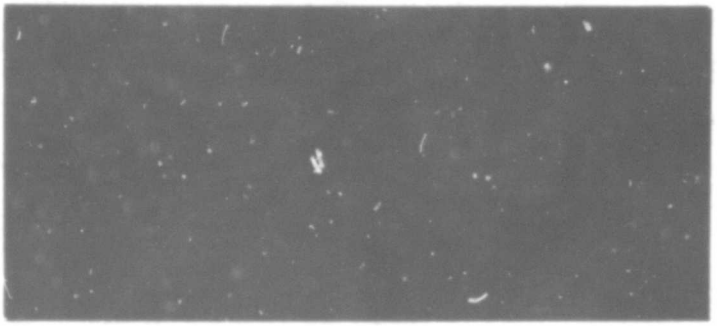

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Drug Effects upon Data Processing as Functions of Storage and Retrieval Parameters

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Abstract

A synopsis of results obtained in four previous experiments with the paced sequential memory task (PSMT) was given to clarify the purpose of the present experiment. Each of these studies included *d*-amphetamine sulfate among various different conditions of drug treatment. These different treatments were imposed to study performance variations with respect to various task parameters, e.g., data rate and storage load, in addition to extra-task features such as incentive conditions.

Throughout these four prior experiments, *d*-amphetamine was consistently the most active drug of the various psychoactive compounds employed. It yielded results ranging from significant enhancement to the significant impairment observed in one study. These results were discussed in relation to variations in task parameters and experimental conditions, in the attempt to isolate the crucial moderators that determine whether amphetamines enhance performance or impair it. Three alternative but non-exclusive hypotheses were advanced. A fifth experiment was designed to discriminate among them. In this study, the drug conditions were (1) *d*-amphetamine sulfate (15 mg/77 kg), (2) sodium amobarbital (96 mg/77 kg), (3) a combination of both drugs in the same dosages, and (4) placebo. Task variations were imposed upon storage load, list length, and method of transcribing answers (varying motor requirements). Results were analyzed both with and without statistical corrections for guessing.

Results showed significant enhancement by *d*-amphetamine in total performance across conditions, with no indications of dependency upon storage load, list length, or method of transcribing answers. The margin

of superiority over placebo showed little variation across these conditions, nor was it appreciably changed by correction for guessing. Amobarbital given separately was closely comparable to placebo. When combined with *d*-amphetamine, it produced a non-significant weakening of the enhancement effect. Contrary to expectation, it also weakened the mood effects.

These results indicated that amphetamine enhancement does not crucially depend upon task difficulty within the ranges employed, nor upon length of exposure to task or the motor requirements of answer-writing, nor does it depend upon the premium placed on willingness to guess. Reversal of *d*-amphetamine enhancement, obtained in the preceding study, was tentatively attributed to increases in requirements for input "filtering," i.e., the need to reject usable data when processing capacity is overtaxed: Amphetamines make people reluctant to accept the need to "filter". This was the only hypothesis that was not overthrown by the data.

Drug Effects upon Data Processing as Functions of Storage and Retrieval Parameters [1]

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Introduction

Synopsis of Previous Results

Amphetamines have frequently been reported to improve cognitive performance under conditions of fatigue or presumed low motivation (due to task length and repetitiousness). It has been pointed out that amphetamine enhancement tends to vary directly with length of task (Weiss and Laties, 1962; Laties and Weiss, 1966). That cognitive enhancement by these drugs may depend upon prior motivational deficiencies is suggested by their general failure to enhance performance at intellectially complex tasks, which are presumably more "challenging": Weiss and Laties (1962), Smith and Beecher (1964), and Hurst and Weidner (1966). Seldom, indeed, has it been suggested that amphetamines may enhance cognitive performance in situations of *supra-optimal* motivation, i.e., "stress."

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Since these drugs appear to increase motivation, the Yerkes-Dodson principle implies that impairment rather than enhancement would result. This seems so self-evident that tactical military use of amphetamines has been condemned in those situations where "investigations incriminated stress and the resultant anxiety, rather than prolongation of work and fatigue, as the conditions under which errors are made." (Davis, 1947, p. 45).

This same logic seems to underly most of the research on performance enhancement under stress. Almost invariably, such studies have involved depressant drugs such as the minor tranquilizers, even though some direct cognitive impairment might be expected from effective dosages. A number of such efforts were reviewed by Hurst (1966).

Nevertheless, there is reason to question whether amphetamines are prejudicial to performance under emotional "stress" or "anxiety." Some prominent mood effects of these drugs are increases in self-rated "confidence," "optimism," "boldness," etc. (Smith and Beecher, 1960; Hurst and Weidner, 1966). Such effects seem paradoxical in view of concommitant findings that the drugs increased "anxiety," even in the same experimental populations. However, a factor analysis of drug-induced state changes by Hurst, Radlow and Perchonok (1967) indicated that the "anxiety" descriptor may be misleading, at least in the case of one frequently-employed instrument: the Nowlis Mood Adjective Check List (Mood ACL). Although Nowlis "anxiety" is relatively independent of other Mood ACL adjectives when normal subject differences are factor analyzed, the structure of drug-induced changes is different: "anxiety" emerges in

a state-factor which also has strong positive loadings on "concentration," "vigor," "egotism," and "confidence." This pattern resembles a state factor which Cattell (1960) has labeled "effort stress" and is quite different from "simple anxiety." Both of these reaction patterns are evoked by perceived threat, but they differ as to the anticipated success in coping with the threat.

It was in consideration of these affective dimensions that we hypothesized amphetamine enhancement under conditions of "task-induced stress." We based this hypothesis upon an inferred "anti-panic" component, rather than any direct cognitive facilitation produced by such drugs. Accordingly, we predicted that the observed performance enhancement from amphetamines would *increase* as motivation ranged upward from the optimal level for a given task.

To test this hypothesis, we conducted a series of "stress" experiments in which *d*-amphetamine was compared with various depressant drugs and stimulant-depressant combinations. The principal test of performance was the paced sequential memory task (PSMT). This task was adapted from that of Lloyd, Reid and Feallock (1960) to provide strong demand stresses. In the version we employed, the PSMT comprises a number of word sequences, presented on audio tape. Each sequence includes a series of "item" words, with an equal number of recall points interspersed among them. The recall points are identified by the names of classes to which various items belong. Thus, the subject may be given the items, "copper," "Buick," and "overcoat," after which the class name "automobile" is presented. He must then recall "Buick." After further item words have been presented, he is given "metal," and must recall copper. This continues until all of the stored items have

been exhausted by corresponding recall points.

A prior series of experiments by Kenneth Lloyd and his colleagues had shown that PSMT difficulty varies lawfully as a function of input rate, average storage load ($\overline{SL}$), and association value between items and class names. A detailed description of the versions we employed is given by Hurst and Weidner (1966).

The PSMT imposes a requirement for time-sharing of registry, storage, and retrieval operations. As input rate or storage load increases, it becomes impossible to satisfy these concommitant demands and data are lost, often in large blocks. From these structural features and numerous unsolicited reports from our subjects, we inferred that the PSMT can be "threatening." We confirmed this inference by observing that Mood ACL "anxiety" increased as test-time approached, especially in subjects working for incentive payments (Hurst & Weidner, 1966). Regardless of whether this "anxiety" represented "simple anxiety" or "effort stress," we could reasonably infer that the task was threatening and that it induced some kind of emotional "stress."

A further advantage of this task is that amphetamine enhancement would not be expected as a result of *non-emotional* components. Running memory span has been tested by Quarton and Talland (1962, Talland and Quarton (1965), and Servais and Hubin (1964). None of these studies showed enhancement from amphetamines. Since the PSMT also involves running memory, one would not expect amphetamines to alter performance on the basis of direct effects upon the requisite cognitive functions. Thus, observed performance changes could more reasonably be attributed to affective components, and the "anti-panic" hypothesis evaluated accordingly.

In the first three experiments with the PSMT, dextro-amphetamine sulfate (*dex*) always produced higher performance means than the other drug conditions. In Experiment 1, *dex* (10 mg) consistently produced higher means than did methylphenidate HCl (10 mg), chlordiazepoxide HCl (10 mg), or placebo, although statistical significance was reached only in the earlier of two test administrations. Superiority of *dex* to placebo was limited almost entirely to the groups tested under "high stress" (incentive payment, based upon performance) rather than under "low stress" (fixed payment). These results support the contention that amphetamine enhancement is *not* limited to conditions of suboptimal motivation. They tentatively support the "anti-panic" interpretation. Some additional weak support comes from the failure of significant enhancement with methylphenidate, a stimulant with much milder mood properties. However, it is questionable whether the dosages of the two drugs were equivalent in other respects.

Experiment 2 was essentially a replication of the first study but with combination drugs substituted for the two conditions, methylphenidate and chlordiazepoxide, which had failed to produce significant effects. Thus, the treatments included *dex* alone (10 mg), *dex* (10 mg) + sodium secobarbital (50 mg), and *dex* (10 mg) + chlordiazepoxide HCl (10 mg). Although all of these *dex*-containing treatments were superior to placebo at all stages of testing, none of the comparisons reached significance. This was rather surprising in view of the greater number of subjects employed (32 per drug condition, vs 16 in Experiment 1). No significant interactions occurred between drug and incentive conditions.

Experiment 3 was designed primarily to confirm or deny the enhancement trend thus far suggested. Since *dex* had always produced positive differences whose significance was sporadic, we sought a more powerful test. Statistical precision was increased by utilizing a test-retest design, and a higher dosage of *dex* was added. Thus, 48 subjects were each tested once with each of the following medications, in counterbalanced order: *dex* (10 mg), *dex* (15 mg), sodium secobarbital (100 mg), placebo, and no drug. To increase stress, the PSMT was presented in series of 30 inputs/minute alternating with series of 20/minute, the rate previously employed. All subjects were paid on a strong incentive basis.

In total performance scores, the previously-employed 10 mg dosage of *dex* exceeded placebo or no drug, although not quite significantly ($.05 < p < .10$). The 15 mg dosage, however, produced over twice this amount of enhancement, and was superior to either control condition at $p < .001$.

The performance margins were equally significant and of closely comparable magnitudes at both data input rates. Thus, although reliable improvement had been demonstrated in a stressful task-situation, we still lacked definitive evidence that the enhancement involved a specific "anti-panic" component. We decided to explore further task parameters for moderating influences upon the drug effect.

In Experiment 4, the 30/minute data rate was compared with the still faster rate of 60/minute. The latter was imposed to bring mean performances below 50% correct, and thus presumably induce greater "stress."

Although the 30/minute vs 20/minute contrast in Experiment 3 had not

moderated the drug effects, we believed this might be due to their frequent alternation. The tendency to panic might involve a mood state that required some time to build up in response in variations in demand-stress. Consequently, we scheduled the two data rates in Experiment 4 as two separate 30-minute blocks separated by a half-hour rest interval. The order of the two rate conditions was counterbalanced across sessions to avoid contamination with differences in drug latency and warm-up effects.

Because of the severe limitations imposed upon response time by the high input rates, the procedure for recording answers was changed. Previously, the subject had been required to write the first three letters of the correct word. Now, he was given an alphabet block for each answer, with instructions to draw a line through the beginning letter of the answer-word.

As in Experiment 3, a test-retest design was employed. Thus, each of 58 subjects was assigned once to each of 4 drug conditions, with order counterbalanced across sessions: *dex* (15 mg), chlordiazepoxide HCl (25 mg), placebo, and no drug.

For the first time, total performance means for placebo and for no drug exceeded *dex*, although the differences were not significant. Both placebo and no drug significantly exceeded chlordiazepoxide. Evidently, an important moderator influence had finally arisen, and subscore comparisons would reveal where it lay.

Orthogonal contrasts of drug latency, as permitted by the counter-balancing of latency with input rate, revealed little that was noteworthy. Both active drugs were slightly inferior to placebo or no drug at both

latencies (70-100 min. and 130-160 min.), but neither latency produced a significant F-ratio when its data were analyzed separately. The moderator influence proved to be input rate. Although chlordiazepoxide produced only slightly less impairment at the lower rate, the *dex* effect was reversed. It significantly impaired performance at the 60/minute rate and non-significantly enhanced it at 30/minute.

This reversal of the drug's effect at very high input rates was counter to the hypothesis of an "anti-panic" component in *dex*. It scarcely need be said that such results also emphasize the need for caution in the operational employment of such drugs, at least until further task parameters are explored for moderator influences.

Potential Interpretations

The following are three hypotheses that can be advanced to explain the reversal of enhancement observed in Experiment 4. They are neither mutually exclusive nor collectively exhaustive:

Hypothesis 1: Enhancement is reversed because dex *intensifies the emotional response to "failure stress."*

It is possible that, although the drug enhances performance in a demonstrably threatening task situation, this effect is reversed when task demands appear "impossible." Amphetamines seem to increase the utility of high achievement (Evans & Smith, 1964; Hurst, 1966b.) This may raise level of aspiration and thus activate the "need to avoid failure" when the subject realizes that he cannot achieve such a level. Threat of failure can be removed by refusing to try.

Hypothesis 2: The change in the method of recording answers may moderate the drug effects.

The letter-checking technique introduced to cope with the high input rates in Experiment 4 requires more searching but less motor activity than the letter-writing technique previously employed. Failure of *dex* enhancement with letter-checking could suggest that the enhancement previously observed, in experiments using the letter-writing technique, resulted simply from an increase in the speed with which subjects could write down letters (cf. Laties & Weiss, 1966).

Hypothesis 3: Dex *influences data-processing strategies in a manner which leads to impairment at very high input rates.*

High input rate imposes filtering demands which increase progressively as the rate goes up. Again assuming that the drug increases utility of achievement, this effect may combine with increased self-confidence to prevent a realistic degree of filtering at very high input rates.

Method

Design of Experiment 5

This study was conducted in an effort to explain the reversal of *dex* enhancement produced under high input rates in Experiment 4. To discriminate among the possible interpretations, we decided, first, to manipulate difficulty via task parameters other than input rate. If the enhancement reversal is associated with threat of failure (H1), then we should expect reversal from any manipulation which increases task difficulty to the necessary level. However, if it is caused by the drug's opposition to adequate filtering (H3), then enhancement should not be

related to difficulty except when difficulty variations impose different filtering demands.

We decided to manipulate difficulty through variations in list length and average storage load ($\overline{SL}$). List lengthening was not expected to affect filtering requirements at constant $\overline{SL}$, but should increase losses from proactive inhibition. Increased storage load might require more filtering, but only to the extent that improved "recirculation" saves more data than are filtered out (cf Broadbent, 1957). Neither list length nor $\overline{SL}$ should produce the filtering demand imposed by excessive input rate, which with deficient filtering will simultaneously overload registry, recirculation, and retrieval operations.

Thus, reversal of enhancement under high load and list length would support H1, whereas failure of the drug effect to interact with these parameters would support H3. The test of H2 was simpler: we used both methods of answer recording, LW (letter-writing, first three letters) and LC (letter checking, first letter.) To facilitate comparison with previous results, we used the 30/minute data rate which was common to both Experiment 3 and Experiment 4.

Each test sequence included either 9, 12, 15, or 18 items plus their recall stimuli. Average storage load was either 3, 4, or 5 items. Each 25-minute test included two sequences of each combination of list length and $\overline{SL}$. Since there were 4 x 3 = 12 such combinations, a test therefore contained 24 sequences, which were separated by 8-second rest intervals. These sequences were arranged in random order throughout each test. Four randomly-equivalent test forms were prepared. Two of these were administered

during each session, one with each method of answering (LW or LC). The order of the two methods was counterbalanced across sessions. Thus, list length, $\overline{SL}$, and method of answering were independent of (1) sessions, (2) order or drug latency within sessions, and (3) each other.

Subjects

Paid volunteers were recruited from a population of university students, graduate and undergraduate, over 21 years of age. Of the 48 who completed the experiment, the raw median age was 21; 35 were male and 13 were female. Although they had all participated in one previous drug experiment, none had been exposed to the PSMT. The volunteer population was screened by the medical supervisor for physical or psychiatric contra-indications, including any current usage of psychoactive drugs.

Each of the original volunteers was told the general nature of the experiment and given a list of nine drugs, including common stimulants, barbiturates, and tranquilizers, from which his medications would be selected. He was then allowed a minimum of two weeks to obtain outside medical advice concerning his participation. This was done to provide informed consent without revealing what kind of drug to expect. Those who passed the medical screening and self-screening were then given the Jackson Personality Research Form (PRF), the Barratt Personality Preference No. 2 (BPP), and the Minnesota Multiphasic Personality Inventory (MMPI). These tests were not a part of the screening procedure, but administered to explore the relationship between subsequent drug effects and personality structure.

Drug Administration

The drug conditions employed were dextroamphetamine sulfate (*dex*), sodium amobarbital (*am*), *dex* plus *am*, and placebo. It was thought that *dex* plus *am* would produce a stronger affective component than would *dex* alone, and thus tend to promote greater performance enhancement through increased resistance to panic. However, this admixture of the barbiturate might also produce a direct cognitive impairment that worked in opposition to the affective component, yielding a net effect of unpredictable magnitude or direction. Interpretation of the *dex* plus *am* effect would therefore be clarified by comparing it with the effect of *am* given alone.

The "no drug" condition, employed in four previous studies of this series, was omitted because none of these experiments had produced a reliable difference between placebo and "no drug." Dosages were adjusted to the two-thirds power of body weight, an estimate of body surface area. The proportionality constants were calculated so as to assign, to a 77 kg subject, a dose of 15 mg of *dex* or 96 mg of *am*. These dosages were the same, whether the drugs were given separately or together. In the latter event, the combined dosage represented the standard ratio supplied in commercial "Dexamyl" (SKF) tablets.

All medications were given orally in matched #3 bright orange capsules. On each session, every subject took two capsules, one at 6:50 p.m. and the second at 7:20 p.m. The first capsule contained either *dex* or placebo, and the second contained either *am* or placebo. This procedure was designed to produce approximately coincident peak effects

from the two drugs, whether taken separately or in combination.

Each subject received each of the four treatments once, during a total of four sessions spaced a week apart. Order effects were controlled by assigning subjects randomly to each of the 24 possible treatment sequences. The data were analyzed according to the sequentially-balanced model, with the slight imbalance due to subject drop-outs corrected by least-squares estimates.

Test Procedure

During each of the four sessions, the schedule given in Table 1 was rigidly followed. The "CFF Test" was a measurement of critical flicker fusion thresholds, adapted for group administration. "Mood ACL" refers to the short version of the Nowlis Mood Adjective Check List. The "Time Perception Test" requires estimating the durations of short sonic pulses, as described by Hurst and Weidner (1966).

The PSMT was administered in the versions described in Table 1. As in Experiments 3 and 4, the subjects were informed that their entire bonuses for the experiment would depend upon relative performances on the PSMT. Each subject would receive a fixed payment of $2.00 per session and a bonus based upon total PSMT performance if he completed all four sessions. Bonuses would range from $16.00, for the subject with the lowest total performance, to $32.00 for him who had the highest total, with equal increments between those values based upon rank within the group. Although scores on all trials would be summed, the LC scores would be adjusted for guessing according to the formula

$$LC\ (C) = LC\ (R) + 1/9\ \text{omits}$$

Table 1

Testing Schedule

Experiment 5

6:40	Names and subject numbers on forms
6:45	Mood ACL #1
6:50	Capsule A
7:00 - 7:10	CFF Test
7:10 - 7:20	Payoff Instructions (first session only)
7:20	Capsule B
7:20 - 7:40	PSMT Instructions (first session only)
7:40 - 8:05	Time Perception Test
8:20	CFF Test
8:30	Mood ACL #2
8:50 - 9:15	First PSMT
9:25 - 9:50	Second PSMT
10:00 - 10:25	Time Perception Test
10:25	Mood ACL #3
10:30	Dismissal

where

LC (R) = total number of right answers in letter-checking trials, and

LC (C) = number of right answers in letter-checking, corrected for guessing.

This is based upon chance expectancy, since there were 9 item words in each class, all beginning with different letters. The LW scores would not be adjusted.

Although payments were based upon LC (C), we planned to analyze results both with LC (C) and with LC (R). This would indicate whether drug enhancement/impairment depends upon the premium placed upon willingness to guess.

Results and Discussion

The mood ACL and the two perceptual measures were primarily intended to assess the consistency of individual differences in drug response, and their predictability from personality measures. This requires data from additional experiments. Consequently, systematic presentation of these findings will be deferred for a future report, and they will be discussed here only to the extent that they reflect upon our present topic.

Table 2 lists PSMT means for the four drug conditions, corrected by least-squares fit for the slight "order" biases created by subject dropouts. Results are combined parametrically to show main effects: e.g., a drug's mean for "letter writing" (LW) was computed from combined data for all LW trials regardless of list length or average storage load ($\overline{SL}$). Drug means under LC were also computed from combined list

lengths and $\overline{SL}$, but were obtained alternatively as LC (R) [percent right answers based upon total possible correct] and LC (C) [percent right answers corrected for guessing, as described above.] Where not otherwise specified, the means in Table 2 were computed from combined LW and LC (C) scores.

Analyses of variance for the sequentially-balanced model were performed with each of the 14 dependent variables listed in Table 2, according to a program which adjusts sums of squares for unequal subclass frequencies due to subject dropouts based upon least-squares estimates of parameters. The resulting F-ratios (d.f. = 3, 138) are included in Table 2.

Where significant F-ratios ($p < .05$) were obtained, paired comparisons of drug treatments were evaluated by t-tests. Since the different drug effects represent separate, prior hypotheses, no adjustments for multiple comparisons were made. The results of these paired comparisons are given in Table 3.

Looking first at total scores, one observes that *dex* was significantly superior to *am* or placebo, and non-significantly superior to *dex + am*. The margins are closely comparable whether the LC scores were corrected for guessing, LW + LC (C), or uncorrected, LW + LC (R). *Dex + am* was significantly better than *am*, and almost significantly better than placebo. The differences between placebo and *am* did not approach significance. Thus, the 100 mg dose of amobarbital seems to have been consistently ineffective: it produced little, if any, difference in the *d*-amphetamine effect when combined with *dex*, and gave essentially a placebo effect when administered separately.

Table 2

Drug Means by Levels of Task Parameters

	Dex	*Am*	*Dex + Am*	Placebo	F
Percent Correct:					
9-word lists	58.7	57.4	60.2	57.7	3.07*
12-word lists	58.6	56.3	57.3	56.9	2.37
15-word lists	56.4	53.9	54.6	54.2	3.48*
18-word lists	56.2	54.9	56.5	55.1	1.89
$\overline{SL}$ = 3.0	70.0	68.0	69.9	68.9	2.94*
$\overline{SL}$ = 4.0	55.6	54.2	54.6	53.8	1.85
$\overline{SL}$ = 5.0	46.0	43.8	45.9	44.5	3.44*
LW	55.3	53.6	55.3	53.9	2.59
LC (R)	56.9	54.7	55.8	55.0	2.62
LC (C)	59.1	57.1	58.3	57.5	2.35
Total, LW + LC (R)	56.1	54.1	55.6	54.5	3.79*
Total, LW + LC (C)	57.2	55.4	56.8	55.7	3.77*
First test in session	57.2	55.8	57.2	55.2	3.23*
Second test in session	57.2	54.9	56.5	56.2	2.57
Percent omitted:					
LW	18.5	20.7	17.3	20.1	4.03**
LC	19.7	21.9	19.1	22.0	3.35*
LW + LC	19.1	21.3	18.2	21.1	5.46**

* ⟶ $.01 < p < .05$

** ⟶ $.001 < p < .01$

Table 3

Paired Comparisons of Treatment Means Having Significant F-Ratios

Percent Correct:

9-word lists	*dex + am > plac ≥ am*
15-word lists	*dex > dex + am ≥ plac ≥ am*
$\overline{SL}$ = 3.0	*dex > dex + am > am*
$\overline{SL}$ = 5.0	*dex ≥ dex + am > am*
Total, LW + LC(R)	*dex > plac ≥ am, dex + am > am*
Total, LW + LC(C)	*dex > plac ≥ am, dex + am > am*

Percent Omitted:

LW	*am ≥ plac > dex + am, am > dex,*
LC	*plac > dex ≥ dex + am, am > dex + am,*
LW + LC	*am ≥ plac > dex ≥ dex + am*

> ⟶ Significantly greater, at or beyond the .05 level

≥ ⟶ Non-significantly greater

Analysis of the drug effects by separate task parameters reveals little suggestion of moderator influences. Although the F-ratios ranged from 1.85 to 3.79, this must be attributed largely to differences in error variances resulting from different numbers of observations. Superiority of *dex* over placebo was maintained, throughout, by about the same small margin. The only moderating influence worth discussing is the "latency" effect. The enhancement margin of *dex* over placebo in the first test per session was over twice as great as in the second test, and so was that of *dex + am*. Although the differential is not statistically significant, it is in the same direction as the results of Experiments 1 and 4 -- the only previous experiments in which two separate PSMT tests were given per session. This may represent a drug latency effect, or it may be that the enhancement influence is weakened with test repetition. This would be consistent with the "anti-panic" hypothesis, since anxiety should tend to diminish with adaptation. It certainly does not support the contention that *dex* enhancement is entirely due to mitigation of fatigue or boredom. The anti-fatigue component, by itself, would yield *least* enhancement in the first test -- a result opposite to that observed.

Inspection of the "omit" frequencies reveals that *dex*, and especially *dex + am*, caused subjects to omit fewer answers than when given placebos. (As usual, *am* alone had no effect.) This suggests that *dex* and *dex + am* made the subjects more willing to guess. However, this suggestion is denied by the comparison of drug effects upon LC (R) and LC (C) scores. The margin of *dex* over placebo was only 0.28% greater with LC (R) than with LC (C), and the margin of *dex + am* over placebo was 0.10% less with

LC (R). The margin of placebo over *am* was identical under both methods of scoring. This shows that guessing caused virtually no change in the observed drug effects, indicating that essentially the same number of wrong answers were made under each treatment condition. The reduction in number of omits under *dex* or *dex + am* is now readily explained: Fewer answers were omitted because more answers were known.

Finally, we must consider the implications of the *dex + am* results. It was hypothesized that this combination, by producing stronger affective changes than *dex* alone, would lead to greater enhancement under the "anti-panic" hypothesis -- provided that the direct cognitive impairment produced by *am* was not excessive. Results for *am* given separately show that this impairment was indeed not excessive, or even measurable. Thus, the hypothesized mood elevation from addition of *am* to *dex* did not lead to better performance. Unfortunately, this increased mood elevation proved to be *purely* hypothetical. *Dex* produced significant ($p < .01$) increases in "vigor," "confidence," "elation," "social affection," and "surgency;" it significantly reduced "fatigue" and "sadness." But instead of heightening the *dex* effect, *dex + am* produced *weaker* effects upon all seven of these mood variables. Similar results were found with CFF. Since *dex + am* failed to exert the desired mood effect, the performance data from this drug combination are of no help in evaluating the role of affective change in performance enhancement under "stress." The reduced enhancement could be attributed either to cognitive impairment or to weaker mood effects. However, the task-parametric analysis provides some relevant information, which we shall use to evaluate the three hypotheses advanced to account for the reversal of *dex* enhancement in Experiment 4.

Hypothesis 1 - that *dex* enhancement will reverse whenever task demands reach a given range of difficulty - is not supported by the present data. Of the parameters that were manipulated, storage load had the greatest effect upon difficulty. The highest level ($\overline{SL}$ = 5) produced 44.5% correct responses under placebo, which is comparable to the 40.3% correct produced by the high input rate of Experiment 4. Yet varying the storage load had little effect upon the *dex* enhancement margin, which was greatest at $\overline{SL}$ = 4, only slightly less at $\overline{SL}$ = 5, and least at $\overline{SL}$ = 3. Enhancement was significant at both of the higher levels. List length also made no consistent difference, with slightly less apparent enhancement at both the highest and the lowest lengths.

Hypothesis 2 - that *dex* enhancement is dependent upon how answers are recorded - was also disconfirmed. The margin of *dex* over placebo differed very little with recording technique, and was actually lowest with LW. Thus, the improvement under *dex* cannot be attributed to being able to write down letters faster.

Hypothesis 3 - that *dex* enhancement is reversed by input-filtering requitements imposed only by high data rates -- cannot be directly evaluated from the present data. It is indirectly supported by the disconfirmation of the other hypotheses, which seems to exhaust the most plausible alternatives. A more direct test of H3 is difficult, since it deals with intervening variables not directly observable.

Conclusions

After five experiments in the same task framework, involving eight psychoactive drugs and drug-combinations, we may conclude as follows:

when normal young adults are rested and well motivated, their performance in concommitant registry, storage, and retrieval operations is remarkably stable.

"Well-motivated" refers to the restriction of task length to less than forty minutes, and further insurance by strong monetary incentives. "Remarkably stable" refers to the fact that no medication yet tried has either impaired or improved performance to any marked degree, although all dosages have been within clinically-effective ranges.

Of the various compounds thus far studied, *d*-amphetamine continues to be the best candidate for performance enhancement. The margin of improvement is small, usually three to four per cent above placebo levels, but has repeatedly reached statistical significance. Within certain limits, it does not seem to matter much how the conditions are varied: drug disguisal, placebo vs no-drug controls, practice effects, methods of answer recording, penalization for guessing, storage load, item list length, or data input rate. The enhancement is still there, small but reliable in the mean. The sole exception occurred when extremely high data rates were employed.

How the enhancement is accomplished remains in question. Our results seem to contradict the notion that amphetamine enhancement depends upon the prior existence of boredom or fatigue. Neither, in the present context, does it seem attributable to direct cognitive stimulation: the evidence cited on page 4 implies that amphetamines do not improve running memory span *per se*.

The "anti-panic" interpretation has been confirmed by some of the findings and opposed by others. It has not been ruled out, but remains

an unconfirmed conjecture.

When task parameters are manipulated, affective responses to "threatening" task demands are interwoven with changes in strategic requirements to an extent which defies interpretation of just what it is the drugs are doing. Consequently, it seems necessary that affective components be manipulated via parameters extrinsic to the task structure. Thus far, such manipulations -- involving the reward-punishment structure -- have yielded only suggestive trends. This implies the need for more powerful and potentially disruptive manipulations. Further clarification may be afforded by analysis of individual differences in the drug response: do they involve differences in susceptibility to "threat"?

References

Broadbent, D.E. A mechanical model for human attention and immediate memory. Psychol. Rev., 1957, 69, 205-215

Cattell, R.B. The dimensional (unitary-component) measurement of anxiety, excitement, effort stress, and other mood reaction patterns. In: Drugs and Behavior, Uhr, L. and Miller, J.G. (eds.) New York: John Wiley,1960.

Davis, D.R. Psychomotor effects of analeptics and their relation to fatigue phenomena in aircrew. Brit. Med. Bull., 1947, 5, 43-45.

Evans, W.O. and Smith, R.P. Some effects of morphine and amphetamine on intellectual functions and mood. Psychopharmacologia, 1964, 6, 49-56.

Hurst, P.M. A viewpoint on drug enhancement. Division of Psychobiology, Institute For Research, State College, Pa. Report No. ONR-H-66-2.

Hurst, P.M. Judgment distortion by amphetamines: some moderating influences. Invited paper at 5th annual meeting of the American College of Neuropsychopharmacology, Dec. 1966. ACNP Proceedings, in press.

Hurst, P.M., Padlow, R. and Perchonok, K. Some dimensions of affective response to drugs. Division of Psychobiology, Institute For Research, State College, Pa. Report No. H-67-3.

Hurst, P.M. and Weidner, M.F. Drug effects upon cognitive performance under stress. Division of Psychobiology, Institute For Research, State College, Pa. Report No. ONR-H-66-3.

Hurst, P.M., Weidner, M.F. and Radlow, R. The effects of amphetamines upon judgments and decisions. Psychopharmacologia, 1967, 11, 397-404.

Lloyd, K.F., Reid, L.S. and Feallock, J.B. Short-term retention as a function of the average number of items presented. J. exp. Psychol., 1960, 60(4), 201-207.

Quarton, G.C. and Talland, G.A. The effects of methamphetamine and pentobarbital on two measures of attention. Psychopharmacologia, 1962, 3, 66-71.

Servais, J. and Hubin, P. Etude psychopharmacologique de l'amphetamine et du meprobamate chez l'homme normal. Int. J. Neuropharmacol., 1964, 3, 517-540.

Smith, G.M. and Beecher, H.K. Amphetamine, secobarbital, and athletic performance. II. Subjective evaluation of performance, mood, and physical states. J.A.M.A., 1960, 172, 1502-1514.

Smith, G.M. and Beecher, H.K. Drugs and Judgment: Effects of amphetamine and secobarbital on self-evaluation. J. Psychol., 1964, 58, 397-405.

Talland, G.A. and Quarton, G.C. The effects of methamphetamine and pentobarbital on the running memory span. Psychopharmacologia, 1965, 7, 379-382.

Weiss, B. and Laties, V.G. Enhancement of human performance by caffeine and the amphetamines. Pharmacol. Rev., 1962, 14(1), 1-33.

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13. ABSTRACT

A synopsis of results obtained in four previous experiments with the paced sequential memory task (PSMT) was given to clarify the purpose of the present experiment. Each of these studies included *d*-amphetamine sulfate among various different conditions of drug treatment. These different treatments were imposed to study performance variations with respect to various task parameters, e.g., data rate and storage load, in addition to extra-task features such as incentive conditions.

Throughout these four prior experiments, *d*-amphetamine was consistently the most active drug of the various psychoactive compounds employed. It yielded results ranging from significant enhancement to the significant impairment observed in one study. These results were discussed in relation to variations in task parameters and experimental conditions, in the attempt to isolate the crucial moderators that determine whether amphetamines enhance performance or impair it. Three alternative but non-exclusive hypotheses were advanced. A fifth experiment was designed to discriminate among them. In this study, the drug conditions were (1) *d*-amphetamine sulfate (15 mg/77 kg), (2) sodium amobarbital (96 mg/77 kg), (3) a combination of both drugs in the same dosages, and (4) placebo. Task variations were imposed upon storage load, list length, and method of transcribing answers (varying motor requirements). Results were analyzed both with and without statistical corrections for guessing.

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Abstract (continued)

Results showed significant enhancement by *d*-amphetamine in total performance across conditions, with no indications of dependency upon storage load, list length, or method of transcribing answers. The margin of superiority over placebo showed little variation across these conditions, nor was it appreciably changed by correction for guessing. Amobarbital given separately was closely comparable to placebo. When combined with *d*-amphetamine, it produced a non-significant weakening of the enhancement effect. Contrary to expectation, it also weakened the mood effects.

These results indicated that amphetamine enhancement does not crucially depend upon task difficulty within the ranges employed, nor upon length of exposure to task or the motor requirements of answer-writing, nor does it depend upon the premium placed on willingness to guess. Reversal of *d*-amphetamine enhancement, obtained in the preceding study, was tentatively attributed to increases in requirements for input "filtering," i.e., the need to reject usable data when processing capacity is overtaxed: Amphetamines make people reluctant to accept the need to "filter". This was the only hypothesis that was not overthrown by the data.