

## A Dual-Task Analysis of Resource Allocation in Dysthymia and Anhedonia

Cindy M. Yee and Gregory A. Miller

Research has shown dysthymic individuals to be hyporesponsive at various stages of information processing, yet it is not clear whether dysthymics are deficient in the amount of available attentional resources for information processing or, instead, in the allocation of those resources. To distinguish between these possibilities, the authors compared dysthymics to anhedonic and normal control Ss during the performance of memory tasks, under conditions of varying task priority and difficulty. Although there were no performance differences, dysthymics and anhedonics exhibited a consistently smaller P300 component of the event-related potential. Furthermore, P300 results indicated that dysthymics and anhedonics responded differently from controls to variations in task demands. Thus, although evidence was obtained for group differences in both resource capacity and resource allocation strategy, the overall pattern of results is interpreted as favoring the latter.

There is increasing evidence that early-onset dysthymia is accompanied by disruptions in cognitive processing, particularly a tendency toward hyporesponsiveness at various stages of information processing (Miller, Yee, & Anhalt, 1994; Yee, Deldin, & Miller, 1992; Yee & Miller, 1988). To account for cognitive processing deficits in mood disorders, some researchers have proposed that depressed mood may increase the information processing load or drain attentional resources that otherwise might be devoted to task performance (for reviews, see Ellis & Ashbrook, 1988; Hasher & Zacks, 1979). The goal of the present research was to explore such a resource allocation account of dysthymia as a step toward identifying possible underlying mechanisms, which could then be used to further our understanding of early-onset dysthymia and of the relationship between this condition and a propensity for developing recurrent episodes of major depression (e.g., Akiskal, 1983; Klein & Miller, 1993; Kovacs et al., 1984). Specifically, we were inter-

ested in adopting one theoretical approach to attention, offered by resource theory, that could be examined empirically with a dual-task paradigm to provide a detailed analysis of cognitive deficits in dysthymia.

To begin to understand abnormal strategies in information processing, researchers have compared early-onset dysthymic and normal control subjects on various tasks. As measured by event-related brain potentials (ERPs) and skin conductance response (SCR), dysthymics were found to be hyporesponsive when anticipating aversive slides (O-wave and SCR; Yee & Miller, 1988), when offered monetary incentives (N200; Miller et al., 1994), and when presented with basic perceptual stimuli (N100–P200; Yee et al., 1992). In each of these studies, however, the hyporesponsiveness did not extend to all aspects of physiological activity, to overt behavioral responses, or to self-report data. Rather than suggesting a global deficit, these results indicate that a particular component of information processing may be impaired in dysthymia, whereby subjects resort to unusual cognitive strategies to achieve normal behavioral performance (Miller & Yee, 1994).

It is unclear why dysthymic subjects are less responsive than normal control subjects when processing task-relevant stimuli. Although group differences of this sort have been attributed to differences in effort or motivation (e.g., Cohen, Weingartner, Smallberg, Pickar, & Murphy, 1982), this possibility is unlikely because group differences in reaction time (RT) and performance accuracy were not obtained in any of our previous studies. An alternative explanation for the observed differences is that under some circumstances dysthymic subjects may need to withdraw from a situation to achieve normal task performance (Miller & Yee, 1994). That is, the attentional demands of certain situations may interfere with performance unless dysthymics are able to disengage from some aspects of it, because they may not have the capacity to process fully all of the available information and perform the required task. One approach to investigating this possibility is to manipulate systematically the processing demands placed on subjects and then observe performance on tasks competing for attentional resources.

---

Cindy M. Yee, Department of Psychology, University of California, Los Angeles; Gregory A. Miller, Department of Psychology, University of Illinois at Urbana-Champaign.

This article is based on a doctoral dissertation submitted by Cindy M. Yee to the University of Illinois at Urbana-Champaign. Portions of this research were presented at the annual meeting of the Society for Research on Psychopathology, Boulder, Colorado, 1990. The research was supported in part by National Institute of Mental Health (NIMH) National Research Service Award MH09624, NIMH Grant MH39628, the University of Illinois Research Board, and the Committee on Research of the Academic Senate of the Los Angeles Division of the University of California.

We gratefully acknowledge the assistance of Arthur Kramer and Michael Coles throughout this study, of Jean Anhalt, Patricia Deldin, and Leyan Fernandes in data collection, and of Jackson Beatty, Daniel Klein, and Keith Nuechterlein for their comments on drafts of this article.

Correspondence concerning this article should be addressed to Cindy M. Yee-Bradbury, Department of Psychology, University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles, California 90024-1563.

### Resource Theory and the Dual-Task Paradigm

Resource theory proposes that the human capacity for processing information may be conceived of as drawing on a finite amount of attentional resources that can be shared during the concurrent performance of two or more tasks. Improvement of performance on one task therefore comes at the expense of performance on other tasks (Kahneman, 1973; Navon & Gopher, 1979; Norman & Bobrow, 1975). Patterns of interference can be examined by "overloading" an individual, such that, as more resources are allocated to one task, performance on another task is expected to decline.

Much of the empirical basis for resource theory was developed using the dual-task paradigm. Two distinct methods for manipulating resource demands have been used in this paradigm. In the first, subjects are instructed to shift their emphasis from one task to another task, over trials. By varying instructed priorities between the two tasks, resource trade-offs are inferred from shifts in performance. With the second method, the difficulty level of the primary task is varied to manipulate resource allocation. An easy primary task is expected to require fewer processing resources and thereby release resources for the secondary task, whereas a difficult primary task will demand more resources and leave an inadequate supply for performance of the secondary task.

The present study, which derives from a paradigm developed by Strayer and Kramer (1990), uses both of these methods and involves visual and auditory recognition running-memory tasks. During each task, subjects were instructed to indicate whether the current stimulus matched the previous stimulus of the same modality. Under single-task control conditions, subjects performed one task during each block of trials. Under dual-task conditions, visual and auditory stimuli were presented rapidly in a random sequence, requiring concurrent task performance. Task priority was manipulated by instructing subjects to maximize their performance on one task or the other. Task difficulty was manipulated by varying the size of the visual memory load.

### ERPs and Processing Resources

A potential limitation of the dual-task methodology is that underlying resources are traditionally inferred solely on the basis of changes in performance (Wickens, 1986). Simple behavioral outputs, such as RT and performance accuracy, do not readily reveal or distinguish intermediate processes. One strategy for circumventing this problem is to include a psychophysiological index that is thought to reflect resource allocation, such as the amplitude of the P300 component of the ERP.

In prior dual-task studies, investigators have evaluated the effect of processing priority on P300 and found that higher priorities are associated with larger P300 amplitudes (Hoffman, Houck, MacMillan, Simons, & Oatman, 1985; Strayer & Kramer, 1990). Other studies have demonstrated that the P300 elicited by primary-task events *increases* in amplitude with increases in primary-task difficulty (Kramer, Wickens, & Donchin, 1985; Sirevaag, Kramer, Coles, & Donchin, 1989; Wickens, Kramer, Vanasse, & Donchin, 1983) and that the P300 elic-

ited by secondary-task events *decreases* in amplitude with increases in primary-task difficulty (Isreal, Chesney, Wickens, & Donchin, 1980; Kramer, Sirevaag, & Braune, 1987; Kramer, Wickens, & Donchin, 1983; Kramer et al., 1985; Strayer & Kramer, 1990). Thus, converging evidence on the allocation of attentional resources is provided by (a) trade-offs in P300 amplitude as a function of processing priority, (b) reciprocal effects of primary- and secondary-task difficulty on P300 amplitude, and (c) performance measures. Furthermore, P300 appears to be sensitive to the allocation of perceptual and cognitive resources but not to those resources that are related to response demands (Donchin, Kramer, & Wickens, 1986).

It is noteworthy that P300 reductions are often observed in clinical samples. Specifically, the amplitude of the P300 component has been found to be attenuated in schizophrenics and, somewhat less consistently, in depressed patients (for reviews, see Mirsky & Duncan, 1986; Pritchard, 1986; Roth, Duncan, Pfefferbaum, & Timsit-Berthier, 1986; Zahn, 1986). Some researchers have proposed that P300 reductions in patients with severe psychopathology may reflect a depleted supply of processing resources (e.g., Mirsky & Duncan, 1986; Nuechterlein, 1990). However, to our knowledge, the dual-task paradigm has not been used to test this hypothesis, despite being well-suited for doing so.

Distinct from P300 amplitude, the peak latency of the P300 component appears to be determined by the time required to recognize and evaluate a task-relevant event, and it is thought to be largely independent of response selection and execution processes (Donchin et al., 1986). In prior studies, P300 latency was found to reflect the termination of a stimulus evaluation process, whereas RT served as an index of the entire sequence of processing from encoding to response execution (e.g., Duncan-Johnson, 1981; Ford, Pfefferbaum, Tinklenberg, & Kopell, 1982; Kutas, McCarthy, & Donchin, 1977; McCarthy & Donchin, 1981). In studies of processing resources, P300 latency also has been found to provide information on intermediate processes, such as stimulus encoding and memory comparison operations, and therefore complements traditional behavioral measures (e.g., Kramer & Strayer, 1988). Moreover, results of a study by Isreal et al. (1980) suggest that changes in P300 latency are independent of P300 amplitude effects under dual-task conditions.

### Dysthymia and Dual-Task Performance

Using a dual-task paradigm and measures of performance, P300 amplitude, and P300 latency, the present study varied task priority and task difficulty to assess cognitive performance in dysthymics. The purpose was to test hypotheses about reductions in processing resources in dysthymics. Such reductions could be the result of various factors, including (a) a smaller pool of available resources and (b) a failure to respond appropriately to task demands despite a normal pool of processing resources (Nuechterlein & Dawson, 1984). Thus, the present study compared these two potential explanations of cognitive anomalies in dysthymia.

If dysthymics have a reduced amount of cognitive resources available, this reduction might become apparent under all or

only some task conditions, depending on the severity of the reduction. For instance, subjects may be able to allocate adequate resources to tasks that place few demands on resources, such as single tasks or simultaneous but easy dual tasks. When presented with a more demanding dual-task situation, however, dysthymic subjects should have an insufficient supply of resources available to meet the demands of both tasks. Performance on the primary task would occur at the expense of the secondary task, as indexed by greater reductions in P300 amplitude to the secondary task, in comparison with that observed for control subjects. If resources are severely limited, such a reduction in processing resources would be apparent even under the less demanding conditions of a difficult single task or an easy dual-task condition, as suggested by reductions in P300 amplitude to the single and secondary tasks, respectively. Either of these patterns of results would be consistent with the hypothesis that dysthymia impairs resource capacity and thereby interferes with task processing.

If, on the other hand, dysthymia is characterized by a deficiency only in the allocation rather than in the overall amount of processing resources, it would follow that abnormal strategies in allocation could be inferred from unusual trade-offs between primary- and secondary-task P300 amplitude. For example, dysthymic subjects might fail to exhibit a differential P300 amplitude as a function of processing priority, instead providing similar responses across conditions.

Regardless of which scenario was obtained, P300 amplitude was expected to be smaller in dysthymics than in normal controls, given that reductions have been observed in depressed subjects. In addition, it was hypothesized that dysthymics might compensate for a relative lack of resources by engaging in extended stimulus evaluation, as indexed by increases in P300 latency. Because overt performance differences have not been obtained in past psychophysiological research on dysthymics (Giese-Davis, Miller, & Knight, 1993; Miller et al., 1994; Yee & Miller, 1988), we did not expect to find performance differences in the present study.

#### Psychiatric High-Risk Control Group

In conducting research on dysthymic subjects, it is useful to include a control group of subjects also suspected of proneness to future psychopathology to determine the specificity of findings for the main group of interest. A primary advantage of including a psychiatric control group in addition to normal controls is that such a group provides an opportunity to determine whether group differences are due to risk factors in general or to disturbances unique to a particular disorder. Therefore, in the present study we included anhedonics, a group that has received much attention in recent psychophysiological research (Miller & Yee, 1994).

Following Meehl's (1962) proposal that anhedonia, or the diminished capacity to experience pleasure, is a biological antecedent of schizophrenia, Chapman, Chapman, and Raulin (1976) devised a scale for physical anhedonia to identify individuals who may be at risk for schizophrenia. Anhedonics have been found to differ from control subjects on a variety of clinical and psychophysiological measures (for reviews, see Chapman &

Chapman, 1985; Edell, in press; Fernandes & Miller, in press; Miller & Yee, 1994; Simons & Miles, 1990). Particularly robust is the finding that P300 amplitude is reduced in anhedonic individuals in comparison with normal controls. As with data obtained from schizophrenics, some investigators have attempted to interpret P300 reductions in anhedonics by proposing that these individuals have fewer processing resources to allocate to task-relevant stimuli (e.g., Nuechterlein, 1990).

Hypotheses for the anhedonic group paralleled those for dysthymics. If anhedonia is characterized by a reduction in the amount of processing resources, primary-task demands would leave insufficient resources for secondary tasks, indexed by reductions in P300 amplitude. Alternatively, if anhedonia is associated with impairment in resource allocation strategy, P300 amplitude would not covary in a normal fashion with task priority or task difficulty. It also was expected that P300 amplitude would be smaller overall in anhedonics than in controls, given that a reduced P300 response has consistently been observed in other samples of anhedonic subjects as well as schizophrenic patients.

## Method

### *Subjects*

A total of 1,142 introductory psychology students were administered, in large groups, the revised General Behavior Inventory (GBI; Depue & Klein, 1988; Depue, Krauss, Spont, & Arbisi, 1989) and the Chapman research questionnaires for physical anhedonia, perceptual aberration, and magical ideation (Chapman & Chapman, 1978; Chapman et al., 1976; Chapman, Chapman, & Raulin, 1978; Eckblad & Chapman, 1983). Of those subjects meeting selection criteria, 12 dysthymics (9 women), 12 anhedonics (7 women), and 12 normal controls (8 women) participated in the study. All subjects were White and did not differ in age across groups.

Dysthymics were defined as subjects scoring at the 90th percentile or above on the GBI Dysthymia scale and at the 85th percentile or below on the GBI Hypomania-Biphasic scale. Anhedonics were defined as subjects scoring at least 2 standard deviations above same-sex means on the physical anhedonia scale and no more than 0.5 standard deviation above same-sex means on the perceptual aberration or magical ideation scales. Normal controls were defined as subjects scoring no more than 0.5 standard deviation above the same-sex mean on any of the scales. In addition, all selected subjects scored below 3 on a 13-item Infrequency scale (Chapman, Chapman, & Miller, 1982) to exclude random responders, and dysthymics responded negatively to three exclusion questions in the GBI (recent bereavement, endocrine problems, and chronic medical problems).

### *Apparatus and Physiological Recording*

Subjects were seated in a quiet, darkened room that was connected by intercom to an adjacent equipment room. The visual stimuli were two-letter character strings (e.g., *FH*) that were presented in the center of a video screen, located approximately 1 m in front of the subject. Each letter in the character string was 12 mm high and 9 mm wide, and the distance between two letters in a string was 3 mm. Stimuli were selected to exclude words and common acronyms. Each character string was presented for 17 ms (plus phosphor decay time). Auditory stimuli were 70-ms tones of 1,000 and 1,200 Hz (65 dB; 10-ms rise/fall time), delivered binaurally through Realistic LV-10 headphones. A new trial began every 1,300 ms. Each trial presented either a visual or an auditory

stimulus; the sequencing of visual versus auditory trials was effectively random. Subjects were allowed 1,000 ms to provide a response. Stimulus presentation and data acquisition were controlled by a microcomputer.

Physiological signals were amplified and monitored with a Grass Model 12 polygraph. To record the electroencephalogram (EEG), we placed Beckman miniature Ag-AgCl electrodes with Grass EC2 paste at midline frontal (Fz), central (Cz), and parietal (Pz) sites (Jasper, 1958), referred to an electrode placed at the left mastoid (A1). EEG activity recorded from the right mastoid (A2-A1) was used subsequently to compute an average mastoid reference (Miller, Lutzenberger, & Elbert, 1991). To identify electrical artifact in the EEG arising from vertical eye movement, we placed Beckman miniature electrodes above and below the left eye. Electrode impedance was below 10 k $\Omega$ . Half-amplitude amplifier bandpass was 0.01 to 30 Hz, and signals were digitized on-line every 8 ms. RT, measured with a resolution of 1 ms, and performance accuracy also were recorded. Heart rate, horizontal eye movement, and nonmidline EEG activity were recorded but were not analyzed for this report.

### Procedure

Prior to the laboratory sessions, subjects participated in an individual lab tour. Subjects were provided with explanations of the study and the physiological recording procedures. They also were screened for factors that might compromise the psychophysiological recordings, including visual and auditory perceptual difficulties and drug use.

Subjects participated in two lab sessions, separated by no more than 1 week.<sup>1</sup> In the first lab session, subjects received extensive practice (approximately 2 hr) on all task conditions to ensure that performance exceeded chance; physiological data were not collected. The practice session ended when subjects reached an asymptote in their performance. Subjects were then scheduled for a lab session that began with the administration of several questionnaires, including the Beck Depression Inventory (BDI; Beck, Rush, Shaw, & Emery, 1979) and the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). Following electrode application and polygraph calibration, we instructed subjects about the tasks. They were encouraged to sit quietly, not blink during trials, and maintain their gaze on a fixation square that was presented in the center of the video monitor. The square, composed of four points at the corners of the area within which the visual stimuli would appear, was presented continuously during a trial block.

A summary of the task conditions is provided in Figure 1. For the single-task conditions, subjects were instructed to ignore the stimuli being presented for one task and to focus entirely on the other task. For the dual-task conditions, task priority was manipulated such that subjects were instructed to maximize their performance on one task or the other. The four priority levels were 100/0, 70/30, 30/70, and 0/100, in which the first number refers to the priority of the visual task and the second refers to the priority of the auditory task. Task difficulty was manipulated by varying the memory load from 1- to 2-back for the visual running-memory task. Subjects were asked to indicate whether the current string of characters was presented on the previous trial or whether it was presented two trials back. The seven combinations of task priority and task difficulty were blocked.

Within each modality, the sequence of match and mismatch trials was effectively random. Visual stimulus presentation was constrained such that the occurrence of strings requiring a match or mismatch response was equally probable during each block of trials. Subjects were instructed to make a button press with the right or left hand to indicate a match or mismatch. For the auditory task, subjects were presented with a series of low-pitched and high-pitched tones. The tones occurred with equal probabilities, and subjects were required to make a right or left button press to indicate a match or mismatch.

The psychophysiological recording session began with subjects receiving one set of seven practice blocks to reacquaint them with each of the single and dual tasks. Then, 21 test blocks (100 trials per block) were completed, providing three replications of the seven task conditions. The order of tasks was counterbalanced across subjects, and adjacent blocks always involved different tasks. The mapping of match/mismatch onto right/left button press was counterbalanced across subjects and tasks but was held constant within subjects across blocks.

Interviewers and experimenters were unaware of group membership throughout subject contact, data collection, and response scoring. Subjects were paid for their participation at the standard campus reimbursement rate of \$3.50 per hour.

### Data Reduction

Data were converted to microvolts on the basis of a pre-session calibration pulse and deviated from an 80-ms prestimulus baseline. Eye movement artifact in the EEG was corrected using a procedure that removes ocular noise (Gratton, Coles, & Donchin, 1983; Miller, Gratton, & Yee, 1988). Low-pass (0–5 Hz) frequency and vector topographic filters were applied to assist in smoothing the waveforms and in distinguishing between overlapping components, respectively (Cook & Miller, 1992; Gratton, Coles, & Donchin, 1989).

Because trial-to-trial "latency jitter" can be considerable in decision tasks, single-trial P300 measures were obtained from a cross-correlation procedure that was applied to the vector-filtered data as recommended by Gratton, Kramer, Coles, and Donchin (1989). Specifically, the segment of each single-trial waveform between 296 and 800 ms that correlated most highly with a template (the positive half-cycle of a 2-Hz sine wave) was identified. P300 amplitude and latency were identified at the midpoint of this template. Cross-trial averages of these scores were then computed for each response type (match/mismatch), stimulus modality, task, and subject, using only correct trials. To eliminate less stable estimates of ERP activity, we excluded from analysis averages that were based on fewer than 15 trials. Fewer than 1% of the data were rejected as a result of this criterion, and no more than one subject's data were ever excluded from any single experimental condition.

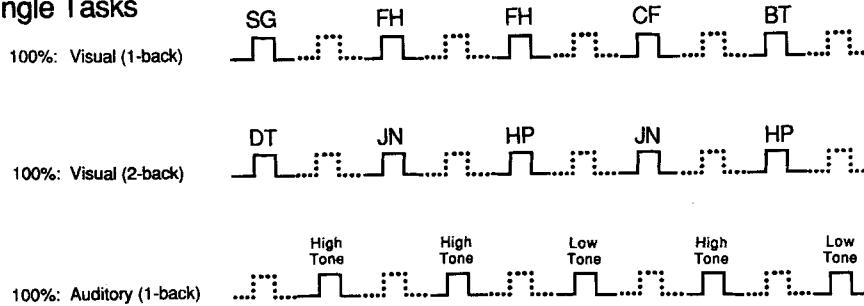
### Results

Hypotheses were tested using analyses of variance (ANOVA) for mixed design (BMDP2V). Performance measures and vector-filtered P300 scores were analyzed using a Group  $\times$  Priority design, computed for each response type (match/mismatch), modality, and difficulty level.<sup>2</sup> Reported significance levels for

<sup>1</sup> Prior to the two lab sessions, subjects also participated in another study consisting of a structured diagnostic interview derived from the Schedule for Affective Disorders and Schizophrenia—Lifetime Version (Spitzer & Endicott, 1978). Although results from this procedure are not yet available, previous validation studies have demonstrated considerable agreement between GBI classification and clinical diagnosis of dysthymia (Depue & Klein, 1988; Depue et al., 1989; Klein, Dickstein, Taylor, & Harding, 1989; Mechanic, Miller, & Klein, 1986).

<sup>2</sup> It is generally well established in the experimental psychology literature that RTs to mismatches are longer than those to matches (e.g., Posner & Boies, 1971). Therefore, analyses including response type as a factor typically yield a highly significant main effect and numerous, significant multiway interactions that involve response type. We initially conducted such analyses and obtained the expected significant main effects as well as the multiway interactions. Some of these findings, however, are difficult to interpret, and for this reason response types in such designs are typically analyzed separately. For example, Strayer and Kramer (1990) used a design similar to ours and chose to analyze re-

## Single Tasks



## Dual Tasks

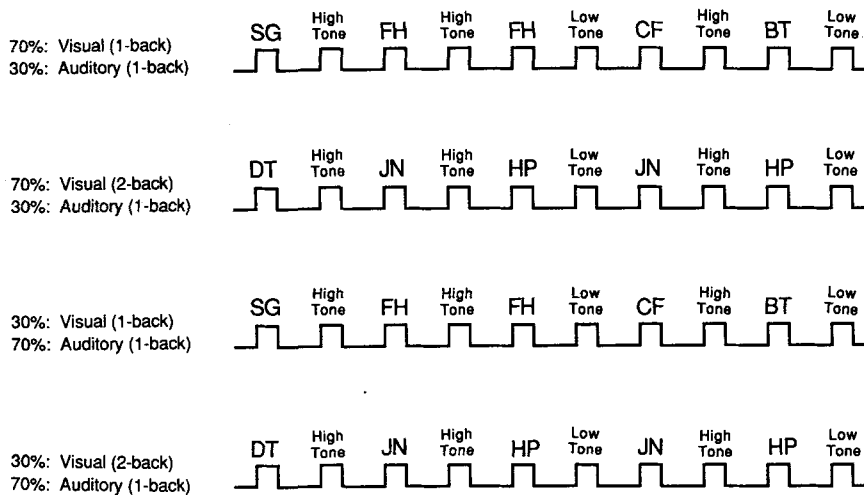


Figure 1. Visual running-memory tasks, auditory running-memory task, and combinations of the tasks in the dual-task conditions. For clarity, visual and auditory stimuli are graphed in alternation, but in the study they were semirandomly ordered. The dotted lines indicate that a stimulus was presented but that subjects were instructed to ignore it. SG, FH, CF, BT, DT, JN, and HP = examples of visual stimuli. 1-back = memory load condition requiring subjects to indicate whether the current string of characters was presented on the previous trial; 2-back = memory load condition requiring subjects to indicate whether the current string of characters was presented two trials earlier. See text for further details.

all analyses reflect a correction for heterogeneity of covariance (Huynh & Feldt, 1976). Post hoc comparisons were computed with Newman-Keuls tests using the .05 level. Gender of subject was approximately balanced across group cells in the design (a chi-square with Yates's correction for continuity did not approach significance,  $\chi^2[2, N = 36] = .28, ns$ ). Gender was not included in analyses reported here because of the small cell sizes and lack of hypothesized gender effects.

### Self-Report Measures

As anticipated, dysthymics reported higher levels of depressive symptoms than did normal control subjects on the BDI,

$F(2, 33) = 6.85, p < .004$ . Post hoc analyses indicated that dysthymics ( $M = 10.0, SD = 5.7$ ) scored higher than normal controls ( $M = 2.9, SD = 2.7$ ) but that neither group differed from anhedonics ( $M = 6.7, SD = 5.1$ ). The rank order of the BDI means for the three groups replicates those obtained in a previous study (Yee et al., 1992). Trait anxiety scores on the STAI also differentiated dysthymics ( $M = 47.1, SD = 12.7$ ) from normal controls ( $M = 35.7, SD = 6.7$ ), whereas anhedonics ( $M = 38.8, SD = 9.9$ ) did not differ from either of the other two groups,  $F(2, 33) = 4.04, p < .03$ .

### Preliminary Analyses

Because it was unclear whether the task difficulty manipulation would be successful in the current study given the results of pilot work, preliminary analyses were conducted on P300 amplitude. Results of a Group  $\times$  Priority  $\times$  Difficulty ANOVA

response types separately. Response type, therefore, was not included as a factor in the ANOVAs reported in this article.

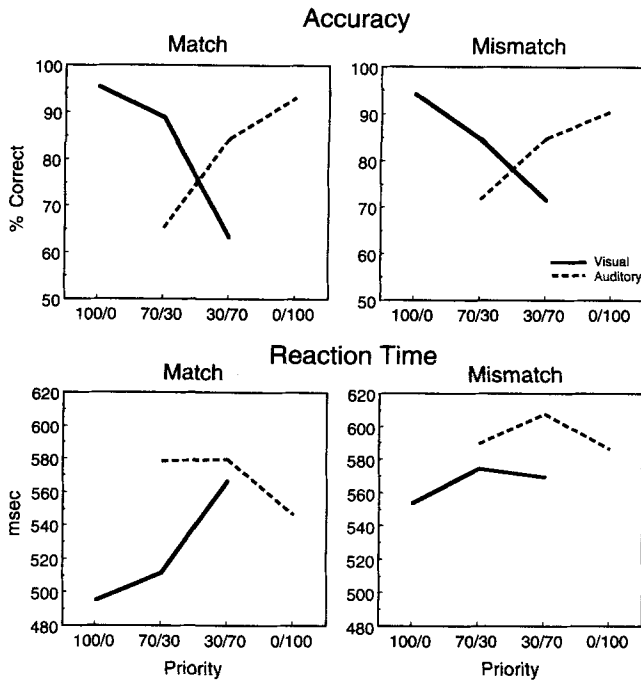


Figure 2. Mean percentage (%) correct visual and auditory performance accuracy and reaction time, under single-task (100/0 or 0/100) and dual-task (70/30 or 30/70; 1-back) conditions, for match and mismatch responses.

indicated that visual P300 amplitude did not increase as expected but instead decreased with increased task difficulty. This occurred on both match and mismatch trials,  $F(1, 31) = 11.15$ ,  $p < .003$ , and  $F(1, 32) = 8.78$ ,  $p < .006$ , respectively. A possible explanation for this reversed difficulty effect is considered in the Discussion section.

There was the option of retaining difficulty level as a factor in the design of the ANOVA. The 2-back condition, however, had been included in the experiment to manipulate task difficulty with the expectation that P300 amplitude would increase at this higher level of difficulty. Because this manipulation was not in the predicted direction and given the uncertain nature of the P300 results for the 2-back condition, the main analyses focused on the effect of the priority manipulation at the 1-back level of difficulty. Comparisons involving the 2-back level of difficulty were restricted to exploratory analyses. Results for the 2-back condition were generally consistent with those obtained under the 1-back condition and are not presented here.<sup>3</sup>

### Processing Priority and Performance

**Accuracy.** As illustrated in the upper half of Figure 2, there were systematic trade-offs in accuracy as a function of task priority. The ANOVAs yielded significant priority effects across response types for visual trials (match:  $F(2, 66) = 109.19$ ,  $p < .001$ ; mismatch:  $F(2, 66) = 38.16$ ,  $p < .001$ ) and for auditory trials (match:  $F(2, 66) = 134.28$ ,  $p < .001$ ; mismatch:  $F(2, 66) = 53.98$ ,  $p < .001$ ). Post hoc comparisons indicated that perfor-

mance was significantly less accurate as task priority decreased from 100/0 to 70/30 and from 70/30 to 30/70. The reciprocal relationships or trade-offs between visual and auditory accuracy are evident in Figure 2. As can be seen, the intersecting lines under the dual-task conditions indicate that improved accuracy on the primary task (70%) came at the expense of poorer performance on the secondary task (30%). There were no significant group effects on accuracy or types of errors (misses and false alarms).

**RT.** The lower half of Figure 2 presents mean RT for each response type, priority condition, and stimulus modality. Visual RT varied significantly as a function of task priority for match trials,  $F(2, 66) = 35.21$ ,  $p < .001$ . Post hoc tests indicated that whereas single-task (100%) and primary-task (70%) performance did not differ, expected dual-task trade-offs were reflected in declines in secondary-task (30%) RT performance. On auditory trials, a significant priority effect also was obtained for match trials,  $F(2, 66) = 6.70$ ,  $p < .005$ , and indicated that RT was slower under dual-task conditions (70% and 30%) in comparison with single-task (100%) performance.<sup>4</sup> There were no group differences in RT.

### Processing Priority and P300

Figure 3 presents grand-average ERP waveforms as a function of group, stimulus modality, and recording site for match and mismatch trials on which subjects responded correctly. Figure 4 illustrates average latency and amplitude values for P300 obtained from the vector-filter scoring procedure. As can be seen in the upper half of Figure 4, effects of the priority manipulation on P300 latency analyses were virtually identical to those obtained from the accuracy data. P300 latency was sensitive to the priority manipulation across response types on visual trials (match:  $F(2, 62) = 54.39$ ,  $p < .001$ ; mismatch:  $F(2, 64) = 19.71$ ,  $p < .001$ ) and auditory trials (match:  $F(2, 66) = 37.24$ ,  $p < .001$ ; mismatch:  $F(2, 66) = 15.93$ ,  $p < .001$ ). Post hoc com-

<sup>3</sup> These results are available on request.

<sup>4</sup> The lack of RT differences on mismatch trials suggests that subjects were using multiple strategies. The pattern of results across performance measures is consistent with the fact that subjects were instructed to emphasize accuracy rather than speed. An advantage of such a strategy is that differences between conditions cannot be attributed to speed-accuracy trade-offs. On the other hand, subjects were aware of an upper limit to the time frame for each response. The presence of such a constraint may not be optimal in eliciting differences in response speed under conditions such as the detection of mismatches in the current study. Using a paradigm similar to that of the present study, Strayer and Kramer (1990) concluded that subjects sometimes operated on the basis of a response deadline. In other words, subjects imposed a deadline for making a response, and if they had not provided a response by that time, they based a response on the partial information that had accumulated up to that point. This type of strategy implies that slow RT conditions are more likely to be affected than fast RT conditions, resulting in no differences between the longer RT conditions. Such an explanation seems plausible, given that RTs to mismatches in the current study were significantly slower than those to matches during both visual and auditory trials,  $F(1, 33) = 57.78$ ,  $p < .001$ , and  $F(1, 33) = 22.40$ ,  $p < .001$ , respectively.

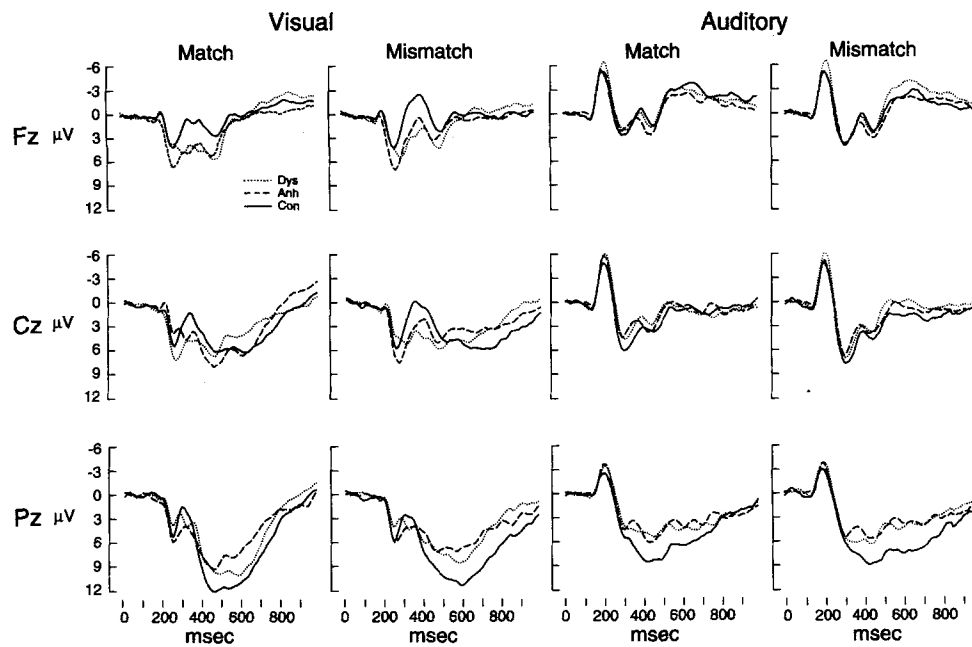


Figure 3. Event-related brain potential waveform averages, for each group, at the three midline recording sites (without latency correction) during visual and auditory (1-back) tasks, for correct match and mismatch responses. Stimulus onset was at 0 ms.

parisons revealed consistently longer P300 latencies in dual-task (70% and 30%) than in single-task (100%) conditions. Additionally, dual-task trade-offs were reflected in secondary-task (30%) P300 latency slowing in relation to primary-task (70%) latency, although this difference did not reach significance for visual mismatch trials. No significant differences were obtained for group.

The dashed lines in the lower portion of Figure 4 depict mean P300 amplitude values for auditory match and mismatch trials. Significant priority effects were obtained on auditory match and mismatch trials,  $F(2, 66) = 12.51, p < .001$ , and  $F(2, 66) = 9.61, p < .001$ , respectively. As expected, resource trade-offs were reflected in secondary-task P300 amplitude decrements in relation to single- and primary-task P300 amplitude across response types. Post hoc comparisons indicated that P300 was reduced during dual-task conditions, in comparison with the single-task condition, for auditory match trials.

#### Resource Allocation in Dysthymia and Anhedonia

As is clear from the waveforms in Figure 3 at the Pz site, dysthymics and anhedonics generated consistently smaller P300s than normal controls but did not differ from each other on visual trials (match:  $F(2, 32) = 3.48, p < .05$ ; mismatch:  $F(2, 32) = 4.49, p < .02$ ) or auditory trials (match:  $F(2, 33) = 4.26, p < .03$ ; mismatch:  $F(2, 33) = 5.86, p < .007$ ). The one exception was that the difference between dysthymics and normal controls on visual match trials did not reach significance in a post hoc test.

On visual match trials, the main effects for group,  $F(2, 64) =$

9.95,  $p < .001$ , and priority were qualified by a significant Group  $\times$  Priority effect,  $F(4, 64) = 3.60, p < .02$ . Figure 5 illustrates this finding and suggests that control subjects appropriately allocated fewer resources to the visual task as processing priority shifted from single- to dual-task conditions and from a primary- to secondary-task emphasis. Dysthymics and anhedonics, on the other hand, failed to show any P300 evidence of changes in resource allocation with shifts in task priority. These observations were generally supported by a Newman-Keuls test, although the difference between the two dual-task conditions for controls was not significant.

On visual mismatch trials, all groups did allocate attention differentially as indicated by the priority effect shown in the lower right panel of Figure 4,  $F(2, 64) = 11.05, p < .001$ . Specifically, P300 amplitude decreased as task priority shifted from single- to dual-task processing.

#### Discussion

The present study used resource allocation theory and a dual-task paradigm in an effort to clarify the mechanisms that might underlie abnormalities in information processing in dysthymia and anhedonia. Behavioral and P300 responses served as measures of the attentional resources invested by subjects in a pair of running-memory tasks, under conditions of varying task priority and difficulty. It was expected that (a) performance and P300 measures would show trade-offs as a function of processing priority and memory load and that (b) dysthymic and anhedonic subjects would differ from normal controls in cognitive resources as reflected in the configuration of P300 responses. In

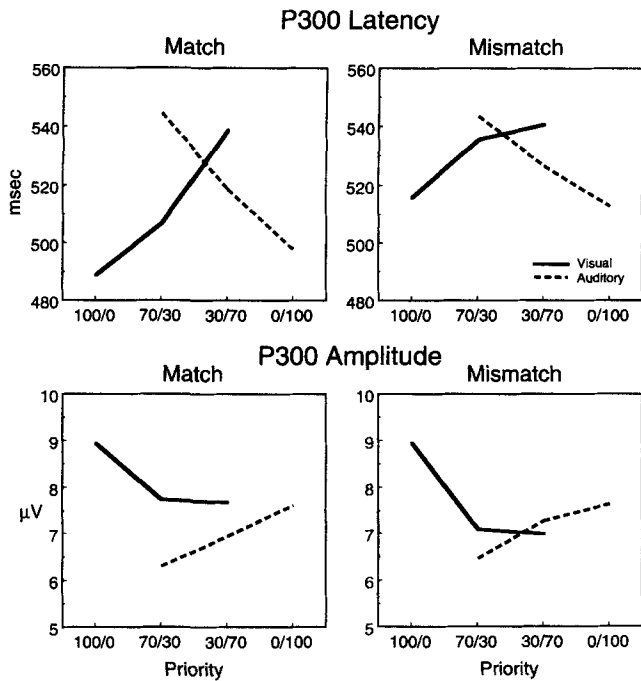


Figure 4. Mean visual and auditory P300 latency and amplitude, under single- and dual-task (1-back) conditions, for correct match and mismatch responses.

the following discussion, we consider results of the task manipulations, differences obtained between the groups, and implications of these data.

*Results of Task Manipulations*

*Stimulus evaluation and response.* The effects of processing priority on performance accuracy and P300 latency supported the predictions of resource theory. As in previous studies (e.g., Hoffman et al., 1985; Strayer & Kramer, 1990), accuracy decreased and P300 latency increased with the transition from single- to dual-task processing and with declines in processing priority under dual-task conditions. The RT data, in comparison, appeared to be influenced not only by attentional demands

but by the strategies used by subjects. For instance, the predicted priority effect was obtained on visual match trials, suggesting that subjects attempted to respond quickly but were constrained when only a limited supply of processing resources was available. In contrast, primary- and secondary-task RTs were comparable on auditory match trials. Such increases in primary-task RT are believed to reflect the cost of managing or integrating two tasks, which has been termed the “cost of concurrence” (Navon & Gopher, 1979). Finally, RT was not found to differ during visual and auditory mismatch trials. As proposed in Footnote 4, subjects may have set a response deadline and as a consequence restricted the range of responses elicited during mismatch conditions.

Taken together, the accuracy and P300 latency data provide converging evidence for limited attentional resources and corresponding trade-offs when simultaneous demands exceed the available supply. Findings for RT are somewhat in contrast and suggest that speed of response may have been influenced by the use of a deadline strategy. It is noteworthy that although subjects may have set a deadline for executing an overt response, they apparently were unable to do so in terms of P300 latency. Therefore, to the extent that P300 latency reflects stimulus evaluation time, it would appear that subjects cannot impose a deadline on the amount of time it takes to evaluate a stimulus.

*Allocation of resources.* The predicted reciprocal effect of the priority manipulation on P300 amplitude was obtained. Consistent with previous research, secondary-task P300 amplitude declined during auditory trials, reflecting the demands on shared resources by the primary task (Hoffman et al., 1985; Strayer & Kramer, 1990). The decrement in primary-task P300 under dual-task conditions, which was not specifically predicted but was also observed in RT, again may reflect the cost of concurrence (Navon & Gopher, 1979). Thus, P300 was found to be a sensitive index of the limited availability of processing resources and the trade-offs imposed by changes in priority allocation.

Results of the task difficulty manipulation were substantially more complex. Specifically, increases in the size of the memory load had the unexpected effect of attenuating P300 amplitude (cf. Kramer et al., 1985; Sirevaag et al., 1989; Wickens et al., 1983). One possible explanation for this inconsistency is that P300 amplitude may have been influenced by the degree of cer-

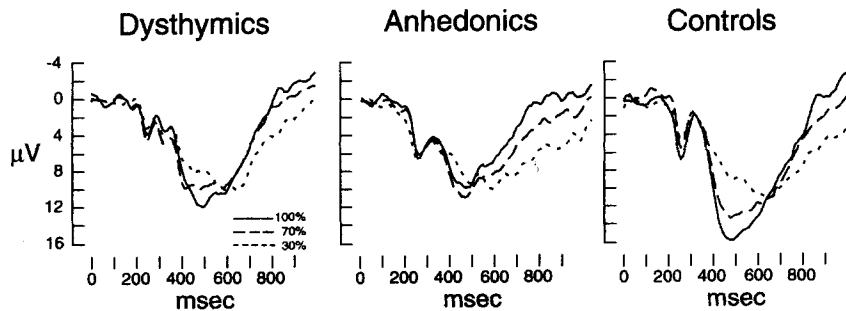


Figure 5. Event-related brain potential waveform averages, for each group, at the Pz recording site (without latency correction) during single- and dual-task visual (1-back) conditions, for correct match responses. Stimulus onset was at 0 ms.



tainty with which subjects made their judgments. Several studies have shown that the magnitude of P300 amplitude is reduced under conditions of uncertainty or equivocation (e.g., Miller, 1986; Parasuraman & Beatty, 1980; for a review, see Ruchkin & Sutton, 1978). In the present study, subjects often reported that they were not confident of their decisions under the 2-back conditions but would respond in spite of the uncertainty. Thus, reduced primary-task P300 may have reflected subjects' lack of confidence in their judgments.

Another possibility is that increasing the memory load in a recognition running-memory task may not be optimal for demonstrating a positive covariation between level of processing demands and amplitude of the P300. The running-memory task can be conceived of as requiring two types of mental operations: rehearsal and comparison. With the presentation of each new stimulus, subjects are likely to update working memory and rehearse or continuously repeat memory set items. In addition, each new stimulus (probe) must be compared with items in working memory. Increasing the size of the memory load from one to two trials, therefore, is expected to affect each of these processes. With the larger memory load, there is likely to be an increase in the demand for resources to perform the rehearsal component of the task. As a consequence, fewer resources might be available for comparing the probe to memory set items, thereby decreasing probe P300 amplitude with increasing task difficulty. These and other hypotheses need to be investigated systematically in future research.

In summary, the pattern of changes for performance and P300 measures in the present study is largely consistent with predictions of resource models of attentional allocation. Trade-offs in performance accuracy, P300 latency, and auditory P300 amplitude were observed as subjects shifted priorities between the memory tasks. Interesting but less conclusive findings resulted from the difficulty manipulation. Having addressed some of the methodological issues and evaluated the success of the task manipulations, we now consider group differences with an emphasis on the priority manipulation.

### *Differences Between Groups*

Dysthymics, anhedonics, and controls did not differ in accuracy or speed of performance during any of the task conditions. This consistent pattern of results implies that the response selection and execution process is intact in dysthymia and anhedonia. The P300 latency results also did not reveal any group differences, suggesting that the timing of stimulus evaluation processes is not impaired in dysthymics or anhedonics. These results must be considered with some caution, as the size of our current samples may limit our ability to obtain significant differences. However, no previous psychophysiological study has found performance differences among these groups (see Miller & Yee, 1994). Moreover, in the present study it is likely that the practice session served to minimize any group differences in performance.

In contrast, the amplitude measure of P300 did yield a number of positive findings. As predicted, visual and auditory P300 amplitudes were attenuated consistently in dysthymics and anhedonics. This reduction in P300 amplitude suggests the avail-

ability of fewer processing resources. However, it would follow from such an interpretation that dysthymics and anhedonics also have fewer resources to devote to a secondary task than do normal controls. Yet the three groups did not differ in P300 amplitude to secondary-task stimuli. This pattern of results argues against the possibility that dysthymics and anhedonics have fewer overall processing resources than control subjects and, instead, favors the alternative explanation that the groups differ in resource allocation strategies.

Empirical support for the resource-allocation hypothesis comes from visual P300 amplitude, which declined with decreasing task priority for normal controls but not for dysthymic and anhedonic subjects during the 1-back, match condition. The absence of an effect of the priority manipulation suggests that dysthymics and anhedonics did not respond to external task demands in the same manner as normal controls. This pattern did not extend to conditions involving a larger memory load or to mismatching stimuli, both arguably more difficult tasks. This specificity suggests that the at-risk groups did not use an optimal (normal) allocation strategy until task demands were fairly heavy. In contrast, normal controls appeared to be able to shift task priority more easily and to be more responsive to external priority demands. A different way to view these results is that perhaps dysthymics and anhedonics recognized that they could perform well enough and without much effort until conditions became more difficult and therefore more resource dependent. The primary distinction between these viewpoints is the extent to which subjects' strategies changed with the task demands placed on them; both accounts suggest that there may be a lack of responsiveness to external priority demands among dysthymics and anhedonics.

Such an interpretation is consistent with the results of investigations on the effects of attentional demands on memory processes in depression. For instance, Krames and MacDonald (1985) found that as task-relevant demands increased, the recall performance of depressed subjects improved and became indistinguishable from that of nondepressed subjects. To assess more directly the role of strategies used during recall testing, Hertel and colleagues provided depressed subjects with external cues to guide their attention and demonstrated that deficits in recall performance could be eliminated (Hertel & Hardin, 1990; Hertel & Rude, 1991). These studies suggest that depressed subjects are capable of performing memory tasks but at times lack the ability to focus attention spontaneously. Thus, there appears to be accumulating support for the possibility that depressed and dysthymic individuals and, perhaps, anhedonics may differ from control subjects in the allocation of processing resources.

A resource-capacity explanation of depressive deficits in memory cannot be ruled out entirely, however, as present findings included overall reductions in P300 amplitude. On the other hand, it is unclear whether resource availability is the most parsimonious account of P300 amplitude reductions in the current study. As maintained earlier, the argument in favor of P300 reflecting capacity reductions is weakened by our failure to find group differences for the secondary task. Moreover, the lack of group differences in performance also is consistent with the proposition that dysthymics and anhedonics do not differ from control subjects in amount of resources available.

Perhaps dysthymic and anhedonic subjects were unable to divert attention away from other cognitive activities and react normally to task demands except when absolutely necessary.

One possible implication of resource allocation deficits in dysthymia is that difficulties in responding appropriately to task demands may signal a more general impairment in the ability to cope adequately with the stressors that arise in everyday life. Stressful events have been shown to be associated with the onset of major depressive episodes and to predict subsequent depressive episodes (e.g., Hammen, Davila, Brown, Ellicott, & Gitlin, 1992; Hammen, Mayol, deMayo, & Marks, 1986). In fact, Goplerud and Depue (1985) reported evidence of prolonged recovery to stress in a small sample of dysthymic subjects. Disruptions in cognitive functioning, therefore, may be another factor associated with risk for developing recurrent episodes of major depression.

Nuechterlein (1990) has proposed that a reduced allocation of resources to evaluate stimuli that would normally be pleasurable may be linked with the decreased capacity for experiencing pleasure reported by anhedonic subjects. This hypothesis can be extended easily to encompass dysthymic subjects who, like anhedonics, frequently exhibit a loss of interest or pleasure in activities. Thus, possible associations may exist between a failure to react appropriately to task demands and apathy or blunted affect toward normally engaging pleasurable events.

Finally, the limited and specific nature of the deficits observed in the present study is consistent with the fact that these data were obtained in individuals at risk. It would be expected that pronounced difficulties in the allocation of resources or overall reductions in processing capacity would emerge only in the presence of more severe symptoms. In fact, deficits in sustained, effortful information processing have been demonstrated consistently in depressed and schizophrenic patients (e.g., Cohen et al., 1982; Nuechterlein, Edell, Norris, & Dawson, 1986; Roy-Byrne, Weingartner, Bierer, Thompson, & Post, 1986).

The lack of differentiation between dysthymics and anhedonics in the present study may reflect similarities in the dysfunctions of attentional allocation that occur in depression and schizophrenia. The relationship between these phenomena remains to be clarified. However, the present study may offer some evidence regarding the likelihood that group differences in the allocation of processing resources are secondary to trait anxiety. It is conceivable that anxiety and accompanying ruminations might account for differences in resource allocation. This seems unlikely, however, as group differences in trait anxiety were obtained only between dysthymics and normal controls, whereas P300 evidence for a potential deficiency in resource allocation was found in both dysthymics and anhedonics. Additional studies are needed to determine whether clinical levels of anxiety might reduce attentional capacity or resources (cf. Mathews, 1990).

### Conclusion

Present results provide evidence that dysthymics and anhedonics differ from control subjects in their ability to direct resources to simultaneous tasks. Although it is unclear whether

anomalies in resource allocation are specific to dysthymia or anhedonia, these results indicate that abnormalities can be found prior to a serious stage of illness, and continuities with patient populations are suggested. It will be important to replicate these findings on a larger sample and extend them to patient populations.

### References

- Akiskal, H. S. (1983). Dysthymic disorder: Psychopathology of proposed chronic depressive subtypes. *American Journal of Psychiatry*, *140*, 11–20.
- Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1979). *Cognitive therapy of depression*. New York: Guilford Press.
- Chapman, L. J., & Chapman, J. P. (1978). *Revised physical anhedonia scale*. Unpublished test.
- Chapman, L. J., & Chapman, J. P. (1985). Psychosis proneness. In M. Alpert (Ed.), *Controversies in schizophrenia* (pp. 157–172). New York: Guilford Press.
- Chapman, L. J., Chapman, J. P., & Miller, E. N. (1982). Reliabilities and intercorrelations of eight measures of proneness to psychosis. *Journal of Consulting and Clinical Psychology*, *50*, 187–195.
- Chapman, L. J., Chapman, J. P., & Raulin, M. L. (1976). Scales for physical and social anhedonia. *Journal of Abnormal Psychology*, *85*, 374–382.
- Chapman, L. J., Chapman, J. P., & Raulin, M. L. (1978). Body-image aberration in schizophrenia. *Journal of Abnormal Psychology*, *87*, 399–407.
- Cohen, R. M., Weingartner, H., Smallberg, S. A., Pickar, D., & Murphy, D. L. (1982). Effort and cognition in depression. *Archives of General Psychiatry*, *39*, 593–597.
- Cook, E. W. III, & Miller, G. A. (1992). Digital filtering: Background and tutorial for psychophysicists. *Psychophysiology*, *29*, 350–367.
- Depue, R. A., & Klein, D. N. (1988). Identification of unipolar and bipolar affective conditions in nonclinical and clinical populations by the General Behavior Inventory. In D. L. Dunner, E. S. Gershon, & J. E. Barrett (Eds.), *Relatives at risk for mental disorders* (pp. 179–202). New York: Raven Press.
- Depue, R. A., Krauss, S., Spont, M. R., & Arbis, P. (1989). General Behavior Inventory identification of unipolar and bipolar affective conditions in a nonclinical university population. *Journal of Abnormal Psychology*, *98*, 117–126.
- Donchin, E., Kramer, A. F., & Wickens, C. (1986). Applications of brain event-related potentials to problems in engineering psychology. In M. G. H. Coles, E. Donchin, & S. W. Porges (Eds.), *Psychophysiology: Systems, processes, and applications* (pp. 702–718). New York: Guilford Press.
- Duncan-Johnson, C. C. (1981). P300 latency: A new metric of information processing. *Psychophysiology*, *18*, 207–215.
- Eckblad, M., & Chapman, L. J. (1983). Magical ideation as an indicator of schizotypy. *Journal of Consulting and Clinical Psychology*, *51*, 215–225.
- Edell, W. S. (in press). The psychometric measurement of schizotypy using the Wisconsin Scales of Psychosis Proneness. In G. A. Miller (Ed.), *The behavioral high-risk paradigm in psychopathology*. New York: Springer-Verlag.
- Ellis, H. C., & Ashbrook, P. W. (1988). Resource allocation model of the effects of depressed mood states on memory. In K. Fiedler & J. Forgas (Eds.), *Affect, cognition and social behavior* (pp. 25–43). Göttingen, Germany: Hogrefe.
- Fernandes, L. O. L., & Miller, G. A. (in press). Compromised performance and abnormal psychophysiology associated with the Wisconsin

- sin psychosis-proneness scales. In G. A. Miller (Ed.), *The behavioral high-risk paradigm in psychopathology*. New York: Springer-Verlag.
- Ford, J. M., Pfefferbaum, A., Tinklenberg, J. R., & Kopell, B. S. (1982). Effects of perceptual and cognitive difficulty on P3 and RF in young and old adults. *Electroencephalography and Clinical Neurophysiology*, *54*, 311-321.
- Giese-Davis, J., Miller, G. A., & Knight, R. (1993). Memory template comparison processes in anhedonia and dysthymia. *Psychophysiology*, *30*, 646-656.
- Goplerud, E., & Depue, R. A. (1985). Behavioral response to naturally occurring stress in cyclothymia and dysthymia. *Journal of Abnormal Psychology*, *94*, 128-139.
- Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, *55*, 468-484.
- Gratton, G., Coles, M. G. H., & Donchin, E. (1989). A procedure for using multi-electrode information in the analysis of components of the event-related potential: Vector filter. *Psychophysiology*, *26*, 222-232.
- Gratton, G., Kramer, A. F., Coles, M. G. H., & Donchin, E. (1989). Simulation studies of latency measures of components of the event-related brain potential. *Psychophysiology*, *26*, 233-248.
- Hammen, C., Davila, J., Brown, G., Ellicott, A., & Gitlin, M. (1992). Psychiatric history and stress: Predictors of severity of unipolar depression. *Journal of Abnormal Psychology*, *101*, 45-52.
- Hammen, C., Mayol, A., deMayo, R., & Marks, T. (1986). Initial symptom levels and the life-event-depression relationship. *Journal of Abnormal Psychology*, *95*, 114-122.
- Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General*, *108*, 356-388.
- Hertel, P. T., & Hardin, T. S. (1990). Remembering with and without awareness in a depressed mood: Evidence of deficits in initiative. *Journal of Experimental Psychology: General*, *119*, 45-59.
- Hertel, P. T., & Rude, S. S. (1991). Depressive deficits in memory: Focusing attention improves subsequent recall. *Journal of Experimental Psychology: General*, *120*, 301-309.
- Hoffman, J. E., Houck, M. R., MacMillan, F. W. III, Simons, R. F., & Oatman, L. C. (1985). Event-related potentials elicited by automatic targets: A dual-task analysis. *Journal of Experimental Psychology: Human Perception and Performance*, *11*, 50-61.
- Huynh, H., & Feldt, L. S. (1976). Estimation of the box correction for degrees of freedom from sample data in the randomized block and split-plot designs. *Journal of Educational Statistics*, *1*, 69-82.
- Isreal, J. B., Chesney, G. L., Wickens, C. D., & Donchin, E. (1980). P300 and tracking difficulty: Evidence for multiple resources in dual-task performance. *Psychophysiology*, *17*, 259-273.
- Jasper, H. H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, *10*, 371-375.
- Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.
- Klein, D. N., Dickstein, S., Taylor, E. T., & Harding, K. (1989). Identifying chronic affective disorders in outpatients: Validation of the General Behavior Inventory. *Journal of Consulting and Clinical Psychology*, *57*, 106-111.
- Klein, D. N., & Miller, G. A. (1993). Depressive personality in nonclinical subjects. *American Journal of Psychiatry*, *150*, 1718-1724.
- Kovacs, M., Feinberg, T. L., Crouse-Novak, M., Paulauskas, S., Pollock, M., & Finkelstein, R. (1984). Depressive disorders in childhood: II. A longitudinal study of the risk for a subsequent major depression. *Archives of General Psychiatry*, *41*, 643-649.
- Kramer, A. F., Sirevaag, E., & Braune, R. (1987). A psychophysiological assessment of operator workload during simulated flight session. *Human Factors*, *29*, 145-160.
- Kramer, A. F., & Strayer, D. L. (1988). Assessing the development of automatic processing: An application of dual-task and event-related brain potential methodologies. *Biological Psychology*, *26*, 231-267.
- Kramer, A. F., Wickens, C. D., & Donchin, E. (1983). An analysis of the processing demands of a complex perceptual-motor task. *Human Factors*, *25*, 597-622.
- Kramer, A. F., Wickens, C. D., & Donchin, E. (1985). Processing of stimulus properties: Evidence for dual-task integrality. *Journal of Experimental Psychology: Human Perception and Performance*, *11*, 393-408.
- Krames, L., & MacDonald, M. R. (1985). Distraction and depressive cognitions. *Cognitive Therapy and Research*, *9*, 561-573.
- Kutas, M., McCarthy, G., & Donchin, E. (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science*, *197*, 792-795.
- Mathews, A. (1990). Why worry? The cognitive function of anxiety. *Behavioral Research and Therapy*, *28*, 455-468.
- McCarthy, G., & Donchin, E. (1981). A metric for thought: A comparison of P300 latency and reaction time. *Science*, *211*, 77-80.
- Mechanic, M. B., Miller, G. A., & Klein, D. N. (1986, August). *Assessment and differentiation of chronic depression in a non-patient sample*. Paper presented at the meeting of the American Psychological Association, Washington, DC.
- Meehl, P. E. (1962). Schizotaxia, schizotypy, schizophrenia. *American Psychologist*, *17*, 827-838.
- Miller, G. A. (1986). Information processing deficits in anhedonia and perceptual aberration: A psychophysiological analysis. *Biological Psychiatry*, *21*, 100-115.
- Miller, G. A., Gratton, G., & Yee, C. M. (1988). Generalized implementation of an eye movement correction procedure. *Psychophysiology*, *25*, 241-243.
- Miller, G. A., Lutzenberger, W., & Elbert, T. (1991). The linked-reference issue in EEG and ERP recording. *Journal of Psychophysiology*, *5*, 273-276.
- Miller, G. A., & Yee, C. M. (1994). Risk for severe psychopathology: Psychometric screening and psychophysiological assessment. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in psychophysiology* (Vol. 5, pp. 1-54). London: Jessica Kingsley.
- Miller, G. A., Yee, C. M., & Anhalt, J. M. (1994). *ERP incentive effects and potential risk for psychopathology*. Manuscript submitted for publication.
- Mirsky, A. F., & Duncan, C. C. (1986). Etiology and expression of schizophrenia: Neurobiological and psychosocial factors. *Annual Review of Psychology*, *37*, 291-319.
- Navon, D., & Gopher, D. (1979). On the economy of the human-processing system. *Psychological Review*, *86*, 214-255.
- Norman, D. A., & Bobrow, D. G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology*, *7*, 44-64.
- Nuechterlein, K. H. (1990). Methodological considerations in the search for indicators of vulnerability to severe psychopathology. In J. W. Rohrbaugh, R. Parasuraman, & R. Johnson, Jr. (Eds.), *Event-related brain potentials: Basic issues and applications* (pp. 364-373). New York: Oxford University Press.
- Nuechterlein, K. H., & Dawson, M. E. (1984). Information processing and attentional functioning in the developmental course of schizophrenic disorders. *Schizophrenia Bulletin*, *10*, 160-203.
- Nuechterlein, K. H., Edell, W. S., Norris, M., & Dawson, M. E. (1986). Attentional vulnerability indicators, thought disorder, and negative symptoms. *Schizophrenia Bulletin*, *12*, 408-426.
- Parasuraman, R., & Beatty, J. (1980). Brain events underlying detection and recognition of weak sensory signals. *Science*, *210*, 80-83.

- Posner, M. I., & Boies, S. J. (1971). Components of attention. *Psychological Review*, 78, 391-408.
- Pritchard, W. S. (1986). Cognitive event-related potential correlates of schizophrenia. *Psychological Bulletin*, 100, 43-66.
- Roth, W. T., Duncan, C. C., Pfefferbaum, A., & Timsit-Berthier, M. (1986). Applications of cognitive ERPs in psychiatric patients. In W. C. McCallum, R. Zappoli, & F. Denoth (Eds.), *Cerebral psychophysiology: Studies in event-related potentials. Electroencephalography and Clinical Neurophysiology*, 38[Suppl.], 419-438.
- Roy-Byrne, P. P., Weingartner, H., Bierer, L. M., Thompson, K., & Post, R. M. (1986). Effortful and automatic cognitive processes in depression. *Archives of General Psychiatry*, 43, 265-267.
- Ruchkin, D. S., & Sutton, S. (1978). Equivocation and P300 amplitude. In D. A. Otto (Ed.), *Multidisciplinary perspectives in event-related brain potential research (EPA-600/9-77-043)*; pp. 175-177. Washington, DC: U.S. Government Printing Office.
- Simons, R. F., & Miles, M. A. (1990). Nonfamilial strategies for the identification of subjects at risk for severe psychopathology: Issues of reliability in the assessment of event-related potential and other marker variables. In J. W. Rohrbaugh, R. Parasuraman, & R. Johnson, Jr. (Eds.), *Event-related brain potentials: Basic issues and applications* (pp. 343-363). New York: Oxford University Press.
- Sirevaag, E. J., Kramer, A. F., Coles, M. G. H., & Donchin, E. (1989). Resource reciprocity: An event-related brain potentials analysis. *Acta Psychologica*, 70, 77-97.
- Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.
- Spitzer, R. L., & Endicott, J. (1978). *Schedule for affective disorders and schizophrenia (SADS)* (3rd ed). New York: Biometrics Research, New York State Psychiatric Institute.
- Strayer, D. L., & Kramer, A. F. (1990). Attentional requirements of automatic and controlled processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 67-82.
- Wickens, C. D. (1986). Gain and energetics in information processing. In G. R. J. Hockey, A. W. K. Gaillard, & M. G. H. Coles (Eds.), *Energetics and human information processing* (pp. 373-389). Dordrecht, The Netherlands: Martinus Nijhoff.
- Wickens, C. D., Kramer, A., Vanasse, L., & Donchin, E. (1983). The performance of concurrent tasks: A psychophysiological analysis of the reciprocity of information processing resources. *Science*, 221, 1080-1082.
- Yee, C. M., Deldin, P. J., & Miller, G. A. (1992). Early stimulus processing in dysthymia and anhedonia. *Journal of Abnormal Psychology*, 101, 230-233.
- Yee, C. M., & Miller, G. A. (1988). Emotional information processing: Modulation of fear in normals and dysthymics. *Journal of Abnormal Psychology*, 97, 54-63.
- Zahn, T. P. (1986). Psychophysiological approaches to psychopathology. In M. G. H. Coles, E. Donchin, & S. W. Porges (Eds.), *Psychophysiology: Systems, processes, and applications* (pp. 508-610). New York: Guilford Press.

Received December 27, 1991

Revision received April 14, 1994

Accepted April 26, 1994 ■

### New Editors Appointed, 1996-2001

The Publications and Communications Board of the American Psychological Association announces the appointment of two new editors for 6-year terms beginning in 1996. As of January 1, 1995, manuscripts should be directed as follows:

- For *Behavioral Neuroscience*, submit manuscripts to Michela Gallagher, PhD, Department of Psychology, Davie Hall, CB# 3270, University of North Carolina, Chapel Hill, NC 27599.
- For the *Journal of Experimental Psychology: General*, submit manuscripts to Nora S. Newcombe, PhD, Department of Psychology, Temple University, 565 Weiss Hall, Philadelphia, PA 19122.

Manuscript submission patterns make the precise date of completion of 1995 volumes uncertain. The current editors, Larry R. Squire, PhD, and Earl Hunt, PhD, respectively, will receive and consider manuscripts until December 31, 1994. Should either volume be completed before that date, manuscripts will be redirected to the new editors for consideration in 1996 volumes.