THE EFFECT OF DEPRESSION ON ATTENTION AS MEASURED BY THE AUDITORY EVOKED POTENTIAL

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The Effect of Depression on Attention as Measured by the Auditory Evoked Potential

A current trend in the study of affective disorders is the focus on the interrelationships among affect, cognition, behavior, and biology. It no longer appears adequate when examining an affective state, as in depression, to neglect all other aspects save the emotional experience. There is a growing body of literature and anecdotal clinical evidence which demonstrates that the affective state is very much tied to cognitive processing and underlying physiological functioning. In the area of cognitive functioning, "depressed patients experience and demonstrate difficulties in concentration, attention, memory and other aspects of information processing" (Weingartner & Silberman, 1982, p. 27). While there is much clinical lore to support cognitive changes in depression, empirical evidence is only beginning to be accumulated. In light of the frequently reported concentration problems, the following is a review of the research which has attempted to evaluate those concentration problems in depression.

Watts and Sharrock (1985) attempted to evaluate the concentration problems reported by hospitalized depressed patients. More specifically, they wanted to differentiate the loss of concentration as being due to either "mind wandering", that is the interference of thoughts, or to "mind blanking". They studied 31 hospitalized psychiatric patients with the primary diagnosis of depression. Questionnaire measures used were the Spielberger Anxiety Questionnaire and the Levine - Pelowsky Depression Questionnaire. The investigators, using a structured interview, confirmed a high frequency of concentration problems in depression, with the greatest problems being in watching TV and reading. The authors suggested that the problems found in TV watching and reading may be a function of both activities depending largely on capacities for registration. Further, on a reading task in which subjects reported when and type of loss of concentration, lapses were due to mind "wandering" significantly more frequently than mind "blanking". The more common contents of the mind wandering were personal concerns, past events, and unpleasant events.

In an earlier study, Smith and Greenberg (1981) examined concentration problems in terms of direction of attention. They assessed the extent to which depression is associated with self-focused attention (attention to personal matters). Smith and Greenberg found private self-consciousness, a measure of the tendency to attend to one's inner thoughts and feelings, to be positively correlated with their self-report depression measure.

In addition to concentration problems being related to a focus on personal matters, changes in time perception also seem to affect concentration. In a study by Wyrick and

Wyrick (1977) the experience of time for hospitalized depressed patients was compared to that of college students. On two estimation measures, the patients overestimated time intervals compared to control subjects. Moreover, the depressed patients focused their attention more on past events, particularly the distant past and less on the present and future.

In addition to concentration problems, memory loss is a frequent complaint of depressives. Breslow, Kocsis, and Belkin (1980) compared the performance of a patient group diagnosed with Major Depression Disorder to a control group on the Wechsler Memory Scale. Data from the scales were grouped into three subfunctions of memory: Mental Control, Verbal Learning, and Visual Reproduction. While the depressed group evidenced memory deficits in all subfunctions, the greatest deficits were seen in the area of Mental Control. Similar results were also reported by Stromgren (1977). According to Breslow, et al., the subfunction of mental control is probably most associated with those aspects of memory function concerned with attention to task. These results imply a possible deficit in the attention and alerting mechanism in the memory deficit of the depressed patients.

Beck's Theory of Depression

Accompanying the growing interest in empirically evaluating changes in cognition associated with depression is the development of theoretical proposals to explain the cognitive changes. One of the first and more prominent theories of depression is that of A. T. Beck. Beck (1967), in his cognitive theory of depression, suggests that thought and affect interact and consequently the emotional aspects of depression are related to negative thoughts. These negative thoughts organize into clusters of attitudes, beliefs, and assumptions about the self, the world, and the future and are labeled "schemata." These depressed schemata are recurrent intrusions into a person's thought processes. For Beck (1967) the dysfunctional schemata have at least two debilitating aspects: the content of the negative self-referrents and the cognitive processing of the negative self-referrents.

Krames and MacDonald (1985) undertook an investigation of the processing aspects of the depressed cognitive schemata. They proposed that if Beck's model was correct, the depressed person is forced to attend to two tasks simultaneously - the demands of the environment and the recurrent intruding thoughts. The dividing of attention between the two tasks could result in the deterioration in performance of one or both tasks. The depressed schemata would use available, allocatable resources in short-term memory thereby limiting the capacity to attend and process other sources of cognitive input. It is assumed that cognitive processing requires attention and incoming information has to compete for space in short term memory (STM). Therefore, if there are multiple sources vying for attention, the more demanding ones will be allocated available STM space, limiting the attentional capacity for other sources of input. Krames and MacDonald (1985) hypothesized that depressed schemata are held in STM and as such use up allocatable space and reduce the depressed person's capacity to attend to other sources of incoming information.

To test their hypothesis Krames and MacDonald used 22 subjects participating in a long-term treatment program and receiving medication. Subjects were classified as depressed or not based on the Beck Depression Inventory. Subjects were tested on a recall task in which they were required to attend to two tasks simultaneously under three increasing levels of difficulty. As expected the depressed group made more errors than the nondepressed group and had poorer recall on the easiest levels of task difficulty. However, at the most difficult task level there was no significant difference in recall between the depressed and nondepressed subjects. The depressive schemata seemed to affect the attentional focus and STM processing of the depressed subjects at the easier levels of task difficulty. The authors suggest that at the more difficult level, the attentional demands of the task were great enough to override the distracting effects of depressive schemata. These subjects, however, were in long-term treatment and receiving medication, which may have confounded the results.

Another hypothesis stemming from Beck's theory is that cognitive functioning in depressed patients is biased toward negatively toned material. Breslow, Kocsis, and Belking (1981) hypothesized that the memory problems of depressed patients in story recall could be the result of selective inattention to the positive aspect of the story. If this hypothesis were true, then depressed patients would show no impairment in the recall of neutral and negatively toned material, but a deficit in the recall of positively toned material. The authors compared a group of hospitalized depressed patients with a matched control group for recall of story elements. There was no difference between the groups for recall of neutral and negative elements; however, the depressed group recalled significantly fewer positive elements than the control group. While the results support Beck's notion that depressed patients are biased away from the positive and more toward the negative, it remains unclear whether the cognitive process affected was selective attention or a later stage of processing such as selective recall, or both. Using story recall as the dependent measure did not allow the authors to differentiate those processes directly affected by depression. The depressed subjects may have selectively inattended to the positive and attended to the negative or selectively recalled only the negative and neutral.

Dunbar and Lishman (1984), in a comparison of depressed and nondepressed subjects on a signal detection task, found no overall difference in subjects' word recognition. However, the investigators found a difference when comparing word recognition for pleasant and unpleasant words. The depressed group demonstrated a preferred recognition for unpleasant material while the nondepressed group showed a preference for pleasant material. The authors suggested that for the depressed subjects, the unpleasant material established a significantly stronger memory trace than for the pleasant material. This stronger memory trace may be the result of the mechanism of selective attention, that is, material congruent with the depressed mood may be attended to selectively.

Beck's theory of depression also includes the proposal that cognitive distortions are associated with depression. Distortions are the result of the negative schemata functioning as a framework to perceive and evaluate incoming information. Derry and Kuiper (1981) examined how the information about the self in the schemata was processed by depressed individuals. The study used clinical depressives, nondepressed psychiatric controls, and normals, and compared each group's performance on adjective recall. While the nondepressed psychiatric controls and normal controls showed superior recall only for self-referenced, nondepressed content adjectives, the depressed group demonstrated superior recall only for self-referenced, depressed-content adjectives. Self-referenced adjectives were those adjectives chosen previously from a large list of adjectives describing the self. The authors concluded that their results support Beck's proposition of an efficient negative self-schema specific to depression.

In a follow-up study, Kuiper and Derry (1982) examined the content of the self-schema in a group of mildly depressed subjects compared to normals. Again they found that in a nondepressed group adjective recall was enhanced for self-referrent, nondepressed content. The mildly depressed subjects, in contrast, showed enhanced recall for both depressed and nondepressed self-referenced content. These two studies suggest that eventual recall of information is enhanced when the incoming information (to be recalled) is already represented in self-schemata. In addition, the studies suggest that the degree of negativity in the self-schemata is an indicator of the severity of depression.

Zuroff, Colussy, and Wielgus (1983) conducted a study similar to Kupier and Derry (1982) to further analyze the selective recall or memory bias found with depression.

Using adjective recall and recognition of self-referenced content, they also found that depressed subjects showed increased recognition and recall for negative self-referenced content. Based on a signal detection analysis, the authors reported that the enhancement found with depressed subjects was due to a more liberal criterion in making the decisions to report negatively toned material than was found in the controls.

Ingram, Smith, and Brehm (1983), using a mildly depressed group and a control group, investigated the effect of the self-schemata on the processing of information. They were interested in how a prior success or failure experience influenced the activation and use of the self-schemata. Like Derry and Kupier (1981), they used recall of self-referenced adjectives as an indicator of the use of the schemata. For the control subjects, a success experience increased the recall of positive self-referrent adjectives, when compared to a prior failure experience. The depressed subjects, on the other hand, showed no increase in recall of positive self-referrent information following a success experience. The authors suggest that cognitive activity during depression is characterized by selective processing at both the input and output stages. During depression, positive self-referrent information is perceived and encoded less efficiently regardless of recent, prior experience, while negative information is accessed out of memory more efficiently.

In light of the increasing evidence in the area of memory changes accompanying mood disturbance, Cohen, Weingarten, Smallberg, Pickar, and Murphy (1982) undertook a study to investigate whether there was a general deficit in the central motivational state in depression which could account for the memory impairments observed in depression. They were interested in the context of information processing as opposed to a single stage of processing. To evaluate their hypothesis they compared a group of depressed inpatients with a control group on a simple motor task requiring sustained effort and a simple memory task requiring little motor activity. The depressed group demonstrated deficits in motor and memory performance that appeared to be proportional to the severity of the depression. The deficits were most noticeable on the tasks requiring greater sustained effort. The authors cautioned that in looking for cognitive deficits in depression, one may be able to produce deficits by increasing task complexity and thereby the effort required by the subjects. This possibility, however, was not supported by Krames and MacDonald (1985) who found depressed subjects' performance to improve with task difficulty.

Information Processing Models

While many investigators have used Beck's theory as a framework for investigating cognitive changes in depression, others have used information processing models. Weingartner, Cohen, Murphy, Martello, and Gerdt (1981) state that during depression, patients show both qualitative and quantitative changes in the manner in which information is processed. These changes appear in many cognitive processes from attention to encoding to memory recall. The authors note that depressed patients seem to use weak encoding strategies to organize and transform information to be remembered. In a series of three studies, the authors set out to investigate whether imposing external structure and organization would reduce/eliminate the learning-memory deficits apparent in depression. In each study, it was observed that the depressed patients did not use encoding operations that would have been useful in organizing information for later recall. However, when the information was structured and organized the depressed patients were able to use it and showed improved learning-recall performance. The authors inferred an encoding impairment "from the finding of a depression related impairment in recall that varies directly with the presence or absence of structure in the information to be processed and later remembered" (p. 46).

In light of the suggested encoding impairment found in the cognitive processing of depressives, it seems advisable at this point to briefly review Hasher and Zacks' (1979) findings concerning memory and effortful processing. According to these authors, automatic and effortful processes are ways of describing the encoding process. Effortful processes are those which deplete the limited attentional capacity, are intentionally initiated, and show benefit from practice. Variations in effortful processing (i.e., encoding) are tied to attentional capacities which are influenced by organismic and environmental states. If this if so, then depression may operate as an organismic state which affects a person's attentional processes and therefore the encoding and memory processes. This is supported by the data cited by Hasher and Zacks which show that the memory dysfunction associated with depression occurs for tasks requiring effortful processing. In light of Beck's theory, the attentional processes may be altered due to the negative cognitions. The depressed person may selectively attend to the negative schemata and use these as a framework to select from the environment that which is consistent and selectively inattend to that which is not consistent for further processing. Also, the negative schema and framework may serve to use up and therefore limit the attentional capacity available for the effortful processes of encoding and memory.

While theory and research point to an attention dysfunction associated with depression, little empirical work has been done to investigate this directly. As can be seen from the studies reviewed thus far, changes in attentional processes have been inferred from evidence concerning encoding and memory functions. It is the purpose of the present study to investigate the attentional changes associated with the depressed state in a more direct way, that is, not relying on the cognitive functions of memory and recall. Using cognitive theory and research as a framework, it is the intent of this study to measure the physiological correlates, using the auditory evoked potential, of changes in selective attention associated with depression. Evoked potentials were chosen because they can bridge the conceptual gap found between the biochemical and behavioral phenomena in psychopathology (Tueting, Kaskey, Buchsbaum, Connolly, Perris, & Roemer, 1984). In doing so a review of the literature concerning evoked potential measures of depression and selective attention follows.

Evoked Potentials

One of the leading investigators in the use of the EEG and evoked potential to understand psychopathology is Charles Shagass (Shagass & Jones, 1958; Shagass & Schwartz, 1962, 1963; and Shagass, Staumanis, & Overton, 1975). In one of his earlier studies, Shagass (1955) was interested in the hypothesis that different emotional states could be characterized by quantitative differences in the photically activated EEG. He used several patient groups diagnosed as anxious, neurotic depressed, psychotic depressed, and schizophrenic. When using 10 light flashes per second as the stimuli, it was found that the female neurotic depressives had a significantly greater response (EEG amplitude) than any of the other groups except for the schizophrenic group. However, at 15 light flashes per second, the female anxiety group had the largest EEG response except for the schizophrenic group. When comparing the ratio of light flicks (15:10) between groups, there appeared to be a continuum of EEG response ranging from a maximum ratio in the anxiety group to a minimum one in the depressed group with the controls in between. Based on these results, Shagass concluded that he had found support for the hypothesis that the quantitative response to photic stimulation did fluctuate in relation to emotional state. He further suggested that the differences found between anxiety and depression involved differences in cerebral excitability.

In another study, Shagass, Roemer, Straumanis, and Amadeo (1980), using a diverse clinical population, compared clinical and control group using multiple sensory evoked potentials. A sensory evoked potential is the EEG response to a specific stimulus. The clinical groups included psychotic depressives, neurotic depressives, and schizophrenics. The sensory modalities used were visual (light flashes), auditory (clicks), and somatosensory (electric pulses). The stimuli were presented in a random order and the evoked potentials were recorded from multiple scalp sites. In general, many differences were found between the clinical groups when compared to a control group. Of particular interest to the present study was the finding that the amplitude of the peak N130 in the somatosensory evoked potential was smaller in the psychotic depressive group compared to the control group. This peak is thought to be associated with selective attention (Shagass et al., 1980). Although the experiment did not involve a selective attention task, Shagass et al. proposed that the finding suggested that the depressive disorder "may be associated with altered functioning in mechanisms that are brought into play by demands for selective attention" (p 202). Although this study included several clinical groups and multiple stimulus modalities, the results must be cautiously interpreted. Like many studies involving clinical groups, the diagnostic criteria used were imprecise, leaving several subjects with only a probable diagnosis.

In a further effort to use physiological data to characterize psychopathology, Shagass, Roemer, and Straumanis (1983) looked at EEG activation as a measure of arousal level in psychiatric disorders. Again, a large group of psychiatric patients, with the diagnoses schizophrenia, mania, major depression, and neurosis were compared to a control group. EEGs were recorded from multiple cites under two conditions - eyes closed and with eyes open while fixated on a stationary checkerboard pattern. To analyze EEG activation levels, several measures were computed from the EEG recordings. These included integrated amplitude, mean frequency, and a "time rising" measure or wave symmetry measure. It was assumed that changes in the control group from the eyes closed to eyes open condition could be interpreted as shifts toward greater cortical activation. Based on this the authors found they could divide the different groups into three levels of EEG activation. The manic and schizophrenic groups could be catagorized at a high level, with control and neurotics at the medium, and major depressives falling into a low level of EEG activation or arousal. Their results were suggestive of the use of physiological measures for the understanding of psychiatric disorders.

Using the same data, Shagass, Roemer, Straumanis, and Josiassen (1984) applied multivariate analysis to select a small number of factors that differentiated between the groups. They then applied discriminant function analyses to these factors to yield one discriminant score that represented the optimal combination of factor scores for a two-group differentiation. The findings suggested that the different clinical groups could be differentiated from one another by the EEG measures, such as (a) non-patients from patients with overt schizophrenia, latent schizophrenia, major depression, or mania; (b) patients with neurosis or personality disorders from those with overt schizophrenia, latent schizophrenia, or mania; (c) patients with major depressions from those with latent schizophrenia or mania. These discriminations were obtained with at least 50 percent sensitivity and diagnostic confidence rates from 69 to 92 per cent. The further analyses of data again supported the possible usefulness of EEG measures in differential diagnoses.

While Shagass and associates have pioneered the work in establishing the use of EEG and evoked potentials as indicators of psychopathology, others have focussed on the their use to study specific disorders, as in the present case, depression.

Buchsbaum, Goodwin, Murphy, and Borge (1971) were interested in the application of a model of a mechanism in the central nervous system to the affective disorder of depression. This model proposed two different ways of modulating the intensity of sensory input. One way was to increase the perceived intensity of stimuli, termed "augmentation" which is seen as an increase to EEG response. The other, which tended to reduce the intensity was labeled "reduction," and seen as a decrease in the EEG response. While each tendency was seen as useful, when applied in excess it was thought to be a mechanism or symptom of psychopathology. To test the augmenting - reducing tendencies in depression, the investigators analyzed the amplitude differences of Peaks P80, N120, and P200 of the visual average evoked potential (VEP). The study compared two groups of bipolar depressives, a unipolar depression group, and a control group. Visual evoked potentials were recorded from the vertex to a series of light flashes of four increasing intensities. The bipolar groups showed significantly greater augmentation on the VEP than the unipolar group and control group. The unipolar depressed group showed significant VEP reduction compared to the control group. The patients with depressive disorders appeared to be functioning at maladaptive poles of the augmenting-reducing continuum. For the authors, a better understanding of the parallels between styles of processing sensory input and clinically observable behavior could be an aid in joining biological findings to psychiatric theories and observations.

In a follow-up study Buchsbaum, Landau, Murphy, and Goodwing (1973) attempted to replicate and extend the finding of Buchsbaum et al. (1971) to evaluate the effects of age and sex on the bipolar-unipolar VEP dichotomy. Using the same subjects and experimental paradigm, Buchsbaum et al. (1973) analyzed the amplitude and latency of VEP peaks P100, N140, and P200. They found the same augmentation in the bipolar group as previously. However, for the unipolar group, only the males showed actual reduction in the VEP in response to higher stimulus intensity. Females in the unipolar group showed smaller amplitudes across stimulus intensities. This was the reverse of the control group where females showed larger amplitude VEPs compared to males. Bipolar patients had longer latencies for all three peaks compared to unipolar patients, while the control group had even longer latencies than the bipolar group. Bipolar and unipolar patients also showed a tendency to decrease latency to a greater extent with increasing stimulus intensity. To further evaluate the relationship of mood and VEP, within-subjects comparisons were made. In both the unipolar and bipolar groups, higher levels of depression were associated with smaller VEP amplitude.

Given the often-cited slowed response time seen with depression, several studies have been done using the evoked potential measure to investigate whether the delay was to be found in stimulus evaluation or in activation and execution of the motor response. To evaluate the components of a response many investigators have looked at the P300 wave of the evoked potential since it is considered to be a measure of stimulus evaluation time. When a stimulus requires a perceptual decision, there is often a late positive component (P300) occurring after 250 msec in the evoked potential (Picton & Hink, 1973). If the delay found with depression occurs during stimulus evaluation then it could be reflected in a change in the P300, such as a longer latency. However, if the delay were in the carrying out of the motor response, no change should be evident in the P300 and the time between the P300 and the response should be increased.

Johnson, Pfefferbaum, Hart, and Kopell (1984) measured the P300 for the VEP in chronic alcoholics and depressed patients. Using three increasingly more difficult choice reaction time (RT) tasks, they found that both the alcoholics and depressed subjects showed significantly later P300 and longer RTs compared to normals. Also, Shagass, Roemer, Straumanis, and Amadeo (1978) and Roth, Pfefferbaum, Kelly, Berger, and Kopell (1981) using auditory evoked potentials, reported smaller P300 amplitudes in depressed patients compared to controls. In contrast, Giedke, Thier and Botz (1981) measuring auditory evoked potentials to a discrimination task, found no change in the P300 but a longer interval between P300 and RT for depressed patients.

In a further study, Gorsel (1984) found no difference in P300 amplitude and latency between a group of non-psychotic depressives and controls. This study was designed to investigate the differences in amplitude and latency of the auditory evoked potential (AEP) between nonpsychotic depressives and a control group. Using both simple and choice RT paradigms Gorsel found for depressives the P200 was significantly larger and later than for controls. He interpreted this as an indication of a higher level of arousal in the depressed group.

Pfefferbaum, Wenegrat, Ford, Roth, and Kopell (1984) examined the P300 for its diagnostic utility in differentiating dementia, depression, and schizophrenia. The study used both a visual and auditory choice RT task. The overall results of the study showed deviations in P300 amplitude and latency for all three groups. However, the deviations were neither consistently large enough nor specific enough to any disorder and as so reflected a common rather than diagnostically specific deficit. As in the Gorsell (1984) study, the depressed group did show a difference in an earlier EP component. For the AEP, the medicated depressed patients had smaller amplitudes for the N100 and P200 peaks. Baribeau-Braun and Leseure (1983), using similar auditory simple and choice RT tasks, also did not find a P300 change due to depression. They offered the explanation that there are many stages in stimulus evaluation, each having a facilitating or inhibiting effect on RT. The P300 represents only a later stage. There is at least one early attentional stage at the level of P50-N100. Furthermore, the frequently used simple and choice RT tasks used to investigate stimulus evaluation and the P300 do not allow assessment of distractability or selectivity of attention to the task-relevant stimuli. This lack of direct measurement of selective attention using the evoked potential is similar to that found in the cognitive literature.

Before continuing with a review of the use of evoked potentials to measure selective attention, a few comments concerning the lack of consistency in cited studies seems in order. A first difficulty in comparing and summarizing the literature concerning physiological measures of depression is the difficulty of diagnosis. There is some lack of agreement on the criteria used for diagnosing depression. As the clinical manifestations of depression have been more and more clarified over the years, comparison of studies across years has become less meaningful. This can be readily seen through the revisions of the Diagnostic and Statistical Manual. In addition the labels used to differentiate types of depression, such as endogenous, neurotic, bipolar, and unipolar, do not identify the degree of severity of depression. This leads to varying levels of depression within each group. These groupings also differ in types of treatment they are receiving at the time of experimentation.

A further and major problem with diagnosis is the low inter-rater reliability (Tueting, Kaskey, Buchsbaum, Connally, Perris, & Roemer, 1984). Since most clinical evoked potential studies are essentially investigations of the concurrent validity of EP measures and clinical measures, the validity of the studies cannot be higher than the lowest reliability of the diagnosis. One solution to the problem of low reliability in diagnosing is to classify clinical phenomena in terms of symptoms and severity of symptoms which should offer more precise classification (Tueting et al, 1984).

Although the reliability of clinical diagnosis has been found to be low, reliability of EP measurements has been found to be adequate for a useful instrument in psychometric terms (Teuting, et al., 1984). One possible concern in the use of EPs is the reliance on one aspect of one component of the EP, such as the P300 amplitude, to demonstrate differences in broad clinical groups. Furthermore, when group differences in EP amplitude and latency are found, the origin of differences if usually speculative. For example, it is often unclear whether an increase in amplitude or latency is primarily the result of a true increase or the result of reduced variability in the averaged EP. The same applies to decreases found.

In light of the above criticisms the present study proposes to examine depression as a symptom as measured by an objective test. As suggested thus far, the cognitive and physiological research indicates an attentional dysfunction in depression using experimental paradigms which do not directly measure attentional mechanisms. It is the purpose of this study to apply an established selective attention paradigm to measure differences between subjects with a depressive symptom and those without signs of depression. By limiting the range of this study to the effect of a particular symptom on a specific mechanism of information processing, it is intended to limit the difficulties encountered when broader areas have been studied.

Selective Attention

Hillyard, Hink, Schwent, and Picton (1973) were among the first to utilize an experimental paradigm designed to elicit the process of selective attention to be measured by the evoked potential. Within the auditory modality, they defined selective attention as "accomplished by unknown brain mechanisms that act both to enhance the information received from selective sound sources and to suppress irrelevant, competing sensory input" (p. 177). In two experiments using auditory stimuli it was found that the N1 peak, a negative component peaking at 80 to 110 ms after stimulus onset, was enhanced when the stimuli were attended to. (Figure 2 is a representation of an AEP). In the first experiment subjects were presented binaural sequences of tone pips. Presented to the left ear was a sequence of 800Hz tone pips, 50 ms in duration, with randomized interstimulus intervals (ISI) between 250 and 1250 msec.

Delivered independently to the right ear was a sequence of 1500Hz tone pips of similar intensity, duration and ISI as the left ear stimuli. The concurrent binaural sequences each consisted of 512 tone pips. Within each ear, about one-tenth of the tone pips were of a higher frequency than the "standards" which were 800 and 1500Hz. These "signals" had frequencies of 840 Hz for the left ear and 1560 Hz for the right ear. Throughout each sequence, the "signal" tone pips occurred randomly every 3 to 20 stimuli. The same stimulus sequences were presented to each subject six times in succession using three instructional conditions. One condition instructed the subject to attend to the left ear, discriminate and count the number of 840 Hz signals and report the number at the end of the sequence. The second condition instructed attention to the right ear and to count the 1560 Hz tones. A third condition instructed subjects to read a novel and disregard tone pips. Data from this condition were not analyzed. The reading condition was used to prevent carry-over effects between successive attend-left and attend-right conditions.

Auditory evoked potentials (AEPs) were recorded from the vertex location. Evoked potentials were averaged separately for the left and right ear for each condition. It was found that the amplitude of N1 evoked by the right ear tones was 20 to 75 percent larger when the subjects were attending to the right ear than when they were attending to the left ear. The AEP from left ear tones produced an N1 22 to 78 percent larger when subjects attended to the left ear as compared to when they were instructed to attend away from the left ear to the right ear.

Experiment 2 of Hillyard et al. consisted of the tones presented as a single sequence rather than as two independent, overlapping sequences as in experiment 1. The time intervals between tones was randomized between 100 and 800 msec. The right ear received tones of 800 Hz, while the left ear received the tones of 1500 Hz. Experiment 2 was identical in all other ways to Experiment 1 except for the deletion of the reading condition. The results were consistent with Experiment 1 in that an increase in N1 amplitude was found when subjects attended to the tones compared to when they attended away.

Hillyard et al. cite three features of their paradigm which were different from other paradigms which had failed to reveal a selective attention effect upon N1. First, the relevant and irrelevant stimuli differed in spatial localization and pitch attributes which made them easily distinguishable. Secondly, because the stimuli were delivered at such a fast rate, it was impossible for the subjects to discriminate stimuli in one ear and fully appreciate the stimuli to the other ear at the same time. Lastly, the frequency discrimination task was difficult as reported by the subjects who heard only a few of the signal tones in the unattended ear.

Hillyard et al. designated left and right ear as the channels of sensory input. The term "channel" refers to sensory input defined by simple stimulus attributes such as modality, spatial location, pitch, or intensity. For the selective attention paradigm, the subject's attention is directed toward one channel over another, such as right over left ear. Due to the early latency of the attention effect upon N1 (evidence as early as 60 msec), Hillyard et al. suggested "that the underlying attentional process is a tonically maintained set favoring one ear over the other rather than an active discrimination and recognition of each individual stimulus" (p. 179). They went on to propose "that the amplitude of N1 indexes the stimulus set which selectively excludes sensory input to the unattended ear from further processing" (p. 179). In other words, subjects selectively attend to one channel of sensory input over another and this difference is manifest in N1 amplitude.

Based on the Hillyard et al. (1973) paradigm, Schwent, Hillyard, and Galambos (1976) investigated the addition of background white noise to the channels (left/right ear) of tone information to see if this would make for an even larger attentional enhancement of the auditory N1 wave. They hypothesized that the background noise would make the stimuli more difficult to discriminate and therefore result in a greater processing effort and increased selectivity of the attentional capacity. In addition to background white noise, they added tone intensities of loud and soft and stimulus presentations in three spatially separated channels, left ear, right ear, and binaurally. There were a total of eight experimental conditions: attention directed to one of two channels, loud or soft tone intensity, and white noise present or absent. Finally, to test whether the "target detection" aspect of the Hillyard et al. (1973) paradigm was mandatory for N1 modification, subjects were instructed to simply count the number of tones in a designated channel.

In the low intensity condition, the N1 was greatly enhanced by attending to the tones. However, with high intensity tones, little enhancement of N1 was found. The addition of white noise further enhanced the amplitude and latency of N1 in both the low and high intensity conditions. So, both lower intensity and/or the addition of background noise increased the attention-related enhancement of N1. To explain the lack of N1 effect in the high intensity condition, the writers suggest that the N1 amplitude "saturates" or reaches a ceiling as stimulus intensity increases. The addition of background noise could therefore serve to lower the threshold of the N1 generator and account for the N1 enhancement seen when background noise is coupled with high intensity stimuli.

The three stimulus channels did not differ significantly in the magnitude of attention-related changes. Also the simple counting task did result in an N1 enhancement as great as that found using the target detection task of Hillyard et al. (1973). For Schwent et al. (1976) this was consistent with the proposal (Hillyard et al., 1973)) "that N1 amplitude indexes a 'stimulus set' mode of attention whereby stimuli are selected for or rejected from further processing on the basis of their 'channel' of origin" (p. 620, 1976).

To understand the effect of the background noise, the authors cite the theoretical proposition of a limited attentional capacity. More of the limited processing capacity would be committed to the attended channel when the above threshold tones must be detected in noise, therefore reducing the resources available to the unattended channel. The effect of background noise is then considered similar to that achieved by the rapid rate of delivery of the stimuli. The use of low intensity tones and/or white noise appears to require more effortful processing and attentional selectivity thereby increasing the attentional capacity occupied which is indexed by an enhancement of the N1 wave.

To further investigate the N1 component as an index of the resources used in the attentional capacity, Hink, Van Voorhis, and Hillyard (1977) compared a divided attention task (stimuli attended to in both ears) to the focused attention task (stimuli attended to in one ear.) They found the greatest N1 enhancement of the AEP to stimuli in the attended ear (channel) and the least N1 enhancement when attention was directed away from that channel. In the divided attention task, they found that stimuli in each ear elicited N1 waves of intermediate amplitude. Their results supported the hypothesis that N1 amplitude is an index of the amount of processing resources committed to a channel.

Naatanen, Gaillard, and Mantysalo (1978) in two experimental situations similar to the Hillyard, et al. (1978) paradigm, suggest a reinterpretation of the N1 effect. Their study used a constant ISI of 800 ms instead of a random ISI. Like Hillyard, et al. (1973) subjects received stimuli in both ears and attended to one ear and counted the number of "signal" tones. In the first experiment, 1000 Hz tones of 31 ms duration were presented at an intensity of 70 db for the standard and 80 db for the signal. In the second experiment the intensity, 70 db, was the same for the standard and signal tones. Pitch varied between the standard (1000 Hz) and signal (1140 Hz).

For the standard tones, an increase in the N1 component due to attention was not found. There was a "slight but systematic negative displacement of the EP to the attended standards relative to the EP to the unattended standards" (p. 317). Usually the displacement began during the downward slope of the N1 component. This negative shift was termed "processing negativity."

In the attention conditions the amplitude of N1 was significantly larger to the signal than to the standard tones. The negative enhancement found with the signal tones had an onset prior to peak N1 and lasted up to the N2 component. Following this there was a larger late positivity in the EPs to the attended signals compared to the unattended signals which did not affect N1. Naatanen, et al. (1978) suggest that this negative process or "mismatch negativity" elicited by attended signals (but not attended standards) reflects a step-by-step process by which the subject ends up with some degree of subjective certainty that something deviating from the standard has occurred. They further suggest that these processes are largely automatic and may be closely related to the orienting response.

In contrast, Naatanen et al. (1978) propose that the shorter latency 'processing negativity' seen with attended standard tones reflects processes which are voluntary and can be directed by instruction and attention. They suggest that the enhanced N1 effect reported by Hillyard, et al. (1973) was the result of this negative shift overlapping the N1 wave.

The difference in the selective attention effects found by Hillyard, et al. (1973) and Naatanen, et al. (1978)

raised the question as to whether the increase in N1 was due to an actual increase in the amplitude of that component or whether a new negative component was being added to the N1 evoked by attended stimuli. Hansen and Hillyard (1980) suggested that a simple increase in amplitudes reflected an enlargement of the exogenous N1 component due to a peripheral gating mechanism. Exogenous components are those which vary as a function of stimulus characteristics (e.g., intensity) and occur within 100 ms post-stimulus. On the other hand, increased N1 amplitude resulting from the additive effects of an endogenous negative wave would suggest a special processing system evoked by attention. Endogenous waves are those which are internally generated by the brain as a function of the cognitive processing of stimuli and occur at later than 100 ms post stimulus. Hansen and Hillyard (1980) undertook a study to investigate the possibility of an endogenous AEP component contributing to the measured N1 amplitude increase under conditions of channel-selective attention.

The stimuli were tones presented binaurally. Tones of 51 ms duration were designated as standards, with tones of 102 ms duration designated as signals Tones were presented with white background noise. In each attention condition, tones of two different frequencies were presented randomly with an ISI of 200 to 500 ms. The lower tone frequency was always 300 Hz. The higher frequency was set at 350 Hz, 400

Hz, and 700 Hz giving three levels of inter-channel frequency separation. Six attention conditions were given with each subject receiving two consecutive conditions at each frequency separation. Subjects were instructed to attend to high tones (or low) and push a response key to the longer duration target tones. The major difference between this paradigm and those previously cited is that channel is defined here as tone frequency, where previously channel was defined as left/right ear.

EEG activity was recorded from FPZ, FZ, CZ, and PZ sites. For each attention condition a difference wave was calculated for the standard tones. This wave, termed Nd, was calculated for each frequency condition by subtracting the average EP to the tones when unattended from the average EP to the tones when attended. The effect of attention seen in Nd was a broad negativity which began before the N1 peak at the 400 Hz channel separation and lasted throughout the analysis epoch. It was also apparent that the onset latency of the Nd increased progressively, while amplitude declined, as the frequency separation between channels was reduced.

A temporal dissociation between the N1 wave and the attention-sensitive Nd could be brought about by manipulating the inter-channel discriminability. While there was a significant delay in onset latency of Nd at smaller frequency separations, the general shape or slope did not change. The peak amplitude of the Nd wave significantly increased as the frequency separation increased from 50 Hz to 100 Hz to 400 Hz. At the FZ location, two separate negative peaks were evident in the Nd wave for the 400 Hz separation and to a lesser extent at the 100 Hz separation. For Hansen and Hillyard (1980) these results pointed to the endogenous nature of the Nd wave and the probability that the previously-found enhanced N1 wave was the result of an overlap between Nd and N1. They concluded that the effect of attention was manifest in the difference wave form which consisted of a broad multiphasic negative component (Nd). The amplitude and onset latency of the Nd could be varied systematically as a function of frequency separation between the tones. In summary, Hansen and Hillyard (1980) stated that the Nd wave was a reliable correlate of selective auditory attention.

As can be seen from the studies reviewed, the scalp-recorded evoked potential provides a reliable electrophysiological measure of the mechanism of selective attention. The paradigm, which directs attention to stimuli in one channel over another, is robust as well as a more direct elicitor of the selective attention process than previous paradigms which relied on response characteristics to infer selective attention (Naatanen, 1982). Previous EP research, using primarily simple and choice RT paradigms, did not provide assessment of selectivity of attention but rather assessed EP components, such as P300, related to other cognitive processes. Specific analyses of the differences between EPs to attended vs unattended stimuli was not possible since the tasks did not require direction or selectivity of attention. Furthermore, any attentional efforts needed by these paradigms could have been disguised by the later cognitive processes the paradigms were designed to elicit.

The selective attention paradigms used by such investigators as Hillyard and Naatanen do not rely on memory or response functions found with the other paradigms, thereby reducing the confounding effects of these factors. Given that one purpose of the present study was to more directly investigate selective attention, a paradigm similar to that of Hansen and Hillyard (1980) was used. The paradigm measures attention relatively unconfounded by other task functions such as memory or motor response. It also allows for the comparison of EPs to attended vs unattended stimuli (Nd wave). The use of this paradigm to measure attentional changes due to an independent variable is supported by the findings of Born, Brauninger, Fehm-Wolfsdorf, Voigt, Pauschinger, and Fehm (1987). These authors examined changes in the Nd wave as a result of differing doses of adrenocorticotropic hormone. They found a linear dose-dependent influence on the Nd wave using the AEP, affirming its (Nd) usefulness as a dependent measure.

Using a selective attention paradigm similar to Hansen and Hillyard (1980), it was predicted that depressed subjects would show attentional differences compared to control subjects. It was further hypothesized that this difference would be seen in the Nd wave. A difference between depressed and non-depressed subjects would support the theoretical proposition that there is a change in attention related to depression which can be examined separately from other cognitive processes. By examining AEP differences, it would be possible to address the issue of changes or shifts in the attentional resources due to depression. Using the size of Nd as an index of the amount of attentional resources committed to a channel, an absolute decrease in Nd found with depression would suggest that: depressed subjects consistently allocate less attentional capacity and therefore less selectivity to external tasks compared to non-depressed subjects.

Control subjects were expected to exhibit a similar pattern of Nd waves as found by Hansen et al. Using the largest channel separation (400 Hz) it was hypothesized that the depressed subjects would have Nd waves with smaller amplitude and later onset compared to controls. This type of result would suggest that the depressed subjects are not allocating as many attentional resources to the attended channel as controls and/or that the selective attention process was not as efficient. This type of result could also lend support to Beck's theoretical proposition of the interference of negative cognitions by using allocatable attentional resources.

At the smallest channel separation (50 Hz), three types of results were suggested. First, that no difference would be found between controls and depressed subjects. This result would support Krames and MacDonald's (1985) finding that on the more difficult tasks, differences due to depression diminish as task difficulty forces depressed subjects to abandon the use of depressed schema. This type of interpretation would be, of course, dependent on a difference being found at the larger channel separation.

The second possible result at the 50 Hz separation is that while no differences between controls and depressed subjects is found at the larger channel separation, delayed latency and decreased amplitude of Nd is found at the smaller channel separation for the depressed group compared to the control group. This would suggest that depression interacts with the increased task difficulty and thereby further reduces the allocatable attentional resources of the depressed subjects (Cohen et al., 1982).

The third possible result at the 50 Hz separation is that regardless of whether depressed and control subjects show differences in amplitude and latency of Nd at both the 50 Hz and 400 Hz separation, they display a similar pattern of change in amplitude and latency from the 400 Hz to the 50

Hz separation. This result would indicate that although depressed subjects appear to allocate less or use attentional resources differently, the attentional process is similar to controls.

The types of results suggested would lend increased support to the usefulness of the evoked potential as a diagnostic tool. Electrophysiological correlates of depression could also carry implications for treatment evaluations. For example, an understanding of whether the attentional difference found in depression was consistent and pervasive might affect the mode and goals of treatment. Improvements due to treatments could then be measured electrophysiologically as well as behaviorally.

Finding no difference would indicate that attentional changes due to depression may be situationally specific, or that cognitive changes seen with depression are not related to attention but rather to other information processing mechanisms. No difference could also indicate that depression must be at a level of severity found only in chronic cases in order to be accompanied by measurable attentional deficits.

Method

Subjects

Subjects were 32 students between the ages of 18 and 44 enrolled in undergraduate Psychology courses at Oklahoma State University. Criteria for subject selection were: a) no known neurological or hearing deficit; and b) no current involvement in chemotherapy for depression or use of street drugs.

The subjects were divided into two groups of 16 subjects each, with one group classified as having depressive symptomatology and the other reporting minimal symptoms. Each group had eight females and eight males. Evidence of depressive symptoms was assessed using the Zung Self-Rating Depression Scale (Zung, 1965) and the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961).

The 32 subjects selected on the basis of the inventories participated in the evoked potential study. Subjects were screened from a pool of approximately 250 students. The larger sample was screened using the Zung Self-Report Depression Scale. Subjects scoring between .45 and 1.00 were classified as belonging in the depressed group, while subjects with scores between .25 and .44 were classified as non-depressed. Zung scores were rank ordered from highest to lowest score. Subjects were contacted for further participation in the study beginning with those obtaining the highest and lowest scores and continuing through the rank order until the desired number of subjects was obtained. Those selected on the basis of the Zung Scale were administered the BDI just prior to participation in the evoked potential study. Criteria for inclusion in the nondepressed group was based on a BDI score of 0-9. A score of 10-63 was used for inclusion in the depressed group. Any subject whose score on the Zung and BDI was not consistent, i.e., placed in different categories, was not included.

On the Zung scale the mean score for the depressed group was .59 (s.d.=.094) with a range of .46 to .71, and for the nondepressed group a mean of .33 (s.d.=.037) with a range of .25 to .39. On the BDI, the depressed group had a mean score of 16.6 (s.d.=6.02) with a range of 10 to 33, while the nondepressed group had a mean of 3.25 (s.d.=2.5) with a range of 0 to 8.

Materials

Depression Measures: The BDI contains 21 multiple choice items. It is designed to measure behavioral manifestations of depression along a continuum of severity (Beck, et al., 1961). Scores on the BDI range from 0 to 63, with scores of 0 to 9 classified as non-depressed (Beck et al., 1961; Bumberry, Oliver, & McCure, 1978; Ingram & Smith, 1984; Morris & Kanfer, 1983; Tanaka-Matsumi & Kameoka, 1986).

The Zung Self-Rating Depression Scale is a 20-item scale measuring symptoms of depression (Zung, 1965). Scores on the Zung range from .25 to 1.00. A score of .45 is considered a cut-off score between subjects with none to minimal symptoms (.25-.44) and subjects with moderate to high levels (.45-1.00) of depression in a college population

(Blumenthal, 1975). The Zung and BDI have a correlation coefficient of .76 (Blumenthal, 1975). The BDI and the Zung self-report inventories have been found to be valid instruments for measuring symptoms of depression in college populations (Blumenthal, 1975; Bumberry, Oliver, & McClure, 1978).

Stimuli

The stimuli in all evoked potential conditions consisted of tones and background white noise presented binaurally. Stimulus presentation was similar to that used by Hansen and Hillyard (1980). The present study differed in that it used two frequency separations instead of three. Tones and background white noise were of equal intensity (60dB SPL), presented over Realistic headphones while the subject was seated in a sound-attenuated and electrically shielded room. Tones of 51 msec were designated as standards and tones of 102 msec were designated as targets.

In each of four conditions, tones of two different frequencies were presented. In each condition, low tone frequency was 300 Hz, while the higher frequency was either 350 Hz or 700 Hz. This gave two levels of inter-channel frequency separation (50 and 400 Hz), respectively. Within each condition tones of low and high frequencies were presented in a random order with equal probability. The interstimulus intervals were 500, 625, 750, 875, and 1000 msec ordered randomly with a rectangular distribution.

EEG Data

Gold-plated disc electrodes were used to collect EEG data. The electrodes were affixed at CZ, FZ, A1, and A2 according to the International 10-20 System. CZ and FZ were referenced separately to linked ear lobes (A1 and A2), with an electrode on the forehead serving as a ground. Electrode impedence was kept below 5 Kohms and checked at the time of placement and after each condition. Eye movement artifact was monitored by two electrodes placed super-orbitally and over the outer canthus of the left eye (Cornwally & Kleerman, 1978). A Grass Model 79 polygraph with band passes of 0.1 to 100 Hz with 60 Hz notch filters was used to amplify the EEG data. A MetraByte DASH 16 A/D conversion board digitized the EEG. Stimulus presentation and data acquisition were synchronized by an IBM PC-XT. For each stimulus, EEG data were collected 30 msec prior to stimulus onset and lasted 357 msec after stimulus onset for a total EP window of 387 msec. Within the EP window, the EEG was sampled every 3 msec.

Procedure

Screening for subjects occured in undergraduate Psychology courses using the Zung Self-Rating Depression Scale. Subjects selected on the basis of the Zung were contacted and scheduled for EP testing within a two week time period. In the laboratory they were given the BDI and participated individually in the four conditions of the selective attention paradigm. If a subject's score on the Zung and Beck were inconsistent (e.g., mildly depressed vs non-depressed) the subject was dismissed from the study without completing the selective attention paradigm.

Following completion of the Beck, subjects were seated in a reclining chair in a shielded room. Informed consent was obtained from each subject and electrodes were affixed.

To familiarize subjects with the tone duration discrimination task, 10 standard and 10 target stimuli of 300 Hz were given, alternating standard and target. The same procedure was used for the 700Hz and 350Hz tones. A practice sequence of 100 tones like the first condition was given prior to the actual experimental conditions. Subjects were instructed to push a response key when they heard a target. The practice sequence was intended to familiarize the subjects with the task so as to eliminate substantial practice effects during the experiment.

The experiment proper consisted of four attentional conditions, each containing 400 tones divided into 200 tones of two different frequencies. Within each frequency were standards and targets with overall probabilities of .4 and .1 respectively. Table 1 illustrates the frequencies and instructions for each condition.

Place Table 1 about here

Within each attention condition, subjects were instructed to focus on one frequency of tones, ignore the other frequency and push a response key when they heard the target tone in the attended frequency. For clarity the conditions were labeled 1, 2, 3, and 4 in Table 1. The first two conditions used frequencies of 300 Hz and 700 Hz. In condition 1, subjects were instructed to attend to the 300 Hz tones. In condition 2, they were instructed to attend to the 700 Hz tones. Conditions 3 and 4 used tone frequencies of 300 Hz and 350 Hz. Subjects were instructed to attend to the 300 Hz tones in condition 3 and to the 350 Hz in condition 4.

Subjects were randomly assigned to different orders of presentation according to a Latin Square of the frequency separations. Brief breaks were taken between conditions at which time electrode impedence was checked.

Data Reduction

Single trial evoked potentials containing excessive eye movement artifact were excluded from the average evoked potentials (AEPs). For the control group the mean number of trials averaged per condition were 316 (condition 1), 316 (condition 2), 312 (condition 3), and 312 (condition 4). The standard deviations were 5.56, 6.37, 15.06, and 7.31 for conditions 1, 2, 3, and 4 respectively. The mean number of trials (and standard deviations) for the depressed group were as follows: condition 1 - 313(8.64), condition 2 - 311(16.67), condition 3 - 314(11.78), and condition 4 - 313(12.48). For each subject, 16 AEPs were calculated, eight from electrode site CZ and eight from electrode site FZ. At each electrode site, two AEPs were calculated for each of the four conditions - one for low frequency standards and one for high frequency standards.

Using the 16 AEPs, four Nd waves were calculated per subject, per electrode location (CZ, FZ). The Nd wave is the difference between the AEP to standard tones when not attended subtracted from the AEP to the same tones when attended (Alho, Paavilainen, Reinikainen, Sams, & Naatanen, 1986; Born, Brauninger, Fehm-Wolfsdorf, Voigt, Pauschinger, & Fehm, 1987; Hansen & Hillyard, 1980; Parasuraman, 1980). From conditions 1 and 2, the AEP to the standard 300 Hz tones in condition 2 (not attended) was subtracted from the AEP to the standard 300 Hz tones of condition 1 (attended) to yield Nd at the 400 Hz separation abbreviated Nd 300(400). The AEPs of the 700 Hz standard tones of conditions 1 and 2 were likewise subracted to give Nd 700(400). For conditions 3 and 4, Nd was likewise calculated to yield Nd 300(50) and Nd 350(50).

From each Nd wave, four dependent measures were taken - two amplitude and two latency measures. The first amplitude measure was peak amplitude, defined as the most negative peak in the 50 - 357 msec poststimulus range (Hansen & Hillyard, 1980; Parasuraman, 1980). The second amplitude measure was the mean amplitude across all data points of the Nd wave within the interval 0 - 357 msec poststimulus (Born, Brauninger, Fehm-Wolfsdorf, Voigt, Pauschinger, & Fehm, 1987). The first latency measure was the latency at the peak amplitude (Hansen & Hillyard, 1980; Parasuraman, 1980). The second was the latency at which the leading edge of the Nd wave reached 25% of the peak amplitude, termed 25% latency (Hansen & Hillyard, 1980).

For each dependent measure analysis of variance procedures were carried out. Factors included were subjects (control X depressed), separation frequency (400 X 50 Hz), and electrode site (CZ X FZ).

Results

Nd Wave

Figure 1 shows the grand averages of the Nd waves from Cz and Fz scalp locations for each group at each frequency separation.

Place Figure 1 about here

Preliminary analysis of variance (ANOVA) procedures for each dependent measure (Mean Amplitude, Peak Amplitude, Peak Latency, and 25% Latency) showed no significant main effects for Sex or Tone frequency (high vs low), nor were interaction effects with the factors Group, Frequency separation, and Electrode location present. Therefore, data were collapsed across Sex and Tone frequency in subsequent analyses as done by Hansen and Hillyard (1980).

Three-way ANOVAs were carried out with the following factors: channel separation (400Hz vs 50Hz), subject group (Control vs Depressed), and scalp location (Cz vs Fz) for each dependent measure. The analysis of mean amplitude produced a significant main effect for frequency separation with the mean amplitude being larger at the 400Hz separation compared to the 50Hz separation ($\underline{F}(1,30)=11.07$, $\underline{p}<.002$). This difference can be seen in the greater negativity of the grand average Nd wave of the 400 Hz frequency separation, compared to the 50 Hz separation illustrated in Figure 1. The analysis of peak amplitude also produced a significant main effect for frequency separation ($\underline{F}(1,30)=21.05$, $\underline{p}<.001$). As with mean amplitude, peak amplitude for the 400Hz separation was greater than for the 50Hz separation.

The main effects of mean amplitude and peak amplitude were not significant for Group and Scalp location, nor were significant interaction effects revealed.

The analysis of peak latency produced a significant main effect for electrode location, with Cz peak latency occurring earlier than Fz ($F(1,30)=4.62$, $p<.03$). The measure of 25% latency was also significant for electrode location ($F(1,30)=5.68$, $p<.02$) with Cz occurring earlier than Fz. The analysis of peak latency and 25% latency data produced no main effect for Group or Frequency Separation, and no significant interaction effects were revealed.

To address the hypothesis that Depressed and Control subjects display the same degree of change in amplitude and latency from the 400 Hz to the 50 Hz frequency separation, the difference of the 400 Hz minus the 50 Hz separation for each subject was computed and analyzed for each Nd measure. The analysis of variance of Group by Scalp location using this difference score was not significant for any of the four dependent measures.

Place Table 2 about here

Table 2 shows group means and standard deviations for each dependent measure from Cz and Fz for the two frequency separations. To analyze the specific predictions made concerning differences between Depressed and Control subject groups, planned comparisons were made using the Dunn's Test (Kirk, 1968). Comparisons between the two groups (Depressed vs Control) were done for each frequency separation at each electrode location. This comprised four comparisons for each of the four dependent measures: at Cz for the 400Hz separation, at Cz for the 50Hz separation, at Fz for the 400Hz separation, and at Fz for the 50Hz separation. None of these comparisons yielded a significant difference between groups.

Since level of depression was proposed as one possible explanation for a lack of group differences, the above planned comparisons were done on a subsample of the groups using the eight subjects with the highest BDI scores for the Depressed group and the eight subjects with the lowest BDI scores for the Control group. The Depressed subgroup had a mean BDI score of 21.37, with a range of 18-33 (s.d.=4.96). The Control subgroup had a mean of 1.75 and a range of 0-3 (s.d.=1.16) on the BDI. The differnce between means of the subsamples were similar to those reported by Krames and MacDonald (1985) who found a BDI mean of 24.8 for the Depressed group and a mean of 6.2 for the Control group. As with the total subject sample, no significant differences were found between Depressed and Control groups using the subsamples. Table 3 shows the means and standard deviations of the subsamples for each dependent measure.

Place Table 3 about here

Average Evoked Response

Figures 2 and 3 show the grand average evoked potentials for each group recorded at Cz and Fz for each frequency separation and attentional direction (attend vs ignore).

Place Figure 2 about here

Place Figure 3 about here

Table 4 shows the group means and standard deviations of N1 peak amplitude and mean amplitude (0-357 ms) at Cz and Fz scalp locations.

Place Table 4 about here

Upon examination of these grand AEPs, there appeared to be an overall greater negativity for the Control group compared to the Depressed group regardless of attentional condition. If this were indeed the case, the Nd wave data would not show group differences. The negativity in the grand AEPs appeared to be most pronounced at the N1 peak. Thus, 2 (frequency separation) x 2 (attend vs ignore) x 2 (groups) ANOVAs were done separately for Cz and Fz using N1 (maximum negative peak between 50 and 200 msec post-stimulus onset) and overall mean amplitude for the entire post-stimulus waveform. As suggested by Figures 2 and 3, N1 was significantly larger in the control subjects than in the depressed subjects at Fz ($\underline{F}(1,30)=4.43, \underline{p}<.04$). The overall mean amplitude measure was somewhat more negative for the contol subjects, but not statistically so, even when the two extreme subsamples were used in the ANOVAs.

As expected, there was a significant difference in mean amplitude between the attend vs ignore conditions at Cz ($\underline{F}(1,30)=8.94, \underline{p}<.005$) and Fz ($\underline{F}(1,30)=15.05, \underline{p}<.0005$). The mean amplitude was larger for the AEPs of the attended conditions as compared to the AEPs of the ignored conditions. This same mean amplitude difference between attend vs ignore conditions was seen with the subsamples as well, at Cz ($\underline{F}(1,14)=4.0, \underline{p}<.06$), and at Fz ($\underline{F}(1,14)=7.14, \underline{p}<.01$).

<u>Behavioral Responses</u>

Hits were defined as responses to targets in the attended channel. A response was considered a hit when it occurred following an attended target tone or following the tone after the target. This was done due to the short ISI and the possibility that the response was to the prior tone. Due to the rapid presentation of tones it was not possible to definitively relate a response to a particular stimulus tone. Also, subjects varied in their response approach with some responding more frequently to attended stimuli than others. Table 5 shows the group means and standard deviations of hits at the 50Hz and 400Hz frequency separations.

Place Table 5 about here

A three-way analysis of variance was carried out with factors Group, Order of presentation of condition, and Frequency separation. There was no significant difference in the number of hits between the Control and Depressed groups. Difference due to order of presentation of conditions was also not significant. There was a main effect for frequency separation ($F(1,30)=6.2$, $p<.01$) with more hits being made by both groups at the 400Hz separation compared to the 50Hz separation.

Discussion

The present study used an experimental paradigm similar to that of Hansen and Hillyard (1980). As predicted, subjects exhibited a similar pattern of Nd waves as found by those authors. Consistent with Hansen and Hillyard (1980), the peak amplitude of the Nd wave was significantly reduced for the 50 Hz frequency separation compared to the 400 Hz frequency separation at both the Cz and Fz electrode locations. This smaller amplitude at the 50 Hz separation was also present with the mean amplitude measure at Cz and Fz.

To explain this reduction in amplitude, it has been suggested by Hansen and Hillyard (1980) that different processing or selection strategies may be operating at the two frequency separations. Within the larger frequency separation, subjects may be able to make absolute judgements concerning pitch and select in a sequential manner, with pitch selection being followed by tone duration judgement. However, at the smaller frequency separation, subjects may only be able to make relative pitch judgements while having to also make parallel judgements concerning tone duration. The change in processing strategy at the smaller frequency separation may be due to greater difficulty in discriminating the two frequencies. This possibility is supported by the decrease in hits seen in the smaller frequency separation in this study and of the Hansen and Hillyard (1980) study.

Also consistent with Hansen and Hillyard (1980) were the latency differences found between scalp locations. Peak latency and 25% latency occurred earlier for the Cz scalp location. This difference suggests that the origin of the Nd wave may have a more posterior scalp distribution.

Replicating the findings of Hansen and Hillyard (1980) further supports the use of the present evoked potential paradigm to elicit the process of selective attention as measured by the Nd wave. The main intent of the present study was to investigate changes in selective attention related to depression as measured by the Nd wave. The present results do not suggest any definitive differences in selective attention between depressed and control subjects.

An overall decrease in the Nd wave was not found; therefore, the hypothesis that depressed subjects allocate less attentional capacity and less selectivity to external tasks was not upheld. Further, the prediction that depressed subjects would have smaller amplitude and later onset at the 400Hz separation, compared to Control subjects, indicating that Depressed subjects were not allocating as many attentional resources to the attended channel as Control subjects, and/or that the selective attention process was not as efficient, was not found.

Hypotheses of group differences at the 50Hz separation were also not upheld. The hypothesis that depressed subjects, compared to control subjects, would have Nd waves with smaller amplitude and later onset at the 400 Hz separation, but not the 50 Hz separation, was not upheld.

Therefore, Krames and MacDonald's (1985) finding that on more difficult tasks, differences due to depression diminish as task difficulty forces depressed subjects to abandon the use of depressed schemata was not supported. Even when the level of depression was equated in the present study (by use of a subsample) with that of Krames and MacDonald (1985), group differences at each frequency separation were not found.

The second hypothesis regarding the 50 Hz separation, of group differences at the 50 Hz separation but not the 400 Hz separation, was not confirmed. This provides no evidence indicates that depression interacts with increased task difficulty to further reduce the allocatable attentional resources of depressed subjects.

The hypothesis that the change in attentional processing from the 400 Hz to 50 Hz separation is similar in depressed and control subjects was upheld. This finding is supported by the lack of differences found between groups in the ANOVAs using the difference score between the 400 Hz and 50 Hz frequency separations.

Differences in selective attention between depressed and control subjects were not supported by the present results. In contrast, the hypothesis of no difference in selective attention between subjects reporting mild to moderate levels of depression and control subjects appears to be supported. All statistical analyses of the Nd wave indicate no difference between the two groups of subjects. Even when the preplanned group comparisons (Dunn's Test) were analyzed again using the t-test as the most powerful statistical test of group differences, not adjusting the alpha level for number of tests computed, no group differences were found.

Theoretically, the results of the present study suggest that cognitive changes seen with depression are not related to selective attention, but possibly to arousal level or other information processing mechanisms such as memory and recall. Prior behavioral research which has inferred attentional changes related to depression has done so from evidence concerning encoding and memory. Also, the evoked potential studies inferring such changes in attentional processes have done so based on studies of cortical excitement, response evaluation, and reaction time. In contrast, the present study used an experimental paradigm and evoked potential measure (Nd wave) considered to be a direct elicitor and measurement (respectively) of selective attention. Therefore, the present results appear to disconfirm attentional changes in depression proposed by previous research. This disconfirmation appears strengthened by the lack of differences between depressed and control subjects seen across all statistical analyses of Nd, including the t-test.

While the present results suggest there is no difference in the selective attention process between depressed and con..ol subjects, this implication must be qualified as pertaining to the particular subject pool sampled. Subjects in the present study were selected from a pool of young adult college students. Depression was defined as self-reported symptoms of a mild to moderate level. Given the subject pool, the lack of a significant difference in Nd wave data between depressed and control subjects may be attributed to the low to moderate levels of depression in the depressed group. If this is the case, then subjects with higher levels of depression might show clearer attentional differences compared to nondepressed subjects. This explanation for the lack of differences found is not supported, however, by the following two results: There was a significant between-group difference evidenced by N1 amplitude at Fz demonstrating measurable physiological difference between groups. In addition, planned comparisons using subsamples with BDI scores (Highest depressed vs lowest controls), which were similar to those in Krames and MacDonald's (1985) study, showed no significant between-group differences for Nd wave data. Therefore, level of depression does not seem a sufficient explanation for the lack of differences found using Nd wave data.

While previous research has found differences between depressed and control subjects with levels of depression comparable to the present study, it is possible that differences in age and medical treatment may be of importance. Of the studies reviewed, the majority drew their sample of depressed subjects from inpatient facilities. In addition, these subjects tended to be older (range 40-70 years) than the subjects in the present study. It is possible that factors associated with age and the need for inpatient treatment may confound the effects of depression on cognitive processes such as selective attention. There is a growing body of research which suggests that depression and early dementia frequently coexist in patients presenting for treatment (McLean, 1987, Teri & Reifler, 1987). Differential diagnois of these two disorders is difficult and often only possible after long-term follow-up (Addonizio & Shamoian, 1987). It is possible in the studies using older inpatients that other physical conditions interacted with depression to produce the results reported. Depressive symptoms of a mild to moderate level in a young adult population may not be sufficient to affect selective attention. However, the effects of severe depression and the interaction of depression with age and other physical conditions such a dementia on selective attention warrant further investigation.

While the present study did not find significant differences for Nd between depressed and control subjects, the results do suggest further research is needed. Supporting this need is a study by El Massioue and Lesevre (1988). The authors used a selective attention paradigm similar to the present study, but with channel designated as right and left ear. The task was considered relatively easy since channel separation was physical. The depressed subjects in this study were inpatients between the ages of 50 and 65 years. Although El Massioui and Lesevre (1988) did not use the Nd wave, but rather averaged evoked responses to stimuli, they found reduced amplitudes for the N2 peak for targets in the depressed subjects compared to control subjects. They also found an increase in amplitude in the N1 time window for the attended channel stimuli for the control subjects but not for the depressed subjects.

The present study also found a difference in the N1 amplitude with the Control group showing greater negativity compared to the Depressed group across attentional conditions. Since the overall mean amplitude measure did not show a group difference, it appears that the greater negativity shown by the Control subjects is only an N1 effect, not an overall negativtiy. Naatanen and Picton (1987) suggest that several different cerebral processes contribute to the N1 wave of the auditory evoked potential. They state that an N1 increase exhibited in the attentional paradigm my be indicative of higher arousal levels and/or sensory sensitivity. They go on to say that attention may directly affect N1 "suggesting that attention is accomplanied by a general and nonspecific increase in cerebral excitability which might increase the amplitude of the N1 wave "(p 406). The component which contributes to this N1 increase is one which is maximally recorded from the frontocentral scalp.

In the present study the N1 difference between groups seen at the frontal scalp location (Fz) suggests that the above interpretation of the N1 increase reported by Naatanen and Picton (1987) is applicable. Therefore, the larger N1 amplitude at the Fz scalp location seen in the control subjects in the present study may represent increased arousal level or sensory sensitivity accompanying the selective attention process, but without group differences occuring in those selective attention processes.

In addition to the present study, the amplitude of N1 has been shown to be smaller in depressed subjects by other investigators (El Massioui & Lesevre, 1988; Pfefferbaum, Wenegrat, Ford, Roth, & Kopell, 1984).
El Massioue and Lesevre (1988) suggest that the differences they found between groups for the N1 and N2 peaks may represent an impairment of the mechanism of selective attention in depressed patients. The present study, however, suggests that the differences between groups are

due to arousal level and not attentional differences. Depressed subjects appear to have lower levels of arousal as reflected in smaller N1 amplitudes. This hypothesis is strengthened by the N1 differences found by others and the low level of arousal associated with depression reported in studies of EEG activation (Shagass, 1955; Shagass, Roemer, & Straumanis, 1983). Further, even though the groups could be differentiated on the basis of the Beck score and N1 negativity, selective attention differences, as measured by the Nd wave, were not found. The results of the El Massioue et al. (1987) and the present study may serve as impetus for further investigation of changes in selective attention as measured by the Nd wave of the auditory evoked potential as well as differences related to N1 and arousal level. As mentioned previously the evoked potential provides a nonintrusive method of evaluatiing processes such as selective attention.

While the present attention paradigm is thought to elicit the process of selective attention, it is possible that attentional changes due to depression may be situationally specific. That is, attentional changes associated with mild to moderate levels of depression may be seen with affectively toned stimuli, but not present with neutral stimuli such as the tones in the present study.

Behavioral studies (Dunbar & Lishman, 1984) have shown that depressed subjects do not necessarily differ from controls in the amount of information recalled but in the nature of the information recalled. Depressed subjects tend to recall more negatively toned material. It is possible that in the behavioral studies the difference in performance seen was not due to amount of attentional resources, but rather the efficiency of attentional resources or other cognitive processes. The depressed subjects may not have been as efficient or flexible in their allocation of attentional resources or direction of attention when presented with affectively toned material. Since the present task did not involve affectively toned stimuli, it remains possible to only speculate about the efficiency and extent of selective attention, as measured by the evoked potential, for depressed and control subjects when presented with affectively toned stimuli.

Investigation of the relationship between level of depression and changes in the Nd wave seems warranted. In reference to the possible impact of affectively toned material, it is also recommended that the stimuli used in selective attention paradigms be expanded to include affectively toned stimuli. Auditory evoked potentials studies of selective attention which have combined the use of tones with other stimuli have been successful in recording AEP changes related to direction of attention. These studies have included the use of spoken language

(Woods, Hillyard, & Hansen, 1984) and music (Neer & Thomas, 1987).

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Table 1

Tone frequencies and instructions of the four attentional conditions

	Frequency 1	Frequency 2
Condition 1	300Hz (Attend)	700Hz (Ignore)
Condition 2	300Hz (Ignore)	700Hz (Attend)
Condition 3	300Hz (Attend)	350Hz (Ignore)
Condition 4	300Hz (Ignore)	350Hz (Attend)

Condition: Standard tone n=160 probability=.4
Target tone n=40 probability=.1

Orders of presentation: Conditions 1, 2, 3, 4
2, 1, 4, 3
3, 4, 1, 2
4, 3, 2, 1

Table 2

Group means, and standard deviations ( ) of each dependent measure at Cz and Fz scalp location for the 400 Hz and 50 Hz frequency separation

Nd measure	Cz		Fz	
	Depressed	**Control**	**Depressed**	**Control**
Peak Amplitude 400 Hz	-3.6409 (1.93)	-4.1733 (2.86)	-3.827 (1.72)	-4.4834 (2.89)
Mean Amplitude	-.9773 (1.19)	-.6985 (1.84)	-1.2114 (1.04)	-.8812 (1.75)
Peak Latency	223.9687 (46.70)	244.3125 (69.76)	262.875 (59.76)	256.218 (68.98)
25% Latency	155.625 (56.21)	176.75 (59.73)	180.375 (49.45)	186 (57.32)
Peak Amplitude 50Hz	-2.3487 (1.32)	-2.677 (1.65)	-2.278 (1.52)	-2.5811 (1.80)
Mean Amplitude	-.0432 (.68)	-.1858 (1.27)	-.0238 (.74)	-.2467 (1.32)
Peak Latency	222.0937 (66.09)	233.4375 (77.78)	235.125 (71.28)	232.09 (67.57)

Table 2 continued

25% Latency	163.5	170.7187	184.969	182.06
	(65.68)	(59.11)	(74.10)	(57.06)

Table 3

Subgroup means and standard deviations ( ) of dependent measures at Cz and Fz for the 400 Hz and 50 Hz frequency separation

Nd measure	**Cz**		**Fz**	
	Depressed	Control	Depressed	Control
Peak Amplitude	-3.53	-3.80	-3.72	-4.10
400 Hz	(2.2)	(3.70)	(1.60)	(3.54)
Mean Amplitude	-1.05	-.09	-1.05	-.57
	(1.49)	(2.27)	(1.19)	(2.31)
Peak Latency	226.13	232.13	277.13	260.25
	(59.03)	(89.14)	(73.67)	(89.10)
25% Latency	160.31	181.75	190.5	195.94
	(73.96)	(72.29)	(61.56)	(67.79)
Peak Amplitude	-2.29	-2.19	-2.06	-2.29
50 Hz	(.82)	(1.23)	(1.27)	(1.52)
Mean Amplitude	-.09	.32	.01	.23
	(.78)	(.76)	(.90)	(.84)
Peak Latency	218.25	225.94	240.94	241.81
	(75.57)	(102.27)	(65.47)	(91.81)

Table 3 continued

25% Latency	152.44	173.06	184.88	194.44
	(84.02)	(76.73)	(78.05)	(67.19)

Table 4

Group means and standard deviations ( ) of N1 and mean amplitude at Cz and Fz scalp location, for the 400 Hz and 50 Hz

	Cz		Fz	
	Depressed	Control	Depressed	Control
N1				
400 Hz				
Attend	-4.62	-5.58	-4.37	-6.10
	(1.4)	(3.33)	(1.32)	(3.32)
Ignore	-4.18	-5.58	-4.31	-5.94
	(1.76)	(2.91)	(1.83)	(2.47)
50 Hz				
Attend	-4.13	-5.39	-4.31	-5.91
	(2.08)	(2.75)	(1.93)	(2.67)
Ignore	-4.51	-5.61	-4.51	-5.99
	(1.71)	(2.73)	(1.64)	(2.98)
Mean Amplitude				
400 Hz				
Attend	-1.44	-1.67	-1.84	-2.47
	(1.24)	(1.99)	(1.07)	(1.58)
Ignore	-.75	-1.24	-1.19	-1.76
	(1.00)	(1.26)	(1.11)	(.93)

Table 4 continued

50 Hz					
Attend	**-1.37**	**-1.85**	**-2.09**	**-2.65**
	(1.18)	**(1.68)**	**(1.33)**	**(1.57)**
Ignore	**-1.04**	**-1.14**	**-1.48**	**-1.86**
	(.88)	**(1.04)**	**(.91)**	**(1.24)**

Table 5

Group means and standard deviations ( ) of hits at 50 Hz and 400 Hz frequency separation

	Depressed	**Control**
50 Hz	47.44	50.44
	(14.11)	(17.23)
400 Hz	53.94	54.75
	(13.11)	(13.55)

Figure Caption

<u>Figure 1</u>. Nd waves from Cz and Fz for each group at each frequency separation.

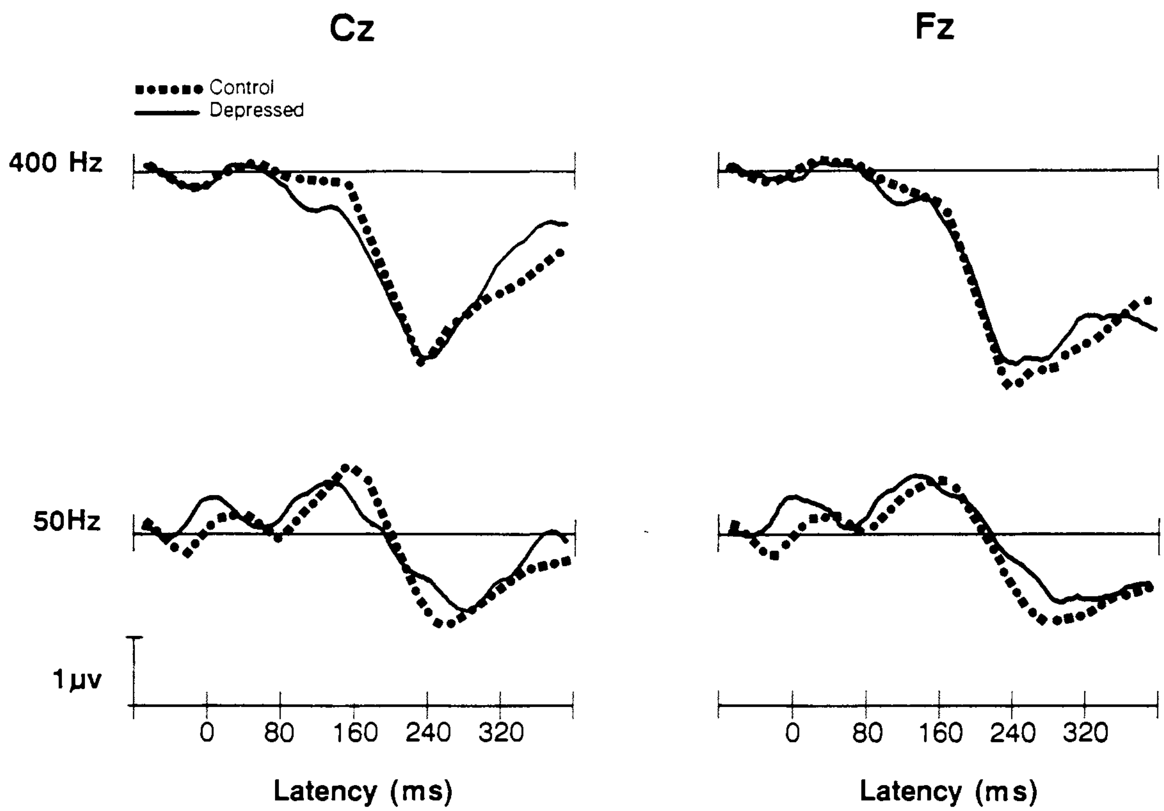
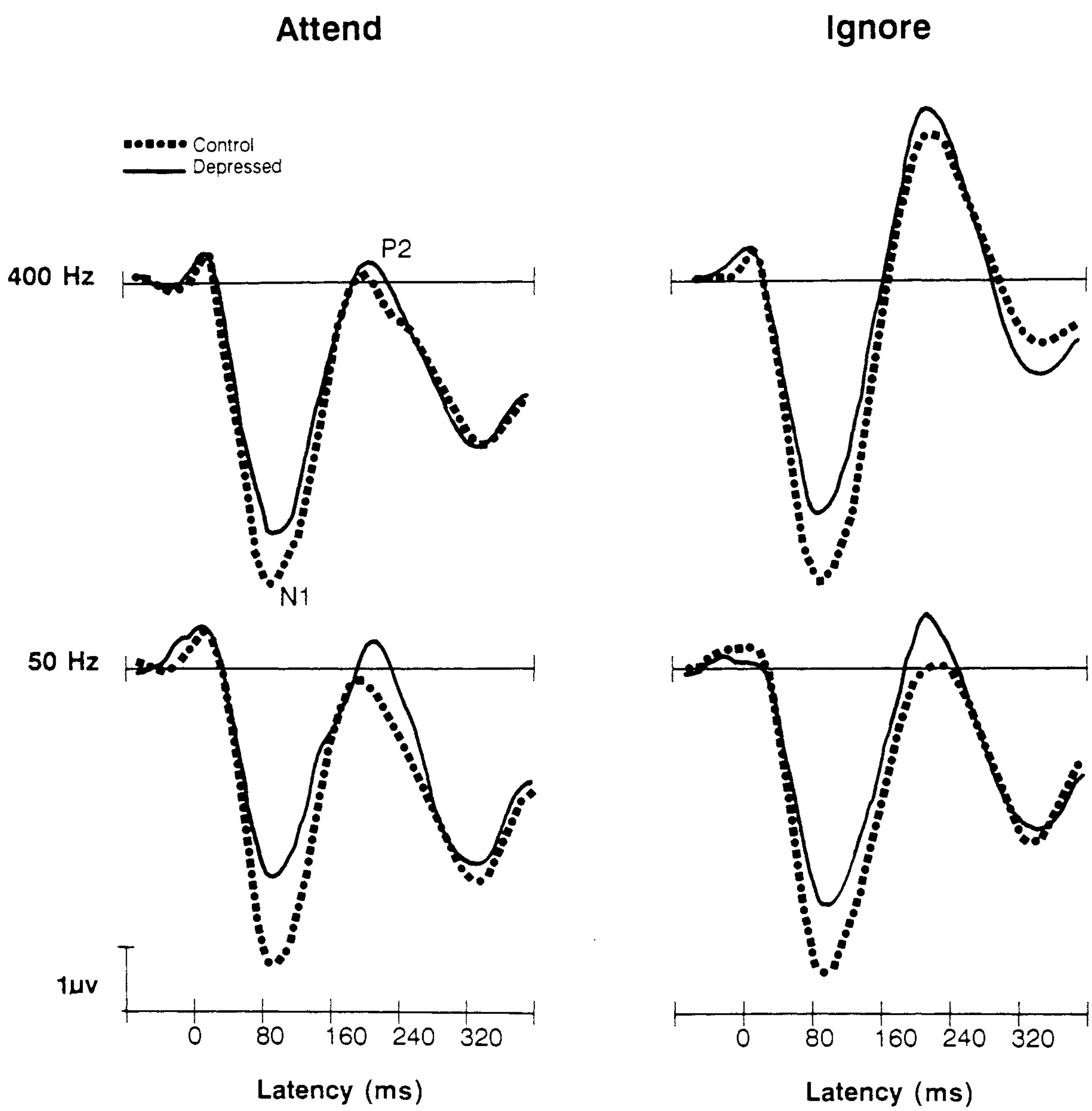

Cz
Fz
Control
Depressed
400 Hz
50Hz
1 µv
0
80
160
240
320
Latency (ms)

Figure Caption

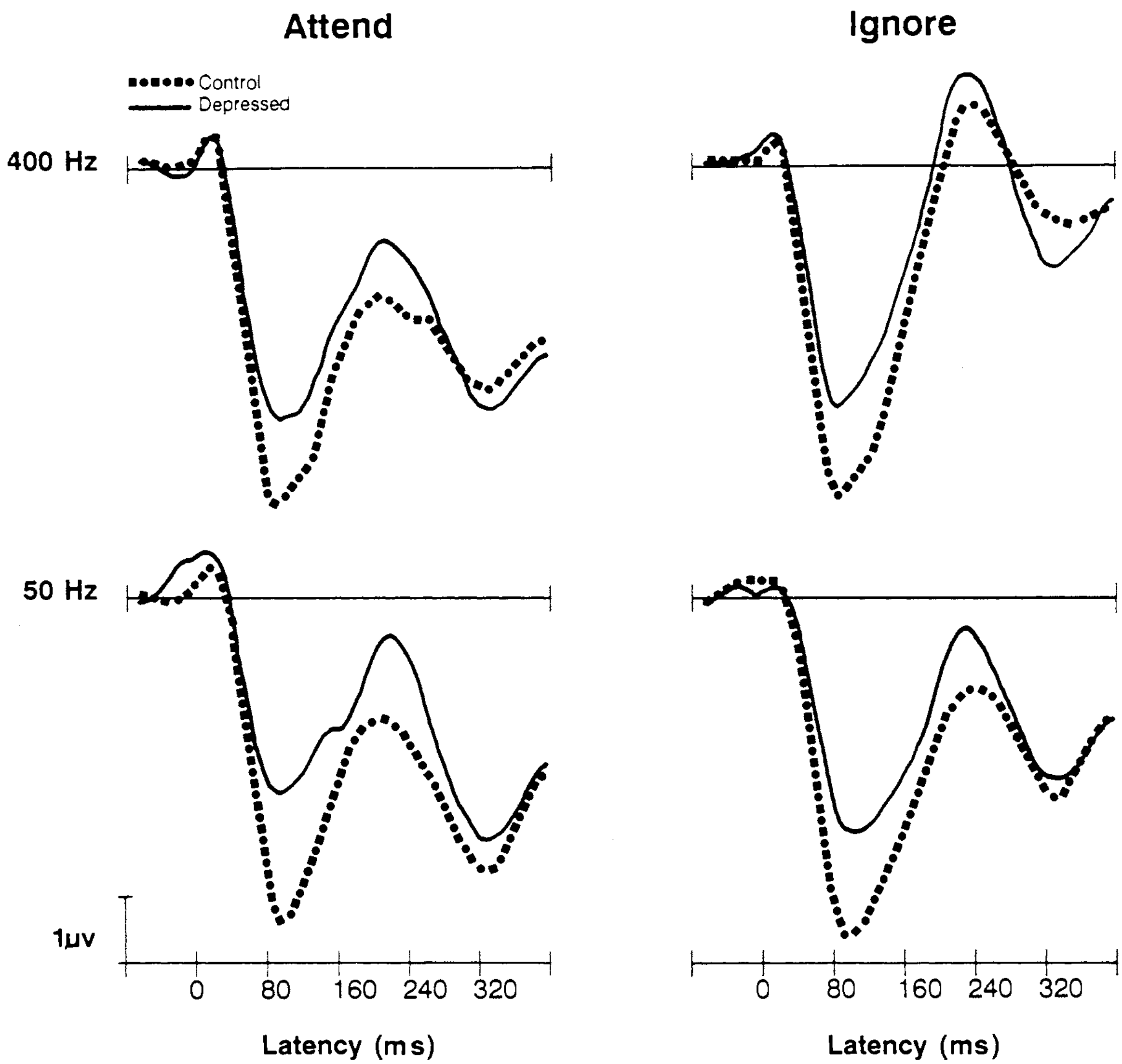
Figure 2. Grand average evoked potentials recorded at Cz for each group.



Attend
Ignore
Control
Depressed
400 Hz
P2
N1
50 Hz
1µv
0
80
160
240
320
Latency (ms)
0
80
160
240
320
Latency (ms)

Figure Caption

Figure 3. Grand average evoked potentials recorded at Fz for each group.



Attend
Ignore
Control
Depressed
400 Hz
50 Hz
1µv
0
80
160
240
320
Latency (ms)

VITA

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