A STUDY OF SNR (F_{SP}) OF ABR IN SUBJECT WITH NORMAL HEARING

Register No. M0118

An Independent Project submitted in part fulfillment for the first year M.Sc, (Speech and Hearing)
University of Mysore, Mysore

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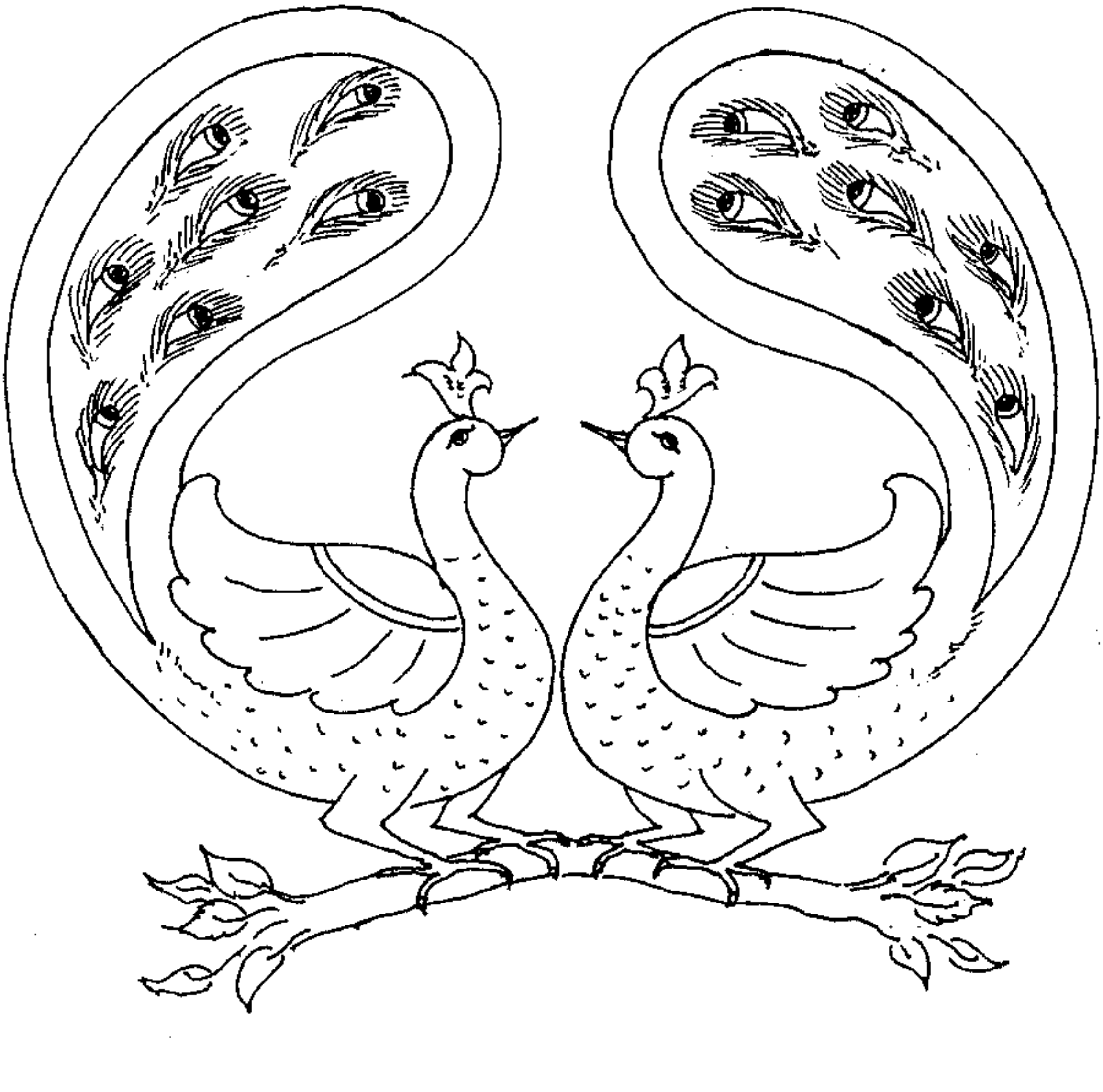
MAY-2002

Dedicated
To
My Parents, Savi & My Nation



CERTIFICATE

This is to certify that the independent project entitled "A STUDY OF SNR (Fsp) OF ABR IN SUBJECTS WITH NORMAL HEARING" is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register No. M0118.

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May 2002

CERTIFICATE

This is to certify that the independent project entitled "A STUDY OF SNR (FSP) OF ABR IN SUBJECTS WITH NORMAL HEARING " has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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DECLARATION

I hereby declare that this independent project entitled "A STUDY OF SNR (F_{SP}) OF ABR IN SUBJECTS WITH NORMAL HEARING" is the result of my own study under the guidance of **Dr.** C.S. **Vanaja,** Lecturer, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

Mysore
May 2002

Reg. No. **M01**18

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INTRODUCTION

Auditory Brainstem Response (ABR) is an activity within the auditory system that is evoked by auditory stimuli (Hall,1992). ABR is used as an electrophysiological test which is used for threshold estimation, and also to find out the site of lesion in an individual. The recording of ABR will be affected by the stimulus properties such as frequency, duration, intensity, rate and polarity; acquisition factors such as electrode montage, skin resistance, location of the electrode placement, filters used and also the signal to noise ratio.

In a standard ABR protocol, a fixed number of stimuli are presented and the responses are averaged. Inorder to obtain a good response, good Signal to Noise Ratio (SNR) is required. It has been reported that as the number of stimuli increases SNR improves (Hood, 1998). However, SNR is also affected by other factors such as intensity of the stimuli, background electrical activity, etc., (Hall, 1992). As the intensity increases the response amplitude increases and becomes greater than the background electrical activity. This results in good morphology of ABR. In other words as the SNR increases, the waveforms or responses are better.

At higher intensity a good SNR may be achieved with lesser number of stimuli where as more number of stimuli are required at lower intensity (Don, Elberling and Waring,1984). In routine testing, a fixed number of stimuli are used across all intensities as the number of stimuli required to obtain a good SNR at different intensities is not known. A measure of SNR can probably help in diciding when the averaging can be stopped .

However, SNR is not same for all the individuals at a particular intensity, this is because the amplitude of the background electrical activity varies from individual to individual. If the testing is repeated the SNR will not be the same, because, the background electrical activity will vary from time to time.

One of the statistical measure of SNR is Fsp. F_{SP} algorithm is used to estimate the likelihood of the presence of ABR, based on F-distribution of the variance of the averaged evoked potential divided by the variance of a single point (SP) in time across successive sample (Stach,1997).

Need for the study:

There are very limited number of studies which have measured Fsp value in ABR. The Fsp value has been generally used to study the number of sweeps required to get a reliable ABR. A few studies have used a pre-determined Fsp value to determine the presence of ABR. However, it is not known whether the same Fsp value can be used while recording ABR with all the instruments and in all the set ups. Also, information regarding Fsp values for normal hearing subjects at different intensities is not available. Hence, the present study was designed to study the Fsp values at different intensities, and to check the efficacy of Fsp criteria in detecting the presence of ABR.

Aim of the study :

The following were the aims of the study.

- Comparison of Fsp value obtained at different intensities in subjects with normal hearing.
- Developing a criterion Fsp value to detect the presence of ABR.

REVIEW OF LITERATURE

ABR is an objective measurement which is used in the threshold estimation and site of lesion testing. This is very useful in testing the individuals who cannot be evaluated using conventional audiometry. For threshold estimation intensity of the stimulus is varied to establish the minimum intensity at which the responses are present, which is also called as ABR threshold. It has been observed that at higher intensity, waves or responses have more amplitude. As the intensity is decreased the amplitude also decreases and at the threshold level it becomes difficult to detect the peaks and determine the presence or absence of a response.

There are two ways to identify the presence of a response. They are 1) subjective determination (visual inspection), 2) objective determination.

1) Subjective determination:

Subjective method is based on the visual inspection of the waveform. This method has an advantage, as sophisticated instruments which have facility for objective determination, are not required. However, lots of training is required for accurate interpretation. Also tester bias can affect the interpretation.

2) Objective determination:

In objective determination, the instrument is programmed to identify the presence of a response based on mathematical or logical criteria or templates of normal ABR. There are many techniques for objective determination of ABR. Some of them are described below:

Correlation Technique : In correlation technique digitally scored data points within a ABR waveform will be subjected to correlation. That is, the data points in one waveform are correlated with each of the corresponding data points in another waveform (Hall,1992).

Cross - Correlation technique: In this technique, the prominent peaks in the averaged response for each block of sweeps are correlated with the template, and if latency of these peaks is slightly different from block to block, the cross correlation technique is used. In this the prominent peaks at higher intensity is correlated with lower intensity. As the intensity decreases this value decreases and finally approaches zero (Hall,1992).

Statistical Method : One of the statistical measure of Signal to Noise Ratio (SNR), Fsp, has also been used in detection of ABR waveform (Elberling and Don 1981, Sininger 1993, Cited in Sininger et al., 2000). According to Sininger et al. (2000), calculation of Fsp is based on the feet that any ABR recording is comprised of both background noise and the response, if the signal is audible to the subject, each recording also contains neural activity from the auditory system that is systematic in scalp recorded morphology and time locked to the onset of the eliciting auditory signal.

Fsp is the measure, based on F-distribution of the variance of the averaged evoked potential divided by the variance of a single point (SP) in time across successive samples (Stach,l997). The following example by Sininger, et al., (2000) explains this concept. The variance of the sampled points acrorss a high amplitude ABR would be large as would the variance across an average response that contained large noise components. The denominator of the ratio is the variance of the set of digitized points at a fixed, post stimulus time (termed "SP") across a group of individual sweeps that make up the average. This value is used to estimate the noise contributing to the average. A very quiet recording in a sleeping infant would show very small change (variance) at a fixed point from sweep to sweep (low value denominator) where as a noisy subject would show a large sweep to sweep variance and have large denominator. Fsp values are updated after each 256 sweeps. As the averaging process reduces background noise, the FSP value associated with a recording containing a true ABR, will grow. When no response is present, the expected value of Fsp will be close to 1. Thus presence or absence of an ABR can be determined based on pre-determined $F_{S}p$ value. The advantage of this method is that, calculations are done by instrument itself. So there is no tester bias and it becomes easy for new practitioners also. But, not all the commercially available instruments have the facility of calculation of Fsp. Also sometimes, human judgment may be better than the instrumental judgement.

Clinical Application of F_{SP}:

A review of literature shows that $F_{S}p$ has been used in clinical application. The clinical application can be categorized as follows.

a) **Stopping criterion** Fsp - When a pre-determined Fsp value is available to detect a response, the testing can be stopped irrespective of number of stimuli if the Fsp value meets that criterion value Sininger et al,(2000).

b) **Determining the number of sweeps required to obtain ABR:** Some subjects will not reach the FSP criterion value but the maximum number of stimuli set in the testing protocol would have got over, so that the testing has to be stopped (Sininger, 1993) (cited in Sininger et al., 2000). However, sometimes large bursts of noise early in a recording may lower the Fsp value regardless of the presence or absence of a true response (Don and Elberling 1994)(ci+ed i« **5inm$_3$e.r** «* **«l** v *°=xO.

c) **Automated Averaging process and stopping rule** : A criterion FSP value can be preset in the instrument when the FSP value of the subject reaches the preset Fsp value the instrument stops the testing. Testing will be stopped if the Fsp value of a subject crossed the criterion value. Otherwise, at the end of a fixed number of sweeps the FSP value obtained would be compared with the preset value. Based on these results, the instrument will be programmed to classify the result as pass or fail.

Research has been carried out to establish a value of Fsp that can determine the presence of a response. Don, Elberling, and Waring,(1984) collected data from 4 females and 2 males (age range 20-32 years) using 10,000 sweeps at seven intensities from 20 dB to - lOdBSL in 5dB steps. Results revealed that Fsp of 3.1 can be taken as a criterion to determine the presence of ABR. In a similar study, Elberling and Don (1984) determined the sensitivity and specificity of Fsp criteria. They reported that Fsp of 3.1 leads to 1% false positive results and with a Fsp of 2.25, the false positive results could be 5%.

F_Sp criterion has been used to determine the presence of response while carrying out research on factors affecting ABR. Sininger and Don (1989) used F_Sp of 2.25 as cut off point while studying the effect of click rate and electrode orientation on threshold of ABR. Similarly Elberling and Don (1987) used F_Sp criterion of 2.1 while describing the threshold chara cteristics of ABR, in addition to Fsp criteria, visual inspection was also used. A comparison of the 2 methods showed that F_Sp was less sensitive in threshold detection. They attributed the higher sensitivity of visual detection method to additional cues such as expected ABR waveforms, the latency at higher level, which are available during subjective determination of threshold.

Sininger, et al., (2000) recorded ABR from 7179 infants to describe the ABR measurement system and the methods used to study new born hearing screening. Among 7179 infants, 4478 were from neonatal Intensive care unit (NICU) and remaining were from a well baby nursery. They also evaluated the ABR detection routine, specifically, the F_Sp, and determined the operating characteristics of Fsp in neonatal screening. The results of the study showed that the number of sweeps required to reach the criterion Fsp of 3.1 depend on factors such as test environment, state of the baby, electrode impedance, recording noise and amplitude of the wave V. Similarly it was also observed that the maximum F_Sp values varied as a function of the recording noise, in addition F_Sp values at 70 dB showed a significant difference across risk groups. Well babies with risk factors demonstrated the largest Fsp at stop (10.06) followed by the well babies without risk factors (8.62) and then neonatal intensive care unit infants (7.47). However, the reason for well babies without risk factor having lower Fsp than well babies with risk fector is not clear. Further research needs to be carried out to check whether the internal noise is really high in babies from NICU.

Thus a review of literature shows that Fsp can be used for objective evaluation. But there is a dearth of information regarding Fsp values in subjects with normal hearing. Hence, the present study was designed to evaluate Fsp value in subjects with normal hearing.

METHOD

Subjects: 40 subjects were selected for the study which included 20 males and 20 females in the age range of 18 years to 30 years.

Only subjects who met the following criteria were selected for the study.

Hearing threshold should be <15 dBHL at octave frequencies from 250 Hz to 8000 Hz.

Normal middle ear functioning as indicated by immittance screening.

No history of any otological diseases.

Instruments used: A calibrated diagnostic audiometer, GSI-61 connected with the headphones (TDH-50P) was used to measure the hearing threshold through air conduction.

A calibrated middle ear analyzer GSI - 33, was used to assess the middle ear functioning.

Calibrated "Nicolet Bravo" auditory evoked potential system with the software version 3.0 was used to record the auditory brainstem responses of the subjects.

Test environment: The testing was carried out in an acoustically treated air conditioned room. Single room situation was used for ABR testing and immittance evaluation. Double room situation was used for pure tone audiometry. The level of humidity and temperature were maintained at optimal levels to avoid extremities throughout the study.

Test procedure:

1) Pure tone audiometry

The subjects were seated in a sound treated room and headphones were placed. Subjects were instructed to indicate whenever they hear the sound. The hearing threshold was checked at octaves from 250 Hz to 8 000Hz.

2) Immittance evaluation:

The subjects were seated comfortably and immittance screening was carried out using 226 Hz probe tone.

3) ABR Recording:

The subjects were seated comfortably and instructed to be relaxed. Electrode sites were cleaned with cleaning gel and silver coated disc type electrodes were placed. The electrode sites used were as follows:

Inverting electrode - Test ear

Non inverting electrode - Non test ear

Common electrode - Fore head

Absolute electrode impedance was checked and testing was carried out when it was <10 k ohm. It was also ensured that the inter - electrode impedance was < 5k ohm.

The headphones were then placed and then the testing was carried out using the following protocol.

1) Signal

Type	-	Broad band clicks
Rate	-	30.1/sec
Intensity	-	80 dBnHL, 60 dBnHL, 40dBnHL, threshold and 10 dB below threshold level.
Polarity	-	Rarefaction
Duration	-	100 / us
No. of stimuli	-	2000 (maximum)

2) Transducer - Headphones (TDH-39P)

3) No. of channels — 1

4) Montages - Forehead - test ear

5) Time window - 10 msec

6) Sensitivity - 50 uv

7) Filter setting - 100 Hz to 3000 Hz

Initially ABR was recorded for stimuli presented at 80 dBnHL, 60 dBnHL, and 40 dBnHL. This was followed by threshold tracing in lOdB steps. The threshold was determined by visual inspection or subjective method. The testing was repeated at the threshold level to check for the replicability. ABR was also recorded at lOdB below the ABR threshold. The Fsp value was noted for each recording.

RESULTS AND DISCUSSION

The data collected in the present study were subjected to appropriate statistical analysis. Mean and SD was calculated for Fsp valuesobtained at different intensities and paired 't' test was carried out to check if there is a significant difference in the mean. The data collected from males and females were initially tabulated separately.

Fsp values for males and females:

Table 1: Comparison of Fsp values of males and females across intensities.

Intensity		Mean	SD	't' value	Significance
80dBnHL	Male	6.43	3.58	1.91	0.072
	Female	11.62	11.73		
60dBnHL	Male	3.15	1.93	1.74	0.099
	Female	4.59	3.21		
40dBnHL	Male	2.25	1.26	1.03	0.316
	Female	2.82	1.72		
Threshold level	Male	0.97	0.46	1.90	0.073
	Female	1.28	0.50		
Below Threshold level	Male	0.68	0.84	0.25	0.803
	Female	0.74	0.46		

Table 1 depicts the comparison of Fsp value obtained for males and females across intensities. It can be observed from the table that there was a difference between males and females only for Fsp value obtained at 80dBnHL.

However, SD shows that there was high variability. The results of paired "t" test revealed that statistically there was no significant difference between Fsp values of males and females. This shows that the amount of background (physiological) noise is probably similar in males and females.

As there was no significant difference between males and females, the data was combined for further analysis and analysis was carried out by taking intensity as a variable.

Fsp values at different intensities

Table 2: Mean and SD of Fsp values at different intensiteis.

Intensity	Mean	SD
80dBnHL	9.02	8.96
60dBnHL	3.87	2.72
40dBnHL	2.56	1.51
Threshold level	1.13	0.50
Below Threshold level	0.71	0.67

As shown in Table -2 there was an increase in Fsp value with increase in intensity. Figure 1 shows representative waveforms of a subject for clicks of different intensities. A glance at the SD value shows that at supra threshold level and below threshold level the variability in Fsp value is high. This can be observed from Figure 2 also. There was less variation in Fsp value at threshold.

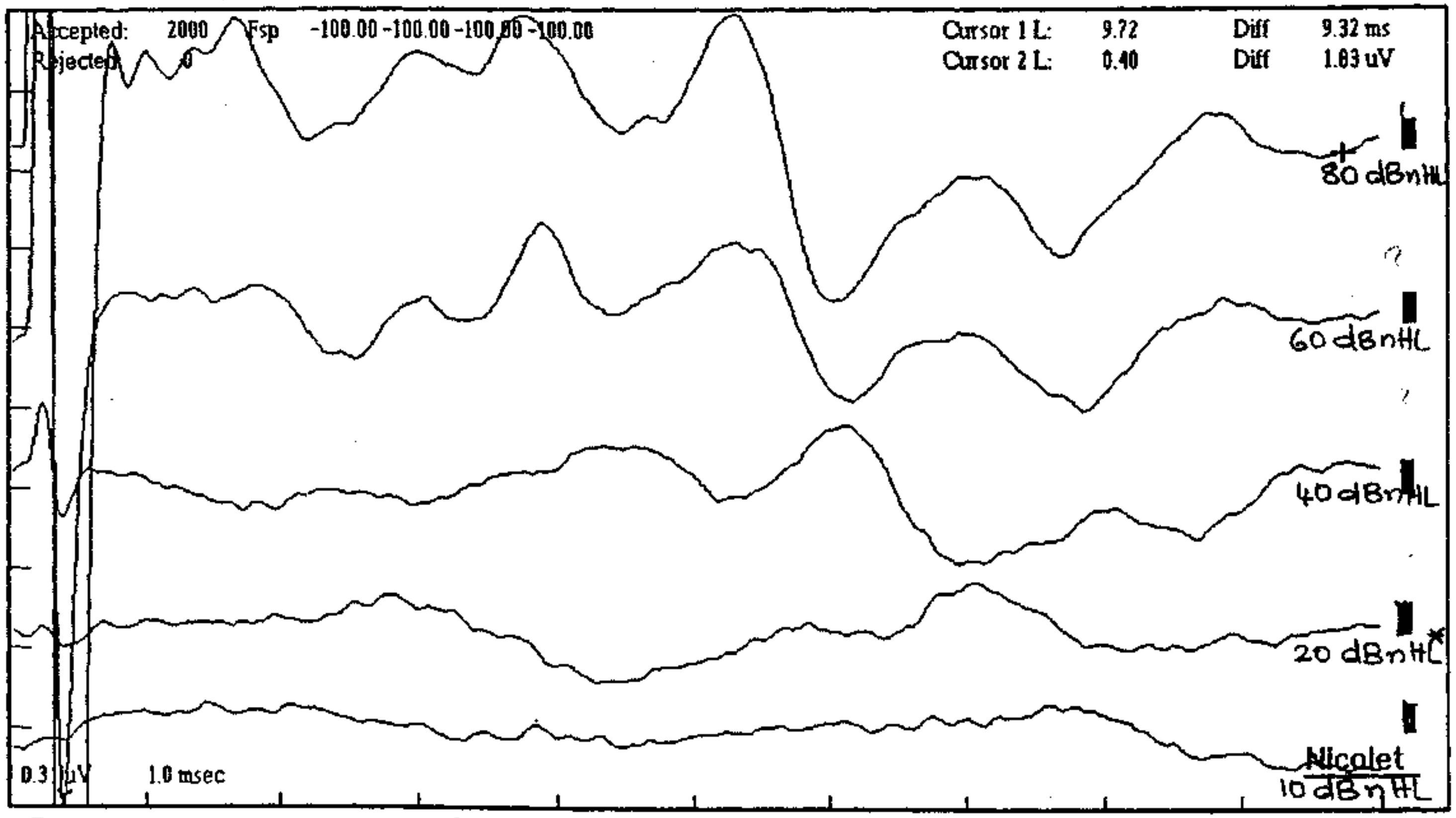

Figure 1: ABR waveforms of a subject at different intensities

Intensity	Fsp Value
80 dBnHL	51.62
60 dB nHL	8.12
40 dB nHL	8.36
20 dB nHL	2.13
10 dB nHL	0.90

* → Threshold.

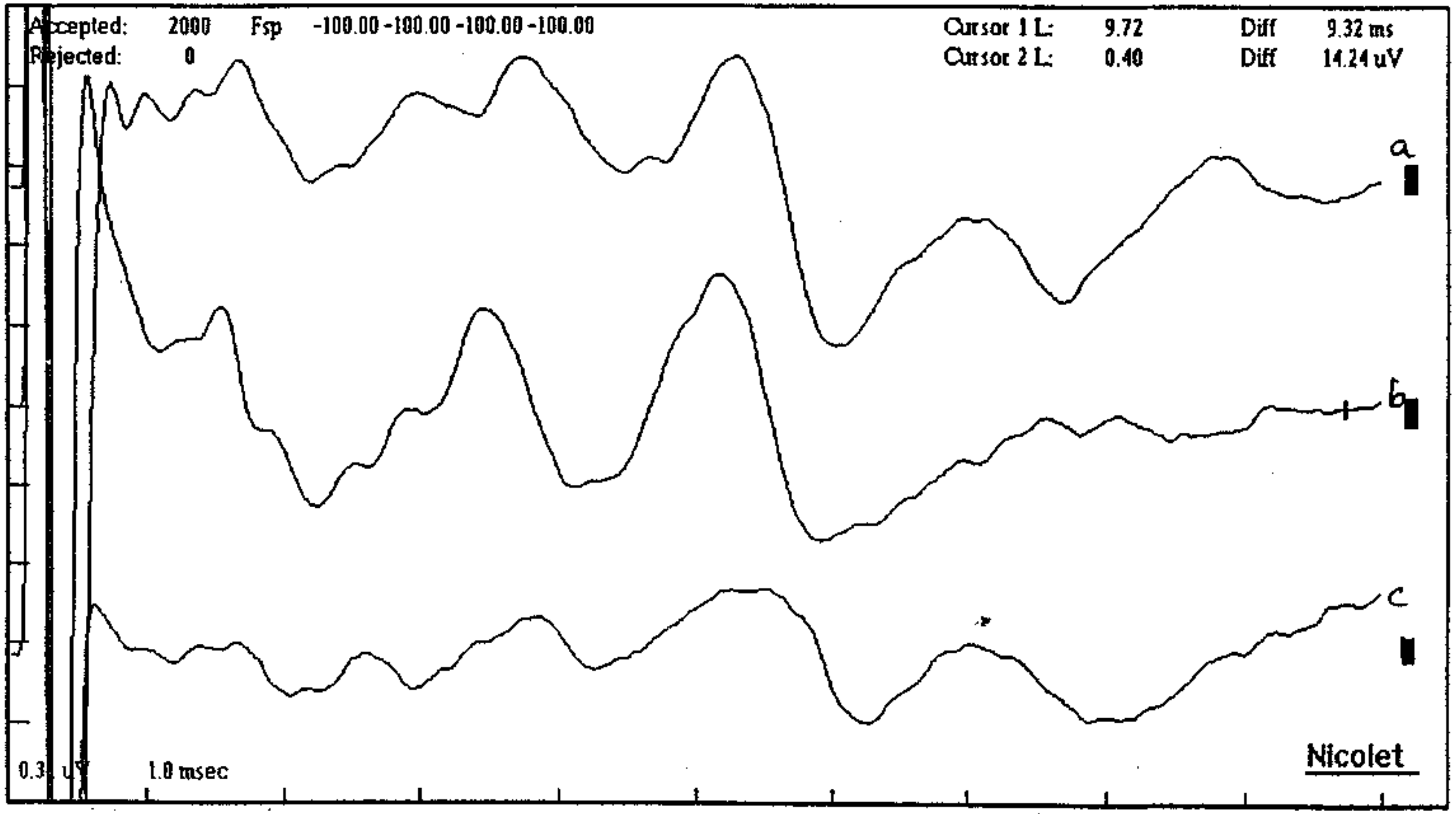

Figure 2: ABR waveforms at 80 dBnHL for three different subjects.

Subject	Fsp Value
a	51.62
b	19.90
c	01.46

Table 3 : Results of paired V test

Intensity	't' value	Significance
80dBnHL and 60dBnHL	4.10	0.000
80dBnHL and 40dBnHL	5.06	0.000
80dBnHL and Threshold level	5.62	0.000
80dBnHL and <Threshold level	5.91	0.000
60dBnHL and 40dBnHL	3.43	0.001
60dBnHL and Threshold level	6.71	0.000
60dBnHL and <Threshold level	7.31	0.000
40dBnHl and Threshold level	6.22	0.000
40dBnHL and <Threshold level	7.39	0.000
Threshold and <Threshold level	3.11	0.003

Paried 't' test showed a significant difference between the Fsp value obtained at different intensities. The 't' value and the corresponding level of significance is show n in Table 3.

These results are similar to that reported by Don, Elberling and Waring (1984), who also reported that as the intensity of the stimuli increases the Fsp improves. This increase in Fsp value with increase in intensity can be explained based on amplitude of ABR of different intensities. It has been reported that increase in intensity will result in increase in amplitude of ABR, (Rosen hamer, Lindstrom and Lundborg (1978) but intensity of the stimulus does not have an effect on background physiological activity. Thus, with increase in intensity, the SNR improves resulting in higher Fsp value.

Detection of presence of ABR based on Fsp value

To check the efficacy of the Fsp value, different criteria were selected and tested for hitrate and missrate. Initially in detection of presence of ABR mean Fsp value at threshold + 2 SD (Standard deviation) was taken as the criteria. Table 4 shows the number of wave forms obtained at threshold and below threshold that would pass this Fsp criteria of 2.13.

Table 4 : Classification of ABR waveforms as pass or fail based on Fsp criteria of2.13.

		Fsp criteria	
		Present	Absent
Visual inspection	Present	2	38
	Absent	1	39

As it can be seen from the Table when mean Fsp + 2 SD was considered to classify the waveforms obtained at the threshold level and below threshold level the percentage of missrate were 95% with hitrate of 5%. The fells alarm was 2.5% and correct rejections were 97.5%. Since the missrate was very high with this criteria, mean Fsp + 1 SD was taken as a criterion value to determine presence of ABR.

Table 5 : Classification of ABR waveforms as pass or fail based on Fsp criteria of 1.63.

		Fsp criteria	
		Present	Absent
Visual inspection	Present	5	35
	Absent	3	37

As seen in Table 5 the results revealed that only a marginal increase in the hitrate from 5% to 12.5%, and a marginal decrease in missrate (95% to 87.5%). However this criteria also resulted in decrease in missrate. These results indicate that Fsp criterion is not a good measure while estimating threshold using ABR.

ABR screening generally carried out at 35dBnHL or 40dBnHL Hall, Kileny and Ruth (1987) (Cited in Hall 1992). Therefore waveforms obtained in the present study at 40dBnHL were classified as pass or fail based on the two criteria mentioned earlier. The results are shown in Table 6 and Table 7 when mean Fsp + 2 SD was considered there was 50% of hitrate and 50% of missrate. Where as when mean Fsp + 1SD was considered there was 72.5% of hitrate and only 27.5% of missrates.

Table 6 : Classification of ABR waveforms as pass or fail based on Fsp criteria of 2.13 at 40 dBnHL.

		Fsp criteria	
		Present	Absent
Visual inspection	Present	20	20
	Absent	0	0

Table 7 : Classification of ABR waveforms as pass or fail based on Fsp criteria of 1.63 at 40 dBnHL.

		Fsp criteria	
		Present	Absent
Visual inspection	Present	29	11
	Absent	0	0

These results indicate that classifying ABR waveforms based on Fsp value is not as accurate as visual inspection. However if one wishes to do ABR screening based on Fsp value, the value of 1.63 (mean Fsp + 1 SD) is recommended to detect the presence of ABR.

SUMMARY AND CONCLUSIONS

ABR is a response recorded from the auditory system that is evoked by auditory stimuli. ABR is an electrophysiological testing which can be used for threshold estimation and site of lesion detection. ABR will be affected by many stimulus related factors, acquisition factors and subject related factors. Inorder to get a reliable response a good SNR is required. There are many measures which represent SNR. Fsp is one of the statistical measure of SNR. Fsp is the ratio of variance of the signal and the variance of noise or background physiological noise. Very few investigators have studied the Fsp value in ABR. Therefore the present study was designed to study the following aims.

- Comparison of Fsp value across intensities.
- Developing criterion Fsp value to detect the presence of ABR.

In the present study, 20 males and 20 females with normal hearing threshold in conventional audiometry served as subjects. The ABR recording was done using "Nicolet Bravo" in a sound treated room, initially, at 80dBnHL, 60dBnHL, 40dBnHL and ABR threshold was traced in lOdB steps. The recording was also carried out at an intensity which was lOdB below threshold level. The Fsp value at each recording was noted down.

The *obtained* data were subjected to statistical analysis. The following conclusions could be drawn from the study.

- There is no difference in males and females in Fsp value.
- As the intensity increases there is a significant improvement in Fsp.
- Fsp is less reliable than visual inspection while estimating ABR threshold.
- In screening ABR, Fsp criterion value (Mean Fsp + 1SD) of 1.63 can be used to determine the presence or absence of ABR. This criteria has a hit rate of 72.5% and miss rate of 27.5%.

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