

## Dual-Task Attention Deficits in Dysphoric Mood

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The attentional functioning of nondysphoric, mildly dysphoric, and moderately to severely dysphoric college students was tested using the attentional blink (AB) paradigm. These groups performed equally well at reporting a single target appearing in a rapidly presented stream of stimuli. All groups showed an AB, with report sensitivity for a 2nd target being reduced when the 2 targets were presented less than 0.5 s apart. Nondysphoric and mildly dysphoric participants showed the same size ABs, but the ABs for moderately to severely dysphoric participants were larger and longer. As predicted, the results showed that moderately to severely dysphoric individuals have attentional impairments. These impairments, however, were evident only in the more demanding dual-task condition.

Difficulties in attention and concentration are characteristic symptoms of major depressive disorder. Indeed, several authors have suggested that depression is associated with reduced attentional functioning (e.g., Hasher & Zacks, 1979). Despite the widespread belief that depression results in poor attentional functioning, there is relatively little evidence to support an unequivocal conclusion that this belief is true. In the following pages, we review the evidence for reduced attentional functioning in depression and then present an approach to studying limitations in attentional processing that we believe solves some of the problems inherent in earlier research.

Note that *attention* is not a singular cognitive process, nor is there a single, all-encompassing definition that is universally accepted. Almost all models of attention assume that there are normal limits to the amount of information one can process at a given moment in time. Models (e.g., Broadbent, 1958; Kahneman, 1973; Navon & Gopher, 1979), however, differ in the manner in which they account for the observed limitations. For example, some models posit limits in attentional capacity resources (e.g., Kahneman, 1973), whereas others believe that some stages of processing can be performed effectively only for one task at a time (e.g., Broadbent, 1958).

Likewise, we need to recognize that depression is a complex syndrome that influences a number of aspects of functioning and could potentially affect attentional processing in a number of ways. Depression could influence biases in the types of information that are attended to as well as reduce the capacity, efficiency, or speed of attentional mechanisms. For example, depression has been suggested to reduce attentional functioning by negatively influencing arousal or by limiting the cognitive resources necessary to devote effort toward controlled processing (Eysenck & Calvo, 1992). In addition, functional attention may be reduced by the frequent presence of self-absorbed thought, impaired distractor inhibition, or failure to initiate organizational strategies that promote the efficient use of available cognitive resources (Ellis & Ashbrook, 1988; Hertel & Rude, 1991; Ingram, 1990; Nolen-

Hoeksema, Larson, & Grayson, 1999). We do not concern ourselves with biases in attention (see Gotlib, Roberts, & Gilboa, 1996; Mathews & MacLeod, 1994, for reviews) but rather with these other aspects of attentional functioning that might bear more directly on issues related to complaints of poor attention and concentration. Thus, in the following review, we use the term *reduced attentional functioning* in a general way that is not meant either to characterize the specific nature of the deficit or to account for it according to a specific model of attention.

### Attentional Deficits in Depression

A large literature supports the proposition that depression is associated with limitations in the effortful processing of information for memory tasks. These studies have provided strong evidence that depression is associated with greater memory impairment to the extent that (a) increased cognitive effort is required (Hartlage, Alloy, Vazquez, & Dykman, 1993), (b) thoughts irrelevant to the task are increased (Ellis, Thomas, & Rodriguez, 1984; Seibert & Ellis, 1991), (c) attention to the task is not constrained (Hertel & Hardin, 1990; Hertel & Rude, 1991), and (d) organizing principles are not provided (Channon, Baker, & Robertson, 1993a; Watts, Dalgleish, Bourke, & Healy, 1990). Although these findings are consistent with impairments in attention, none of the studies are able to confirm that deficits in attention are responsible for the observed differences in memory. Memory performance can be affected as much by problems in retrieval as by deficits in encoding (Hertel, 1998). To make specific conclusions about attentional functioning, it is necessary to use tasks that do not rely on memory and that minimize retrieval demands. In addition, for those studies that have reduced the depressive memory impairment by manipulating the conditions of learning, it has not been possible to separate online attentional processing from planning and organization.<sup>1</sup> One explanation for poorer performance in the absence of organizational assistance is that there is not a reduction in

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<sup>1</sup> The term *on-line* is used here to refer to attentional processing that is performed at the time of stimulus presentation or shortly thereafter. This can be contrasted with *off-line* processes such as strategic planning before stimulus presentation or retrieval or maintenance strategies after stimulus presentation.

attentional processing per se, but rather a failure to initiate strategic use of organizing principles or elaborative thinking. Alternatively, it could be that attentional functioning is reduced, but the manipulations of attention or material organization help the depressed participants maximize existing attentional functioning.

Research using measures that are not as dependent on memory processes has been conducted. For example, digit span tests can be construed as tests of attentional capacity. Breslow, Kocsis, and Belkin (1980) found differences between depressed and nondepressed participants on the digit span test. However, other comparisons between depressed and nondepressed participants have not yielded differences in performance on the digit span test (Gray, Dean, Rattan, & Cramer, 1987; Stromgren, 1977) or have produced mixed results (Colby & Gotlib, 1988). Channon, Baker, and Robertson (1993b) compared depressed patients with controls on a variety of working memory tasks, which were potentially related to attentional resources, and found very few differences. For the most part, these types of tasks have not revealed depression-related deficits in attention.

Several problems arise when one tries to interpret results from the studies cited above. Tasks that test working attentional load (working memory), like the digit span, have the advantage that they involve relatively short retention intervals and thus may say more about attention than memory retrieval. However, they are presented at a relatively slow pace to ensure accurate perception. They often allow for active rehearsal and chunking of material. Even though varying the number of items in a given trial increases cognitive load, they involve attention to a single item or set of items at a time, thus limiting the cognitive complexity of the tasks. In addition, it has been suggested that cognitive functioning may vary with the severity of depression (Sweeney, Wetzler, Stokes, & Kocsis, 1989). However, most of these studies have made a dichotomous comparison, using various criteria for assigning participants to the depressed group. The inconsistent results of studies of attention in depression could be due to sample variability as much as to using tasks that tap multiple and various cognitive processes.

We are left with a puzzling state of affairs. There is a large memory literature that strongly suggests depression-related impairments in the recall of nonaffective, neutral information (for reviews see Burt, Zembler, & Niederehe, 1995; Johnson & Magaro, 1987; Mathews & MacLeod, 1994) and attempts to explain these impairments in terms of deficits in the capacity or allocation of attentional resources (Ellis & Ashbrook, 1988; Hasher & Zacks, 1979; Hertel & Rude, 1991). However, there is little direct evidence from controlled studies of attention to suggest that attentional resources are reduced in depression (Channon et al., 1993b; Gray et al., 1987).

### The Attentional Blink

In the light of the previous discussion, we wanted to conduct a study that could characterize the hypothesized attentional processing deficits associated with depression in a more exacting fashion by using a task that minimized the roles of strategic planning, memory maintenance, and retrieval. To do this, we felt that a particular cognitive task, rapid serial visual presentation (RSVP), was ideal. RSVP has been used to study the nature and limitations of human attentional processing. This methodology consists of the successive presentation of stimuli, such as letters and words, in the

same location. The stream of stimuli may contain 6 to 20 items, which are presented at rates of about 10 items per second. In the typical single-task RSVP experiment, participants are asked to attend to and report one of the items, a target. For example, a participant may be asked to name the lone white letter presented among black letters *or* may be asked to report whether a specified letter (e.g., X) was present or absent in the stimulus stream. It has been found that young, mentally and physically healthy participants are able to accurately report any single target, no matter where it appears in the stream of stimuli, even though it is presented for only about 100 ms (Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1994).

In a typical dual-task RSVP, participants are asked to attend to and report two targets presented in the same stimulus stream. For example, Raymond et al. (1992) asked participants to report the identity of a lone white letter (the first target, or T1) presented among black letters and then to report whether the letter X (the second target, or T2) was present in the stream of stimuli following T1. In such experiments, the report of T1 is unimpaired. However, these experiments reveal limitations in attentional processing in that there is a cost to paying attention to T1. Having first paid attention to T1, it is very difficult for participants to accurately report on the presence of T2 if it occurs within a short period of time (less than half a second) after T1. However, if T2 is presented more than half a second after T1, then T2 report accuracy can reach the levels achieved during single-task performance. This phenomenon has been called the *attentional blink* (AB) and seems to last for approximately 500 ms (Chun & Potter, 1995; Raymond et al., 1992; Shapiro et al., 1994).

The AB paradigm is very well suited to examining the hypothesized attentional limitations of depression. The timing and nature of the stimuli are well controlled. The fast, computer-driven nature of stimulus presentation and the use of simple, overlearned alphanumeric characters reduce the possibility of elaborate rehearsal strategies during stimulus encoding. In addition, the simple nature of the stimuli and tasks minimizes the need or usefulness of pretrial strategic planning. Critically, the task is primarily an encoding task that involves few cognitive resources of the type traditionally considered under the label of *memory*. The participant simply identifies the presence or absence of the stimulus immediately after its presentation, with the proportion of correct responses serving as the basis for the dependent measure. In addition, the duration of time necessary for T1 encoding can be tracked across time by examining T2 performance at various positions after T1. Thus, we are able to characterize the degree to which stimuli at any particular position are encoded as well as the temporal pattern of any attentional deficits that are observed.

Dozens of AB experiments have been performed with young, healthy, nondepressed participants, allowing researchers to learn much about the attentional processing limitations that underlie the AB. For example, Chun and Potter (1995) showed that the AB does not result from task-set switching (reconfiguring attentional resources from the T1 task to a different T2 task). The AB does not result from T1 perceptually interfering with T2, given that T2 performance is not impaired when T1 is present, unless participants are instructed to attend to T1 (Raymond et al., 1992). Furthermore, the AB does not result from differences in number, or order, of response requirements of single- versus dual-task trials (Shapiro et al., 1994). Both behavioral and electrophysiological

data have clearly shown that although T2 cannot consciously be reported during the AB, its semantic representation is fully activated. During the AB, T2 can prime a subsequent stimulus (Shapiro, Driver, Ward, & Sorensen, 1997) and produce a brain wave component that indexes semantic activation (Luck, Vogel, & Shapiro, 1996). Therefore, the constellation of AB research with nondepressed participants strongly suggests that the AB reflects attentional processing limitations that impair conscious stimulus encoding (Arnell & Jolicoeur, 1999; Chun & Potter, 1995).

Several attentional models postulate two processing stages in stimulus encoding (Chun & Potter, 1995; Jolicoeur, 1999; Kanwisher, 1987; Treisman & Gelade, 1980). A brief and complete activation of stimulus information occurs in the first stage. This first stage is assumed to have no capacity limits and to be performed automatically and effortlessly. However, representations formed in this stage cannot serve as the basis for report and are subject to rapid decay or overwriting by subsequent information unless they are selected for second-stage processing. In the second stage, selected representations are transformed into more robust conscious representations that can serve as the basis for report or response. In this stage, the selected stimuli are fully identified and consolidated into awareness into a store such as working memory. However, this second stage is capacity limited, and consolidation is assumed to be an effortful and attention-demanding process.

In the AB paradigm, both T1 and T2 must undergo consolidation in Stage 2 for them to be reported correctly. If T2 is presented after T1 consolidation has been completed, then T2 will be consolidated without problems. However, if T2 is presented before T1 consolidation is completed, T2 will need to wait for Stage 2 processing resources to become available. If other stimuli are presented after the T2 stimulus, and before T2 entering Stage 2 processing, then these will replace the Stage 1 representation of T2, and consolidation of T2 will fail even when Stage 2 resources become available (Chun & Potter, 1995; Jolicoeur, 1999).

The one exception to the general rule that T2 will be lost to further processing while T1 is being consolidated has been called *+1 sparing*. A typical AB often has a pattern in which T2 performance is better at Position 1 than at Position 2 or even 3. This effect has been labeled *+1 sparing* because the T2 accuracy is relatively spared in the first position after T1 (Potter, Chun, Banks, & Muckenhoupt, 1998). This *+1 sparing* is explained in AB models by assuming that T1 and T2 can go through Stage 2 consolidation together (at the same time) if T2 is presented soon enough after T1, that is, before T1 consolidation begins.

In summary, it has been suggested that depression is associated with reductions in attentional functioning, although most of the research testing this hypothesis has been based on measures of memory rather than encoding. In the present study, the AB task was used to address the question of whether dysphoric individuals would show attentional processing limitations in the form of conscious stimulus encoding.<sup>2</sup> Although there has been some debate about whether the use of college students selected on the basis of self-report questionnaires can help us learn about the nature of clinical depression (Coyne, 1994; Flett, Vredenburg, & Krames, 1997), we felt that it would be more ethical and practical to do some of the initial theory testing with a college student sample. We made sure to measure depressive symptoms over more than one occasion (to provide some evidence of stability) and to consider levels of symptoms that are often considered clinically

meaningful, and we attempted to rule out common alternative explanations for those symptoms. In this manner, it was our hope that the results from our dysphoric sample could be more readily generalized to a sample whose members had received a diagnosis of major depressive disorder. Positive findings would justify follow-up research with a clinical sample, thus extending our knowledge about cognitive limitations across diagnostic boundaries.

We hypothesized that dysphoria would be associated with deficits in consolidating target items presented in a stream of rapidly presented visual stimuli. In the present study, we compared the performance of dysphoric and nondysphoric participants in single- and dual-task RSVP conditions. In both conditions, the stimuli were exactly the same. Participants were presented with a series of single black letters, with one white letter presented near the middle of the stream. In half of the streams, the letter X was presented randomly in one of eight positions following the white letter, and in half of the streams, the letter X was not presented. In the dual-task condition, participants were to name the lone white T1 letter and then state whether an X was present or absent in the post-T1 stream. In the single-task condition, they were told to ignore the white letter and to simply state whether an X was present or absent in the letter stream.

Stimulus consolidation is resource limited and attention demanding. In keeping with the memory literature, which shows increasing depression-related deficits with increased cognitive load, we expected that dysphoric participants would be especially impaired on the dual-task RSVP stream, particularly when the two targets were presented closely in time. That is, it was predicted that having first identified the white letter, dysphoric participants would be less able than nondysphoric participants to detect the X when it appeared in the first several positions after the white letter. To the extent that depressed mood may reduce attentional consolidation abilities even when attention was focused on a single task, it was also possible that dysphoric participants would not be as accurate as nondysphoric participants in detecting the presence of the X even in the single-task condition.

The issue of anxiety was also considered given that it often coexists with depression. The relationship between anxiety and attention, especially selective attention, has been studied by a number of investigators (see Mathews & MacLeod, 1994, or Mogg & Bradley, 1999, for reviews). Although some research has concerned itself with determining whether anxiety interferes with the accuracy and efficiency of information processing, the results are somewhat mixed. The extent to which state anxiety interferes with performance may depend on individual differences in trait anxiety and the nature of the task, for example, how complex the task is and whether it is primarily a cognitive or a motor task (Eysenck & Calvo, 1992). No one, to our knowledge, has published research investigating the influence of anxiety on RSVP task performance. Because symptoms of depression and anxiety often coexist and because it is possible that arousal at the time of testing might

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<sup>2</sup>In keeping with established convention, we use the word *dysphoric* rather than the word *depressed* throughout the article to refer to our participants, to acknowledge that they were identified on the basis of a symptom-severity measure rather than on clinical diagnosis (Kendall, Hollon, Beck, Hammen, & Ingram, 1987).

influence performance on this task, we chose to measure state anxiety, so that any contribution of anxiety to the relationship between dysphoria and attentional functioning might also be examined.

## Method

### Participants

Participants were recruited from lower level undergraduate psychology classes over the course of 2 semesters. In the Department of Psychology at North Dakota State University, all consenting students in freshman and sophomore level classes, which allow extra credit for participation in research, complete a survey that contains information pertinent to current research. Owing to space considerations and the respective needs of multiple researchers, the content of this screening survey varies from term to term. One semester, the primary measure of depressive symptoms was the Geriatric Depression Scale (GDS; Yesavage et al., 1983). This is a 30-item scale with a yes or no response format. Others have reported this measure to be reliable and valid when used with college-age adults (Ferraro & Chelminski, 1996; Rule, Harvey, & Dobbs, 1989). In the second semester, the Short Form of the Beck Depression Inventory (BDI-SF) was used. This is a 13-item scale that has been shown to correlate well with the long form (Beck & Beck, 1972). Recommended cutoff scores for determining a meaningful level of depressive symptoms were used. Those participants scoring 10 or higher on the GDS and 7 or higher on the BDI-SF or scoring less than 4 on either form were considered potential candidates. In addition, participants were screened for alcohol use. The CAGE is a 4-item questionnaire that has been shown to be sensitive to potential alcohol abuse (Mayfield, McLeod, & Hall, 1974). Those students who responded positively to 2 or more alcohol items were excluded from participation. Thus, respondents who scored either high or low on a measure of depression and reported few problems with alcohol were invited to participate.

At the time of participation, the students were asked about their psychiatric history. Only 1 participant reported receiving current treatment for a psychiatric problem. She had been prescribed bupropion for depression, had been taking the same dose for 1.5 years, and was one of the participants currently symptomatic in the moderate to severe range. None of the participants had ever received electroconvulsive therapy.

At the time of the experiment, participants completed the long form of the Beck Depression Inventory (BDI; Beck, Rush, Shaw, & Emery, 1979). To be included in the study, participants needed to again score low or high on the BDI. A minimum score of 10 on the BDI was required to be included in the dysphoric groups. Most students participated in the experiment within 3 weeks of completing the screening questionnaire. Requiring participants to meet a minimal cutoff score on two assessment occasions separated by 1 to 3 weeks makes it more likely that the depressed mood is stable and a closer approximation to major depressive disorder (Kendall, Hollon, Beck, Hammen, & Ingram, 1987). Because variability of results in previous literature on cognition and depression could be related to symptom severity, we chose to break our sample into three groups. We used commonly recommended cutoff scores on the BDI to place individuals in the nondysphoric (<10), mildly dysphoric (10–18), and moderately to severely dysphoric (>18) groups (Beck, Steer, & Garbin, 1988).

Of the 68 persons invited to participate in the study, 36 met the inclusion criteria. All were undergraduate psychology students who participated in the study in return for extra credit that could be applied to their course grade. There were 27 women and 9 men. They ranged in age from 18 to 36 years, with a mean age of 20 years. Table 1 lists the cell sizes, demographic makeup, and BDI scores for each of the resulting groups. The groups did not differ significantly in composition with respect to age or sex ( $p > .35$ ).

Table 1  
*Demographic Variables and Beck Depression Inventory (BDI) Scores for Each Dysphoria Group*

Group	n	%	Age		BDI score		
			Range	M	Range	M	SD
Nondysphoric	17	70.1	18–31	20.2	0–6	1.82	1.67
Mild	10	60.0	18–24	19.4	11–18	13.50	2.06
Moderate–severe	9	88.9	18–36	21.2	21–37	27.22	5.36

### Design

The design was a 3 (dysphoria level)  $\times$  2 (dual task, single task)  $\times$  2 (T2 present, absent)  $\times$  8 (T2 position) mixed factorial. On the trials in which T2 was present, it was presented subsequently to T1 in one of eight stimulus positions. T2 presence or absence and T2 position were within-subject variables that varied randomly within blocks, with the constraint that each possible combination of these factors occurred equally often every 32 trials. Each participant performed one dual-task and one single-task block with starting order counterbalanced across participants. Each participant performed 320 trials in a single experimental session. Including the provision of informed consent, the collection of demographic and self-report data, and performing the attention task, each session lasted for approximately 1 hr.

### Stimuli and Apparatus

Stimuli and tasks closely followed the basic AB paradigm (Raymond et al., 1992). The visual stimuli were letters that included all the letters of the alphabet. Each letter except T2 was chosen randomly by the program. T2 was always the letter X and was present on half of the trials. On T2-absent trials, a random letter replaced the X. When present, T2 appeared randomly in one of the eight positions immediately following T1 and was never presented before T1 in the stream. The X was never used as T1 or as a filler letter. The number of letters presented before T1 (either six or nine) was chosen randomly for each trial. The random placement of T1 is necessary to ensure that the task continues to demand attention from the start. Varying T1 between two positions is enough to keep the placement unpredictable for the participant. At least nine letters always succeeded T1. The letters were presented one at a time in RSVP in the same location in the center of a uniform gray field (see Figure 1). Each letter was presented for 90 ms, followed by no interstimulus interval (ISI). These timing conditions produced a display rate of 11.11 letters/second. All of the visual characters were black, except T1, which was white. All letters were capitalized and presented in 18-point Courier New font. At this size, the letters subtended approximately 1.14° of visual angle in height and width at an approximate binocular viewing distance of 25 in. The experiment was controlled and timed with E-Prime (Psychology Software Tools, 1999) software running on a Dell OptiPlex GX1p computer with a Pentium II processor and a 17-in. Dell Trinitron color monitor.

In summary, each participant saw a series of 19 letters, presented 1 after another very rapidly. The entire stream lasted for a total of 2.11 s. Two unique stimuli served as targets. T1 was presented in white, and T2 was the letter X.

### Measures

*Beck Depression Inventory* (Beck et al., 1979). The BDI is one of the most frequently used instruments in depression research. It is a self-report instrument consisting of 21 items, each of which contains four sentences arranged in order of severity. The respondent is to choose the one sentence that best describes his or her feelings over the past 2 weeks. Scores can

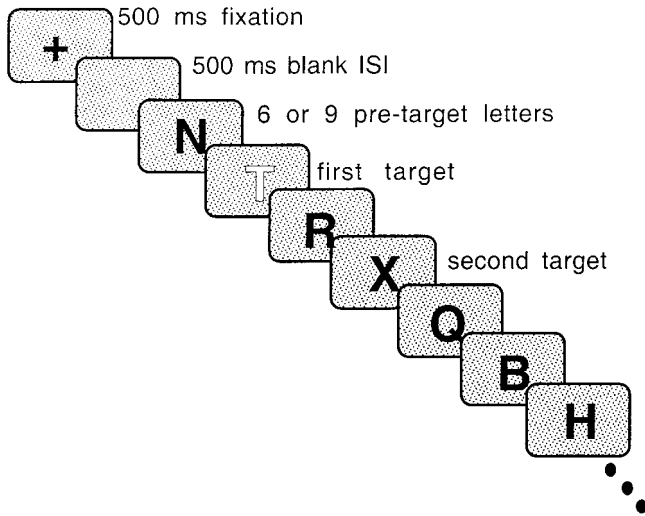


Figure 1. The sequence of stimulus events within a stream. A fixation cross was presented for 500 ms, followed by a 500-ms blank interstimulus interval (ISI), and then the stream of letters. Six or 9 letters preceded the white target letter, and either 12 or 9 letters, respectively, followed it. On half of the trials, the letter X target was presented in one of the eight positions after the white letter (in this case, Position 2). All letters were presented one at a time in the same spatial location.

range from 0 to 63, with higher scores representing higher levels of depression. This instrument has demonstrated excellent reliability ( $\alpha = .86$ ) and validity (Beck et al., 1988).

*State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).* The STAI was developed to measure subjective feelings of tension, apprehension, nervousness, and worry at either a particular moment in time or as a relatively enduring and typical response to situations that might provoke anxiety. We used the state version, STAI Form Y-1. On 20 items, the respondent rates whether he or she is experiencing the particular feeling, on a 4-point scale ranging from *not at all* (1) to *very much so* (4). Scores can range from 20 to 80, with higher scores indicating higher levels of anxiety. The STAI has been normed for use with a variety of populations and has demonstrated adequate reliability and validity (Spielberger et al., 1983).

**Procedure**

After we obtained informed consent, participants responded to demographic questions and completed the BDI and the STAI. They were then given instructions for the RSVP task. Each participant performed at least four practice trials to begin the experiment. Participants continued to perform practice trials until they demonstrated to the experimenter that they could perform both the T1 task and the T2 task successfully in isolation. Participants initiated each trial by pressing the spacebar on the

keyboard. Each trial began with the presentation of a black fixation cross in the center of the screen for 500 ms, followed by a 500-ms blank interval before the start of the stimulus stream.

On dual-task blocks, participants were given instructions to identify the white letter on each trial and to decide whether an X was presented in the stream in any position after the white letter. Participants were informed that the X would never come before the white letter. Participants were told to do their best on both tasks but to treat the white-letter task as the primary task, and the X detection as the secondary task. Immediately after each dual-task stream, participants were prompted by a sentence on the computer screen telling them to press the key matching the identity of the white letter. After entering a response, they were then prompted by another sentence on the screen to press the 0 key if the X was absent and the 1 key if the X was present. On single-task blocks, participants were told to ignore the white letter and just decide whether the X was present or absent. At the end of each single-task stream, participants were prompted only by the sentence asking them to press the 0 key if the X was absent and the 1 key if the X was present. For both blocks, accuracy was stressed, and participants were aware that their response times were not being recorded.

**Results**

*Target 1 Performance*

T1 accuracy rates for each dysphoria group are presented in Table 2 for each T2 position when the X was present and also for when T2 was absent. Overall, participants produced 94.3% correct T1 identification. There were no significant differences in accuracy among the three dysphoria groups for the primary T1 task, for all trials, T2-present trials, and T2-absent trials ( $F_s < 1.0$ ). Also, a  $3 \times 8$  mixed-measures analysis of variance (ANOVA) with dysphoria group and T2 position as factors was performed on T1 accuracy rates and revealed no significant main effects or interaction (all  $F_s < 1.0$ ). Thus, the results clearly indicate that the three dysphoria groups performed T1 equally well both when T2 was present and when it was absent. Furthermore, all participants treated T1 as the primary task and did not sacrifice T1 accuracy to help them report T2, even when T2 was presented closely after T1.

*Target 2 Performance*

The primary data of interest were each participant's X-detection performance (i.e., the ability to accurately detect the X when presented in the stimulus stream, or *hits*). As is commonly done in AB experiments, mean detection rates on dual-task trials were calculated only for those trials in which the participant correctly identified T1. (Recall that the AB represents the cost to attending to T2 having first attended to T1.) We were interested in the participants' sensitivity to the X independent of their bias to respond "present" (i.e., we wanted to distinguish participants who

Table 2  
Target 1 (T1) Accuracy for Each Dysphoria Group as a Function of Target 2 (T2) Position

Group	T2 position								T2 absent
	1	2	3	4	5	6	7	8	
Nondysphoric	91.2	93.5	88.2	92.9	94.1	94.1	92.9	92.9	92.4
Mild	87.0	93.0	93.0	93.0	93.0	96.0	91.0	90.0	92.1
Moderate-severe	92.2	88.9	92.2	93.3	90.0	93.3	94.4	88.9	91.1

were good at the X task—and therefore reported the X as present when it was present and absent when it was not present—from those participants who simply responded “present” a lot whether or not the X was presented).

To accurately measure sensitivity, we examined false-alarm rates (the percentage of X-absent trials in which the participant reported the X as present) in addition to hit rates. Although there was no significant difference in the mean false-alarm rates for the three dysphoria groups ( $F < 1.0$ ) for dual-task trials (19.9%, 15.3%, and 21.1% for nondysphoric, mildly dysphoric, and moderately to severely dysphoric, respectively), and for single-task trials,  $F(2, 33) = 2.01, p > .15$  (15.2%, 12.0%, and 8.7% for nondysphoric, mildly dysphoric, and moderately to severely dysphoric, respectively), false-alarm rates varied dramatically across individual participants (ranging from 1% to 52% of X-absent trials). Accordingly, the nonparametric sensitivity measure  $A'$  was used to calculate performance for each participant in each condition.  $A'$  (Snodgrass & Corwin, 1988) is a sensitivity measure that takes into account both hits and false alarms. It varies from 0 to 1.0, with .5 indicating null sensitivity (equal percentage of hits and false alarms) and 1.0 indicating perfect sensitivity (100% hits, 0% false alarms). Because no X was presented on X-absent trials, false-alarm rates could not be broken down by position. Thus, an overall false-alarm rate for the X-absent trials on each block (dual task and single task) was used for each participant. Because a constant false-alarm rate was used for each participant on each block, this amounts to adding or subtracting a constant from the hit-rate data. Thus, the  $A'$  dual-task and single-task functions had the same shape across T2 position as the percentage correct data—only the height of the functions may have changed from participant to participant. This procedure has been used in previous AB studies (e.g., Arnell & Jolicoeur, 1999). Mean T2 sensitivity (expressed in  $A'$ ) is presented in Figure 2A (dual-task trials) and 2B (single-task trials) as a function of T2 position and dysphoria group.<sup>3</sup>

The T2 sensitivity ( $A'$ ) means were submitted to an ANOVA with instructions (dual task or single task) and T2 position (1–8) as within-subject factors and dysphoria level (none, mild, or moderate to severe) as a between-subjects factor. The analysis revealed a significant main effect of instructions,  $F(1, 33) = 69.45, p < .01$ ; a significant main effect of T2 position,  $F(7, 231) = 12.58, p < .01$ ; and a significant Instruction  $\times$  T2 Position interaction,  $F(7, 231) = 13.51, p < .01$ . This interaction is the statistical signature of the AB. T2 sensitivity was relatively high at all T2 positions on single-task blocks (mean sensitivity about .90) but was dramatically lower at some early T2 positions on dual-task trials. There was no significant main effect of dysphoria level overall ( $F < 1.0$ ), and dysphoria level did not interact with instructions,  $F(2, 33) = 1.87, p > .16$ , or with T2 position,  $F(14, 231) = 1.23, p > .25$ . However, most important, dysphoria level entered into a significant three-way interaction with instructions and T2 position,  $F(14, 231) = 2.07, p < .02$ . This interaction indicates that the AB changed with level of dysphoria.

An examination of Figure 2 suggests that T2 sensitivity for nondysphoric and mildly dysphoric participants was approximately equal in all conditions. However, T2 performance for moderately to severely dysphoric participants appears lower than that of the other two groups, but only in the dual-task condition and only during the AB interval. Within-Subject Instruction  $\times$  Position

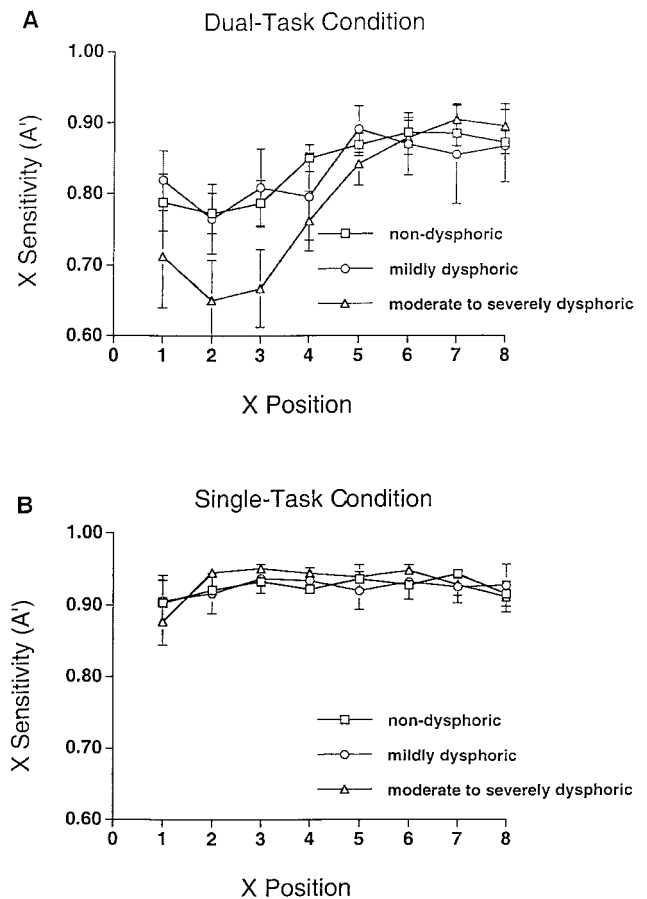


Figure 2. Mean X-detection sensitivity (in  $A'$ ), averaged across participants, as a function of the position of the X after the white target letter and dysphoria group. (A) The mean X-detection sensitivity on dual-task trials in which participants were asked to report the identity of the white letter and whether the X was present or absent. (B) The mean X-detection sensitivity on single-task trials in which participants were asked to ignore the white letter and just report whether the X was present or absent.

ANOVAs performed separately for each dysphoria level revealed a significant Position  $\times$  Instruction interaction for each group (all  $ps < .05$ ), demonstrating an AB for each dysphoria level. The difference in sensitivity for the single-task and dual-task conditions was calculated separately for each position and used as an estimate of the dual-task cost at that position. Planned comparisons using Tukey's honestly significant difference procedure for alpha correction were performed on these scores, comparing nondysphoric and mildly dysphoric participants. No significant differences between nondysphoric and mildly dysphoric participants were found at any position. The minimum difference required for identifying a significant effect was .111. The largest difference among

<sup>3</sup> The same pattern of means was found when percentage correct T2 hits was used as the dependent variable. Moderately to severely dysphoric participants showed a lower percentage of T2 hits, compared with nondysphoric participants, in the early positions on dual-task trials. The difference between these groups in hits on the dual-task trials ranged from 11% at Position 1 to 19% at Position 4.

these comparisons was .038. When the difference in sensitivity for the single- and dual-task conditions was compared for mildly dysphoric and moderately to severely dysphoric participants, no significant differences were found at any position. The minimum difference required for identifying a significant effect was .182, and the largest difference among these comparisons was .157. However, when the difference in sensitivity for the single- and dual-task conditions was compared for nondysphoric and moderately to severely dysphoric participants, significant differences were observed at Positions 2 and 3 (differences of .148 and .138, respectively, were both larger than .136, which was the minimum difference required for significance). There were no significant differences at any other positions.

Furthermore, the AB interval appears to be lengthened for the moderately to severely dysphoric participants, extending out to Position 4. T2 sensitivity at Position 8 (the last position is typically the best performance and the furthest away from T1 influences) provides an estimate of maximal T2 performance under dual-task conditions in the present experiment. To examine the duration of the AB for nondysphoric and mildly dysphoric participants separately from moderately to severely dysphoric participants, we performed planned comparisons using paired-samples *t* tests with Dunnett's alpha correction where sensitivity scores at each position in the dual-task condition were compared with Position 8 in the dual-task condition. For nondysphoric and mildly dysphoric participants, only Positions 2 and 3 showed significant reductions in T2 sensitivity compared with Position 8 (*ts* = 3.67 and 3.40, respectively, with critical *t* = 2.81). However, for moderately to severely dysphoric participants, Positions 2–4 showed significant reductions in T2 sensitivity compared with Position 8 (*ts* = 3.39, 3.62, and 4.85, respectively, with critical *t* = 3.29). These results suggest that the AB lasted approximately 100 ms longer for the moderately to severely dysphoric participants compared with the nondysphoric and mildly dysphoric participants.

These results indicated that the T2 sensitivity of mildly dysphoric participants did not differ from the T2 sensitivity of nondysphoric participants in any conditions. Moderately to severely dysphoric participants' T2 sensitivity was also not different than that of nondysphoric participants in the later positions of the dual-task trial. Performance in the later positions of the dual task can be likened to single-task conditions in that once T1 has been encoded, attentional resources can once again be fully devoted to looking for an X in the stream. Performance by moderately to severely dysphoric participants was significantly reduced in Positions 2–4 under dual-task conditions, when the encoding of T1 and the continued search for an X must occur simultaneously.

Depression scores from the BDI and anxiety scores from the STAI were significantly and positively correlated ( $r = .74, p < .01$ ), indicating a strong correspondence between reports of depression and anxiety symptoms. We thought it would be appropriate to test for the unique contributions of these moods to the AB. The size of the AB was calculated for each participant by summing the difference in *A'* values between the single-task and dual-task trials across the first four positions. In this manner, the lower the sensitivity on dual-task trials, relative to single-task trials, the greater the size of the AB. Hierarchical regression analyses were conducted with BDI scores and STAI scores as potential predictors of AB size. When entered first as a predictor, BDI scores explained a significant amount of variance,  $F(1, 34) = 7.96, p < .01, R^2 =$

.19. When STAI scores were then added after BDI scores, they did not account for significant additional variance ( $p > .26$ ). When STAI scores were entered first as a predictor, they explained a significant amount of variance,  $F(1, 34) = 8.16, p < .01, R^2 = .19$ . When BDI scores were then added after STAI scores, they also did not account for significant additional variance ( $p > .30$ ).

## Discussion

It has been suggested that depression is associated with reduced attentional functioning (Hasher & Zacks, 1979). Some studies support this hypothesis, although the research is based largely on tests of memory performance rather than tests of encoding (e.g., Ellis & Ashbrook, 1988; Hertel & Rude, 1991). The present study was designed to address this limitation in the literature. It was hypothesized that dysphoria would be associated with deficits in consciously consolidating targets presented in a stream of rapidly presented visual stimuli. This was predicted to be especially true when the task was made to be more demanding by requiring the participants to attend to two objects in a single stimulus stream. Two primary results were obtained. We found that dysphoric individuals did not differ from nondysphoric individuals in their ability to detect the presence of a single target in a stream of rapidly presented stimuli, that is, when detecting the X was their only task. Nor did dysphoric individuals differ from nondysphoric individuals in their ability to detect the X when it was presented more than half a second after a first target that also required attention. However, as hypothesized, moderately to severely dysphoric participants showed clear encoding deficits on the dual-attention task. Having first attended to the white letter, moderately to severely dysphoric participants were less able than nondysphoric participants to detect T2 (X) if it appeared in Positions 2 and 3 after T1 and, relative to their own maximal performance, continued to show poorer X detection into the fourth position. In other words, moderately to severely dysphoric participants showed a deeper and longer AB than did nondysphoric participants. Moderately to severely dysphoric individuals performed as well as nondysphoric individuals when T1 could be ignored and in later positions on the dual-task trial when, presumably, the encoding of T1 had been completed. Our interpretation of the deficits that appear in the early positions of the dual task would be that moderately to severely dysphoric participants took longer to consolidate T1 and, thus, showed poorer detection of T2 during the time required to consolidate T1.

In relating these findings to the previous literature, two issues should be highlighted: the nature of depression and the nature of the cognitive task. In the past, it has been suggested that cognitive functioning may vary with the severity of depression (Hartlage et al., 1993; Sweeney et al., 1989). Consistent with this suggestion, deficits in the dual-attention task were limited to those participants with the highest levels of depressive symptoms.<sup>4</sup> This result could be taken to suggest that reduced attentional functioning is indeed

<sup>4</sup> The very high positive correlation between BDI scores and STAI scores and their respective associations to AB size makes it possible that anxiety could be modulating the observed AB effects in addition to or instead of dysphoria per se. The results are discussed here in terms of dysphoria primarily because our hypotheses were based on our understanding of dysphoria. In addition, the main ANOVA analyses were based on a

a characteristic of dysphoria but that it may appear only in those individuals with relatively severe or numerous depressive symptoms. With so few participants in the severe range of depressive symptoms, it is not possible to determine from our data if the relationship between cognitive impairment and symptom severity is discontinuous or linear beyond some critical level of symptom severity.

In addition, although we limited our investigation to participant groups that are identified only on the basis of a severity score, we would note that it has frequently been argued that depression is a complex disorder that potentially includes several subtypes (cf. Haslam & Beck, 1994). Thus, it is also conceivable that attention problems may be associated with particular depressive symptoms or symptom clusters rather than just the severity of symptoms. We do not know if those who are more likely to complain of problems in concentration and memory are the same as those who perform more poorly on our laboratory measures. Nor do we know the extent to which the variables of appetite, energy, and sleep might also be associated with attention performance. Further research should be directed toward clearly establishing the presence of attentional deficits associated with depression, exploring the nature of the deficits, and determining their association with potential symptoms or symptom patterns.

Null results may have been found in previous examinations of on-line attentional functioning due to the nature of the tasks used in those studies. Although moderately to severely dysphoric participants in the present study showed a deeper and longer AB than nondysphoric participants, they performed as well as nondysphoric participants in the single-task condition and in the dual-task condition when the targets were separated by greater than 500 ms. It is possible that dysphoric individuals have difficulty allocating their attention only in situations where more than one stimulus must be attended, and therefore such deficits will only be observed under dual-task conditions. However, it is also possible that dual-task conditions are not necessary to observe attentional deficits in dysphoric individuals, but that the task must be sufficiently difficult so that the performance of even nondysphoric individuals begins to suffer. Further experiments could dissociate these alternatives. For example, the rate of stimulus presentation could be increased in the single-task condition. If X-detection sensitivity dropped off for moderately to severely depressed participants at this faster rate but nondysphoric participants' sensitivity remained the same, then the results would suggest that moderately to severely depressed individuals can exhibit even single-task attentional deficits provided the task is demanding enough. Investigations of this sort are currently under way in our laboratories. Previous attempts to find attentional deficits in depressed individ-

uals that produced null results may have used tasks that were not sufficiently attention demanding or used a measure that involved only a single cognitive task (Sweeney et al., 1989).

Several potential explanations of the nature of the observed deficit are worth considering. Perhaps dysphoric individuals are less motivated to perform well, are less aroused, or have difficulty switching from one cognitive task to another. Even the single-task condition was not an easy attentional task. Normal, young, healthy participants typically average approximately 90% correct X detection in the single-task condition at the rate of presentation used here. Indeed, all three dysphoria groups also averaged approximately 90% correct X detection in the single-task condition. Even severely dysphoric participants were able to perform this attention-demanding, single-task condition just as well as the nondysphoric participants. The three dysphoria groups performed equally well in the single-task condition, on the T1 task in the dual-task condition, and on the T2 task at later positions in the dual-task condition. These results appear to rule out general motivational factors or overall arousal as possible explanations for the attentional deficit observed in the moderately to severely dysphoric participants. If general arousal or motivational factors were responsible, the performance of dysphoric participants would have been reduced, relative to nondysphoric participants, for both T1 and T2 tasks and at all stimulus positions; yet this was not the case.

The finding that the moderately to severely dysphoric participants showed a larger and longer AB but had no other accuracy deficits relative to nondysphoric participants is a unique pattern among the special population groups tested thus far with the AB paradigm. Isaak, Lahar, and McArthur (1996) found deeper ABs for older adults (62–77 years) in the dual-task condition. However, older adults' accuracy rates were also lower by a comparable amount in the single-target condition, suggesting that older adults were simply less able to perform the RSVP task overall. Husain, Shapiro, Martin, and Kennard (1997) reported lower dual-task T2 performance for right-hemisphere stroke patients with and without hemispatial neglect; however, these patients also displayed lower accuracy in the single-task condition relative to nonpatient matched controls. Lower performance on all conditions (single and dual task) may be expected in these groups given the chronic arousal problems found in right-hemisphere patients and the generally slower processing speed of older adults (e.g., Salthouse & Babcock, 1991). In contrast, it appears that moderately to severely dysphoric participants show a relatively unique pattern of deficits that cannot be explained simply by appealing to general arousal or motivational factors.

Deficits in task-set switching for moderately to severely dysphoric individuals may also seem to be a potential explanation for their larger and longer ABs relative to nondysphoric individuals. Participants are asked to do two different tasks on each trial (i.e., report the identity of the white letter and the presence or absence of X). Could it be that the AB results from the participants setting out to identify the white letter and then requiring time to switch their task-set to X detection? In this manner, T2 performance improvements across positions would be due to the time needed to switch task set, not to recovery from T1 processing (e.g., Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995). Although task-set switching may contribute to the magnitude of the AB under some conditions, robust ABs are still observed under conditions that do not support task-set switching, such as when both tasks are

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design that separated participants into groups on the basis of their BDI scores. Therefore, it is only valid to discuss the ANOVA results in terms of dysphoria groups, not anxiety groups. If one were interested primarily in understanding major depressive disorder, the generally high correlation between depression and anxiety suggests that anxiety is an important component of depression and that these factors do not have to be isolated to meaningfully examine the effect of depressive symptoms on the AB. From a theoretical point of view, we would encourage researchers to continue to look for the unique and overlapping effects of anxiety and depression on attentional functioning.



the same on dual-task trials (e.g., report the identity of the two numbers presented among letters, as was done by Chun & Potter, 1995). Furthermore, in many experiments, including the present one, T2 accuracy shows +1 sparing in that accuracy is better at Position 1 than at Position 2 or 3. The presence of the +1 sparing effect provides evidence against task-set switching because all switching arguments postulate lowest accuracy at Position 1. (See Potter et al., 1998, for more details on this argument and Visser, Bischof, & Di Lollo, 1999, for a review of +1 sparing.) In the present experiment, the +1 sparing shown by moderately to severely dysphoric participants suggests that their larger and longer AB is not likely to be the product of increased task-switching difficulties.

If the larger and longer AB observed here for moderately to severely dysphoric participants is not the result of differences in motivation, general arousal, or task-set switching, then to what might it be due? The AB is often thought to reflect limitations on encoding stimuli into conscious awareness (e.g., Chun & Potter, 1995; Jolicoeur, 1999; Shapiro, Arnell, & Raymond, 1997). T1 and T2 are thought to be processed to the level of semantics in a parallel first stage of processing. T1 undergoes a second stage where it is consolidated into working memory and is available for awareness. However, this second stage is resource limited, and T2 must wait while T1 is processed. When T2 occurs shortly after T1, T2 is replaced by subsequent stimuli, and its representation may decay before it can be consolidated into awareness for report (Chun & Potter, 1995; Jolicoeur, 1999). According to this theory, larger and longer ABs are the result of T1 requiring more Stage 2 processing resources for a longer time, so that T2 must wait for a longer time, thereby making it more susceptible to loss. Indeed, the larger and longer AB observed in the moderately to severely dysphoric participants compared with nondysphoric participants in the present study strongly resembles the pattern that is found when a manipulation is applied to the T1 task to increase its processing demands (e.g., Jolicoeur, 1999; Seiffert & Di Lollo, 1997). For example, Jolicoeur (1999) found that the AB was larger when T1 required a four-alternative speeded response than when T1 required a two-alternative speeded response, despite the fact that the T2 task remained unchanged.

Therefore, the present pattern of results leads us to conclude that conscious stimulus consolidation is impaired in dysphoria. As stated above, it is possible that impaired consolidation may be observed whenever an attentional processing task is sufficiently difficult or perhaps only under dual-task attention conditions, and these possibilities require further testing. Furthermore, it is still not clear whether the attentional encoding deficit in dysphoria is due to a general slowing of central processing or whether the central processing resources available for the task are reduced by the dysphoric individual's engaging in extra-task processing such as rumination, or both. Further experiments are under way to dissociate these possibilities. Further research is also needed to extend these findings to clinically depressed samples. It is clear, presently, that all individuals have limited attentional abilities but that moderately to severely dysphoric individuals show exacerbated limitations compared with nondysphoric individuals under dual-task conditions where the encoding of two targets overlaps in time. Furthermore, the nature of the present design allows us to attribute the performance deficits to attention per se as opposed to

strategic planning, memory limitations, motivation, arousal, or task switching.

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