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Effects of Anxiety on Analogical Reasoning: A Test of Three Theoretical Models

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Three mediational theories of anxiety and performance, namely, cue utilization theory (Easterbrook, 1959), attentional theory (Mandler & Sarason, 1952; Wine, 1971), and working memory capacity theory (M. W. Eysenck, 1979), were compared for their efficacy in explaining anxiety-induced performance decrements on a task of analogical reasoning. One hundred two subjects who varied in their trait and state anxiety levels completed 100 geometric analogies under either relaxed (reassurance, non-time-limited) or stressed (ego-threat, time-limited) conditions. Response time and error rate data for nine levels of task complexity (1-, 2-, and 3-element analogies with zero, one, or two transformations per element) were analyzed by means of multivariate analysis of variance. Results in the relaxed condition supported attentional theory in that the more anxious subjects were both slower and less accurate than were the less anxious subjects. In the stressed condition, none of the three anxiety–performance theories was supported. More anxious subjects were faster but made more errors than did less anxious subjects. Thus in the stressed condition, performance differences suggested differences in speed–accuracy trade-off strategies rather than differences in processing abilities. The limitations of attentional theory and the need to study the effects of anxiety and time stress on information processing are discussed.

In studies of the effects of anxiety on the process of abstract reasoning, researchers have generally found that as anxiety level increases, performance on tasks of abstract reasoning becomes increasingly impaired. This relationship holds for both trait and state anxiety, generalizes across a variety of abstract reasoning tasks, and affects both performance speed and accuracy.

For example, Mandler and Sarason (1952) found that more trait-anxious subjects (as identified by the Taylor Manifest Anxiety Scale) had significantly longer solution times for Kohs Block Design problems than did subjects low in trait anxiety. Siegman (1956), using the same index of trait anxiety, obtained a correlation of −.41 between anxiety and Raven's Progressive Matrices scores. Mayer (1977) exposed subjects high and low in trait anxiety (as identified by their State–Trait Anxiety Inventory scores) to time stress, and found that highly trait-anxious subjects had longer solution times and lower accuracy scores than did subjects low in trait anxiety, for a series of abstract reasoning tasks (i.e., anagram, water jar, card trick, and matchstick problems).

Beier (1951) induced state anxiety in subjects by giving them false, ego-threatening Rorschach interpretations before administering the Abstract Reasoning Test (a subtest of the Differential Aptitudes Test). He found that those subjects who had been exposed to the stress manipulation showed debilitated accuracy, which indicated an impairment in categorizing ability. Cowen (1952), using the same means of stress induction as did Beier, found that for Luchin's Water Jar task, ego-threatened subjects exhibited more rigid solutions, slower response times, and more nonsolutions

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on an extinction problem than did subjects who had received false, ego-enhancing Rorschach interpretations. Schacter (1977) used time stress to induce state anxiety and found that stressed-group subjects had poorer Raven's Progressive Matrices scores than did non-time-limited subjects.

A major goal in explicating the relationship between anxiety and abstract reasoning is to identify the mediational processes by which anxiety impairs abstract reasoning performance. Three explanations seem likely: cue utilization theory (Easterbrook, 1959), attentional theory (Mandler & Sarason, 1952; Wine, 1971), and working memory capacity theory (M. W. Eysenck, 1979). Each of these three explanatory theories has been supported empirically; however, according to each theory, a different mediational process is operating. The predictions of cue utilization theory and attentional theory are orthogonal to each other, whereas the working memory capacity theory predictions are not independent of either of the former two theories. Our purpose is to determine which of these three anxiety–performance theories accounts for anxious subjects' performance.

In making such a determination, it is important to collect both trait and state anxiety data, because each theory differs in the extent to which it generalizes to each type of anxiety. As it stands, neither cue utilization theory nor attentional theory are limited in their generalizability to one or the other type of anxiety, whereas working memory capacity theory clearly generalizes to state anxiety only.

It is also necessary to specify what aspect of abstract reasoning ability will be studied. Anxiety has been shown to affect a variety of types of abstract reasoning tasks, each of which taps a somewhat different cognitive process. Some of these processes have been better explicated than others through the development of a more complete theory of task. One aspect of abstract reasoning for which a strong theory of task is being developed is analogical reasoning. Not only are the cognitive processes involved in the performance of analogical reasoning tasks becoming well understood, but the tasks themselves also contain high ecological validity. As noted by Sternberg and Gardner (1983), tasks of analogical reasoning provide a reliable and valid measure of general intelligence, or *g*, which has led to their inclusion on numerous aptitude test batteries. In addition to these advantages, a geometric analogical reasoning task similar to that developed by Mulholland, Pellegrino, and Glaser (1980) allows for a simultaneous test of the comparative efficacy of the three anxiety–performance theories. For these reasons, we used an adaptation of the Mulholland et al. geometric analogies task.

Before we present experimental hypotheses, the major premises and predictions of each theory are outlined, as is the internal structure of the analogical reasoning task.

Cue Utilization Theory

Easterbrook (1959) provided an explanation of the relationship between emotional arousal and performance in which anxiety was viewed as one variant of emotional arousal. The major premises of his theory are that (a) emotional arousal acts consistently to decrease the range of cues that an organism uses, (b) the simultaneous use of task-relevant and task-irrelevant cues causes some degree of performance decrement, and (c) task-irrelevant cues are excluded before task-relevant cues as the range of cues is restricted. In general, these three propositions suggest that the relationship between emotional arousal and performance is curvilinear (e.g., Yerkes & Dodson, 1908): Underaroused subjects perform inefficiently because they are including too many task-irrelevant cues along with the task-relevant ones; overaroused subjects experience performance decrements because they are excluding some portion of the necessary task-relevant cues; optimally aroused subjects perform most efficiently, because ideally they are excluding all task-irrelevant cues and including all task-relevant cues. However, Easterbrook's hypothesis also implies that performance is a function of the relationship between emotional arousal and the information-processing demands of the task. In tasks that have a low information load (i.e., few task-relevant cues, requiring a narrow range of cue utilization for optimal performance), high arousal leads to better performance. In tasks with a high information load (i.e., many task-relevant cues, requiring a broad range of cue utilization for optimal efficiency), this performance advantage reverses. From the foregoing discussion, it would be predicted that less anxious subjects should outperform more anxious subjects on tasks containing many relevant cues, whereas more anxious subjects should outperform less anxious subjects on tasks that contain few relevant cues.

Attentional Theory

Mandler and Sarason (1952) hypothesized that testing situations evoke a learned anxiety drive, which elicits either (a) task completion responses, which function to reduce the level of felt anxiety, or (b) task interference responses, which consist of "feelings of inadequacy, helplessness, heightened somatic reactions, anticipations of punishment or loss of status and esteem, and implicit attempts at leaving the task situation. It might be said that these responses are self rather than task centered" (Mandler & Sarason, 1952, p. 166). They further hypothesized that in evaluative situations, less anxious subjects emit task completion responses, whereas more anxious subjects engage in task interference responding. In her review article, Wine (1971) proposed that Mandler and Sarason's hypothesis was predictive of a pattern of generalized performance decrements for more anxious subjects in relation to less anxious subjects, if the existence of a limited attentional capacity was assumed. This prediction stems from the premise that in evaluative situations, less anxious subjects, who emit task completion responses, allocate all of their attentional resources to the designated task, whereas more anxious subjects, who emit task interference responses, divide their attention, allocating only part of their attentional resources to the task and the remainder to self-relevant (i.e., task-irrelevant) concerns.

Unlike cue utilization theory, attentional theory is not modified by task chracteristics. Whereas according to the former, more anxious subjects will outperform less anxious subjects in the case of few-cue tasks, according to the latter, given the presence of evaluative conditions, more anxious subjects will never outperform less anxious subjects on any type of task.

Working Memory Capacity Theory

Working memory capacity theory (M. W. Eysenck, 1979) stems from the attentional theory hypothesis that off-task cognitive self-concern "competes with task-relevant information for space in the processing system" (p. 364). However, Eysenck made the further assumption that the working memory component of the processing system is most directly involved in the simultaneous processing of task-relevant and task-irrelevant information. Baddeley and Hitch (1974) proposed that working memory is characterized by a limited-capacity central processing space. If self-relevant concerns are presumed to preempt some portion of this limited capacity, then a reduced capacity remains available for the processing of task-relevant information, which results in performance decrements. In addition, the extent to which performance is impaired will be a direct function of the demands placed on working memory by task-relevant concerns. For tasks that place a high load on working memory, less anxious subjects should outperform more anxious subjects because the latter have less working memory capacity available to process all of the incoming task-related information than do the former.

Like attentional theory, working memory capacity theory implies that there exists no situation in which more anxious subjects will outperform less anxious subjects. Unlike the former theory, however, the latter theory is predictive of differential performance for more anxious subjects as a function of differing task characteristics.

In addition, working memory capacity theory may be distinguished from cue utilization theory in two ways. First, as previously noted, according to working memory capacity theory, there is no type of task on which more anxious subjects would outperform less anxious subjects. According to cue utilization theory, on the other hand, more anxious subjects will outperform less anxious subjects specifically on few-cue tasks. Second, according to working memory capacity theory, the more anxious subjects will experience their most impaired performance on tasks containing a high working memory load, whereas according to cue utilization theory, these subjects will experience their most impaired performance on tasks containing many cues. Although the many-cue situation intuitively may seem to be identical to the high working memory load situation, it is in fact possible to vary these two task com-

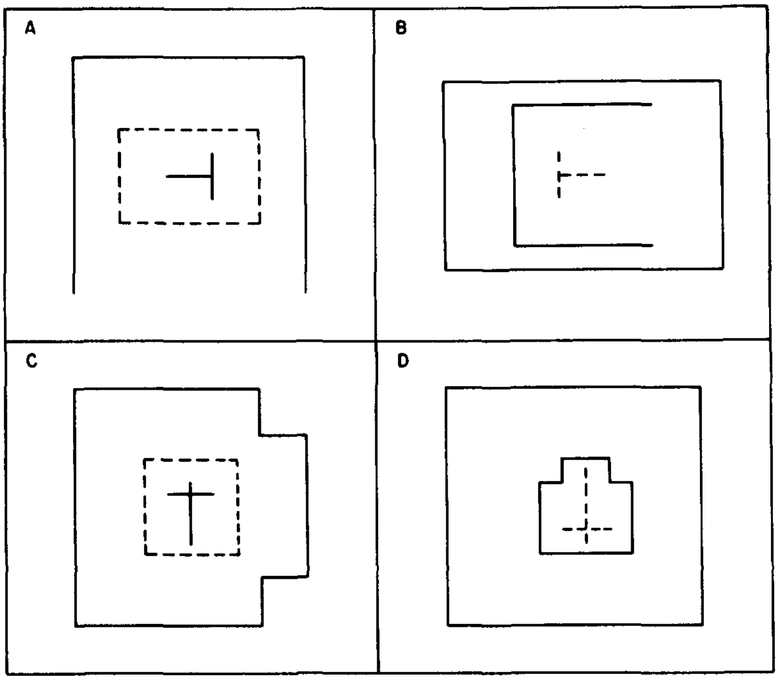

Figure 1. Sample 3-element two-transformation analogy problem.

ponents independently. This is indeed what was done in the version of the analogical reasoning task that we used, which made this task a particularly useful one for providing a test of the three anxiety-performance theories.

Analogical Reasoning Task

The Mulholland et al. (1980) task consisted of a series of geometric analogies, each of which was of the form A:B::C:D. The A, B, C, and D terms were each composed of one, two, or three geometric shapes (i.e., elements) to which zero, one, two, or three transformations per analogy term had been applied. The elements that constituted the A term were identical to those that constituted the B term; the C- and D-term elements were likewise identical, but the A- and B-term elements differed from the C- and D-term elements. The subjects' task was to decide whether each analogy was true (i.e., the rules that were used to transform the A term into the B term were identical to those that were used to transform the C term into the D term) or false (i.e., the A-to-B transformation rules differed from the C-to-D transformation rules). Mulholland et al. presumed that true analogies are processed exhaustively because every element and transformation must be processed in order to verify the truth of an analogy. False analogies, however, do not require exhaustive processing because the first incorrect element or transformation encountered will render an analogy false and will terminate the information search. We used this same format in constructing the analogies used in our investigation, with one modification: We composed analogy problems that had zero, one, or two transformations applied to each element of a term, not to the term as a whole. (An example of such a modified geometric analogy is shown in Figure 1.)

This resulted in the creation of nine types of analogies that were based on different element and transformation combinations: 1E0T (one element, zero transformations per element), 1E1T, 1E2T, 2E0T, 2E1T, 2E2T, 3E0T, 3E1T, and 3E2T.[1]

[1] Analogy problems containing one element, three transformations per element, were included in the original thesis for purposes of replicating the Mulholland, Pellegrino, and Glaser (1980) study. These analogies were excluded from our study in order to facilitate the conduct of

Two measures of performance were collected in both the Mulholland et al. (1980) study and our study: response time, which Mulholland et al. found to be a function of both the number of elements and the number of transformations present (which suggests that both elements and transformations are processed serially), and error rate (number of errors/number of analogies completed), which they found to be determined exclusively by the transformational complexity of the analogy problem.

The advantage of this task for our investigation was that it independently varied number of cues and working memory load. Assuming that number of cues increases as number of elements increases and as number of transformations increases, there are six different partial orderings of cues on a few- to many-cue continuum (Craig, Humphreys, Rocklin, & Revelle, 1979; Revelle, 1973; see Figure 2). In Figure 2, we show that the 1E0T, 1E1T, and 2E0T analogy types may be classified as few-cue problems, whereas the 2E2T, 3E1T, and 3E2T analogy types may be classified as many-cue problems; the other analogy types fall between these endpoints. Recall that according to Easterbrook's hypothesis, the less anxious subjects will outperform the more anxious subjects on the many-cue problems, and this trend reverses on the few-cue problems.

On the other hand, Mulholland et al. (1980) found that multiple transformations of a single element required more space in the working memory store than did single transformations of multiple elements. This suggests that the 1E0T, 2E0T, 3E0T, 1E1T, 2E1T, and 3E1T analogy types impose a low working memory load, whereas the 1E2T, 2E2T, and 3E2T analogy types impose a higher working memory load. According to working memory capacity theory, the less anxious subjects will outperform the more anxious subjects on analogy types that impose a high working memory load.

By combining this information, it is possible to outline the predictions of the three theories. According to cue utilization theory, less anxious subjects will outperform more anxious subjects on the 2E2T, 3E1T, and 3E2T analogy types, and will be outperformed by them on the 1E0T, 1E1T, and 2E0T analogy types. Conversely, according to working memory capacity theory, the less anxious subjects will perform equivalently to the more anxious subjects on the 1E0T, 2E0T, 3E0T, 1E1T, 2E1T, and 3E1T analogy types, and will outperform them on the 1E2T, 2E2T, and 3E2T analogy types. Lastly, according to attentional theory, the less anxious subjects will outperform the more anxious subjects on every analogy type.

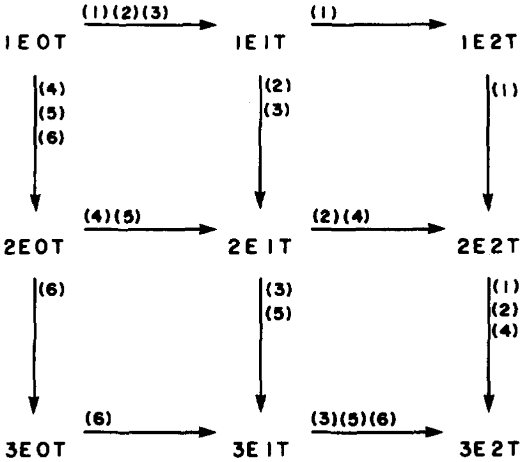

Figure 2. The six partial orders resulting from a factorial combination of elements and transformations. (Arrows with the same superscript make up one partial order. Each ordering represents cells that may be unambiguously ordered with respect to increased cue requirements.)

The orthogonality of cue utilization theory and attentional theory may now be examined more closely because one can demonstrate that their theoretical predictions provide nonoverlapping information in both the few- and the many-cue situation. With few cues, according to cue utilization theory, the less anxious subjects are relatively impaired because they are including more task-irrelevant cues than are the more anxious subjects. In this same case, however, according to attentional theory, the more anxious subjects are relatively impaired because they are excluding some portion of both task-relevant and task-irrelevant cues through inattention, whereas the less anxious subjects are not. Thus in the few-cue case, the simultaneous operation of both mediational processes tends to equalize the performance

the multivariate analyses of variance. Separate analyses indicated that the results for the 1E3T case were wholly consistent with the obtained findings for the other nine analogy types.

of the less anxious and the more anxious subjects. The less anxious subjects are impaired by their inclusion of too many task-irrelevant cues for efficient information processing, but are benefited by attending to all task-relevant cues that they process; the more anxious subjects are benefited by excluding more task-irrelevant cues, but are impaired by failing to attend to all of the necessary task-relevant cues.

In the many-cue case, however, the more anxious subjects would be expected to exhibit significantly impaired performance in comparison with the less anxious subjects. This occurs because the less anxious subjects are benefited both by their inclusion of more task-relevant cues and by the direction of their complete attention to the task, whereas the more anxious subjects are debilitated both because they include fewer task-relevant cues as a result of their restricted range of cue utilization, and because they further narrow this restricted range by excluding some additional portion of cues through inattention. Therefore, if the two independent mediational processes occur simultaneously, the performance of the less and the more anxious subjects will conform to a fan-fold pattern of interaction. If only the cue utilization theory predictions are operative, the data will conform to a crossover pattern of interaction, whereas if only the attentional theory predictions are operative, the data will be described solely by a significant main effect of anxiety.

According to working memory capacity theory, the more anxious subjects should perform as well as the less anxious subjects on problems with a low memory load, but less well on problems with a high memory load. Unfortunately, this predicted pattern is not orthogonal to either of the other two anxiety–performance theories. Thus a combination of a main effect of anxiety and an interaction of anxiety with task complexity could be taken as evidence for all three theories.

Overview

Subjects differing in both trait and state anxiety level solved analogy problems under either relaxed (non-time-stressed reassurance) or stressed (time-stressed ego-threatened) conditions. The relaxed condition provided a conceptual replication of the Mulholland et al. (1980) study. The stressed condition was used to induce differences in state anxiety levels among subjects per the state–trait theory of anxiety, according to which a stressor must be present to induce a high state anxiety in highly trait-anxious subjects. The analogy problems differed in both the number of cues that they contained and the presumed amount of processing space that they required in the working memory store. Response time and accuracy data were collected from each subject for each analogy and were subsequently analyzed by means of a multivariate analysis of variance (MANOVA) technique.

According to cue utilization theory, less anxious subjects would outperform more anxious subjects on the many-cue analogies, and would be outperformed by them on the few-cue analogies. According to working memory capacity theory, less anxious subjects would outperform more anxious subjects on the high working memory load analogies. According to attentional theory, less anxious subjects would outperform more anxious subjects on every type of analogy, irrespective of the number of cues or the amount of processing space required in the working memory store. The term "outperform" in this context refers to the attainment by subjects of both faster response times and lower error rates.

Method

Subjects

The subjects were 102 students (57 male and 45 female) enrolled in an introductory psychology course at Northwestern University. The data of 6 additional subjects were excluded from the final analysis for the following reasons: Three subjects failed to complete all of the personality inventories, the data of 2 subjects were lost because of malfunctions of the computer hardware, and 1 subject was excluded for failing to follow instructions. Subjects received partial course credit for participating in the experiment.

Individual differences in trait and state anxiety were assessed by the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). A median split was used to classify subjects as being either less or more trait anxious (Mdn = 35.0) and less or more state anxious (Mdn = 37.5). This yielded a group composed of 51 less and 51 more trait-anxious subjects, and 51 less and 51 more state-anxious subjects. The state portion of the STAI was administered before subjects began the experimental task, after they completed the first 50 analogies, and after they completed the last 50 analogies; the latter two state anxiety scores were averaged in order to provide the measure of state anxiety level for each subject. We reasoned that the average of the second and third state anxiety scores represented the mean level of state anxiety that was induced or maintained by the experimental manipulation over both halves of the experimental task, whereas the first score primarily reflected subjects' level of state anxiety when they were faced with participating in a computerized psychology experiment. Subjects were randomly assigned to either the relaxed or stressed condition before the initial personality inventories were completed.

Materials

Anxiety measures. Both the state and trait portions of the STAI were used to obtain a measure of subjects' level of state and trait anxiety (Spielberger et al., 1970).

Geometric analogies. As stated previously, elements and transformations were combined to form 10 analogy types (see Footnote 1). For each analogy, the elements contained in the A and B terms were identical, as were the C- and D-term elements, but the A- and B-term elements differed from the C- and D-term elements.

Ten practice analogies and 100 task analogies were created from a pool of eight elements (i.e., square, U-shape, square with cut corners, rectangle, triangle, T-shape, line, and dagger) and three transformations (i.e., size increases or decreases, dashed-to-solid or solid-to-dashed transformations, and 90°, 180°, or 270° rotations of the elements; see Figure 1). All analogies were drawn with the use of Apple II computer graphics and were presented to subjects via a black and white Leedex monitor and an Apple II computer.

Ten analogies (one of each type; 5 true and 5 false) were presented as practice items to familiarize subjects with the task. Subjects were also provided with a "practice problem analogy feedback sheet," which provided step-by-step solutions to the 10 practice analogy problems. Of the remaining 100 analogies, 2 of each analogy type, 1 true and 1 false, were randomly selected to be time-limited analogies for the stressed-group subjects. Thus all subjects received 100 analogies in the experimental task; relaxed-group subjects solved 100 time-unlimited analogies, and stressed-group subjects solved 80 time-unlimited and 20 time-limited analogies. For all subjects, every block of 10 analogies contained 1 of each type of analogy, 5 of which were true and 5 of which were false. Within each block, time limits were enforced on 2 problems (1 true and 1 false) in the timed condition. Blocks and trials within blocks were randomly permuted among subjects. A cardboard mask was used to reduce erroneous responses by subjects as they used the Apple II keyboard.

Procedure

All subjects were run by one of two female experimenters or the first author. On entering the experimental testing room, all subjects successively completed the state portion of the STAI and the trait portion of the STAI.[2] Subjects then worked through the experimental task at their own pace on microcomputers in separate carrels. Between 1 and 5 subjects were run per session. The task was explained through the use of verbal and graphic examples.

After the explanatory phase, relaxed-group subjects were told that

> These analogies are part of a new, trial set. We are trying to find out which of them are easy for people, and which are difficult, so don't be concerned if some analogies seem harder to solve than others. Just work at a comfortable pace, do your best, and have fun with the task.

Stressed group subjects were told that

> These analogies are highly similar to those used on intelligence tests and college and graduate school admission tests, all of which predict IQ and academic success in college. To approximate the real-life conditions under which these tests are administered, all analogy problems will be strictly timed. You will have only a short length of time to answer each analogy problem before it disappears from the screen and the next analogy is presented. If you fail to solve a problem before it disappears, it will be scored as an error. Therefore, you should try to solve each analogy as quickly and accurately as possible.

In actuality, only the 20 time-limited analogies disappeared from the monitor screen for stressed-group subjects. Time limits for these analogies were set in the following manner: (a) a base-level time limit was set for each timed analogy on the basis of an estimated item difficulty derived from the number of elements and transformations present in that analogy; (b) each time a subject responded to a timed analogy before the expiration of the time limit, the time limits of all the remaining timed analogies were decreased by 30%; and (c) each time a subject failed to respond to a timed analogy before its time limit expired, the time limits of all the remaining timed analogies were increased by 10%. Thus we individually tailored time limits to subjects' response speeds, ensuring that even the fastest responding subjects missed an average of 75% of the time-limited analogies, in an effort to make the time stress manipulation believable.

Because approximately three fourths of the 20 time-limited analogies disappeared from the monitor screen before stressed-group subjects could respond to them, no response time or error rate data could be collected on these analogies for stressed-group subjects. Therefore, performance data were compared across all subjects for only the 80 time-unlimited analogy problems.

After receiving the anxiety manipulation instructions, all subjects worked through the 10 practice analogies with the help of the practice problem analogy feedback sheet. They were then informed that they were about to begin the experimental task. Relaxed-group subjects were again reminded to work at a comfortable speed, to do the best they could, and to relax, whereas stressed-group subjects were reminded that because they would be timed, they should work as quickly and accurately as possible. Subjects then completed the first 50 analogies at their own pace, with both their response times and responses being recorded covertly by the computer. After presenting the 50th analogy, the computer instructed subjects to fill out the state portion of the STAI. On completing the STAI, relaxed-group and stressed-group subjects were again given their respective instructions regarding their approach to the experimental

[2] The Eysenck Personality Inventory (H. J. Eysenck & Eysenck, 1964) was also administered for use in further research.

task. Subjects continued to work through the remaining 50 analogies at their own pace, and again filled out the state portion of the STAI after completing the 100th analogy. The experimenter was present in the experimental testing room throughout the experiment. Subjects were debriefed when all subjects had completed the experiment.

Results

As a manipulation check to ascertain the extent to which state anxiety resulted from exposing highly trait-anxious subjects to a stressor, we performed a univariate analysis of variance (ANOVA) with state anxiety as the dependent variable and with experimental condition, trait anxiety, and administration (i.e., first, second, or third administration of the state-anxiety inventory) as the independent variables. Significant main effects were obtained for (a) experimental condition, $F(1, 99) = 5.15$, $MS_e = 183.09$, $p < .025$; (b) trait anxiety, $F(1, 99) = 35.17$, $MS_e = 78.69$, $p < .0001$; and (c) administrations, $F(2, 198) = 11.57$, $MS_e = 23.00$, $p < .0001$. Significantly higher state anxiety scores were obtained by stressed-group subjects than by relaxed-group subjects (39.43 vs. 34.37), and by more trait-anxious subjects than by less trait-anxious subjects (41.76 vs. 31.91). State anxiety scores increased with successive administrations (35.19 in the first administration, 37.06 in the second administration, 38.39 in the third administration). There was also a significant Experimental Condition × Administrations interaction that reflected an increase in state anxiety from the first to second administration for the subjects in the stressed condition but not for those in the relaxed condition. In Table 1 we present the state anxiety means by experimental condition, trait anxiety level, and administration period.

The anxiety–performance theory predictions were tested via two repeated measures MANOVAS. Response time and error rate served as the dependent variables in both analyses. Experimental condition, trait anxiety, elements, and transformations served as the independent variables in the first analysis; state anxiety was substituted for trait anxiety in the second analysis. Separate analyses were conducted because of an obtained correlation of .55 between trait and state anxiety. Significant sources of variance that did not include trait or state anxiety are reported first.

Table 1
Mean State Anxiety Scores by Experimental Condition, Trait Anxiety, and Administration Periods

Condition	Less trait anxious	More trait anxious
Relaxed		
Administration 1	31.00	39.54
Administration 2	29.40	39.50
Administration 3	30.43	40.82
n	30	21
Stressed		
Administration 1	30.86	39.23
Administration 2	35.52	44.09
Administration 3	36.33	46.00
n	21	30

Significant main effects were obtained in the multivariate analysis for (a) experimental condition, $F(2, 97) = 97.57$, $p < .0001$; (b) elements, $F(4, 390) = 162.42$, $p < .0001$; and (c) transformations, $F(4, 390) = 167.08$, $p < .0001$. Univariate tests indicated that all three main effects attained significance for both response time and error rate, as follows: experimental condition, $F(1, 98) = 155.67$, $MS_e = 58.73$, $p < .0001$ for response time, and $F(1, 98) = 111.86$, $MS_e = 0.04$, $p < .0001$ for error rate; elements, $F(2, 196) = 488.34$, $MS_e = 10.50$, $p < .0001$ for response time, and $F(2, 196) = 19.94$, $MS_e = 0.01$, $p < .0001$ for error rate; and transformations, $F(2, 196) = 392.04$, $MS_e = 9.75$, $p < .0001$ for response time, and $F(2, 196) = 109.40$, $MS_e = 0.01$, $p < .0001$ for error rate. As expected, mean response times were slower and mean error rates were lower in the relaxed condition than in the stressed condition.

In addition, the following interactions attained statistical significance in the multivariate analysis: Experimental Condition × Elements, $F(4, 390) = 44.10$, $p < .0001$; Experimental Condition × Transformations, $F(4, 390) = 44.30$, $p < .0001$; Elements × Transformations, $F(8, 782) = 57.10$, $p < .0001$; and Experimental Condition × Elements × Transformations, $F(8, 782) = 17.58$, $p < .0001$. Univariate *F*s for these interactions were as follows: Experimental Condition × Elements, $F(2, 196) = 97.10$, $MS_e = 10.50$, $p < .0001$ for response time, and $F(2, 196) = 17.21$,

Table 2
Mean Response Times and Error Rates for the Experimental Condition × Elements × Transformations Interaction

	No. transformations					
	0T		1T		2T	
No. elements	Mean response time	Mean error rates	Mean response time	Mean error rates	Mean response time	Mean error rates
			Relaxed condition (n = 51)			
1E	3.40	.012	6.74	.034	6.99	.079
2E	6.06	.014	10.67	.032	15.49	.039
3E	8.46	.010	18.06	.044	26.01	.083
			Stressed condition (n = 51)			
1E	1.93	.046	3.14	.118	3.44	.228
2E	2.71	.073	5.19	.198	6.58	.284
3E	3.86	.093	8.21	.253	10.01	.375

$MS_e = 0.01$, $p < .0001$ for error rate; Experimental Condition × Transformations, $F(2, 196) = 78.94$, $MS_e = 9.75$, $p < .0001$ for response time, and $F(2, 196) = 40.48$, $MS_e = 0.01$, $p < .0001$ for error rate; Elements × Transformations, $F(4, 392) = 138.54$, $MS_e = 4.05$, $p < .0001$ for response time, and $F(4, 392) = 3.79$, $MS_e = 0.01$, $p < .005$ for error rate; and Experimental Condition × Elements × Transformations, $F(4, 392) = 36.72$, $MS_e = 4.05$, $p < .0001$ for response time. Response time and error rate means are presented in Table 2.

None of the sources of variance that included trait anxiety attained significance in the multivariate analysis. In the case of state anxiety, the following main effects and interactions attained significance in the multivariate analysis: state anxiety, $F(2, 97) = 4.84$, $p < .01$; Experimental Condition × State Anxiety × Elements, $F(4, 390) = 2.74$, $p < .05$; Experimental Condition × State Anxiety × Transformations, $F(4, 390) = 2.53$, $p < .05$; and Experimental Condition × State Anxiety × Elements × Transformations, $F(8, 782) = 2.64$, $p < .01$. Univariate analyses indicated that all three of the interactions were significant for response time: Experimental Condition × State Anxiety × Elements, $F(2, 196) = 4.90$, $MS_e = 10.50$, $p < .01$; Experimental Condition × State Anxiety × Transformations, $F(2, 196) = 4.79$, $MS_e = 9.75$, $p < .01$; and Experimental Condition × State Anxiety × Elements × Transformations, $F(4, 392) = 4.32$, $MS_e = 4.05$, $p < .01$. In Table 3 we present the means for the four-way interaction. The main effect of state anxiety was significant for error rate: state anxiety, $F(1, 98) = 5.13$, $MS_e = 0.04$, $p < .05$. More anxious subjects had a higher mean error rate than did less anxious subjects (.154 vs. .070).

At this point, our response time results may be compared with those obtained originally by Mulholland et al. (1980). Our relaxed condition provides a conceptual replication of the Mulholland et al. study, as the latter did not study the effects of time limits on analogical reasoning performance. Therefore, the following discussion refers primarily to the relaxed condition results.

As mentioned in the previous discussion of the analogical reasoning task, true and false analogies require different processing strategies; that is, true analogies require exhaustive information processing, whereas false analogies do not. One plausible hypothesis that would explain the significantly longer response times for the more anxious subjects in the relaxed condition could be that they failed to detect these different strategies. Such a failure could be reflective of more anxious subjects' relative inflexibility in their approach to the performance of abstract reasoning tasks (Beier, 1951; Cowen, 1952). Exhaustive processing of both true and false analogies by more anxious subjects would take more time than would the exhaustive processing of true analogies and the nonexhaustive processing of false analogies. A second plausible hypothesis that would explain the relatively slower response times of the more anxious subjects could be that they are excessively cautious (see Ruebush, 1960), which could lead to exhaustive processing for both true and false analogies. Operation of either the detection failure factor or the cautiousness factor would result in a difference in mean processing time on false analogies for subjects who differ in their anxiety level; more anxious subjects predictably would have significantly longer response times on false analogies than would less anxious subjects. Furthermore, more anxious subjects predictably would not differ significantly in their response times for true and false analogies, whereas less anxious subjects would have significantly longer response times for true than for false analogies. For those problems that were answered correctly, we tested these predictions via a 2 × 2 × 2 × 3 × 3 (Experimental Condition × State Anxiety Level × True or False Analogy Type × Elements × Transformations) univariate ANOVA. We found no significant Experimental Condition × State Anxiety Level × True or False Analogy Type interaction, which suggests that more and less anxious subjects did not use different information processing strategies for false analogies.

It is also instructive to compare the response time results of our study with those obtained by Mulholland et al. (1980) on correct true analogies only. Mulholland et al. pointed out that time to solution on this analogy type, because of its exhaustive information processing requirements, "should be a monotonic function of increases in the structural complexity of items" (p. 262). A 2 × 2 × 3 × 3 (Experimental Condition × State Anxiety Level × Elements × Transformations) univariate ANOVA was performed; response time on correct true analogies served as the dependent variable, and

Table 3
Mean Response Times and Error Rates for the Experimental Condition × State Anxiety × Elements × Transformations Interaction

No. elements	0T Mean response times	0T Mean error rates	1T Mean response times	1T Mean error rates	2T Mean response times	2T Mean error rates
	Relaxed condition: less state anxious (n = 35)					
1E	3.15	.007	5.69	.012	6.89	.011
2E	5.69	.025	9.91	.021	14.53	.025
3E	8.11	.061	16.94	.043	24.51	.061
	Relaxed condition: more state anxious (n = 16)					
1E	3.97	.023	9.03	.018	7.21	.008
2E	6.87	.055	12.32	.055	17.57	.086
3E	9.21	.117	20.52	.031	29.28	.133
	Stressed condition: less state anxious (n = 16)					
1E	1.98	.047	3.35	.045	3.71	.070
2E	2.78	.117	5.68	.180	7.43	.196
3E	4.40	.180	9.64	.242	12.32	.352
	Stressed condition: more state anxious (n = 35)					
1E	1.91	.046	3.04	.086	3.31	.104
2E	2.68	.118	4.96	.207	6.19	.279
3E	3.62	.250	7.56	.304	8.96	.386

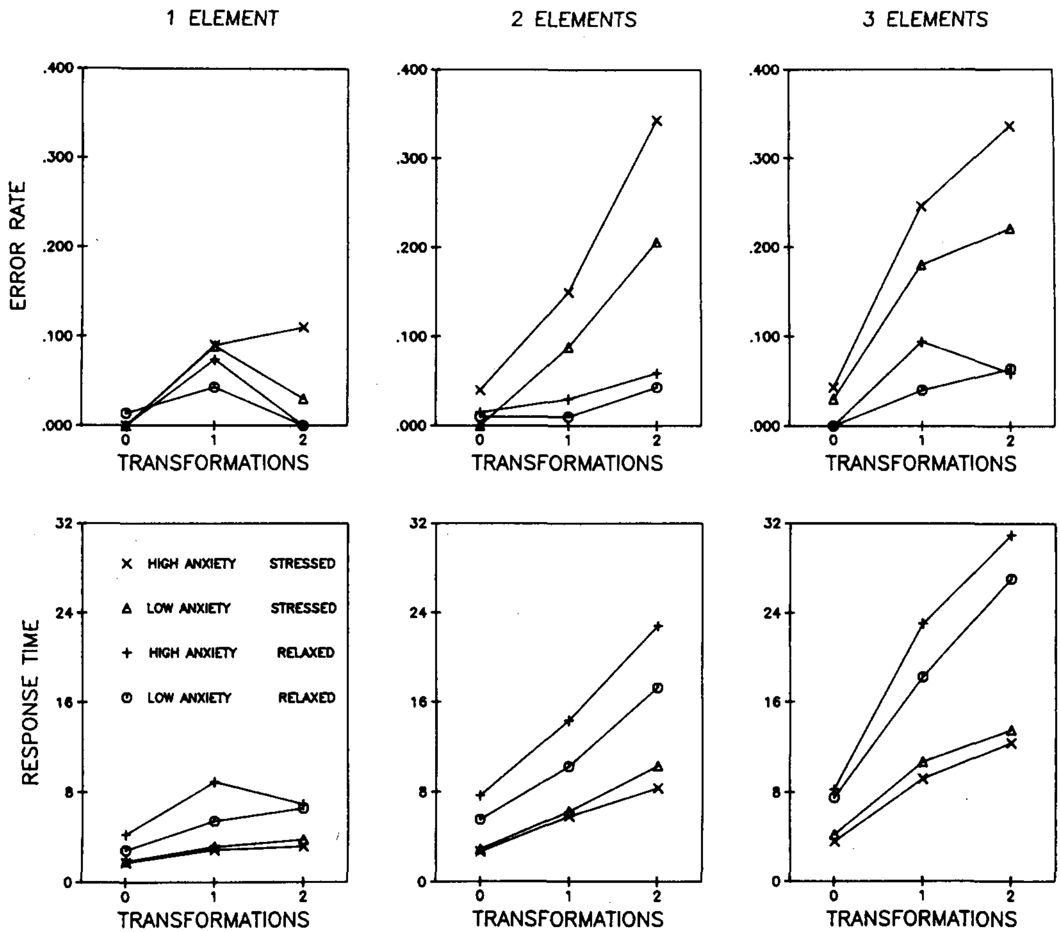

Figure 3. Error rates and response times for true analogies. (Error rates are calculated for all true analogies. Response times are calculated for true analogies that were solved correctly.)

$n = 99$.[3] In addition to the effects of elements and transformations, there was a significant Condition × State Anxiety interaction, $F(1, 95) = 6.59$, $MS_e = 551.65$, $p < .01$. Cell means in seconds were as follows: Relaxed condition/less state anxious = 11.20, relaxed condition/more state anxious = 13.67, stressed condition/less state anxious = 6.05, and stressed condition/more state anxious = 5.20 (see Figure 3). Relaxed condition results indicate that Mulholland et al.'s findings appear to be moderated by state anxiety; more anxious subjects exhibited a generalized performance decrement (i.e., significantly slower response speeds and significantly higher error rates) when compared with less anxious subjects.

Discussion

These results provide a clear comparison of the attentional, cue utilization, and working memory capacity theories of the relationship between anxiety and performance. The pattern of performance decrements predicted by attentional theory was strongly supported for state anxiety in the relaxed condition. More state-anxious subjects exhibited a generalized performance decrement, characterized by

[3] Three subjects did not answer any true analogies correctly, and their data were therefore excluded from the analysis.

slower response times and higher error rates than those obtained by less state-anxious subjects, both for all analogies and for the exhaustively processed true analogies. Neither cue utilization theory nor working memory capacity theory received any support whatsoever in our study.[4]

The stressed condition results are uninterpretable from an anxiety–performance perspective. None of the three anxiety–performance theories tested were predictive of the occurrence of the obtained results. The stressed condition results suggest that both the less anxious and the more anxious subjects became involved in a speed–accuracy trade-off, but the fact that each group engaged in a different type of speed–accuracy trade-off is suggestive of strategy differences between the two groups.

These results place important limitations on the generalizability of attentional theory. The results of our study indicate that the attentional theory explanation describes neither the abstract reasoning performance of subjects who differ in their level of trait anxiety, nor that of subjects who differ in their level of state anxiety who are placed in a time-limited situation. It is not altogether surprising that the attentional theory predictions held for state anxiety but not for trait anxiety, as the former represents the level of anxiety that is actually present during task performance, whereas the latter represents only a potential to experience anxiety during task performance. Our results do, however, indicate a need to include some measure of state anxiety in future investigations of the anxiety–performance relationship.

The fact that attentional theory (or either of the other two anxiety–performance theories examined) is not predictive of the performance of time-stressed subjects who differ in their level of state anxiety is of considerably more concern. This finding strongly suggests that time stress alters information processing in a different manner than does ego threat, the latter generally having been the only stressor used in tests of the attentional theory to date.

One possible theoretical framework for explaining the individual differences found in speed–accuracy trade-off selection in the stressed condition comes from the literature on the relationship between (a) prediction and control and (b) anxiety. The general finding in this area has been that a lack of prediction or control (or both) over aversive stimulation causes an increase in anxiety (cf. Monat, Averill, & Lazarus, 1972; Pervin, 1963). The stressed condition provided such an aversive situation in which some measure of prediction and control had been lost: Subjects did not know how quickly they needed to respond in order to avoid having the analogy disappear from view prematurely. One way to regain some of this lost prediction and control was to speed up responding to the point at which it fell within the time limits, despite the likelihood of decreased accuracy. This was in fact the type of speed–accuracy trade-off that characterized the more state-anxious subjects. These subjects were aware that they were experiencing high levels of anxiety (as indicated by the STAI, a self-report measure of anxiety) and may have been adopting a strategy that minimized the additional anxiety that resulted from an unpredictable and uncontrollable situation. Conversely, the less anxious subjects experienced lower levels of anxiety and did not have the same motivation to adopt a coping strategy that minimized additional sources of anxiety. Therefore, the less anxious subjects could allow themselves more time in which to consider their response, which results in a higher level of accuracy.

From Table 1, it initially appears that the data in our study do not support the state–trait theory of anxiety. This theory is predictive of the occurrence of a fan-fold interaction between trait anxiety and experimental condition in that more trait-anxious subjects would be expected to obtain slightly higher state anxiety scores in the relaxed condition and much higher state anxiety scores in the stressed condition than would less trait-anxious subjects. In our study, not only did the more trait-anxious subjects exhibit much higher state anxiety

[4] This study can be seen as supporting Humphreys and Revelle's (1984) distinction between personality traits and motivational states: that traits affect performance only through their effects on motivational states. Furthermore, Humphreys and Revelle's hypothesis that state anxiety reduces the resources applied to on task effort is compatible with our findings, as well as with attentional theory in general.

scores than did the less trait-anxious subjects in both experimental conditions, but also the less trait-anxious subjects reported a substantial rise in state anxiety in the stressed condition.

These results, however, may actually be compatible with the state–trait theory if one assumes that the more trait-anxious subjects perceived some type of threat to be present in the relaxed condition. Although this condition contained no overt stressors, it is possible that two types of covert stress may have been present: observer-induced stress, from the experimenter's presence in the experimental testing room for the duration of the experiment, and stress induced by the process of social comparison, from subjects' being run in groups rather than individually. Both types of stressors represent forms of social evaluation, which is an ego-involving process. As Wine (1971) noted, ego-involving instructions are particularly effective in stimulating highly anxious persons to engage in ruminative, self-deprecatory thinking, an activity that she argued produces the type of generalized performance decrements that we observed in our study. The fact that attentional theory was supported in this condition lends support to this explanation.

Lastly, the main effect findings for elements and transformations should be noted because they depart from those of Mulholland et al. (1980). Mulholland et al. found that although both the number of elements and the number of transformations contributed significantly to response time, only transformations made a significant contribution to error rate. Our results, however, showed that number of elements and number of transformations made significant contributions to both response time and error rate. This difference is partly due to a change in terminology between the two studies. Mulholland et al. reported effects for total number of transformations, whereas we are reporting on transformations per element. Thus the total number of transformations in our study are a function of both elements and the number of transformations per element.

It is clear that although attentional theory was the only anxiety–performance theory to be supported, it may hold only in cases in which ego threat is used as a stressor, and it may not be descriptive of the performance of persons who differ in their level of trait anxiety. Furthermore, time stress, though quite effective as an induction technique for state anxiety, appears to produce patterns of performance decrements that are not explainable by current mediational theories of anxiety and performance. The results from the time-stress condition suggest that speed–accuracy trade-offs occur and appear to be influenced by individual differences in anxiety. These trade-off effects, however, apparently represent a different modification of information processing than that described by conventional theories of anxiety and performance. Future investigations could be directed at testing the limits of attentional theory with different types of stressors, and at attempting to account theoretically for the relationship among anxiety, time stress, and performance.

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