The ABR parameters were set to filter the signal with a low cutoff of 100 Hz and a high cutoff of 1500 Hz and to presents rarefaction clicks at a rate of 37 clicks per second. To determine the presence or absence of a response, the AUDIOscreener utilizes a Fsp algorithm. The Fsp algorithm is the ratio of the level of the signal + noise divided by the level of the noise alone to determine if a response is present. When a high number occurs in the numerator and a small number in the denominator, a large Fsp is obtained. A Fsp value of 3 or greater is needed to obtain a pass, meaning that a response to the stimulus is present among the noise. When the numerator and the denominator are similar, a small Fsp is obtained, indicating that a response to the stimulus is not present yielding a refer response for the test. In order to screen via a bone conduction oscillator the AUDIOscreener was modified from

its original air conduction transducer set up. An external amplifier was attached to drive a B71 bone conduction oscillator at the same level as the air conduction transducer.

Determining dBnHL

The AUDIOscreener was preprogrammed to record responses in dBHL for air conducted stimuli. In order to compare the difference between air and bone conducted responses; the dBnHL for bone conduction was determined. To find the dBnHL, the mean behavioral bone conduction threshold to the click stimulus was found. For these subjects, this value was 20 dBHL. This mean was then subtracted from each subjects' behavioral bone conduction threshold, and the resulting level was each individual's threshold in dBnHL.

Procedure

All subjects signed informed consent documents prior to the beginning of data collection in accordance with the Institutional Review Board. Subjects first responded behaviorally to an air conduction click presented by the AUDIOscreener. The AUDIOscreeners was then utilized to determine the lowest level at which an ABR was detected by the AUDIOscreener. The presentation level started at 45 dBnHL and descended in 5 dB increments to 0 dBnHL regardless of the subjects' response.

Bone conduction testing followed the same procedure as outlined above for the air conduction testing except that a bone conduction oscillator was used. Forehead placement was chosen because it is less susceptible to threshold variability than mastoid placement (Wever, E. & Lawrence, M. 1954).

Results

This study was designed to determine if the responses obtained by a bone conduction transducer are equal to the traditional air conduction transducer for ABR screenings utilizing the AUDIOscreener. Results for behavioral air conduction testing revealed a mean of 5.7 dB with a standard deviation of 4.7 dB. The mean ABR threshold was 9.9 dB with a standard deviation of 8.3. The modal difference was 5 dB. The dB difference between the behavioral threshold and the ABR threshold for all of the subjects is shown in Figure 1. Screener thresholds were consistently higher than behavioral thresholds.

Results for behavioral bone conduction testing revealed a mean of 1.1 dB with a standard deviation of 8.6 dB. The mean ABR threshold was found to be 6.7 dB with a standard deviation of 12.4. The distribution of differences between the ABR and behavioral thresholds revealed a more even distribution across the dB range as shown in figure 2. Four individuals were at 0 and 20 dB, 6 individuals were at 5 dB, and 3 individuals at 10 and 15 dB. It is important to note that variability in responses was greater for the ABR screener then for the behavioral thresholds regardless of the mode of transduction.

To determine if responses obtained by a bone conduction transducer were equal to those obtained by a traditional air conduction transducer and how closely the results for behavioral testing corresponded with the results obtained with the AUDIOscreener, a T- test was performed on the data obtained. When the values for air and bone conducted ABR thresholds were compared, no significant difference ($p<0.150$) was found. A significant difference ($p<0.026$) was observed between the air conduction behavioral and ABR thresholds. Similarly, a

significant difference ($p < 0.046$) was found between the bone conduction behavioral and ABR thresholds.

Discussion

The finding that behavioral thresholds lower then screener thresholds is consistent with other findings (Hall 1992). The 4.7 dB difference noted between air and bone for both behavioral and ABR results could be attributed to placement of the oscillator on the forehead. (Mason's notes) The large standard deviation could be partly attributed to the step size used. The smallest step size available on the AUDIOscreener is 5 dB. If a smaller step size were used then, when comparing thresholds for individuals, the difference between individuals might be smaller thus resulting in a reduced deviation.

Research by Weber on adult subjects has found differences between air and bone conducted ABR testing. Latencies for bone conduction stimulation were on average 0.5 msec longer then that of air conduction (Weber 1983). However, this finding is not the case in ABR latencies for neonates. Lower thresholds, shorter latencies, and larger amplitudes of the response have all been found when bone conduction ABR testing has been done on the neonatal population (Erenberg 1999). This is thought to be a result of the smaller temporal bone, incomplete ossification of the bone structure, and stimulus spectrum (Weber 1983 & Erenberg 1999). The larger response amplitude has been attributed to the binaural stimulation for bone conduction stimulation when compared to monaural stimulation for air conduction testing (Cornacchia, Martini & Morra 1983). A difference in the spectrum of the stimulus for the air and bone conduction stimuli, and the frequency response of the cochlea at birth when compared to an adult has also been attributed to this finding. The bone conduction oscillator has been found to

contain a lower frequency spectral content when compared to the air conduction transducer, with no energy above 2000/2500 Hz (Weber 1983 & Mauldin & Jerger 1979). The auditory system in the developing neonate response to lower frequency information at the basal portion and only after development of the system does it begin to respond to higher frequency information (Weber 1983). The high frequency portion of the click for air conduction may not even be used when a pass response is obtained. Therefore, even if no transient middle ear problem is present, bone conduction testing in the neonatal population may be the most ideal mode of testing.

Two problems can result if bone conduction ABR testing is the only screening tool. Conductive and unilateral hearing loss will be missed because bone conduction stimuli bypass the middle ear and unilateral loss because the better cochlea will still be responding. If a refer response is obtained from the traditional air conducted mode of testing and also from the bone conduction mode, then these results would indicate that the loss is truly sensorineural. If air conduction results in a refer and bone conduction results in a pass then the patient has a conductive loss. For both a conductive and sensorineural loss follow up testing is needed. When a bone conduction transducer is used in a test battery along with air conduction ABR, valuable information is obtained and hearing loss will be detected more accurately.

One area of further study is determining the optimal coupling force for the bone conduction oscillator on a newborn's head. This is an issue because a newborn's head is much smaller then an adult's and the bones of the skull are not completely fused. The headband for the oscillator would need to be modified to make it more conducive to testing under these conditions. It would also be beneficial to evaluate a masking system to be used with the bone conducted ABR so that each ear could be tested individually. Because there is little interaural attenuation for bone conduction testing, a pass response could be obtained in the presence of a

hearing loss. This could occur simply because the pass result was obtained from the good ear, and the ear with the hearing loss was not even assessed.

Results of this study reveal that there are issues that exists that need to be addressed before a bone conduction ABR transducer is used as a screening tool. Future studies should be completed in order to see if these findings could be replicated. Although bone conducted ABR would be a very useful screening tool, this study's results show that the available screener does not yield the capability to do so yet.

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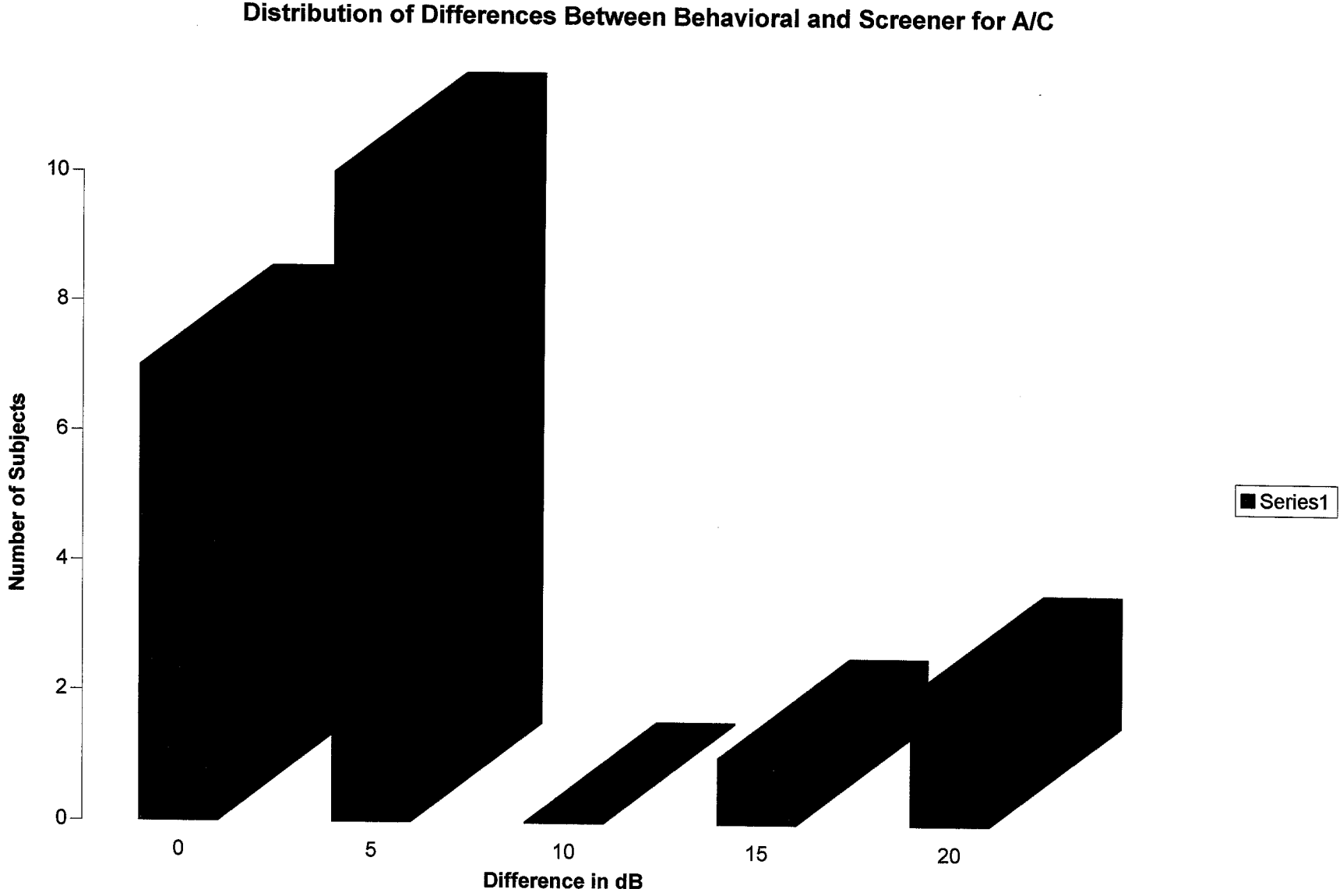
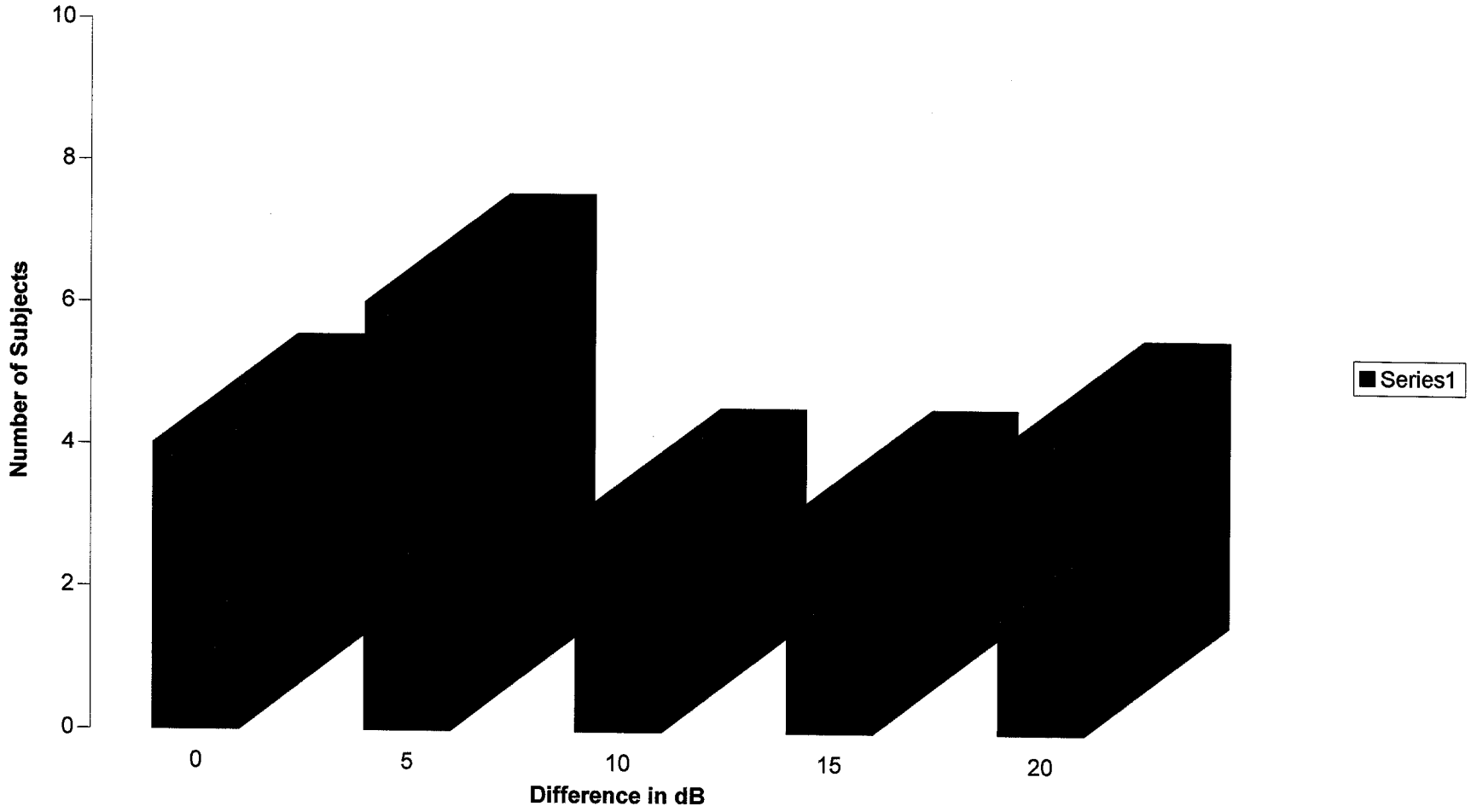
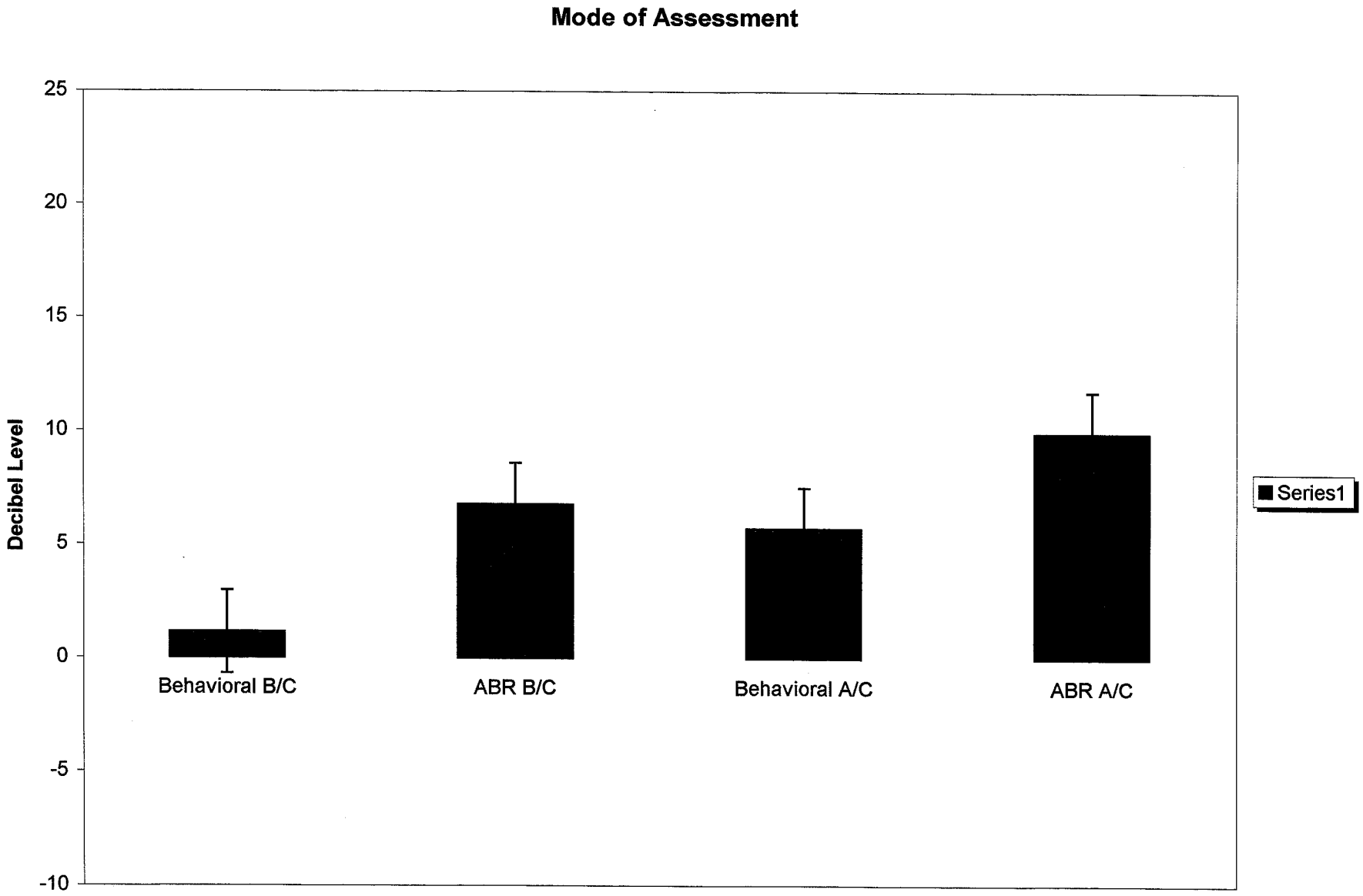

Distribution of Differences Between Behavioral and Screener for A/C
Number of Subjects
10
8
6
4
2
0
0
5
10
15
20
Difference in dB
Series1

Distribution of Differences Between Behaviroal and Screener for B/C




Mode of Assessment
Decibel Level
25
20
15
10
5
0
-5
-10
Behavioral B/C
ABR B/C
Behavioral A/C
ABR A/C
Series1