P_{300} : A COMPARISON BETWEEN ACTIVE LISTENING PARADIGM AND A PASSIVE LISTENING PARADIGM

Register No.M2k09

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

All India Institute of Speech and Hearing
Manasa Gangothri
Mysore

MAY 2001

Dedicated to

The Divine Grace

&

My Dad

Now Neither time nor distance

can come between us.

CERTIFICATE

This is to certify that the Independent Project entitled : **"P300 : A COMPARISON BETWEEN ACTIVE LISTENING PARADIGM AND A PASSIVE LISTENING PARADIGM"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register No.M2k09.

Dr. M. Jayaram
Director
All India Institute of
Speech and Hearing
Mysore 570 006.

Mysore
May 2001

CERTIFICATE

This is to certify that this Independent Project entitled : "P_{300} : A COMPARISON BETWEEN ACTIVE LISTENING PARADIGM AND A PASSIVE LISTENING PARADIGM" 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.

Ms. Vanaja C.S
GUIDE
Lecturer in Audiology
Department of Audiology
All India Institute of
Speech and Hearing
Mysore 570 006.

Mysore
May 2001

DECLARATION

I hereby declare that this Independent Project entitled "P_{300} : A COMPARISON BETWEEN ACTIVE LISTENING PARADIGM AND A PASSIVE LISTENING PARADIGM" is the result of my own study under the guidance of Ms.Vanaja, C.S., Lecturer in Audiology, 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 2001.

Reg. No.M2k09

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INTRODUCTION

An evoked potential refers to a series of electrical changes occurring in the peripheral and central nervous system, usually related to the sensory pathways (McPherson and Starr, 1993, Cited in McPherson, 1996). Depending on the sensory system that is being stimulated, the evoked potential may be referred to as an auditory evoked potential (AEP), visual evoked potential (VEP) or somatosensory evoked potential (SSEP). Each of these sensory evoked potential may be further categorized according to specific usage. For example, in the auditory system further categorization may include the brainstem auditory evoked potential (BAEP), the middle latency auditory evoked potential (MAEP) and the long latency auditory evoked potentials (LAEP) (McPherson, 1996).

The slow or long latency auditory evoked potential are low voltage (microvolt), discrete electrical potentials occurring in the electroencephalogram (EEG) to a time locked sensory stimulus. These slow (or) long latency potentials can again be categorized into exogenous and endogenous potentials (Butcher, 1994). Exogenous potentials are those which are elicited by some external event related to the dimensions of the stimulus. Endogenous potentials are changes in the brain's electrical activity that occur in response to internal events, such as perception or cognition. These endogenous potentials are also referred to as event related potentials (Butcher, 1994).

There are four major types of event related potentials that are classified more on the basis of function than on time. The P300 (also referred to as cognitive evoked potentials), the Contingent Negative Variation (CNV), and the N400 and P_{500} which appear to be related to language and linguistic features of speech (McPherson, 1996). The P_{300} response is essentially a component within an extended LLR time frame that is recorded under special stimulus conditions. P300 reflects the semantic, cognitive processing and attention. It was originally described by Sutton, Baren, Zubin and John (1965) P_{300} occurs when the subject consciously recognizes the presence of a change in the acoustic stimulus and when there is a task relevancy (i.e.) by a stimulus that requires some response or judgement and whose occurrence is uncertain (McPheson, 1996). P_{300} is theorized to be independent of evoking stimulus (Butcher, 1994).

Applications of P300

The diagnostic applications of P_{300} is in its use in the evaluation of patients who are suspected to have disorders affecting their cognitive functions such as Alzimer's Disease (St.Clair, Blacbum, Blackwood and Tyrer, 1988) and other forms of dementia (Goodin, 1990). With these group of patients, the theoretical function of a response is in the detection of a processing impairment through response abnormalities, before the patients behaviour on traditional measures of cognitive function would be affected (Butcher, 1994).

The second category of potential application is directly related to the auditory perceptual skills - in particular, the evaluation of sensitivity and discrimination skills through a physiologic response. Because the response appears to be present when a patient perceives something relevant about the stimulus, it can be used in some difficult to test population, for whom auditory processing abilities are questionable (Butcher, 1994). Additionally, it could be used to determine whether a patient is capable of perceiving a difference between two or more stimuli (Kileny, 1991).)

Elicitation of P_{300}

(Literature has evidenced the importance of task relevance to P_{300} elicitation. So, an "oddball paradigm" is generally used to elicit this response, in which, a deviant or rarely occurring stimulus is presented in a series of frequent or standard stimuli. In this procedure, comparisons are made between the averaged responses of standard and deviant stimuli. For auditory testing, the use of tonal stimuli has been frequently reported. Investigators have reported the use of active discrimination (Kileny, 1991) or signal detection paradigms. (Paul and Sutton, 1972) or passive paradigms, in which no active behavioral response is required (Polich, 1989).) While the response made (such as active discrimination or ignoring the stimulus) has been shown to affect the P_{300} response characteristics, presence of a P_{300} response does not always require the active participation of the subject.

The Need for the Study

Audiologists have become increasingly interested in the cognitive responses because, they form a class of responses which has potential in providing a means of evaluating higher level processing skills. But there has been no general agreement upon how to best formulate the psychological correlates of P_{300} (Squires, Squires, and Hillyard, 1975). It appears to be a part of the decision complex and undoubtedly overlaps with other late components, having different scalp distributions (Snyder, Hillyard and Galambos, 1980).

"Perhaps the best approach for now is to continue systematically investigating the characteristics of and variables relating to the P_{300} component".

- *Jaynee Butcher (1994).*

So the present study compares the influence of one of the major psychological variable affecting this endogenous potential (i.e.) the effect of active listening and passive listening conditions towards the eliciting stimulus.

One of the clinical applications of P_{300} is to assess the auditory processing, abilities. In an effort to enhance the objectivity in the assessment of central processing difficulties, interest has been focused on the use of event related potentials (Musiek and Baran, 1987). Some patients find it difficult to understand the instructions and carryout the required task during the active listening condition. So, it would be advantageous if P_{300} could be elicited using a passive paradigm in such cases. However, before using it on the clinical population, it has to be verified to check if there is a difference between P_{300} response that is recorded during active and passive listening correlates. Considering the above needs, the study was taken up with the following aims:

(1) To study the latency, amplitude and morphology of P300 elicited in a passive listening condition.

(2) To compare the P300 elicited under active and passive listening condition.

(3) To compare the P_{300} in male and female groups in both the conditions.

(4) To check if there is any significant difference between latency and amplitude of the response recorded from vertex electrode placement (C_z) and parietal electrode placement (P_z) in both the conditions.

REVIEW OF LITERATURE

P300 was first discussed by Sutton, et al., (1965) is a component of human auditory evoked potential that is not affected by the physical parameters of the eliciting stimuli. This component rather appeared to reflect the cognitive processing of stimulus information on the part of the subject. The most common designation given to this component is 'P_{300}' referring to its polarity (positive) and approximate latency following stimulus presentation (Price and Smith, 1974).

The amplitude of P_{300} is about 15 microvolts, and under certain conditions, it may be bimodal (i.e.) P300a and P300b. According to Polich (1989) and Roth (1973) (cited in Kraus and McGee, 1994), the 'a' component is usually seen when there is a large stimulus difference whether or not a subject is actively attending to stimulus sequence but the 'b' component is reported only when subject is actively discriminating between stimuli. In normals, it can be recorded as early as 250 ms or as late as 400ms. Normal variations are a characteristic feature of endogenous evoked responses. The variations in the waveform is determined by differences in test paradigm and subtle variations in subject's attention to stimuli.

The P300 response is essentially a component within an extended auditory long response time frame that is recorded under special stimulus conditions. According to McPherson (1996), the P300 occurs when a subject consciously recognizes the presence of a change in the acoustic stimulus. The P_{300} is elicited by "task relevancy" (i.e.) by a stimulus that requires some response or judgement and whose occurrence is uncertain.

"Selective Attention" is an important brain function that allows a person to process some type of stimulus events in preference to others (Hillyard, 1989) (cited in McPherson, 1996). A characteristic feature of P300 and other cognitive endogenous event related potential is attention to one stimuli vs. another. Process of attention, auditory discrimination, memory and semantic expectancy appeared to be involved in the generation of P_{300} (Picton and Hillyard, 1988 , cited in Kraus and McGee, 1994). It has been suggested that P_{300} may be a neural correlate of sequential information processing, short term memory, and/or decision making (Squires, Donchin, Squires and Grossberg, 1977; Donchin, 1981).

Physiological Correlates of P300

The P300 originates from non-specific, unknown neural generators and is felt to be an electrophysiological manifestation of strategies used by the Central Nervous System (CNS) in selective attention activities, including frontal cortex (Courchesene, 1978), auditory cortex of superior temporal lobe (Kileny and Robertson, 1985), hippocampus and associated brain sites (Okada, Kaufman, Williamson, 1983) Comparison of recording obtained from implanted electrodes and surface electrodes revealed that P300 was generated from sequential generators for the N2-P3-N4 subcomponents, with N2 and N4 from the non-specific sensory system and P3 from the specific auditory system Consequently, it is proposed that there is a sequentially non-specific - specific - non-specific (N2-P3-N4) activation of overlying generators for the P300 Although the precise generators are still not fully resolved, there is evidence of a sub-thalamic and medial geniculate origin, with other activity noted in the gyrus orbitalis, rostral thalamus and anterior commissure. In a very simplistic form, one could say that P300 includes responses from frontal cortex, centroparietal cortex and hippocampus (McPherson, 1996).

Buchwald (1990 , cited in McPherson, 1996) suggested that although the generator sites of P300 are still unknown, maturation of P300 provides some insight into the ontogeny of the developing brain for cognitive versus sensory brain systems. P300 is not mature until about 14 years of age P300 latency has been found to decrease with increase in cognitive development, stemming from maturation in children (Howard and Polich, 1985). Adult aging and neurological impairment have been correlated with increase in *P*300 latency (Goodwin, Squires, Henderson and Starr, 1978; Polich, Howard and Starr, 1985a). Thus, P_{300} is beginning to provide electrophysiological index of the cognitive processes that co-vary with physiological change.

Clinical Application of P300

A review of literature suggests that there is a widespread interest in P300 responses both on the part of audiologists and on the part of other professionals interested in cognitive auditory processing abilities. One of the distinct advantages of the P_{300} response is that it is less dependent on the physical characteristics of the stimulus employed than are the exogenous potentials. Additionally, although it does require attention to task relevant stimulus items, no active behavioral response is required from the subject. For these reasons, there is a renewed interest in the use of this response in the evaluation of patients having suspected or confirmed diagnosis of disorders affecting cognitive functions. Application of P_{300} can be discussed under the following categories :

(i) Defective Cognitive Function

Several studies have compared P_{300} and other event related potentials obtained for young adults and/or normal elderly with elderly demented patients (Ball, Marsh, Schubarth, Brown and Standburg, 1989; Neshige, Barrett and Shibasaki, 1988). They report significant response abnormalities in demented patients compared to normal control. Neshige et al. (1988) reported that significant prolongation of both N_2 and P_{300} responses was evident for both groups of demented patients namely one having known Alziemer's Disease and the other having multi-infarct dementia. No significant amplitude changes were reported. Ball et al. (1989) conducted a longitudinal study comparing latency changes in the auditory P_{300} responses for probable Alziemer's Disease (pAD) patients and normal controls. At the beginning of the study, the pAD group had significantly prolonged P_{300} latencies and greater rate of change relative to normal subjects. It was concluded that the increased rate in the P_{300} latency in the demented patients may be reflective of the accelerated aging process in that group.

Auditory ERP's were employed by Finley, Faux, Hutcheson and Amstutz (1985) to study children with cognitive disorder. They found that compared to normal controls, children with organically confirmed cognitive problem had significantly delayed P_{300} latency. In addition, they reported that children with organic disorders could be differentiated from those with functional disorders or psychiatric disorders on the basis of P_{300} latency.

(ii) Language and Speech Motor Disorders

Selinger, Prescott and Schucard (1989) compared ERP's using a verbal and a non-verbal paradigm from aphasic subjects with those of normal subjects. They also compared the patient's endogenous responses to traditional aphasia tests. The results yielded hemispheric differences in the aphasic group during the verbal task which were not evident in the normal subjects

Niwa, Ohta and Yamazaki (1983) compared P300 from four autistic subjects with four patients with Down's Syndrome and five normal controls using three response modes. In examining a passive sequence, autistic children had decreased response amplitude relative to the other subject groups. Since the group studied was very small, the results cannot be generalized. Dawson, Findley, Phillips, Galpert and Lewy (1988) (cited in Butcher, 1994) examined the relationships among response characteristics, language impairment and intelligence in autistics children. They also studied the hemispheric effects by recording responses from three scalp locations. The autistic children exhibited decreased response amplitude at the vertex and left hemispheric sites to the tonal stimulus, and increased amplitude at the right hemispheres site to the syllable stimulus. Furthermore, degree of language impairment was correlated with increased response amplitude for the right hemisphere. It was concluded that there was differential hemispheric involvement in autistic children.

P300 has also been suggested as a tool for quantifying hemispheric asymmetries and in detecting dichotic deficits. Jerger, Alford, Law, Rivera and Chmiel (1995) reported that the N2-P3 complex accurately reflects the phonemic categorization of speech stimuli. Analysis of acoustic structure of words must precede identification of its meaning. These phases of speech processing are associated with ERP components that differed in their timing. Dunchan-Johnson and Donchin (1982) recorded P300 latency and reaction time (RT) in a task, where letters were preceded by either a matching letter or neutral stimulus or a mismatching letter. RT and P_{300} were not delayed in the first two condition but delayed in the mismatched letter.

(Hi) Other Neurologic Disorders

Pratapchand, Sinniah and Salem (1988 , cited in Butcher, 1994) examined changes in the P300 responses over time for patients having concussions and normal controls. They found abnormal latency and amplitude values initially for the patients. However the abnormalities seen resolved over time. So, they suggested P_{300} as a useful measure of cerebral dysfunction in head trauma patients.

Newton, Barrett, Callanan and Towell (1989) compared the ERPs of MS patients with age-matched controls. While all the subjects had normal exogenous responses, approximately half of the patients had abnormal cognitive responses. Ruschkin and Sutton (1994) compared the P300 response obtained from patients with MS and age matched normal as a means of evaluating their working memory impairment. Their results indicated that the P_{300} amplitude tended to be smaller in the patients with MS but there was no difference in latency.

(iii) Evaluation of specific auditory perceptual skills:

The other major application of P_{300} is in the evaluation of specific auditory perceptual skills. Although there has been no absolute agreement about how to formulate the psychological correlates of P300, the data support the concept that a task relevant event is a necessary, if not sufficient condition for eliciting a P300. Because it is, in that respect, a measure of stimulus processing, it appears to have potential value in the assessment of hearing sensitivity and auditory processing abilities. Jirsa and Clontz (1990) compared P_{300} in subjects with confirmed CAPD and age matched children. Their results indicated that patients with CAPD either failed to generate a P_{300} or produced a P_{300} which was significantly longer in latency and reduced in amplitude compared to the normal control group. Moreover, when the clinical group was subdivided into four subgroups, on the basis of the degree of central auditory involvement, those subjects in the group with most severe involvement exhibited the longest P2-P3 interval. Thus P_{300} can be used as a clinical tool to predict the severity of processing disorders also.

Radhika (1998) studied the auditory late latency potentials in learning disabled children and reported that P_{300} was absent in nine out of twelve cases and in the remaining cases, there was a reduced amplitude. Guruprasad (2000) studied the P_{300} in seven learning disabled children and reported abnormalities in P_{300} like absence of waveform, poor morphology with increased latency and reduced amplitude.

From the above discussion, it is evident that P_{300} has a wide range of clinical applications. Although it is useful in discussing group differences of clinical population relative to normal population, P_{300} response does not appear to be useful in differentiating individual patients, nor does it appear to be valuable in the differential diagnosis of various possible disease processes (Butcher, 1994). This could be because P_{300} obtained from the normal population, has large variations. So, to understand the phenomenon behind P300, reviewing the normal variations of this potential is very critical.

VARIABLES AFFECTING P300

The variations in P_{300} amongst the normal population has been studied by various investigators. The following is a review of various variables affecting P_{300} which can be grouped as : (i) Factors related to stimulus (ii) Factors related to response mode and (iii) Factors related to subject characteristics.

(i) **Factors related to stimulus** : Studies have been carried out to investigate the effects of stimulus variables such as (a) intensity (b) frequency and (c) probability on P_{300} parameters.

(a) *Intensity* - P300 is an endogenous component since its amplitude, latency and scalp distributions does not depend upon the physical attributes of the evoking stimulus (Donchin, Ritter and McCallum, 1978 , cited in Butcher, 1994). But Butcher (1983)(Cited in Butcher, 1994), utilized an oddball paradigm and reported that changes in the intensity of the rare stimuli, had a significant effect on the latency of the P_{300} response. When the stimulus intensity was increased from l0 dBSL to 50 dBSL, the average reduction in latency was 29.3msec.

Papanicolaou, Loring, Raz and Eisenberg (1985) reported that P300 amplitude was not significantly affected by the intensity of the stimulus. However a statistically significant increase in P300 latency contingent on reduction of stimulus intensity was noted. Hence, it is important to ascertain that the effective stimulus intensity remains constant across the groups which are compared. Polich (1989) (cited by Butcher, 1994) examined the effects of changes in stimulus frequency, intensity and duration on the auditory P_{300} response. He reported that both latency and amplitude for the response were affected significantly by changes in frequency and that P_{300} latency was affected by an interaction of stimulus intensity and duration.

(b) *Frequency* - Literature available on varying the frequency of either the frequent or infrequent stimuli and studying its effects on P300 is very limited. One study by Butcher (1994) utilized an oddball paradigm and reported that change in the stimulus frequency had no significant effect on P300 response.

(c) ***Probability*** - Squires, Wickens, Squires and Donchin (1976) (cited in Butcher, 1994) reported that there is a complex relationship between stimulus probability, stimulus sequence and P_{300} They hypothesized that the expectancy is determined in a linear fashion by three factors: (1) the memory for event frequency (i.e. target frequency) within the prior stimulus sequence (2) the specific structure of the prior sequence, and (3) the global probability of the event.

According to Picton, Stuss, Champagne and Nelson (1984), the probability of the signals eliciting the P_{300} shows significant effect on P300 amplitude and latency. These effects do not change with age, suggesting that the probability determinants of the P_{300} remain constant across the life span. Butcher (1994) has stated that the size of the P300 complex elicited by a given stimulus increases with the number of different stimulus preceding it. Conversely, the size of P_{300} complex decreases as runs of like stimuli precede the target.

ii) **Response Mode and Measurement Related Variables** : P_{300} response is reported to vary according to the type of response made by the subject. This response mode is determined by task given to the subject depending on the test paradigm used. P_{300} is also reported to vary with the site on the scalp from which it is recorded and also the particular modality from using which it is recorded. Some of the studies that have studied these variables are discussed here.

a) ***Task given*** **-** Butcher (1983) (cited in Butcher, 1994) compared the responses of P300 obtained during three response types. Subjects were instructed to : (i) mentally acknowledge (ii) silently count (iii) silently count and press a button in response to rare stimulus presentations. The data indicted that changes in the response mode had a significant impact on P_{300} amplitude. To be specific, no differences were noted between the two counting conditions, a large amplitude reduction was present, when the subjects were only mentally acknowledging the tones. No latency effects were seen as a function of response mode.

b) ***Task*** *difficulty* - Another factor affecting the P_{300} is the task difficulty. This factor specifically becomes important if the response is to be utilized with patients having suspected cognitive (or) auditory processing deficits Polich (1987) (cited in Butcher, 1994) examined the P300 response obtained for 'easy' and 'hard' auditory discriminations, and concluded that processing difficulty does affect the latency and amplitude of P300 response. Results also suggest that the effects are independent of stimulus probability unless differences in task requirement affect the encoding of stimuli employed.

c) Electrode site placement/scalp distribution - The P300 is a positive potential that is broadly distributed with a maximum amplitude observed at the midline over the centro-parietal areas. The maxima moves slightly depending on the task. For example, in a signal detection paradigm, the maxima is largest at the vertex, and indiscrimination tasks, it is largest just posterior to the vertex (Simson, Vaughen and Ritter, 1978). Likewise, Snyder, Hillyard and Galambos (1980) observed an amplitude maxima for the P_{300} just anterior of the vertex for the "oddball" paradigm. Thus, electrodes should be placed minimally at F_z, C_z and P_z for optimum recording and referenced to linked mastoids. (McPheson, 1996).

d) ***Various modality elicited P_{300}*** - P300 also varies with respect to the modality through which the response is elicited, like auditory modality or visual modality or any other language modality. For example, Picton, et al. (1984) report that the P_{300} evoked by the visual stimulus was delayed by approximately 90 msec, than that by the auditory stimuli which was explained by the difference in the transmission time to the cortex. The authors also report that P_{300} component evoked by somatosensory signal was delayed and larger than auditory (or) visual signal. This was explained as the somatosensory task being more difficult than the auditory task. Holcomb (1988) reported eliciting P300 through other strategies like semantic priming task, using language modality (i.e.) through verbal stimuli. Neville, Snyder, Knight and Galambos (1978) report that very reliable alterations in the N100 and P_{300} components were observed, elicited by words and found to be greater in left hemisphere than right. The review of the literature showed that P_{300} could be used to index perceived meaning of words, different linguistic categorization, the study of speech perception, the study of semantics and the study of reading. (Woodwords, Owens and Thompson, 1990). Furthermore, P_{300} has been suggested as a tool for quantifying hemispheric asymmetries and in detecting dichotic deficits (Jerger et al. 1995).

(iii) **Subject Characteristics -** The relationship of age, gender and attention with P_{300} have also been studied by various investigators. The following is a review of the effect of these variables.

a) *Age*- McPherson (1996) reported that P_{3a} component, in the auditory modality, has a smaller amplitude with a slightly more frontal distribution, in the earlier stages of development than in the later stages of development, but P_{3b} component does not show changes in morphology, amplitude or scalp distribution. McPherson, Tures, Starr (1989) reported that the P_{300} is not well established till 5 years; and after five years, the latency decreases with age. An increase in latency was again seen after fifty years of age. Similar results have been reported by other investigators. Buchwald (1990)(cited in McPherson, 1996) reported that waveforms do not generally each adult values until 17 years of age. Barajas (1990) has shown that P_{300} reaches its shortest latency at about 18-24 years of age and then increases at the rate of approximately 1.25 msec, per year until 78 years of age.

A study by Saravanan (1997) about the age related changes in P_{300} shows that there was a clear developmental trend in the P_{300}

latency (i.e.) latency in children were longer that that of adults, but the difference was not statistically significant. He also reported that there was no developmental trend in the P300 amplitude and no significant difference between children vs. adults. Thus, age of the subject should be considered while interpreting the results of P300.

b) ***Gender*** - A majority of the studies report of no difference among males and females, in the evoked P_{300} (Polich, Howards and Starr, 1985b; Spongberg and Decker, 1990). However, a study by Picton, et al. (1984) reported amplitude of the P_{300} component in male subjects was less when compared to that of female subjects. The difference was small when compared to the general variability of P300 latency. They attributed this difference to physical difference in head size or skull thickness rather than any cognitive differences between the sexes.

c) ***Attention-*** Polich (1986) noted that attention was a necessary factor in the generation of P_{300} component, and a decrease inattention is related to a decrease in response amplitude. This effect of attention is reported to be similar across all sensory modalities (i.e.) auditory, visual and somatosensory (Hohnobein, Fallenstein, Hoormann and Blanke, 1991). McPherson (1996) categorized P_{300} in essentially three attention conditions i.e. (1) active attention in which the traditional oddball paradigm is used and the subject must perform some mental or response task to the rare (i.e.) target stimuli. (2) A passive attention condition in which subject is not instructed to respond to the rare stimuli (i.e.) target stimulus (3) an ignore condition whereby the subject is told to ignore the rare stimuli. (The subject is given some other task such as reading). The P_{300} is most robust in the active attention condition, showing the greatest amplitude and shortest latency. In the passive condition, there is a reduction in the amplitude relative to active attention condition. Finally, in the ignore condition, the P_{300} is either greatly reduced or in some instances absent.

Pfefferbaum, Ford, Weller and Kopell (1985), used another paradigm similar to oddball paradigm and, elicited P_{300}, using an active discrimination task. This paradigm used a warning stimulus that indicated as to whether or not the subject is to respond to the imperative stimulus. Often there are two warning tones; one that requires a response and one that does not require response, hence the term "go/no go" was used to describe this paradigm. This paradigm produced waveform similar to that obtained in the attentive condition.Polich (1989) studied P300 elicited with a passive tone sequence paradigm through two experiments. In the first experiment, he compared P_{300} elicited from the passive paradigm with that from an active discrimination (oddball) task. In the passive sequence paradigm subjects were instructed to 'day dream' when the stimuli were presented. The stimuli were a series of 10 tones of 50 msec, duration and 60 dB SPL of which the first 6 tones were always 1000 Hz standard tones with the 2000 Hz target presented randomly, at either 7th/8th/9th/10th tone position. (Standard tones were presented at the remaining non-target positions). The 10 tone sequence was followed by a silent interval of 4-6 sec. before the next series began. A total of 20 sequences were presented. After the passive paradigm, they were given the active discrimination paradigm in which they were instructed to indicate the occurrence of the target tone. Additionally, 20 subjects who had received both paradigms were again presented with passive sequence paradigm and were asked to make the same finger movement discrimination response to the target tone. The results showed that the passive sequence paradigm yielded P_3 wave forms remarkably similar to those obtained from an active discrimination since both demonstrated central parietal maximum scalp distributions and virtually identical peak latencies. In the second experiment, he compared P_3 from tone sequence paradigm while the subjects were passively ignoring tones, with a condition in which they were presented with tone sequences while also working on a complex word puzzle. The puzzle solving secondary task produced a decrease in P_3

amplitude relative to ignore condition, although P_3 latency was unaffected. Because of these results, it was suggested that the passive sequence paradigm may be a useful and reliable means of eliciting P_3 ERP in subject populations or experimental situations in which active discrimination task cannot be performed.

Other investigators have also reported that P_3 can be elicited even in the absence of a direct target stimulus response (Donchin, et al., 1978, cited in Butcher, 1994 and Johnson, 1986). Theoretical explanations for this component are typically based on information processing models, which assume active task participation. In a study using auditory stimuli, Squries, Olio, Sander (1989) (cited in Polich, 1989) evaluated P_3 components from passive and active discrimination conditions in which an infrequently occurring target stimulus was made physically very discrepant from the standard tone (e.g. 250 Hz vs. 3000 Hz). The passive task produced P_3 like potentials with a central-parietal maximum that were smaller (5-8 uv) than those from active task and tended to decrease with repeated target stimulus presentations, although the peak latencies were comparable between the two conditions.^

Polich (1989) concluded that passive paradigms can provide similar information as active discrimination tasks, but that amplitude differences between the procedures may make component measurement difficult, even though peak latency may be the variable of major interest.

Hohnsbein, et al., (1991) studied the effects of cross modal divided attention on late ERP components in simple and choice reaction tasks. Since changes in stimulus evaluation time is reflected on the P_{300} latency, they hypothesized that the latency of P_{300} should be longer for divided than for focused attention. They expected this delay to occur in both choice reaction tasks and simple reaction tasks, as the evaluation of well known stimuli is supposed to be performed compulsively (Teichner and Krebs, 1974 , cited in Hohnsbein, et al. 1991). So, they studied P_{300} across two modalities (auditory, visual), for two tasks (simple reaction and choice reaction) for focused and divided attention condition. The results showed that there was no latency difference noted between choice and simple reaction tasks suggesting that the duration of stimulus evaluation appears to be virtually the same for both tasks. This shows that even in a simple task, stimulus is evaluated (which is done compulsively), suggesting that an automatic stimulus evaluation may occur even in the "ignore' condition described by Polich (1987b). A compulsive stimulus evaluation process should not rely heavily on the processing resources and should therefore not be seriously impaired by the division of attention.

Thus, the review of literature so far shows that there are a lot of variables which affect P_{300}. The relationship between the psychological correlates that affect P_{300} and its latency, amplitude or morphology is not well established. This study has attempted to study one of the variables, namely, attention and its influence on P300 in two conditions, the active listening and passive listening, so that this test procedure can be more effectively used with the clinical population who cannot make an active behavioral response.

METHODOLOGY

The present study was designed to investigate the following aims:

1. To study for the latency, amplitude and morphology of P_{300} elicited in a passive listening condition.
2. To compare the P300 elicited under active and passive listening condition.
3. To compare the P300 in male and female subject groups in both the conditions.
4. To check if there is any significant difference between latency and amplitude of the response recorded from vertex electrode placement (C_z) and parietal electrode placement (P_z) in both the conditions.

SUBJECTS

A group of thirty subjects (fifteen males and fifteen females) in the age range 18-25 years were taken up for the study. Subjects who met the following criteria were included for the study:

-> Normal hearing (Criteria : Behavioural threshold less than 15 dB HL for octave frequencies from 250 Hz to 8 kHz) in both the ears.

-> No history of otologic (ear discharge/perforation/tinnitus), medical, neurologic or psychological problems.

EQUIPMENT USED

The following instruments were used for the study:

(1) Audiometer GSI-61 with TDH-50P earphones with MX-41 /AR ear cushions was used for hearing testing

(2) Immittance meter, GSI-33 was used for ruling out the middle ear pathology

(3) Nicolet Bravo System with TDH-39 earphones with MX-41 /AR ear cushions and silver-coated disc type electrodes were used.

PROCEDURE

The data collection included the following 2 stages:

Stage -1 : Hearing testing.

Stage -2 : Electrophysiological testing.

STAGE-1: Hearing testing

An initial hearing testing was done for all the subjects to ensure that the behavioral air conduction thresholds for octave frequencies between 250 Hz -8000 Hz was less than 15 dB HL

Middle ear screening to rule out middle ear pathology was done using an immittance meter.

STAGE-2 : Electrophysiological testing

This forms an important step in the successful recording and hence great care was taken to ensure correct details of protocol and electrode setting.

a) **Setting up the instrument** - An oddball paradigm was used to elicit P300. The protocol used for testing is described in Table-1.

Table-1: The protocol used for testing

Type of stimulus	Tone burst
Polarity	Rarefraction
Intensity and frequency	Infrequent stimuli: 2000 Hz at 80 dB nHL* Frequent stimuli: 500 Hz at 80 dBnHL*.
No.of stimuli	300 stimuli were presented of which 80% was frequent stimuli and 20% was randomized infrequent stimuli.
Presentation	Monoaural
Mode	Air conduction
Transducer	Headphones TDH 39 with MXH-41/AR Cushions
Analysis time	600 ms
Sensitivity	lOOuV
Filters	1-30 Hz

* 0 dB nHL = 11 dB SPL for 500 Hz and 9 dB SPL for 2000 Hz toneburst.

b) Preparing the subject

(i) Electrode placement - Electrode sites for two channel recording were selected. The non-inverting electrodes were connected to vertex (C_z) and parietal (P_z) with the common at forehead (F_{pz}). The inverting (active) electrodes were connected to the mastoids of both ears, Ml (to the left ear mastoid) and M2 (to the right ear mastoid). The two inverting electrodes were connected with a jumper.

The electrode sites were prepared before placing the electrodes by scrubbing vigorously with an abrasive liquid substance. In scalp site, hair was first parted with one hand and then site was prepared. Each electrode was dabbed with a paste or a gel and taped to the site securely with a plaster. It was ensured that the absolute impedance of each electrode was $<5000\ \Omega$ and inter-electrode impedance was $<2000\ \Omega$.

(ii) Instructions to the subject - After the electrode placement, the following instructions were given to them:

They were instructed to relax themselves and at the same time to remain alert, throughout the test.

They were asked to keep their eyes open and to fixate their vision to one spot to minimize alpha interference.

For the first recording (passive condition), they were asked to relax and not to pay attention to what they were listening. For the second recording, (active condition) they were asked to make a mental count of the rarely occurring, high pitched tones in the series of tones that were presented to them. At the end they were asked to report the number of target stimuli they had counted. Subjects were asked to avoid any time locked physical responses like eye blinking with each presentation of rare stimuli.

(iii) Data Collection - After instructing the subjects, the earphones were placed on the subject's ears, being careful not to dislodge any electrodes. Red phone to the right ear and blue phone to the left ear and centre of earphone diaphragm was directly placed over the ear canal opening. The electrode leads and electrode box were as far away from the earphones as possible to minimize artifacts. P_{300} was then recorded from the subject using the protocol described earlier.

IDENTIFICATION OF P300 WAVEFORM

The P300 was identified in the response for infrequent stimuli by visual inspection. The third positive peak from the baseline, following the N_{200} was considered as P_{300} The latency of P_{300} and N_2-P_3 amplitude was recorded for each condition. Whenever there was a bifid peak, the latency of the P_{300} 'b' component was considered.

RESULTS AND DISCUSSION

The study was taken up with the aim of studying the latency, amplitude and morphology of P300 elicited in the passive listening paradigm and compare the same with the P_{300} elicited in the active listening paradigm. The data obtained from thirty subjects (fifteen males and fifteen females) was statistically analyzed. Initially, the results were analyzed separately for male and female group to check if there is a significant difference in latency and amplitude, using the non-parametric test of significance, the Mann-Whitney U-Test of significance. But, since most of the parameters showed no significant difference between the two groups, all the subjects were considered as one group for further analysis. The statistical test of significance, the parametric 't' test was then applied to compare the results of passive listening paradigm with that of active listening paradigm.

ACTIVE PARADIGM

The three parameters studied were morphology latency and amplitude.

(i) Morphology

Morphology was described in terms of presence or absence of waveforms, single peak or bifid peak, sharp or broad and clear or noisy waveforms.

In this condition, all fifteen subjects in both the groups had P_{300} peaks at C_z and P_z sites. Among females,ten had single peak while five had bifid; ten had sharp peak while five had broad peak and twelve had clear waveforms peak while two had noisy waveform, when recorded from C_z site. At P_2 site, twelve had single peak while three had bifid; nine had sharp while six had broad peaks and all the waves were clear.

Amongst males, eight had single peak while seven had bifid peak; eleven had sharp peak while four had broad peak; four had clear waveform and one had noisy waveform when recorded from C_z site. At P_z site, thirteen had single peak while two had bifid peak; eight had sharp peak while seven had broad peak and thirteen clear waveform while two had noisy waveform.

Thus, a majority subjects had single, sharp and clear peaks in this condition. This result is in concurrence with other studies which report variability in P_{300} amongst normals (i.e.) presence of bifid peak (or) a single peak (McPherson, 1996; Saravanan, 1998).

(ii) Latency

Table-2: Mean and SD value of latency of P_{300} elicited in the active condition.

	Males		Females		Combined group	
	C_z	Pz	C_z	P_z	C_z	Pz
Mean (in msec)	317.4	330.66	315.63	318.16	316.52	324.42
SD (in msec)	31.37	28.45	32.7	29.65	31.5	29.25

It can be observed from Table 2 that the mean latency for males at was 317.4 msec, at C_z. with a SD of 31.37 and at P_z, the mean was 330.66 msec, with a SD of 28.45 whereas for females, the mean latency was 315.63 msec.at C_z with a SD of 32.7 and 318.16 msec, at P_z with a SD of 29.65. The test of significance showed no significant difference between male and female group for P_{300} recorded from both C_z (Probability value of 0.52) and P_z site (probability value of 0.165). A majority of the studies reported in literature also indicates no significant difference between P_{300} recorded from males and females (Polich et al.,1985; Sponberg and Decker, 1990).

The mean for the combined group was 316.52 msec, at C_z with a SD of 31.50 and a range of 220.5 msec, to 382 msec. At P_z, the mean was found to be 324.42 msec, with a SD of 29.25 and a range of 288 msec, to 397.5 msec. A comparison between latency of P300 recorded from C_z and P_z sites revealed longer latency at P_z site, but it was not statistically significant. This result is similar to the reports of McPherson (1996) and Saravanan (1998).

The latency of P300 obtained in the active condition is comparable with to that reported in other studies (Butcher, 1994; Price and Smith, 1974; Saravanan, 1998).

(iii) Amplitude

Table-3: Mean and SD of amplitude of P_{300} elicited in the active

	Males		Females		Combined group	
	C_z	P_z	C_z	Pz	C_z	Pz
Mean (in uv)	3.52	3.56	6.51	4.82	5.01	4.19
SD (in uv)	2.52	2.78	3.32	2.77	3.27	2.8

Inspection of Table 3 shows that mean amplitude for the male group at C_z was 3.52 uv with a SD of 2.52 and at P_z the mean was 3.56

uv with a SD of 2.78. The female group had a mean amplitude of 6.51 uv with a SD of 3.32 at C_z and at P_z, the mean was 4.82 uv with a SD of 2.77. A comparison between the groups showed lesser amplitude for males. The results of Mann-Whitney U-test of significance between males and females showed a statistically significant difference between the amplitude values at C_z site (Probability value of 0.0066) but not at P_z site (Probability value of 0.152).

In the past, investigations of amplitude of P_{300} in males and females have yielded equivocal results. A study by Polich, et al. (1985) report no significant difference between fifty males and fifty females in either latency or amplitude of the P_{300} responses whereas Picton, et al. (1984) reported a smaller amplitude of P_{300} responses in males compared to females. Picton et al. (1984) interpreted this difference to some physical difference in head size or skull thickness. The difference in the reports could have been because of the high variability of P_{300} recorded even in normal subjects. The results of this study supports the report of Picton et al. (1984). However, the SD was large for both males and females indicating high variability among the subjects.

The mean amplitude for the combined group was found to be 5.01 uv with a SD of 3.27 and a range between 0.38 uv to 12.87 uv at C_z

recording site. At P_z site, the mean amplitude was 4.19 uv with a SD of 2.8 uv and a range between 0.53 uv to 10.8 uv. The amplitude observed in the present study is less than that reported in the literature (McPherson, 1996; Saravanan, 1998). It is difficult to explain the difference in results especially because Saravanan (1998) has used a protocol similar to that used for active condition in present study. One of the difference in methodology used in the two studies is in terms of magnitude of deviation and the other difference between the two studies is the instruments used for is for recording P_{300} Further studies need to be carried out to check whether there is a difference in the measurement of amplitude in the two instruments.

The amplitude of P_{300} recorded at C_2 site was larger than that recorded at the P_z site but this difference was not statistically significant (probability value was 0.41). This result is in concurrence with the report by McPherson (1996) and Saravanan (1998).

PASSIVE PARADIGM

The same three parameters were studied in passive condition and were compared with that elicited in active condition.

(i) Latency

Table-4 Shows the mean and standard deviation of the latency of P_{300} obtained at C_z and P_z site for passive condition.

	Males		Females		Combined group	
	C_z	Pz	C_z	Pz	C_z	P_z
Mean (in msec)	314.85	306.79	299.16	296.4	308.43	302.07
SD (in msec)	33.85	39.04	55.16	45.07	43.31	41.19

The mean latency for the male group at C_z was 314.85 msec, with a SD of 33.85 msec, and at P_z it was 306.79 msec, with a SD of 39.04 msec, whereas for the female group, the mean latency at C_z was 299.16 msec, with a SD of 55.16 msec, and that of P_z was 296.4 msec, with a SD of 45.07 msec. A comparison between groups showed longer latency in males, but the results of Mann-Whitney U-test of significance revealed that the difference was not statistically significant (probability value : 0.26 at P_z and 0.52 at C_z). The mean latency for the combined group was 308.43 msec, at C_z with a standard deviation of 43.31 and it ranged from 231 msec, to 408 msec; while at P_z the mean was 302.07 msec, with a SD of 41.19 msec and a range from 238.5 msec, to 375 msec.

The latency recorded from C_z was longer than the latency recorded from P_z site. This difference was statistically significant (at a probability level 0.014). In passive condition, the latency reflects an automatic stimulus evaluation by the subject (Polich, 1987b). So, the results of this study shows that, this automatic stimulus evaluation could have been done at P_z first and then at C_z site showing an increased latency at C_z site.

A comparison of the latency of P_{300} at C_z site in active condition and passive condition showed a longer latency in active condition than that recorded in passive condition. But the difference was not statistically significant at 0.05 level (probability value was 0.12). At P_z also, the latency in active condition was longer than that of passive and this difference was statistically significant at 0.01 level. These results contradict the report of Pfefferbaum, et al. (1985) and Polich (1989) who observed that there was no change in latency when P_{300} was recorded in the passive condition. This could have been because of the difference in the methodology and stimuli used in the two studies. Pfefferbaum et al. (1985) used an imperative stimuli 'to warn' the subject to respond or not to respond, whereas in this study, the subjects were not given any warning stimuli. In the investigation by Polich (1989) the target stimuli used was not completely randomized within the series of non-target stimuli, allowing some degree of predictability of the target, whereas, in the present study, the target stimuli were completely randomized within the series of non-targets stimuli.

In the present study, latency of P300 in active condition was prolonged when compared to the passive condition possibly because of subject's evaluation of the stimulus, like recognition of the target and discriminating it from the non-target in the active condition. Because the passive paradigm did not demand any stimulus evaluation from the subject's part, the latency of the P300 obtained, could have been lesser. It has been reported in the literature that there is an increase in latency with increased stimulus evaluation time (Kutas, McCarthy and Donchin, 1977; Ritter, Simson, Vaughen, and Friedman 1979).

(ii) Amplitude

Table-5: Mean and SD value of amplitude of P300 obtained at C_z and P_z site for passive condition.

	Males		Females		Combined group	
	C_z	Pz	C_z	P_z	C_z	Pz
Mean (in uv)	2.59	2.37	3.69	2.99	2.93	2.67
SD (in uv)	1.41	1.42	1.47	1.36	1.46	1.4

The mean amplitude for the male group at C_z was found to be 2.59 uv with a SD of 1.41 uv and at P_z, it was 2.37 uv with a SD of 1.42 uv whereas for female group, the mean was found to be 3.69 uv at C_z with a SD of 1.47 uv and at P_z the mean was 2.99 uv with a SD of 1.36 uv. There was no significant difference between the two groups (probability value at C_z was 0.163 and at P_z was 0.3). The mean of the combined group at C_z was 2.93 uv with a SD of 1.46 and a range between 1.18 uv to 6.36 uv. At P_z, the mean amplitude was 2.67 uv with an SD of 1.4 and a range between 0.35 uv to 6 uv. A comparison of amplitude of P_{300} recorded from C_z and P_z site revealed greater amplitude at C_z site than P_z site in this condition. But this difference was not statistically significant (probability level was 0.852).

At C_z site, the mean amplitude between active and passive conditions were compared and the results revealed greater amplitude in active condition which was statistically significant at a 0.0002 level. At P_z site also, the active condition amplitude was significantly greater than passive condition at 0.001 level. A lowered amplitude in the passive condition as compared to active condition could be, due to the increased attention and task relevancy involved in active condition. This is in concurrence with the results of study by Polich (1986) and Pfefferbaum, et. al. (1985).

(iii) Morphology

In the passive condition, at C_a out of fifteen females studied, six did not show P_{300} waveform. Among the remaining subjects, five showed single peak and four bifid; seven showed sharp peak and two broad peak and seven had clear waveforms while two were noisy. Similarly, at P_z site, nine had P_{300} response whereas the same six subjects did not show any peak. Of the nine subjects, six had single peak whereas three had bifid peaks; six had sharp peaks and three had broad peaks. In this condition, all nine had clear peaks.

Amongst males, two subjects did not show any P_{300} whereas thirteen had P_{300} waveforms. Of the thirteen, eight had single peak at C_z and five had bifid form; eleven had sharp peak whereas two had broad one and twelve had clear waveforms whereas one had noisy waveform. At P_z, eight had single peak, and five had bifid peaks, nine had sharp peaks and three had broad ones and twelve were clear whereas one was noisy.

Comparison of the morphology of P_{300} waveforms elicited in the two conditions revealed absence of P_{300}, in passive condition in eight subjects even though they had P300 in active condition. Other parameters such sharpness and clarity were variable in both the conditions.

For eight subjects who did not show P_{300} in passive condition, the amplitude of P300 elicited in the active condition at P_z recording site was also less than the mean amplitude and was variable at C_z site. It is also evident that the amplitude of P_{300} is generally less in the passive condition than in the active condition. Hence, in these eight subjects, the amplitude in passive condition was probably so less that it was masked by the physiological noise.

To summarize, passively elicited P300 was similar in morphology to that elicited in active condition, with a reduced latency and amplitude (as shown in figure 1 and 2). It also shows that P_{300} recorded at C_z site was more robust than at P_z site in both the conditions. But P300 elicited in the passive condition is variable amongst the reported studies because it depends on the test protocol and stimuli used.

Dept. of Audiology, All india Institute of Speech and Hearing
Manasa Gangothri
Mysore, Karnataka
Tel: 0821-514449

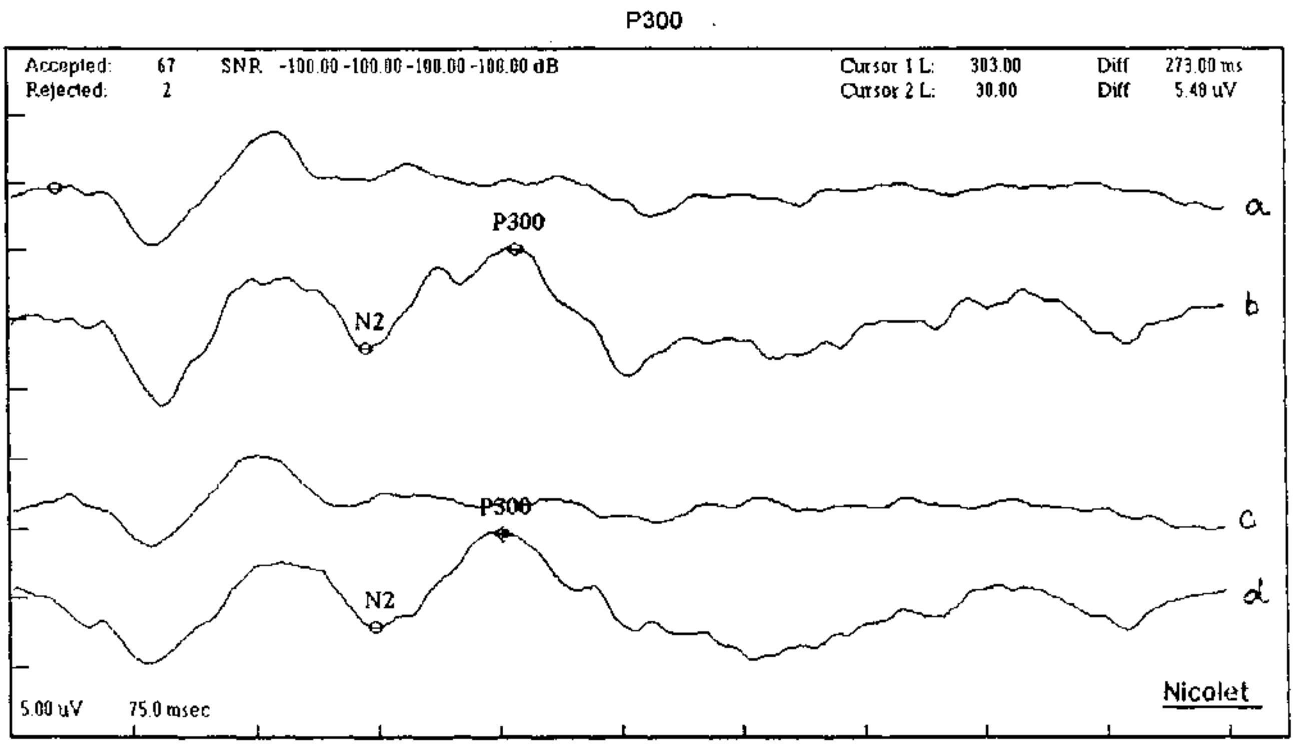

Figure 1: P_{300} elicited in the active paradigm

Wave a - Response for frequent stimuli recorded from C_z.
Wave b - Response for infrequent stimuli recorded from C_z
Wave c - Response for frequent stimuli recorded from P_z.
Wave d - Response for infrequent stimuli recorded from P_z

Dept. of Audiology, All india Institute of Speech and Hearing
Manasa Gangothri
Mysore, Kamataka
Tel: 0821-514449

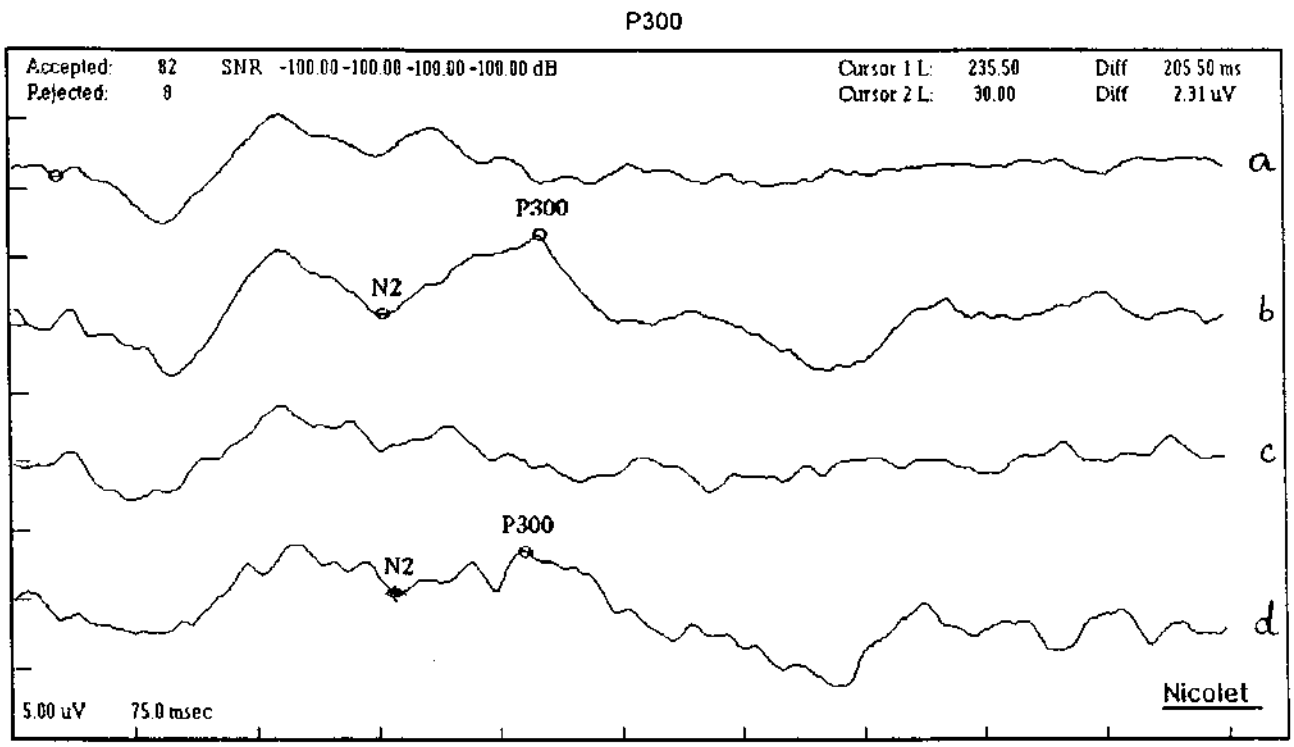

Figure 2: P_{300} elicited in the passive paradigm

Wave a - Response for frequent stimuli recorded from C_z.
Wave b - Response for infrequent stimuli recorded from C_z.
Wave c - Response for frequent stimuli recorded from P_z.
Wave d - Response for infrequent stimuli recorded from P_z

SUMMARY AND CONCLUSION

The P_{300} is an endogenous positive response which occurs at around 300 msec, latency with an amplitude of about fifteen millivolts (Kraus and McGee, 1994). This peak becomes bimodal i.e. P_{300a} and P_{300b} under certain recording and stimulus conditions (McPherson, 1996). This potential is greatly influenced by alerting, attention arousal, subject's psychological state and it varies with development or aging of the subject. But of the endogenous potentials studied, P300 appears to have the most immediate relevance to clinical audiology especially in the evaluation of disorders affecting cognition and evaluation of auditory processing abilities. (Amongst the clinical population, some patients might find it difficult to understand the instructions and carryout the required task in the traditional active listening condition. So, it would be advantageous if P_{300} could be elicited using a passive paradigm in such cases.

The present study was taken up with the aim to study the P_{300} elicited in the passive condition and to compare the same with that elicited in the active condition. A comparison was also made between the P_{300} elicited in males and females, in both conditions, and also recordings from vertex and parietal electrode sites.

P300 was recorded from thirty normal hearing young adult subjects (fifteen males and fifteen females) using both passive and active paradigms. The equipment used to record P_{300} was Nicolet Bravo System with TDH-39 earphones with MXH-41/AR cushions. The subjects were instructed to relax and not to pay attention to the stimuli during passive paradigm whereas they were requested to count and report the number of randomly occurring high pitched tones during the active paradigm. The stimuli used had a series of nontarget 500 Hz rarefaction toneburst at 80 dB nHL in which the target stimuli, 2000 Hz rarefraction toneburst at 80 dB nHL occurred randomly. 300 stimuli were presented, of which 80% was nontarget, frequent stimuli and 20% was randomized target stimuli. Results were recorded from vertex (C_z) and parietal (P_z) sites for both conditions. The morphology, latency and amplitude of responses were studied.

The following observations were made from the study:

- Morphology was highly variable in both the conditions.
- P300 was absent in eight subjects in the passive condition, although it was present in the active condition.
- P300 elicited in the passive paradigm had significantly longer latency at C_z than at P_z recording site.

- No significant difference was noted in amplitude of P300 recorded from C_z and P_z site in passive listening conditions.
- No significant difference was noted in latency or amplitude of P_{300} recorded from C_z and P_z site in active listening condition.)
- Latency of P_{300} elicited in active condition was significantly longer than the P_{300} in passive condition at the P_z site.
- Similar trend was also seen at the C_z site but the result was not statistically significant.
- Amplitude was greater in the active condition than in the passive condition at both C_z and P_z electrode sites.
- There was no significant difference between males and females with respect to the P_{300} recorded in passive condition and active condition, except for the amplitude of P_{300} recorded from C_z site in the active condition.

Suggestions for further research

- For the passive condition to be clinically applicable, the norms for P_{300} should be established in a bigger population, across various subgroups like children, adults and geriatrics.
- The physiological basis underlying the phenomenon of obtaining or not obtaining P_{300} in subjects when they are passively listening or the scalp distribution of the peak can be studied in future to understand the cognitive response better.
- It can be researched to see if passive P_{300} helps in the identification of those with cognitive problems/central auditory problems.

BIBLIOGRAPHY

Ball, S.S., Marsh, J.T., Schbarth, G., Brown, W.S. & Standburg, R. (1989). Longitudinal P_{300} latency changes in Alzkeimer's disease. Journal of Gerontology; 44(6), 195-200.

Barajas, J.J. (1990). The effects of age on human P_3 latency. Acta Otolaryngologica Suppl. (Stockholm), 476(157), 157-160.

Butcher, J. (1994). Cognitive auditory responses. In J.T.Jacobson (Ed). Principles and Applications in Auditory Evoked Potentials. Massachusetts : Allyn and Bacon.

Courchesene, E. (1978). Neurophysiological correlates of cognitive development : Changes in long latency event-related potentials from childhood to adulthood. Electroencephalography and Clinical Neurophysiology, 45,468-482.

Donchin, E. (1981). Surprise! .... Surprise? Psychophysiology, 18,493-513.

Dunchan-Johnson, C.C. & Donchin, E. (1982). The P_{300} component of the event related brain potentials as an index of information processing. Biological Psychology, 14,1-52, Abstract from www.medline.com

Finley, W.W., Faux, F.S., Hutcheson, J., Amstertz, L. (1985). Long latency event related potentials in the evaluation of cognitive function in children. Neurology, 35, 323-327.

Goodin, D., Squires, K., Henderson, B. & Starr, A. (1978). Age related variations in evoked potentials to auditory stimuli in normal human subjects. Electroencephalography and Clinical Neurophysiology, 44,447-458.

Goodin, D.S. (1990). Clinical utility of long latency 'cognitive' event - related potentials (P_3) : The pros. Electroencephalography and Clinical Neurophysiology. 79(1), 2-5 Discussion 1.

Guruprasad, A. (2000). Evaluation of central auditory processing disorders in children with learning disability. Unpublished Independent Project, University of Mysore, Mysore.

Holcomb, D.T. (1988). Automatic and attentional processing : An event related potential analysis of semantic priming. Brain and Language, 35, 60-85.

Hohnsbein, J., Falkenstein, M., Hoormann, J. & Blanke, L. (1991). Effects of crossmodal divided attention on late evoked response potential components. I. Simple and choice reaction tasks. Electroencephalography and Clinical Neurophysiology, 78, 438-446.

Howard, L. & Polich, J. (1985). P_{300} latency and memory span development. Developmental Psychology, 21, 283-289. Abstract from www.medline.com

Jerger, J., Alford, B., Law, H., Rivera, V. & Chimiel, R. (1995). Dichotic listening, event-related potentials and inter-hemispheric transfer in the elderly. Ear and Hearing, 16, 482-497.

Jirsa, RE. & Clontz, KB. (1990). Long latency auditory event related potentials from children with auditory processing disorders. Ear and Hearing, 11(3), 222-232.

Johnson, R. (1986). A triarchic model of P_{300} amplitude. Psychophysiology, 23, 367-384.

Kileny, P. (1991). Use of electrophysiologic measures in the management of children with cochlear implants brainstem, middle latency and cognitive (P300) responses. American Journal of Otology, 12,37-42.

Kileny, P. & Robertson, C.M.T. (1985). Neurological aspects of infant hearing assessment. Journal of Otolaryngology, 14, (Supple. 14), 34.

Kraus, N. & McGee, T. (1994). Auditory event related potentials. In J.Katz (Ed.). Handbook of Clinical Audiology. Maryland : Williams and Wilkins.

Kutas, M. & Hillyard, S.A. (1980). Reading senseless sentences : Brain potentials reflect semantic incongruity. Science, 207, 203-205. Abstract from www.medline. com

Kutas, McCarthy, G, & Donchin, E. (1977). Augmenting mental chronometry : The P_{300} as a measure of stimulus evaluation time. Science, 197,792-795.

McPherson (1996). Late potentials of the auditory system. Sandiego : Singular Publishing Group, Inc.

McPherson, D.L., Tures, C. & Starr, S.A. (1989). Binaural interaction of the auditory brainstem potentials and middle latency auditory evoked potentials in infants and adults. Electroencephalography and Clinical Neurophysiology, 74, 124-130.

Musiek, F.E. & Baran, J.A. (1987). Central auditory assessment. Thirty years of challenge and change. Ear and Hearing, 8,225-365.

Newton, M., Barrett, G., Callanan, M. & Towell, A. (1989). Cognitive event related potentials in multiple sclerosis. Brain, 112, 1637-1660.

Neshige, R, Barrett, G. & Shibasaki, H. (1988). Auditory long latency event related potentials in Alzheimer's disease and multi-infarct dementia. Journal of Neurology, Neurosurgery and Psychiatry, 51(9), 1120-1125.

Niwa, S., Ohta, M. & Yamazaki, K. (1983). P_{300} and stimulus evaluation processes in autistic subjects. Journal of Autism and Developmental Disorders, 13,33-42.

Okada, Y.C., Kaufinan, L., Williamson, S.J. (1983). The hippocampal formation as a source of the slow endogenous potentials. Electroencephalography and Clinical Neurophysiology, 55, 417-426.

Papanicolaou, A.C., Loring, D.W., Raz, N. & Eisenberg, H.M. (1985). Relationship between stimulus intensity and the P_{300} Psychophysiology, 22,326-329.

Paul, D.D. & Sutton, S. (1972). Evoked potential correlates of response criterion in auditory signal detection. Science, 177, 362-364.

Pfefferbaum, A., Ford, J.M., Weller, B.J. & Kopell, B.S. (1985). Evoked related potentials to response production and inhibition. Electroencephalography and Clinical Neurophysiology, 60, 423-434.

Picton, T.W., Stuss, D.T., Champagne, S.C. & Nelson, R.F. (1984). The effects of age on human event related potentials. Psychophysiology, 21,312-326.

Polich, J. (1987). Task difficulty, probability and inter-stimulus interval as determinants of P_{300} from auditory stimuli. Electroencephalography and Clinical Neurophysiology, 68, 311-320.

Polich, J. (1987b). Comparison of P_{300} from a passive tone sequence paradigm and an active discrimination task. Psychophysiology, 24,42-46. Abstract from www.medline.com

Polich, J. (1989). P_{300} from a passive auditory paradigm. Electroencephalography and Clinical Neurophysiology, 74(4), 312-320.

Polich, J. (1986). Attention, probability and task demands as determinants of P_{300} latency from auditory stimuli. Electroencephalography and Clinical Neurophysiology, 63, 251-259.

Polich, J., Howard, L. & Starr, A. (1985a). Effects of age on the P_{300} component of the event related potential from auditory stimuli, peak definition, variation and measurement. Journal of Gerontology, 40, 721 -726. Abstract from www.medline.com

Polich, J., Howards, L. & Starr, A. (1985b). Stimulus frequency and masking as determinants of P_{300} latency in event related potentials from auditory stimuli. Biological Psychology, 21, 309-318. Abstract from www.medline.com

Price, R.L. & Smith, D.B.D. (1974). The P_{300} wave of the average evoked potential : A bibliography. Physiological Psychology, 2, 387-391.

Radhika, A. (1998). Auditory late latency potentials in learning disabled children. Unpublished Independent Project, University of Mysore, Mysore.

Ritter, W., Simson, R., Vaughen, H., and Friedman, D. (1979). A brain event related to the making of a sensory discrimination. Science, 203,1358-1361.

Ruschkin, D.S. & Sutton, S. (1994). Event related potential evidence for verbal working memory deficit in multiple sclerosis. Brain, 117, 289-293.

Saravanan, E. (1997). Age related changes in P_{300} Unpublished Independent Project, University of Mysore, Mysore

Selinger, M, Prescott, T. & Schucard, D. (1989). Auditory event related potential probes and behavioural measures of aphasia. Brain and Language, 36,377-390.

Simson, R., Vaughen, H. & Ritter,W. (1978). The scalp topography of potentials in auditory and visual discrimination tasks. Electroencephalography and Clinical Neurophysiology, 42, 528-535.

Snyder, E., Hillyard, S.A. & Galambos, R. (1980). Similarities and differences among the P_3 waves to detected signals in three modalities. Psychophysiology, 17, 112-122.

Sponberg, T. & Decker, T.N. (1990). Auditory P_3 latency and amplitude relation to earlier exogenous auditory events. Scandinavian Audiology, 19,73.

Squires, N.K. Squires, K.C. & Hillyard, S.A. (1975). Two varieties of long latency positive waves evoked by unpredictable auditory stimuli in man. Electroencephalography and Clinical Neurophysiology, 38, 387-401.

Squires, N.K., Donchin, E., Squires, K.C. & Grossberg, S. (1977). Bisensory stimulation : Inferring decision related processes from the P_{300} component. Journal of exceptional Psychology Human Perception and Performance, 2, 299-315. Abstract from www.medline.com

St,Clair, D., Blackburn, I., Blackwood, D. & Tyrer, G. (1988). Measuring the course of Alzimer's disease. A longitudinal study of neuropsychological function and changes in P3 event related potential. British Journal of Psychiatry, 152(48), 48-54. Abstract from www.medline.com

Sutton, S., Baren, M., Zubin, J. & Joh, E.R. (1965). Evoked potential correlates of stimulus uncertainty. Science, 150,1187-1188.

Woodword, S.H., Owens, J. & Thompson, L.W. (1990). Word to word variation in event related potentials, component latencies spoken words. Brain and Language, 33,488-503.