AUDIO – VISUAL INTERACTION IN P300

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May 2012.

DEDICATED TO MY ACHAN, AMMA & TO MY GUIDE

CERTIFICATE

This is to certify that this dissertation entitled **'Audio-visual interaction in P300'** is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No.: 10AUD001. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **'Audio-visual interaction in P300'** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled **'Audio-visual interaction in P300'** is the result of my own study under the guidance of Dr. Sandeep M. Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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Chapter 1

INTRODUCTION

P300 is an endogenous component of the human event related potential (ERP) that has been studied extensively in both clinical and experimental settings. The most frequently used paradigm in P300 research has been the two-stimulus oddball task, in which a participant must discriminate between infrequent target and frequent non target stimuli. In these paradigms, the infrequent, task-relevant target stimulus is associated with large P300 components with maximal amplitude at posterior electrodes. The classical P300 component or P3b, which occurs 300-600msec after a target stimulus in oddball paradigms and has a parietal distribution on the scalp, has been linked to the cognitive processes of context updating, context closure, and event-categorization (Donchin & Coles, 1988; Verleger, 1988; Kok, 2001), whereas the slightly earlier P3a, which has a frontocentral distribution, has mainly been associated with the orienting response (Friedman, Cycowicz & Gaeta, 2001).

Amplitude, latency and age dependency of the P300 wave also varies with electrode site. Analysis of the topographic distribution of P300 latencies demonstrated that P300 latency was dependent on electrode location. P300 scalp distribution is characterized by amplitude change over the midline electrodes (F_z, C_z, P_z) that increases from the frontal to the parietal electrode sites for target stimuli (Johnson, 1993). 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.

Visual influences in the auditory cortex would result from feedback projections from polysensory areas (Calvert, Campbell, & Brammer, 2000; Miller and

D’Esposito, 2005), particularly from the superior temporal sulcus. In the speech domain, several studies have shown that auditory event-related potentials (ERPs) can be altered by visual speech cues as early as the N1 stage (Besle, Fort, Delpuech, & Giard, 2004; Mottonen, Schurmann, & Sams, 2004; Wassenhove, Grant & Poeppel, 2005) that is, during the building of an auditory neural representation (Naatanen & Winkler, 1999).

Talsma, Dotty and Woldorff (2007) reported that when attention was directed to both auditory and visual modalities simultaneously, audio-visual interaction occurred in early sensory processing. When only one modality was attended, the interaction processes was delayed to late processing stage.

1.1 Justification for the Study

In humans, cross-modal enhancement of neural activity has been demonstrated using electrophysiological recordings (Giard & Peronnet, 1999; Foxe, Morocz, Murray, Higgins, Javitt & Schroeder, 2000) and neuro imaging measures (Calvert, Campbell & Brammer, 2000). Also, various behavioral studies have shown that behavioral responses to auditory (A) and visual (V) stimuli are improved when those stimuli are accompanied by a task-irrelevant stimulus in a different modality, such that bimodal audio-visual (AV) stimuli are detected and discriminated more accurately than either visual or auditory unimodal stimuli (Odgaard, Arieh & Marks, 2004; Lippert, Logothetis & Kayser, 2007).

One of the advantages of ERP recordings is that the precise time course of cross-modal integration can be studied in different brain areas. Considering that the event related cortical auditory potentials are influenced by cognition, information from the visual mode may influence their generation. Although it is clear that audio-visual integration enhances speech perception, the neuro-physiological basis of it is yet to be completely explored. The P300 being the first true event related potential, is expected to show changes with polysensory stimulation. As the investigations pertaining to this are lacking, the present study is taken up. Further, the study aims to explore the influence of unimodal versus bimodal stimulation on the scalp distribution of the P300 which is not known till date.

1.2 Objectives of the Study

There were 2 specific objectives of the study:

1. To study interaction in the processing of auditory and visual stimuli in the generation of P300.
2. To study the latency and amplitude differences across the electrode sites to determine the scalp distribution.

Chapter 2

REVIEW OF LITERATURE

Auditory evoked potentials (AEPs) are electrical potentials generated within the auditory system when evoked by an external auditory stimulus. On the basis of underlying mechanism of generation AEPs can be classified as endogenous responses and exogenous responses. Exogenous responses consist of potentials like ABR, MLR, P60, N100, P160, T- Complex and certain components of LLR. Endogenous response on the other hand consists of potentials like N200, P300, N400, P500, CNV and Processing Negativity.

Exogenous responses depend primarily on the physical parameters of the eliciting stimuli and change depending on the dimensions of the external stimuli (Donchin, Ritter & McCallum, 1978). Endogenous responses on the other hand depend on the inherent factors like cognition (Donchin, Ritter & McCallum, 1978; Desmedt & Debecker, 1979).

The cognitive aspects of the evoked potentials are highlighted through the use of the term event-related potentials (ERPs). It reflects mainly sensory processing during which the performance of a given task results in change in the content of thought and the attentional resources allocated. P300 is one such event related response described as 'cognitive evoked response' as its presence depends on the discrimination between frequent versus infrequent stimuli, attention to infrequent stimulus and memory (Sutton, Braren, Zubin & John, 1965).

To evoke P300, a unique paradigm called odd-ball paradigm is used. In an odd ball paradigm, a series of one type of frequent stimuli (standard stimulus) is presented along with a different type of infrequent (target) stimulus (Squires, Wickens, Squires, & Donchin, 1976) in which the subject has to react to the presence of infrequent stimulus (Donchin, et al., 1978). P300 is produced whenever the subject attends to the infrequent stimulus (target stimulus).

Context updating theory described by Polich (2007) on the generation of P300 is illustrated in the Figure 2.1. The theory represents the underlying brain activities involved during the revision of mental representation for the stimulus in an odd ball paradigm (Donchin, 1981). After the initial sensory stimuli, an attention driven comparison evaluates the representation of the previous event in the working memory. If no stimulus change is detected, current schema of the stimulus context is maintained and only sensory potentials are evoked, where as detection of stimulus change results in 'updating' of neural stimulus representation of the initial stimuli in the working memory, producing P300. Thus discriminating a target from the standard stimulus produces a robust P300. The stimulus change may be in different parameters of sound such as intensity, frequency and duration.

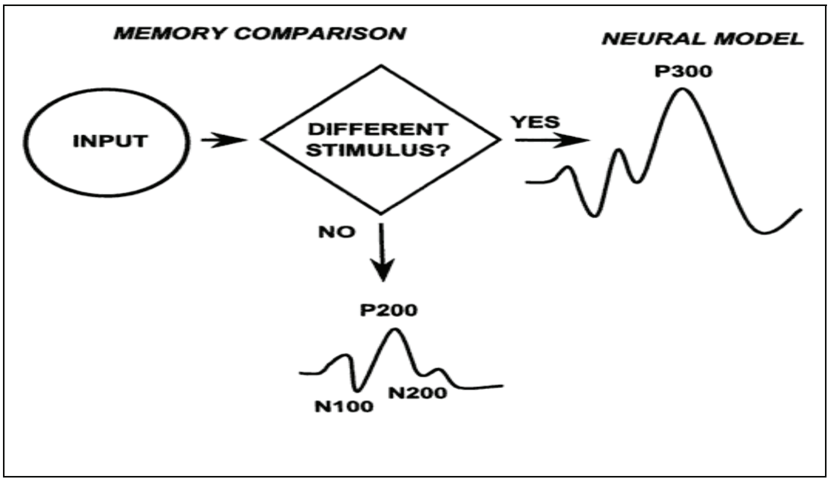

Figure 2.1: Illustration of P300 context updating model given by Polich (2007).

2.1 Components of P300

Broadly, there are two important latent components of P300. Although these are merged into a single wave in some individuals, a sub group may show a bifid wave with two distinct peaks. A P300 response elicited during passive listening is called as P3a (Polich, 1989) and the P300 elicited when the subject is actively attending to infrequent stimuli is called P3b. The latency of P3a component is shorter, occurring around 50ms earlier than P3b (Knight, 1996) and its amplitude is smaller with rapid habituation than conventional attention-dependent P3b. P3a can be observed during an odd ball paradigm in 10-20% of normal young adults (Polich, 1988).

P3a has a frontocentral distribution and is mainly associated with the orienting response (Friedman, Cycowicz & Gaeta, 2001). The P3b component, occurring at 300-600ms after a target stimulus in oddball paradigms has a parietal distribution on the scalp, which represents cognitive processes of context updating, context closure, and event-categorization (Donchin & Coles, 1988; Verleger, 1988; Kok, 2001).

Depending on the paradigm used and the subject population, latency of P3b can vary between 250 and 600ms (Donchin, Ritter & McCallum, 1978; Snyder, Hillyard & Galambos, 1980), 220 and 380 ms (Hall, 1992) and 220 and 300 ms (Polich 1988).

2.2 Generators and Scalp Distribution of P300

Understanding the generator sites of P300 is essential as the knowledge regarding the generator sites of P300 can provide insight regarding the various underlying cognitive process. Through various methods like intracranial recordings, lesion studies and functional imaging studies, it has been found that the brain areas involved in the generation of P300 is complex with the simultaneous activation of multiple overlapping sites.

P300 is broadly distributed with maximum amplitude observed at the mid line over centro-parietal area and amplitude decreases as the non inverting electrode is placed towards more anterior sites (Polich et al, 1997). The maximum moves slightly depending on the task. For detection task P300 is maximum at frontal-central & for discrimination tasks, its largest just posterior to the vertex (Simon, Vaughen & Ritter, 1976).

Johnson (1993) found that P300 scalp distribution is characterized as the amplitude change over the midline electrodes (F_z, C_z, P_z) that increases from the frontal to the parietal electrode sites for target stimuli. Figure.2.2 illustrates the amplitude variation of P300 across different electrode sites (Cited in Electrically evoked auditory cortical event related potentials by Beynon, 2005).

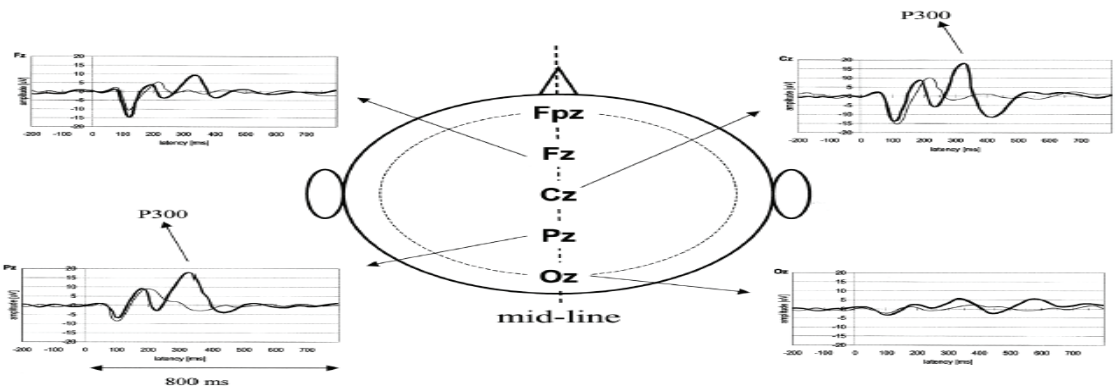

Figure.2.2: The amplitude variation across the electrode sites (Fz, Cz, Pz & Oz) in a normal subject (Cited in Electrically evoked auditory cortical event related potentials by Beynon, 2005).

Buchwald (1990) found that areas involved in the generation of P300 to be the primary auditory cortex and the polysensory association cortex. While Picton and

Hillyard (1974) reported P300 response can also be seen in the temporo-parietal association cortex. Harrison, Dickerson, Song and Buchwald (1990) examined the role of polysensory association cortex, assumed to be important in human P300 generation.

Knight (1996) reported interaction between frontal lobe and hippocampal temporo-parietal function to be important for P300. Gordon, Rennie and Collins (1990), using MEG found that the generator sites of auditory P300 are either in temporal cortex or hippocampus.

Linden (2005) found that P300 target-related responses were seen in the parietal cortex and the cingulated. The novelty-related activations were found in the inferior parietal and prefrontal regions. Stimulus modality-specific contributions are reported to also come from the inferior temporal and superior parietal cortex for the visual and from the superior temporal cortex for the auditory modality.

The contributing generators also depend on the mode of stimulation. Downar, Crawley, Mikulis and Davis (2000) identified brain regions responsive to changes in visual, auditory and tactile stimuli for unimodal and multimodal stimulus conditions. Unimodally responsive areas comprised of visual, auditory and somatosensory association cortex whereas multimodally responsive areas encompassed of right-lateralized network including the temporoparietal junction, inferior frontal gyrus, insula, left cingulate and supplementary motor areas. Figure 2.3 represents brain areas activated to independent changes in visual, auditory and tactile stimuli for unimodal and multimodal stimulus conditions.

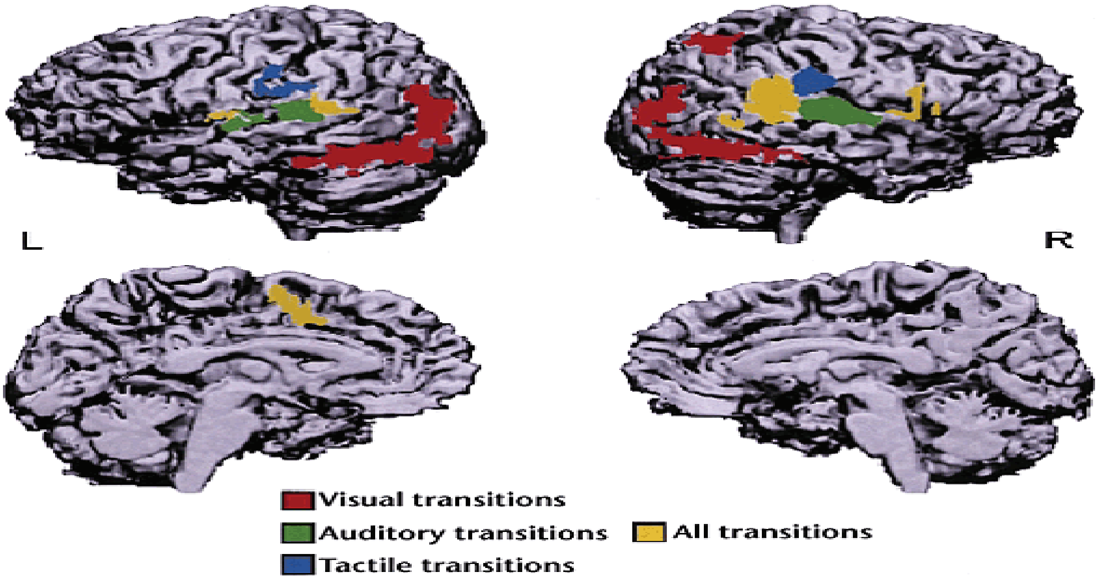

Figure 2.3: Illustrates brain regions activated by transitions of the visual, auditory and tactile stimuli during P300 recording (Downar, Crawley, Mikulis & Davis, 2000).

2.3 Variables Affecting P300

Both stimulus and subject related factors affect P300. The following two subsections separately review in brief about the influencing factors.

2.3.1 Stimulus related factors

2.3.1.1 Stimulus modality

The event-related P300 potential component is not modality-specific i.e., any sensory modality can be used to elicit the P300 response. In descending order of clinical use these are: auditory, visual, somato-sensory, olfactory or even taste stimulation (Polich & Pitzer, 1999). The shape and latency of the P3 wave differs with each modality. For example, in auditory stimulation, the latency is shorter than in visual stimulation (Katayama & Polich 1999). This indicates that the sources generating the P3 wave differ and depend on the stimulus modality (Johnson, 1989).

P300 varies with respect to the modality through which the response is elicited, like auditory modality, visual modality or any other language based modality. Picton, Stuss, Champagne and Nelson (1984) reported that the P300 evoked by visual stimulus was delayed by approximately 90ms than that of auditory stimulus which was explained by the difference in the transmission time to the cortex. The P300 component evoked by somato-sensory signal was delayed and larger than auditory or visual stimuli.

Knott et al. (2003) investigated the effects of stimulus modality on P300 in young and elderly adults. Larger P300 amplitude was obtained while using visual stimuli to elicit P300 compared to that of auditory stimuli in both the populations. Similar to Picton et al. (1984), the latency of P300 was prolonged with visual mode of stimulus presentation.

There is an interaction of age effect with modality effect. Johnson (1989) evaluated the effects of stimulus modality in young and older children using auditory and visual modality. ERPs were collected using two different tasks (count and reaction time) in an oddball paradigm. P300 latencies in the auditory modality presented a relatively abrupt change around 12 year of age on an average, thereafter P300 latency changed slightly. But on the other hand latencies of visual P300 presented much slighter and steadier decrease with age. Visual P300 latencies were shorter than auditory P300 in younger children but eventually became larger than auditory P300 in older children. There were no significant changes observed among two modalities in terms of P300 amplitude.

2.3.1.2 Stimulus intensity

Papanicolaou, Loring, Raz and Eisenberg (1985) manipulated the intensities of the stimulus from 15 up to 65 dB in an auditory oddball paradigm to investigate its effect on P300 potential. Intensity variations had an impact on P300 latency, but not amplitude. On the contrary Vesco, Bone, Ryan and Polich (1993) found reduced amplitude along with longer peak latencies at low intensity stimuli. Further intensity effects are seen in both auditory as well as visual modalities (Covington & Polich, 1996; Polich, Ellerson & Cohen, 1996).

2.3.1.3 Stimulus probability

The P300 response is optimally evoked by unpredictable, infrequent acoustic stimuli presented randomly with a probability of 15 to 20% in an odd ball test paradigm. The probability in P300 measurement usually recommended is 80% for standard & 20% for target stimuli. Figure 2.4 illustrates P300 response obtained for tonal contrasts with the standard stimulus being 500 Hz (85%) probability and deviant stimulus being 1000 Hz (15%) probability (Beynon, 2005).

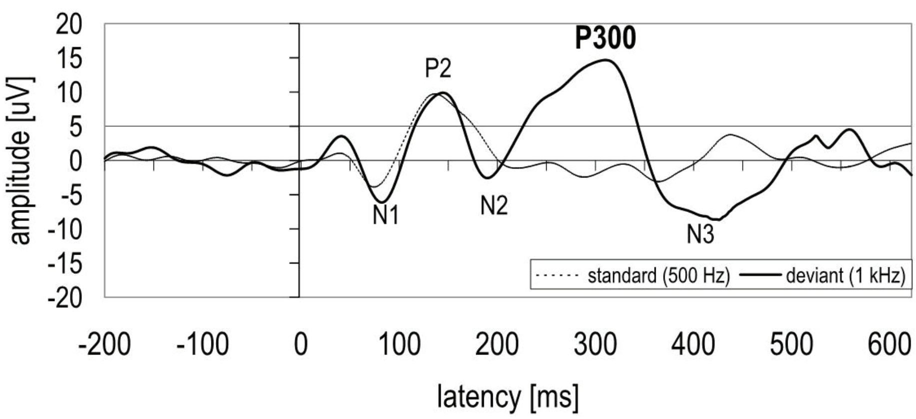

Figure 2.4: Illustrates P300 response obtained for tonal contrasts with the standard stimulus being 500 Hz (85%) probability and deviant stimulus being 1000 Hz (15%) probability (Cited in Electrically evoked auditory cortical event related potentials by Beynon, 2005).

Polich (2003) found that decrease in stimulus target probability generally increased the P300 amplitude and lengthened the peak latency, which was more evident in easy tasks than difficult tasks.

2.3.1.4 Target-to-Target Interval

P300 amplitude for a target in the oddball task increases as the number of consecutive standards preceding the target increases. That is, P300 amplitude to a target preceded by a single standard is relatively small, whereas amplitude to a target preceded by several standards is relatively large. More importantly target-to-target interval of 6 to 8s or greater eliminates the probability effects (Polich, 1990).

Gonsalvez and Polich (2002) manipulated the number of preceding non target stimuli (0, 1, 2, 3) and inter stimulus interval (1, 2, 4 s) in order to systematically assess target to target interval affects on P300 values using auditory and visual stimuli. In the results increase in P300 amplitude was seen with increasing non target sequence length for both auditory and visual stimuli when ISI is constant. Increasing non target sequence length also demonstrated a reliable decrease in P300 latency for both auditory and visual stimuli and was shorter for auditory than visual stimulus conditions.

2.3.1.5 Passive versus active task

P300 is elicited either in a passive mode or active mode. In a passive mode subject does not pay attention to the stimulus while in active mode, he/she is asked to selectively attend to the target, infrequent stimulus.

Bennington and Polich (1999) compared effect of passive and active task on P300 for auditory and visual stimuli. P300 amplitude was larger in active task conditions (raising finger) than passive ones (day dreaming) and, for the auditory stimuli than visual stimuli but the scalp topography did not vary reliably in general for task conditions and stimulus types. P300 latency was shorter for the auditory compared to visual stimulus conditions even so, latency shifts with respect to task difficulties were not significant in either of the stimulus conditions. P300 amplitude for the stimulus-sequence paradigm is smaller and latency is shorter in passive listening conditions, with auditory stimuli being the stronger stimuli to evoke better P300.

Polich (1998) found that amplitude of P300 component declines with repeated stimulation during passive discrimination of standard/target stimuli as size of ERP component depends on the amount of change required to update the memory representation.

2.3.1.6 Task difficulty

P300 latency becomes longer, amplitude becomes smaller as the difficulty of the listening increases (Katayama & Polich, 1998). Highly novel target produces larger amplitude and short latency response (Ritter, Simpson, Vaughan & Macht, 1982). Latency of P300 which measures the stimulus evaluation time depends on the processing required for particular task i.e. latency is relatively short when task is easy and long when task is difficult.

Polich (2003) conducted a study on auditory P300 by manipulating combinations of stimulus target probability (10% versus 30%), task difficulty (easy versus hard), and inter-stimulus interval (5s versus 2s). Results showed that easy tasks experiments elicited larger amplitude and reduced peak latency of P300 when compared to that of difficult task experiments.

2.3.1.7 Sound environment

Arikan, Devrim, Oran, Inan, Elhih and Demiralp (1999) found distinct differences in the P300 response when recordings are made with the stimulus presented in the silent environment versus in background noise. Nature of the background sound, white noise versus culturally significant music can influence P300. When the P300 is recorded with frequent versus rare stimuli presented in competing noise, amplitude is usually reduced directly as a function of the SNR.

2.3.2 Subject related factors

Some of the important subject related factors that influence P300 are given below.

2.3.2.1 Attention

McPherson and Salamat (2004) found a direct relation between inter stimulus interval (ISI) and, both behavioral reaction time and P300 latency. Longer ISIs was associated with longer reaction times and prolonged P300. Hence it was concluded that P300 latency is a reflection of information processing time.

In dual task paradigm, Singhal, Doerfling and Fowler (2002) found that subject performance for visual task during auditory P300 measurement involving a dichotic listening task was associated with decreased amplitude of P300. As difficulty of the visual task increased attention was allocated more to visual modality, amplitude of P300 reduced. Polich (1987) demonstrated that P300 latency was longer and amplitude larger when the subject silently counted the target signals versus when the subject pressed a button with a thumb.

The P300 amplitude which reflects the amount of attention allocated to a given task (Donchin & Coles, 1988) can show maximum values of about 20µV. There is an inverse relationship between the subjective probability of the stimulus and the P300 amplitude (Duncan-Johnson & Donchin, 1977; Donchin & Heffley, 1979). Therefore, the P300 amplitude is often seen as a measure of central nervous system activity in the attentional processing of incoming information in a context (Donchin & Coles, 1988; Polich, 1998).

2.3.2.2 Sleep

Cote (2002) found that P300 recorded with Fz electrode sites is absent in stage I & II. In Stage I and rapid eye movement (REM sleep-Vth stage where brain is active with posterior electrodes similar to awakened state), P300 was obtained while P300 was not apparent during stage II. Koshino, Nishio, Omoroi, Murata, Sakamoto & Isaki (1993) reported amplitude of P300 decreases and amplitude increases during the transition from alert awake state to drowsiness and the to sleep stage I. P3a can be consistently recorded in sleep (Atienza, Cantero & Escera, 2001). Sleep deprivation increases latency & reduces amplitude of P300 (Danos, Kasper, Scholl, Kaiser, Ruhrmann, Hoflich & Moller 1994).

2.3.2.3 Body temperature

Geisler and Polich (1992) conducted an experiment to understand the impact of body temperature on P300 latency and amplitude. Negative correlation between peak latency of P300 and body temperature was found, where as on an average peak latency was minimal when body temperature was 38 degree Celsius. In general, there was a decrease in latency of P300 up to 100 ms (from 350 ms to 250 ms) when body temperature was increased from 35.5 to 38 degree Celsius. But there was no significant change observed in the amplitude of P300.

2.3.2.4 Motivation

Johnson (1986) found that attaching monetary value to correct identification of target signal produces larger P300. Larger amplitude of P300 was obtained for motivational instructions than neutral ones.

2.3.2.5 Memory

Memory updating for target signal is required as standard forms good representation. Stimuli that were made distinctive were more likely to be recalled and elicited larger P300 components during encoding than those that were not recalled. However, P300 size was directly affected by the rehearsal method, such that component amplitude was larger to the items subsequently recalled if participants used rote rather than a semantic strategy (Fabiani, Karis & Donchin, 1986).

Johnson, Pfefferbaum and Kopell (1984) studied the relationship between P300 and long-term memory. Their subjects were presented with a list of target words, called Study series, which were supposed to be memorized. These words were later tested for recognition by presenting it along with new, distractor words. On completion of these behavioral tasks, P300 were recorded using target stimuli alone initially with a probability of 1.0. Later on both the target words and distractors presented repeatedly to investigate the effect of repeated presentation on long-term recognition memory. Results of the study revealed larger P300 amplitude for target words in general in its initial presentation and shorter latency for those target words which were memorized by the participants in the behavioral task. With repeated presentation of target words, the amplitude of P300 increased gradually by maintaining the latency constant. During test series, with repeated presentation of target words P300 amplitude increased and latency shortened when compared to that of distractor words. Those words which were recognized frequently elicited larger and earlier P300 than those were recognized less frequently. These findings illustrate the impact of repetition of target on memory tracing of the individual which in turn trigger larger and earlier P300.

Lawrence and Polich (1985) reported the correlation between memory and P300. Increase in memory span, measured using WAIS digit span, was associated with decreases in peak latency for children. This suggests that the rapid increase of memory span with development has been attributed to increases in the efficiency with which children can process information.

2.3.2.5 Drugs

Lorist, Snel and Kok (1994) studied the effect of caffeine on P300 using visual stimuli. Results showed that mental fatigue due to deprivation produced a significant reduction in amplitude of P300 and prolongation of peak latency. Caffeine was found to increase P300 amplitude as it resulted in boosting up of the CNS activity, and it eliminated the difference in P300 latency between the fatigued and rested subjects which was evident in placebo conditions.

Studies on effect of acute intake of ethanol on P300 reported a shift in neural generator site of P300 to more inferior position in the brain (Lukas, Mendelson, Kouri, Bolduc & Amass, 1990). Decrease in P300 amplitude due to alcohol intake was prominent over the right hemisphere compared to that of left hemisphere (Porjesz & Begleiter, 1981).

2.4 Audio-visual Interaction in P300

One of the advantages of ERP recordings is that the precise time course of cross-modal integration can be studied in different brain areas. Considering that the event related cortical auditory potentials are influenced by cognition, information from the visual mode may influence their generation.

An understanding of the timing or order of processing of audio-visual stimuli in the brain provides important information regarding the mechanisms by which skilled reading abilities are acquired and maintained in typically developing individuals. Moreover, the paradigm helps in examining perception and reading in younger populations, and in populations with reading difficulties. For example, if dyslexia stems from difficulties in integrating letters across the auditory and visual domains, it is important to know at what level auditory and visual letter information are integrated in normal readers in order to infer the level at which processing may have been disrupted in individuals with dyslexia (Andres , Cardy & Joanisse, 2011).

Visual influences in the auditory cortex would result from feedback projections from polysensory areas (Calvert, Campbell & Brammer, 2000; Miller & D'Esposito, 2005), particularly from the superior temporal sulcus (STS).

Studies have shown that behavioral responses to auditory (A) and visual (V) stimuli are improved when those stimuli are accompanied by a task-irrelevant stimulus in a different modality, and that bimodal audio-visual (AV) stimuli are detected and discriminated more accurately than either visual or auditory unimodal stimuli presentation (Odgaard, Arieh & Marks, 2004; Frassinetti, Bolognini & Ladavas, 2002).

Raij, Uutela and Hari (2000) investigated the neural representations of audio-visual objects, by recording neuro magnetic cortical responses to auditory, visual, and audio-visually presented single letters. The auditory and visual brain activations first converged around 225 ms after stimulus onset and then interacted predominantly in the right temporo-parietal junction (280-345 ms) and the left (380-540 ms) and right (450-535 ms) superior temporal sulci. These multisensory brain areas, playing a role in audio-visual integration of phonemes and graphemes, participate in the neural network supporting the supramodal concept of a 'letter'. The dynamics of these functions indicate interplay between sensory and association cortices during object recognition.

Watson, Azizian, Berry and Squire (2005) found that the target stimulus (word 'globe') elicited a large P300 component with maximum amplitude related non target stimulus (picture of a 'globe') although the two P300s were morphologically similar.

Li, Wu and Touge (2010) investigated auditory detection enhancement by cross modal audio-visual interaction, by comparing the ERPs elicited by the audio-visual stimuli to the sum of the ERPs elicited by the visual and auditory stimuli. They identified two brain regions that showed significantly different responses: the centro-medial area at 280-300 ms and the right fronto-temporal area at 300-320 ms. This provides ERP evidence that behavioral detection of an auditory stimulus is enhanced by the interaction of auditory and visual stimuli around 300 ms in a polysensory region of the brain. ERP results suggest that the enhanced auditory detection by cross-modal audio-visual interaction originates from late-stage cognitive processing rather than early-stage sensory processing.

Andres, Cardy and Joanisse (2011) investigated the effect of audio-visual congruency on P300 potential. Consonant and vowel letters were presented along with auditory stimuli in congruent and incongruent conditions. Congruency effects were seen for both standard and deviant stimulus with an increase in P300 amplitude and increase in P300 latency in incongruent condition for standards compared to congruent trials. Increase in P300 latency was seen for deviants in incongruent condition which reflects delayed perceptual processing and categorization.

Fort, Delpuech, Pernier and Giard (2002) assessed the effect of unimodal (auditory or visual) and non redundant bimodal condition (auditory & visual) on ERPs. Event-related potential analysis revealed the existence of early (200 ms latency) cross modal activities in sensory specific and nonspecific cortical areas suggesting cross modal interaction for stimulus content which is either redundant or non redundant. Cross modal interaction resulted in facilitation effect (shorter reaction time) for the detection of bimodal stimuli compared to unimodal stimuli.

Talsma, Dotty and Woldorff (2007) reported that when attention was directed to both auditory and visual modalities simultaneously, audio-visual interaction occurred in early sensory processing. When only one modality was attended, the interaction processes was delayed to late processing stage.

2.5 Applications of P300

2.5.1 P300 as an index of cognitive function

In clinical practice, P300 recordings have been applied as a psychophysiological tool in the early diagnosis of several neurological disorders, such as Alzheimer's disease (Olichney & Hillert, 2004), schizophrenia (Heidrich & Strik, 1997; Kirino, 2004), epileptic patients (Caravaglios, Natale, Ferraro, Fierro, Raspanti,

& Daniele, 2001; Wambacq & Abubakr, 2004), traumatic brain injuries (Lew, Slimp, Price, Massagli & Robinson, 1999; Mazzini, 2004), alcoholism and drugs (Polich & Criado, 2006) and also to study the processing of speech in children (Henkin, Kileny, Hildesheimer & Kishon-Rabin, 2008; Newman, Connolly, Service & Mclvor, 2003).

Cognitive skills as attributes of human ERPs can be studied in information processing. Since P300 is one among the most significant ERPs it can be utilized to evaluate the cognitive function in human beings. The most replicable biological marker in schizophrenia is the amplitude reduction in P300 component of ERPs (Ford, 1999).

Huang, Chou, Lo and Cheng (2011) conducted a study on P300 using both visual and auditory stimuli separately in 43 individuals with Schizophrenia and 40 normal control subjects. The results of the study indicated that there was a significant reduction in amplitude and prolongation in latency of P300 in schizophrenic patients compared to that of control group with auditory stimuli (with & without counting conditions) and visual stimuli (without counting) owing to the slowness of controlled cognitive function in individuals with schizophrenia. But there was no significant difference between patients group and control group with visual stimuli (with mental counting) suggesting that the time of mental processing may not be delayed at least with visual stimuli. The task relevant sources of activity changes more specifically with visual stimuli than with auditory stimuli. Hence it suggests the need for integrating audio visual stimuli in clinical evaluation and intervention of individuals with schizophrenia.

Fjell et al. (2008) studied the relationship between P300 brain potentials, cortical thickness and cognitive function in aging using three stimulus visual odd ball paradigm. In the young group, thickness of cortical areas were only weakly related to amplitude or latency of P300 where as P3a amplitude effects were found in the parietal area, the temporo-parietal area and part of the posterior cingulate cortex. Thicknesses of large frontal regions were especially related to P3b latency. Hence it can be concluded that thickness in specific cortical areas can be correlated with scalp recorded P300 in elderly and in turn these relationship supplements our understanding on higher cognitive functioning in elderly.

2.5.2 P300 in the detection of Auditory Processing Disorder

Jirsa and Clontz (1990) assessed auditory processing in children with auditory processing disorders and normal children using P300 and found that there was a significant latency increase for P300 component in processing disordered group. According Mullis, Holcomb, Diner and Dykman (1985) P300 latency is directly related to speed of information processing and CAPD children have difficulties in this area which was reflected as longer P3 latencies.

2.5.3 P300 as an index of neural plasticity

Hassaan (2010) used P300 for the assessment of the progress of CANS function after training in children with auditory processing disorder who received auditory training for auditory temporal processing, auditory memory and auditory attention. P300 was obtained both before and after 8 weeks of training period. Amplitude measure increased significantly in all improved children indicating that P300 amplitude was the strongest reflectance of improvement among both parameters (latency, amplitude). P300 latency which indicates neural conduction time did not shorten after intensive auditory training. The amplitude enhancement paralleled the improvement in central auditory and cognitive abilities.

Kubo, Yamamoto, Iwaki, Matsukawa, Doi and Tamura (2001) recorded P300 postoperatively in 50 post-lingually deaf adult cochlear implantees. The subjects were divided into two groups (fair and good hearing group) of 25 each based on their Consonant Recognition Scores (70% scores as the dividing line). The results of the study indicated that the average latency of P300 was significantly longer in the fair hearing group compared to that of the good hearing group when measured at 1 month post operatively. The follow up study done at 6 month postoperatively again revealed a significant increase in Consonant Recognition Scores and a decrease in P300 latency in both the groups and both these measures were correlated. The findings of this study are suggestive of a new horizon application of P300 where the regular systematic measurement of latency and amplitude of P300 in cochlear implantees post operatively can bring out an objective measure of success of rehabilitation.

Chapter 3

METHOD

The study was based on the hypothesis that cross modal interaction of auditory and visual domain has an effect on the latency and amplitude of P300. The following method was adopted to experimentally investigate interaction in the processing of auditory and visual stimuli in the generation of P300 and also the effect of electrode site on P300.

3.1 Participants

Twenty adults (10 males & 10 females) in the age range of 18 to 25 years participated in the study. All the participants had puretone thresholds within 15dB HL at octave frequencies between 250 and 8000 Hz. Their speech identification scores (SIS) were normal in both quiet and noise (SIS above 90% in quiet & above 60% in noise). All the participants had normal middle ear functioning indicated by A type tympanogram and presence of acoustic reflexes bilaterally. They had normal or corrected-to-normal vision verified using a Snell's chart at a distance of 6 feet. They did not have complaint of any neurological problems.

All the participants were meritorious students from different parts of the country pursuing their bachelor's or master's degree in Speech and Hearing. The participants were screened for central auditory processing disorders using Speech in noise test (SPIN) in which they obtained a score of >60% in both ears. They were blind folded to the purpose of the study and a written consent was taken from each subject prior to testing.

3.2 Instrumentation

Technical equipments were required for preliminary evaluation as well as for the actual experiment. The following were the equipments used in the study.

1. A calibrated Madsen Orbiter – 922 (Version 2) dual channel clinical audiometer was used for pure tone and speech audiometry.
2. A calibrated GSI tympstar immittance meter was used for evaluating middle ear status.
3. Intelligent hearing systems (IHS version 4.3.02) AEP system with smart EP software was used for recording and analyzing P300.
4. A computer with Adobe Audition (Version 1.5) was used for the generation of auditory stimulus.
5. A laptop computer was used for visual stimulus presentation.

3.3 Test Environment

Recording of the stimulus and all the audiological testing were conducted in sound treated rooms where the noise levels were within permissible limits (ANSI.S3.1, 1991). The rooms were also electrically insulated.

3.4 Stimulus and Acquisition Parameters

Auditory and visual stimuli were used for recording P300. The stimuli consisted of two CVC words; /cat/ and /bat/. The two CVC words were chosen as they were minimal pairs and were picturable. A minimal pair was preferred as the two words of the pairs would elicit similar LLRs, which in turn was necessary for better P300 detectability. The pictures of the cat and bat were used as visual stimuli.

The CVC syllables were spoken by an adult native Kannada speaker and were recorded by a unidirectional microphone in a sound treated room. Stimuli were digitally recorded using Praat Software (version 5.1.31) at a sampling frequency of 44,100 Hz and 16 bit digitization. The stimuli were then edited for noise and hiss reduction using Adobe Audition (Version 1.5). They were normalized to the same scaling factor and were edited to restrict the duration to 250 ms.

The two auditory stimuli were presented in Odd ball stimulus paradigm. Stimulus /cat/ was presented frequently while the stimulus /bat/ was presented infrequently. In the audio-visual mode of presentation, visual stimuli which included pictures of /cat/ and /bat/ were presented only with infrequent auditory stimulus-/bat/. Depending on the visual stimuli presented, audio-visual mode was either termed as congruent or incongruent. If picture of /bat/ was presented along with the auditory infrequent /bat/, it was Audio-visual congruent condition. On the other hand, if picture of /cat/ was presented along with the auditory infrequent /bat/, it was Audio-visual incongruent condition. The oddball paradigm involved the presentation of one infrequent after two frequent stimuli.

The auditory stimulus was 250 ms in duration while the visual stimulus was 1000 ms in duration. The visual stimulus was triggered along with the auditory stimuli through an external laptop during audio-visual presentation. The stimulus and the acquisition parameters used to record P300 are given in the Table 3.1.

Table 3.1: Stimulus and acquisition parameters used to record P300

Stimulus parameters			
Stimulus		*Auditory*	*Visual*
	Auditory mode	F Cat	Nil
		I Bat	Nil
	AV congruent	F Cat	Nil
		I Bat	Bat
	AV incongruent	F Cat	Nil
		I Bat	Cat
Intensity	80dBnHL		
Number of sweeps	300		
Repetition rate	Auditory stimulus -1/s Visual stimulus – 1/3s		
Frequent : Infrequent	2:1		
Transducer	ER 3A insert phones		
Presentation ear	Binaural		
Acquisition parameters			
Amplification	50,000		
Filter setting	1-30 Hz EEG filters		
Artifact rejection threshold	+/- 100µV		
Analysis time	-100 to +750ms		
Number of recordings	2		
Electrode montage	*Vertical montage* Positive – Cz, Pz Negative – Linked Mastoids Ground - Nasion		

3.5 Test Procedure

The participants underwent preliminary hearing evaluation before the electrophysiological testing. The preliminary evaluation battery included case history, puretone audiometry, immittance evaluation and speech perception in noise testing. A detailed case history from all the participants was taken to rule out any past or present otological and neurological complaints. Puretone audiometry using modified

Hughson-Westlake procedure (Carhart & Jerger, 1959) was carried out to evaluate pure tone thresholds at octave frequencies from 250 Hz to 8 kHz for air conduction and from 250 Hz to 4 kHz for bone conduction modes.

Immittance evaluation involved tympanometry and acoustic reflex testing. Tympanometry was carried out using 226 Hz probe tone. The peak static admittance and peak pressure were estimated by sweeping the pressure from +200 to -400 dapa. In reflexometry, ipsilateral and contralateral reflex thresholds were measured at 500Hz, 1kHz, 2kHz and 4kHz.

The Speech perception in noise was assessed using standardized monosyllabic words in English developed by Rout and Yathiraj (1996). The words were presented at 40 dBSL (with reference to pure tone average at 500 Hz, 1kHz & 2kHz) at 0 dBSNR and the speech identification scores in percentage was estimated in the two ears.

The actual experimental paradigm involved recording of the P300. Only those individuals who fulfilled all the participant selection criteria served as participants of study. To record P300, the participants were made to sit in a comfortable reclining chair and were asked to relax. The Cz and Pz electrode sites were cleaned with skin preparation gel and the disc electrodes were placed using a conduction paste. Prior to recording P300, an absolute impedance of less than 5 kOhms and relative impedance of less than 2 kOhms was ensured.

The participants were asked to open their eyes and minimize eye blinks of the target EEG to reduce contamination from alpha activity. The participants were instructed to pay attention to the blocks of stimuli which were presented and were asked to mentally count the infrequent stimulus (bat) during the auditory presentation mode. During audio-visual presentation mode, the participants were asked to press an arrow key in a computer keyboard, after hearing each stimulus and to watch the monitor kept in front of subject which displayed the pictures. The visual stimulus would arrive along with infrequent auditory stimulus, and was triggered to the arrow key pressed for the second frequent stimulus. The visual stimulus, although triggered to the second frequent, was displayed along with infrequent stimulus only.

P300 was recorded from Cz and Pz electrode sites, for 3 different stimulus paradigms: The 3 stimulus paradigm included, auditory, audio-visual congruent and audio-visual incongruent. The order of the 3 paradigms was randomly used.

3.6 Response Analysis

The P300 was identified in each participant, for each stimulus paradigm, and at each electrode site. The response was analyzed to note down onset latency, peak latency, offset latency and the peak amplitude. The responses were subjectively analyzed by two experienced audiologists and the average waves recorded for the frequent and infrequent stimuli were compared. P300 was detected in the infrequent wave. The criteria for onset and offset latency were set based on grand averaged waveforms of infrequent stimulus in each modality. A representative recording with target parameters marked is shown in Figure 3.1.

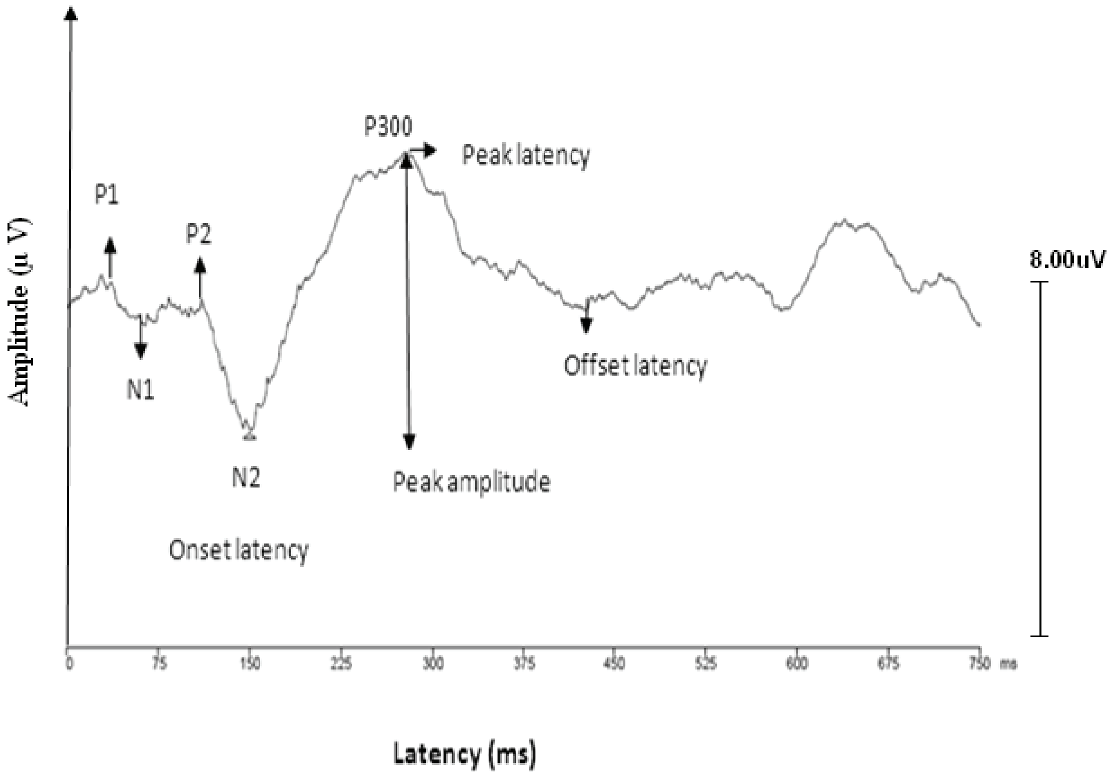

Figure 3.1: A representative wave recorded in auditory modality with the target parameters marked.

Chapter 4

RESULTS

The primary aim of the present study was to analyze the effects of audio-visual interaction on P300 latency and amplitude. The secondary aim was to evaluate the effect of electrode site on P300 latency and amplitude. While statistically testing these effects, presentation mode and electrode site were treated as independent variables, and amplitude and latency of P300 served as dependent variables. The statistical analysis was carried out using Statistical Package for Social Sciences (SPSS version 16) and the following statistical tests were carried out:

1. Descriptive statistics was done to obtain mean and standard deviation (SD) of latency and amplitude of P300 elicited by three types of stimuli, in the two electrode sites. Descriptive statistics were also used to calculate the mean and SD of the AV index of latency and amplitude.

2. Paired t-test was carried out to analyze the effect of electrode site (Cz versus Pz) on the latency and amplitude of P300.

3. Repeated measures ANOVA was done to analyze the effect of stimulus condition on latency and amplitude of the P300. This was done separately for the responses from Cz and Pz electrode sites.

4. Bonferroni post-hoc test was used for pair-wise comparison in instances where there was a significant main effect of the stimulus condition.

5. Pearson correlation co-efficient was determined to analyze the relationship between audio-visual indexes obtained in congruent and incongruent conditions.

For the clarity of presentation, results of the study have been organized under the following headings:

4.1 Effect of electrode site on P300.

4.2 Effect of stimulus condition on P300.

4.3 Correlation of latency index and amplitude index.

4.4 Morphological changes in P300.

4.1 Effect of Electrode Site on P300

The effect of electrode site was tested for both latency and amplitudes of P300. The results are reported separately for the 2 parameters.

4.1.1 Effect of electrode site on latency of P300

There were 3 latency parameters measured in the P300 waves: onset latency, peak latency and offset latency. The effect of electrode site was analyzed for all the 3 parameters. Figure 4.1 shows the mean and standard deviation of the onset latency, peak latency and the offset latency recorded at the Cz and Pz electrode sites.

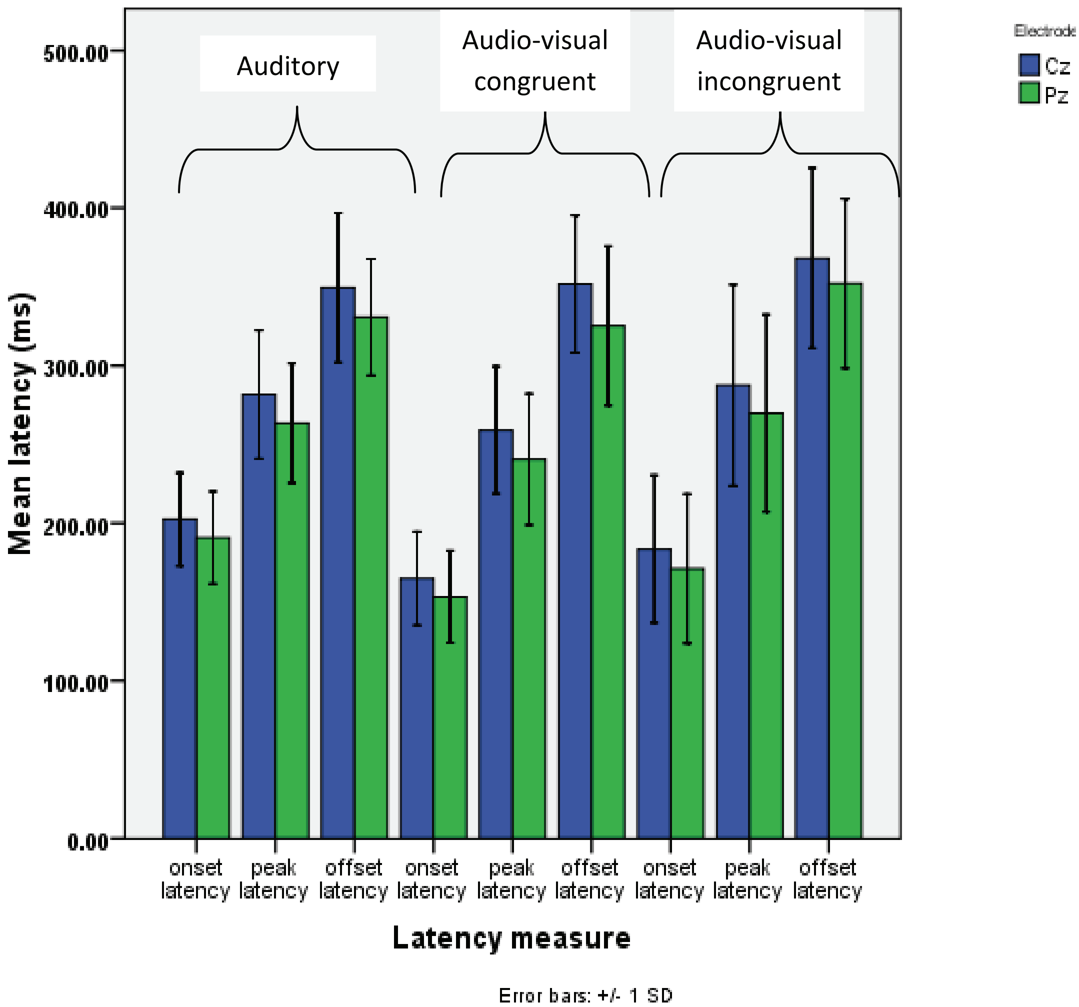

Figure 4.1: Mean and standard deviations of onset latency, peak latency and offset latency of P300 recorded at Cz and Pz electrode sites.

The data showed that the mean latencies of the Cz electrode site were prolonged compared to that in Pz electrode site. This was true in all the three modalities and for all the three latency parameters. The observed mean differences were then tested for statistical significance on paired t-test. The results of paired t-test (Table 4.1) showed that there was a significant difference between the latencies recorded from the 2 electrode sites. This was true in all the three stimulus conditions. Figure 4.2 represents the waveforms for three stimulus conditions across the two electrode sites.

Table 4.1: Results of paired t-test comparing the onset latency, peak latency and offset latency recorded from Cz and Pz electrode sites in the three stimulus conditions

Conditions	**Parameters**	**t value**	**df**
Auditory	Onset latency	6.222*	19
	Peak latency	1.823*	19
	Offset latency	2.618*	19
Auditory-visual (Congruent)	Onset latency	4.062*	19
	Peak latency	2.779*	19
	Offset latency	3.544*	19
Auditory-visual (Incongruent)	Onset latency	3.237*	19
	Peak latency	4.444*	19
	Offset latency	4.309*	19

*Note: *- p<0.05*

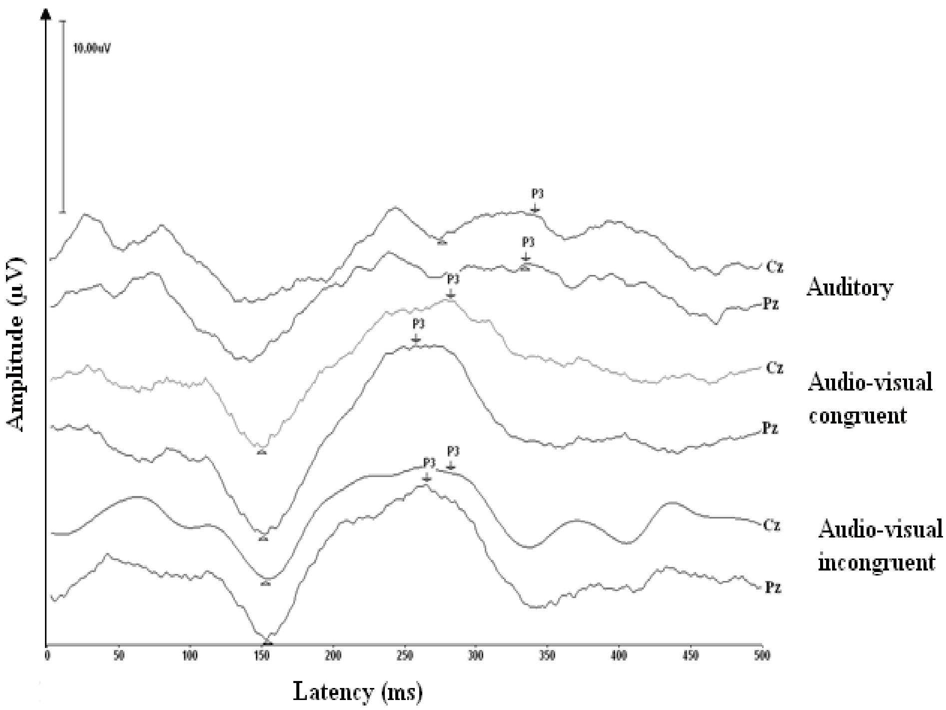

Figure 4.2: Waveforms for three stimulus conditions at two electrode sites.

4.1.2 Effect of electrode site on amplitude of P300

The mean and standard deviation of the peak amplitude of P300 are given in Figure 4.3. The mean amplitudes in Pz were higher than that in Cz in all the three stimulus conditions.

The comparison of mean amplitudes between the two electrode sites was done on paired t-test separately for each stimulus conditions. Results (Table 4.2) showed significant difference between the two electrode sites in their mean amplitudes, in all the three stimulus conditions.

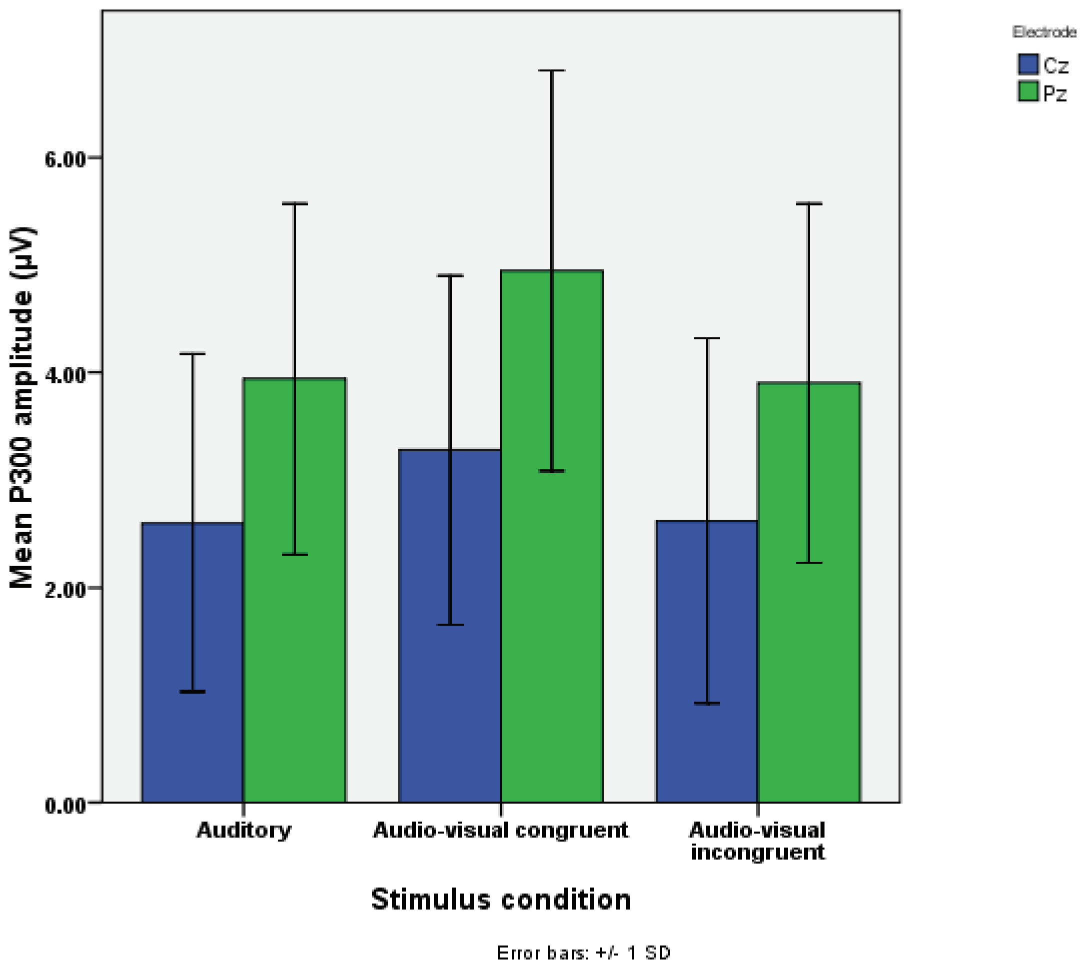

Figure 4.3: Mean and standard deviation of the peak amplitude of P300 in the 3 stimulus conditions.

Table 4.2 Results of paired t-test comparing amplitude recorded from Cz and Pz electrode sites in the three stimulus conditions

Conditions	t value	df
Auditory	-10.75*	19
Audio-visual congruent	-6.523*	19
Audio-visual incongruent	-7.556*	19

*Note: *- p<0.05*

4.2 Effect of Stimulus Condition on Latency and Amplitude of P300

4.2.1 Effect stimulus condition on latency of P300

The mean and standard deviation of onset latency, peak latency and offset latency in the three stimulus conditions are shown in Figure 4.1. The effect of stimulus condition on the latency parameters was analyzed separately for the data of Cz and Pz electrode sites. In general the mean latencies were shorter in audio-visual congruent condition compared to that in auditory and audio-visual incongruent conditions. The effect of stimulus condition was tested on Repeated measures ANOVA and the results (Table 4.3) of Cz site showed a significant main effect of stimulus condition on only onset latency. The effect was absent on peak latency and offset latency. On the other hand at the Pz electrode site, there was significant main effect of condition on all the three latency parameters.

Whereever there was a significant main effect of condition, pair-wise comparison was tested using Bonferroni post hoc test. The results of the Bonferroni post hoc test showed that, for the data of Cz electrode site there was a significant difference between the onset latency recorded in the auditory and the audio-visual congruent condition. However there was no significant difference in the onset latency between auditory and audio-visual incongruent and, audio-visual congruent and audio-visual incongruent condition.

Similar pattern of results as in Cz electrode site was obtained at Pz site with a significant difference between the onset latency, peak latency and offset latency recorded in the auditory and the audio-visual congruent condition. However there was no significant difference in the onset latency and peak latency between auditory and audio-visual incongruent and audio-visual congruent and audio-visual incongruent conditions.

Table 4.3: Results of Repeated measures ANOVA for latencies across three stimulus conditions at two electrode sites

Electrode site	Parameters	F	df (error)
Cz	Onset latency	11.32*	2 (18)
	Peak latency	2.456	2 (18)
	Offset latency	1.227	2 (18)
Pz	Onset latency	11.872*	2 (18)
	Peak latency	3.487*	2 (18)
	Offset latency	3.716*	2 (18)

*Note: *- p<0.05*

4.2.2 *Effect of stimulus conditions on amplitude of P300*

The mean and standard deviation of the amplitude recorded in the three stimulus conditions at the two electrode sites are shown in Figure 4.3. The mean amplitude was higher in the audio-visual congruent condition compared to auditory and audio-visual incongruent conditions. The mean data was similar in the auditory and audio-visual incongruent condition. The same trend was observed at both the electrode sites. Repeated measures ANOVA was used to test the effect of stimulus condition on amplitude and the results showed a significant main effect of stimulus condition on amplitude of P300 at Cz [$F(2,18) = 4.291$, $p = 0.021$] and Pz [$F(2,18) = 7.208$, $p = 0.002$].

As there was a main effect of stimulus condition, the pair-wise comparison was tested using Bonferroni post-hoc test. The results showed that audio-visual congruent condition was significantly different from auditory as well as in audio-visual incongruent condition. However there was no significant difference in amplitude between auditory and audio-visual incongruent condition. The results were same for both Cz and Pz.

4.3 Correlation of Latency Index and Amplitude Index

Results in the previous sections showed that the effect of stimulus condition was present on both latency and amplitude of P300. However, it did not give the picture of the effects of two audio-visual conditions (congruent & incongruent) related with each other.

To derive this relationship, latency and amplitude indexes were determined. This was done by taking the difference in the latency obtained in audio-visual conditions and auditory mode. The difference values obtained by subtracting audio-visual congruent from auditory were termed, latency index I and amplitude index I. Whereas the difference values obtained by subtracting audio-visual incongruent from auditory were termed, latency index II and amplitude index II. These indexes were calculated separately for the data from Cz and Pz electrode sites. To see the relation between the changes seen due to audio-visual congruent and AV-incongruent stimulus paradigms, Index I was correlated with Index II. This was done separately for Cz and Pz electrode site.

4.3.1 *Results of Cz electrode site*

Figure 4.4 shows scatter plot showing the relationship between Index I and Index II derived for onset latency, peak latency, offset latency and peak amplitude at Cz site. As can be observed in the figure, there was a direct relationship between index I and index II in all the four target parameters. The relationship was statistically tested on Pearson Correlation test. The correlation coefficient thus derived is given in Table 4.4. Results showed a significant low correlation between index I and index II in onset latency and offset latency. But indexes derived from the peak amplitude showed high positive correlation.

Table 4.4: Correlation coefficient showing the relationship between index I and II derived for onset latency, peak latency, offset latency and peak amplitude

Electrode Site	**Paramaters**	**r**
Cz	Onset latency	0.474*
	Peak latency	0.301
	Offset latency	0.517*
	Amplitude	0.809**

*Note: *- p<0.05, **- p<0.01*

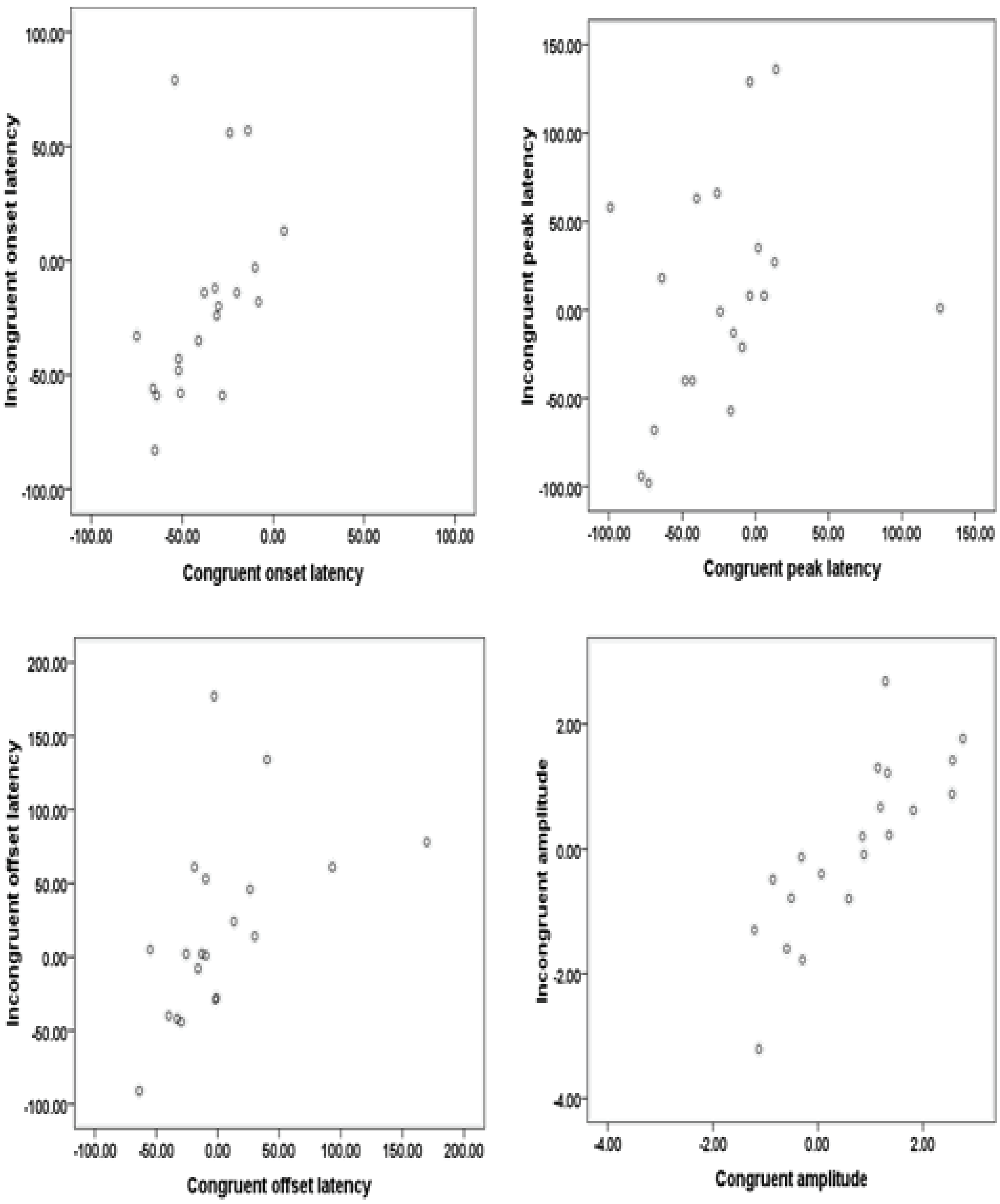

Figure 4.4: Scatter plot showing the relationship between Index I and Index II derived for onset latency, peak latency, offset latency and peak amplitude at Cz site.

4.3.2 *Results of Pz electrode site*

Figure 4.5 shows scatter plot showing the relationship between Index I and Index II derived for onset latency, peak latency, offset latency and peak amplitude at Pz site. As can be observed in the figure, there was a direct relationship between index I and index II in all the four target parameters. The relationship was statistically tested on Pearson Correlation test. The correlation coefficient thus derived is given in Table 4.5. Results showed a significant low correlation between index I and index II for peak latency. But indexes derived from the peak amplitude showed high positive correlation. There was no significant correlation between index I and index II for onset latency and offset latency.

Table 4.5: Correlation coefficient showing the relationship between index I and II derived for onset latency, peak latency, offset latency and peak amplitude

Electrode Site	**Paramaters**	**r**
Pz	Onset latency	0.261
	Peak latency	0.481*
	Offset latency	0.444
	Amplitude	0.880**

*Note: *- p<0.05, **- p<0.01*

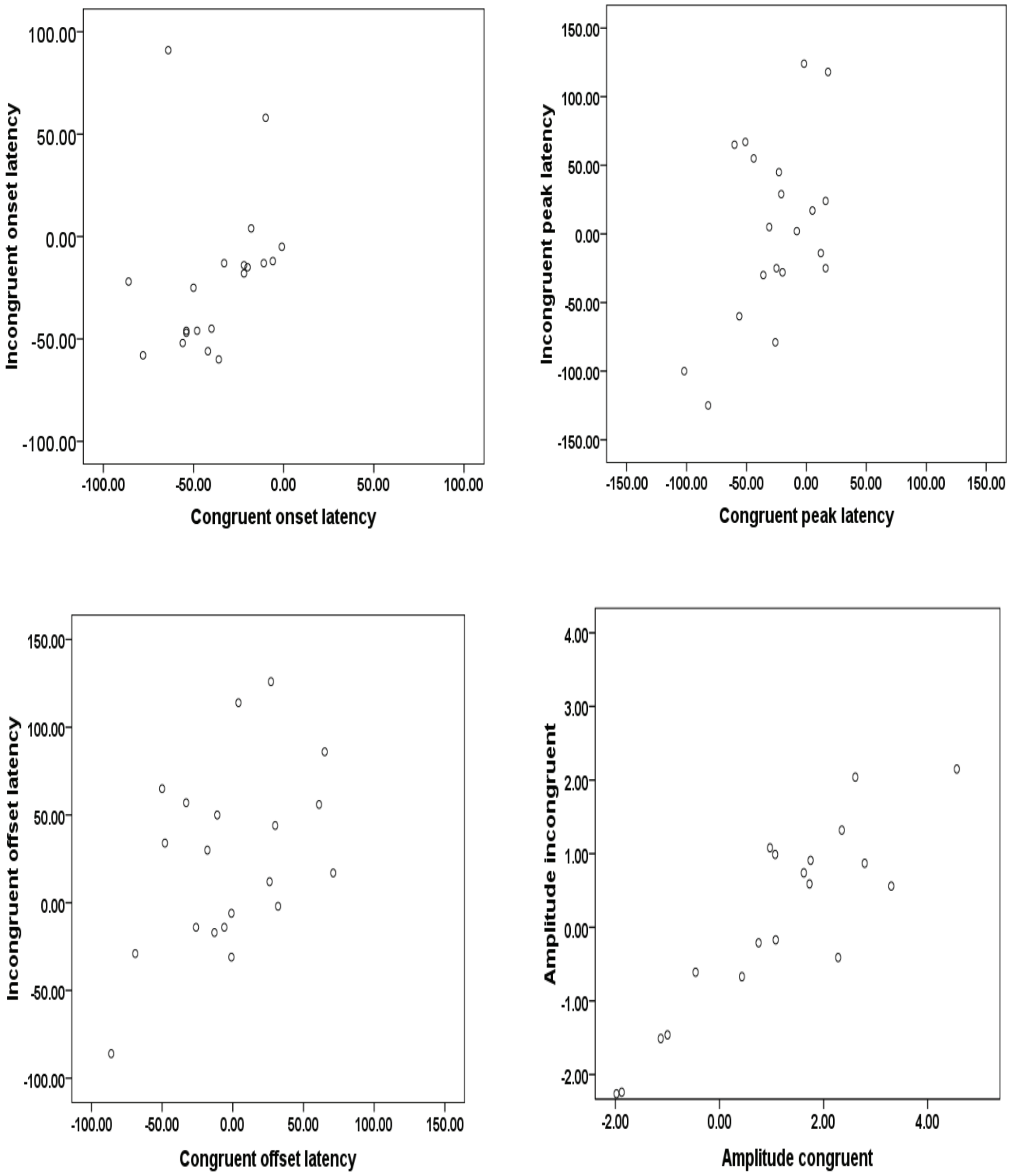

Figure 4.5: Scatter plot showing the relationship between Index I and Index II derived for onset latency, peak latency, offset latency and peak amplitude at Pz site.

4.4 Morphological Changes in P300

For all the subjects, better waveforms were obtained in Pz site compared to Cz site. Comparison of P300 waveforms across auditory condition, audio-visual congruent and audio-visual incongruent conditions showed that the amplitude of P300 was larger in audio-visual conditions compared to auditory condition. It was observed that in auditory condition, a single P300 peak was seen. Whereas bifid peaks (P3a & P3b) were present in conditions. Broadening of the P300 peak was noticed in audio-visual condition when compared to auditory condition. Figure 4.6 represents the mean waveforms of P300 depicting morphological changes in P300 across the three stimulus conditions.

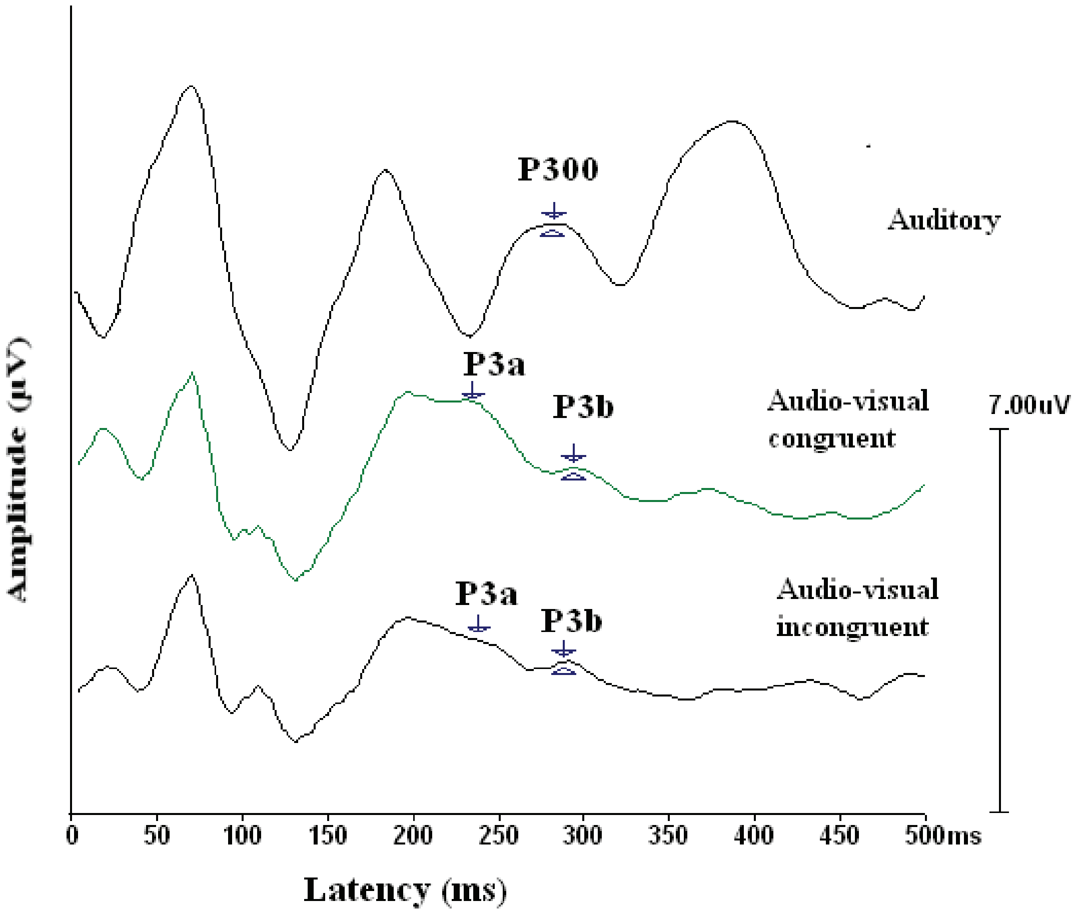

Figure 4.6: Mean waveforms of P300 in the auditory, audio-visual congruent and audio-visual incongruent conditions showing difference in the morphology. Auditory P300 shows single peak while audio-visual condition shows bifid peak.

Chapter 5

DISCUSSION

P300 is an endogenous potential recorded for an odd ball paradigm. Considering that the potential is generated by auditory association areas, it was hypothesized in the present study that the P300 shall differ in bimodal stimulation compared to unimodal stimulation. Further, to understand the scalp topography of the bimodal P300, the effect of electrode site on P300 was analyzed. The analysis of independent effects of the 2 variables; mode of stimulation and the electrode site on the latency and amplitude of P300 showed some interesting findings. Attempt has been made to justify these findings and derive appropriate implications in the following sections.

4.1 Effect of Electrode Site on P300

The present study revealed that longer latencies (onset, offset & peak latency) and reduced amplitude in Cz site than Pz site. It is evident from this result that spatial amplitude distribution of P300 is largest at the parietal electrode sites and is attenuated as the recording site move to central locations. The exact source of the potential, region of integration and the principal components contributing cannot be inferred due to the reduced number of electrodes used in this study. However, the findings suggests that the distribution of the electrical field and the dipole of the potential can be better recorded from the regions closer to the parietal lobe compared to mid and frontal regions of the brain.

These observations are in accordance with various earlier studies. Katayama and Polich (1998) obtained P300 using three stimulus odd ball paradigms and found that P300 target amplitude was larger across the midline electrode sites, being largest over the parietal site. Polich et al. (1997) assessed correlational association between peak amplitude and latency for the P300 using auditory discrimination task. They found that for the target stimuli, P300 amplitude and latency were negatively correlated over the frontal-central and right medial/lateral recording sites. Similar results were reported by Johnson (1993) and Comerchero and Polich (1999). In these studies larger P300 amplitude have been recorded at parietal site.

4.2 Effect of Stimulus Conditions on Latency and Amplitude of P300

As evident from the results of the present study at Pz electrode site, all the 3 latency parameters (onset latency, peak latency & offset latency) were shorter in audio-visual congruent condition compared to auditory mode and audio-visual incongruent conditions. This is an electrophysiological evidence of the earlier onset of neural processing pertaining to sound discrimination, underlying P300. Functionally, this may mean earlier perceptual processing in audio-visual congruent condition suggesting that bimodal condition accelerates the detection of the stimulus. However, this needs to be experimentally confirmed through correlation of behavioral and electrophysiological findings.

These findings are consistent with the findings of Fort, Delpuech, Pernier and Giard (2002). They assessed the effect of unimodal (auditory or visual) and non redundant bimodal conditions (auditory & visual) on ERPs. Event-related potential analysis revealed the existence of early (200 ms latency) cross modal activities in sensory specific and nonspecific cortical areas suggesting cross modal interaction resulting in facilitation effect (shorter reaction time) for the detection of bimodal stimuli compared to unimodal stimuli. Similar findings were reported in various earlier studies (Raij, Uutela & Hari, 2000; Odgaard, Arieh & Marks, 2004; Frassinetti, Bolognini & Ladavas, 2002).

Behavioral studies (Sumby & Pollack, 1954; O'Neil, 1954; Neely, 1956; Erber, 1969; Grant & Seitz, 2000., Rudmann, McCarley & Kramer, 2003; Bernstein, Auer & Takayanagi, 2004; Ross, Saint-Amour, Leavitt, Javitt & Foxe, 2007) unanimously show better speech perception in auditory-visual mode compared to that in auditory mode. The earlier latency of P300 may be the neurophysiological basis for the behavioral advantage in AV mode. Auditory-cognitive processing of information is expected to be better in auditory-visual congruent condition since the system is able to utilize the information from both the modalities in a complementary manner.

There was no significant difference in latencies (both in Cz and Pz) between auditory condition and audio-visual incongruent condition and, between audio-visual congruent and audio-visual incongruent condition. The exact underlying physiological reason could not be derived for this. Logically, it was expected that the AV incongruent condition would be delayed than that in auditory mode, as the incongruency between the 2 modalities would create confusion. But the absence of the difference between the latencies of 2 stimulus conditions indicates that the processing is delayed by the incongruency. This probably is because, in instances of incongruency, the processing may be primarily determined by the dominant modality, which is auditory in this case.

The P300 picked up at Cz electrode site however showed the same trend as in Pz but only in onset latency. This could be due to differential contributions of the latent components of P300 at the 2 sites. That is, some of the latent components of P300 picked up at Pz are not picked up at Cz. Unlike at Pz, the latent components contributing for peak latency of the response at Cz were probably not sensitive to the differences in the mode of stimulation.

The present study indicated that the mean amplitude was higher in audio-visual congruent condition than auditory and audio-visual incongruent conditions. There was no significant difference in mean amplitude between auditory and audio-visual incongruent conditions. The finding again can be justified with the integration of the complimentary cues provided in the auditory and visual modes. Because the cues provided in the incongruent condition were not complimentary, enhancements in the amplitude were not seen in the audio-visual-incongruent condition. Li, Wu and Touge (2010) investigated auditory detection enhancement by cross modal audio-visual interaction, by comparing the ERPs elicited by the audio-visual stimuli to the sum of the ERPs elicited by the visual and auditory stimuli. Results suggested that behavioral detection of an auditory stimulus is enhanced by the interaction of auditory and visual stimuli around 300ms in a polysensory region of the brain.

4.3 Relation between Changes Seen in Congruent and Incongruent Conditions

Because the mean changes in audio-visual incongruent condition were not significantly different from that in auditory condition, it was of interest to study the relation between the changes seen in the 2 audio-visual conditions. This would help in inferring whether the changes seen in the audio-visual incongruent were facilitative or deleterious.

Results showed a significant positive correlation between the 2 indexes derived. This supports that the changes seen in the audio-visual incongruent were facilitative, like in audio-visual congruent condition, although not to a noticeable extent.

Overall, from the findings it can be derived that bimodal presentation, neurophysiologically, is beneficial over unimodal presentation for the speech processing. Within bimodal conditions, congruent condition is more facilitative compared to incongruent condition and P300 can evidence the modality-based changes in the cortical auditory processing.

Chapter 6

SUMMARY AND CONCLUSIONS

The study was adopted to experimentally investigate interaction in the processing of auditory and visual stimuli in the generation of P300 and also the effect of electrode site on P300. Presentation mode and electrode site were treated as independent variables, and amplitude and latency of P300 served as dependent variables. The present study was designed with following objectives:

1. To study interaction in the processing of auditory and visual stimuli in the generation of P300.
2. To study the latency and amplitude differences across the electrode sites.

As a first step towards the objectives, a group of normal hearing individuals was selected as participants of the study. Two CVC words; /cat/ and /bat/ and pictures of the cat and bat were chosen as stimuli to record P300. The stimulus conditions consisted of auditory, audio-visual congruent and audio-visual incongruent. Responses were measured from Cz and Pz electrode sites. The results thus obtained were tabulated and statistically analyzed using Paired t-test, Repeated measures ANOVA, Bonferroni post-hoc test, and Pearson correlation co-efficient to determine whether it supports or rejects the assumptions of the study.

The results indicated that there was a significant difference between the latencies and amplitude recorded from the 2 electrode sites in all the three stimulus conditions. The mean latencies of the Cz electrode site were prolonged compared to that in Pz electrode site. The mean amplitudes in Pz were higher than that in Cz in all the three stimulus conditions.

The mean latencies were shorter in audio-visual congruent condition compared to that in auditory mode and audio-visual incongruent conditions. Cz site showed a significant main effect of stimulus condition on only onset latency. The effect was absent on peak latency and offset latency. On the other hand at the Pz electrode site, there was significant main effect of condition on all the three latency parameters, with a significant difference between auditory and the audio-visual congruent condition. The mean amplitude was higher in the audio-visual congruent condition compared to auditory and audio-visual incongruent conditions in both the electrode site.

From the findings of the study it can be inferred that the distribution of the electrical field and the dipole of the potential can be better recorded from the regions closer to the parietal lobe compared to mid and frontal regions of the brain. The P300 recordings supported earlier perceptual processing and better speech perception in auditory-visual mode compared to that in auditory mode suggesting that bimodal condition accelerates the detection of the stimulus.

The P300 picked up at Cz electrode site however showed the same trend as in Pz but only in onset latency indicating that the latent components contributing for peak latency of the response at Cz were probably not sensitive to the differences in the mode of stimulation. But, in instances of incongruency, the processing may be primarily determined by the dominant modality, which is auditory in this study. Finally, it is concluded that both changes seen in audio-visual congruent and audio-visual incongruent conditions are facilitative but in audio-visual congruent condition the facilitation in evident.

Implications of the Study

The findings of the present study have important implications in diagnostic as well as rehabilitative audiology. The present study proved that P300 can be an objective index of facilitation by bimodal presentation (audio-visual). Hence it can be used in the assessment of cross modality integration at the cortical level in individuals with auditory processing disorders. P300 can also be used to monitor the progress secondary to training of cross modality integration.

Future Directions

The present experimental paradigm can be tested in clinical disorders to check for its sensitivity. Future studies may correlate the behavioral audio-visual speech perception and audio-visual P300 in different modalities, to verify P300 as an objective neurophysiological index of the functional benefits.

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