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The Interactive Effect of Personality, Time of Day, and Caffeine: A Test of the Arousal Model

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SUMMARY

The personality dimension of introversion/extraversion is one of the few personality dimensions that can be reliably identified from study to study and investigator to investigator. The importance of this dimension within personality theory is due both to the stability of the trait and the influential theory of H. J. Eysenck. The basic assumption in Eysenck's theory of introversion/extraversion is that the personality differences between introverts and extraverts reflect some basic difference in the resting level of cortical arousal or activation. Assuming that there is a curvilinear relationship (an inverted U) between levels of stress and performance leads to a test of this arousal theory. That is, moderate increases in stress should hinder the performance of introverts who are presumably already highly aroused. However, the same moderate increase in stress might help the performance of the presumably underaroused extraverts.

Revelle, Amaral, and Turriff reported that the administration of moderate doses of caffeine hindered the performance of introverts and helped the performance of extraverts on a cognitive task similar to the verbal test of the Graduate Record Examination. Assuming that caffeine increases arousal, this interaction between introversion/extraversion and drug condition supports Eysenck's theory. This interaction was explored in a series of experiments designed to replicate, extend, and test the generality of the original finding. The interaction between personality and drug condition was replicated and extended to additional cognitive performance tasks. However, these interactions were affected by time of day and stage of practice, and the subscales of introversion/extraversion, impulsivity, and sociability, were differentially affected. In the morning of the first day, low impulsives were hindered and high impulsives helped by caffeine. This pattern reversed in the evening of the first day, and it reversed again in the evening of Day 2.

We concluded that the results from the first day of testing require a revision of Eysenck's theory. Instead of a stable difference in arousal between low and high impulsives, it appeared that these groups differed in the phase of their diurnal arousal rhythms. The result is that low impulsives are more aroused in the morning and less aroused in the evening than are the high impulsives.

A variety of peripheral or strategic explanations (differences in caffeine consumption, guessing strategies, distraction, etc.) for the observed performance increments and decrements were proposed and tentatively rejected. It seems probable that some fundamental change in the efficiency with which information is processed is responsible for these performance changes.

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One of the few personality dimensions that most personality theorists agree is robust enough to identify from study to study and investigator to investigator is that of introversion/extraversion. It has been shown that this personality dimension can be identified in such varied item sets as behavioral measures (Eysenck, 1947), peer ratings, and self-report inventories (Cattell, 1957, 1973; Howarth, 1976; Norman, 1969). Introversion/extraversion has also been identified as a prominent factor in a set of items sampled from all major personality inventories (Browne & Howarth, 1977). H. J. Eysenck (1947, 1967), more than anyone else, has popularized this trait and contributed to its theoretical development and measurement. Eysenck's theory of introversion/extraversion has received enough support for him to claim (1976) that it represents a paradigm of personality measurement. It has been reported that differences in introversion/extraversion are related to differences in physiology, vigilance performance, social interaction, sexual behavior, creativity, effectiveness of cognitive processing, susceptibility to stress, and many other diverse experimental and observational findings. In this article we will show that some of these findings, specifically the differential susceptibility to stress of introverts, are quite reliable but that they may not be related to the overall concept of introversion/extraversion.

Specifically, we shall report on a series of studies attempting to replicate, define the boundary conditions, and extend the basic findings of Revelle, Amaral, and Turriff (1976), who showed that on a cognitive task, time pressure and caffeine interacted with introversion/extraversion. The cognitive task employed was a 60-item multiple-choice test of verbal ability similar to the Graduate Record Examination. Each subject served in each of three testing conditions. In one condition, the subjects had as much time as they needed to complete the test. During the remaining two testing conditions, subjects were allowed a limited amount of time to complete the test. In one of the two timed conditions, subjects were given a placebo, and in the other condition they were given 200 mg of caffeine. When the number of items answered correctly was corrected for guessing and standardized within time conditions, the performance of introverts was found to fall by .63 *SD* when they were going from the relaxed condition to the timed plus caffeine condition. The performance of the extraverts, on the other hand, increased by .43 *SD* when they were going from the relaxed to the timed plus caffeine condition. The current article is a report on six studies, five of which are reported for the first time here, that have followed that initial finding. Before describing this research, however, it is necessary to consider some issues relevant to the performance of introverts and extraverts in arousing or stressful conditions.

Arousal Theory of Introversion/Extraversion

H. J. Eysenck's basic theory of introversion/extraversion can be summarized as the logical derivation from three hypotheses.

1. The first hypothesis is that individual differences in introversion/extraversion are related to differences in the resting (basal) level of cortical arousal or activation. It has been reported that compared to extraverts, introverts are more sensitive to auditory stimulation (Smith, 1968) and to pain (Haslam, 1967); have higher sedation thresholds (Sloane, Davidson, & Payne, 1965); higher levels of skin conductance (Revelle, 1974); and have more spontaneous galvanic skin responses (Coles, Gale, & Kline, 1971). Introverts have also been

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reported to be more resistant to the decrement in vigilance performance that is associated with low levels of arousal (Carr, 1971; Keister & McLaughlin, 1972; Krupski, Raskin & Bakan, 1971). Similarly, Crider and Lunn (1971) reported that the orienting response habituates more quickly among extraverts than among introverts.

2. The second hypothesis is that there is an optimal level of arousal for any particular task. In other words, there is a curvilinear relationship (an inverted U) between levels of arousal and performance (Broadhurst, 1959; Duffy, 1962, 1972; Yerkes & Dodson, 1908). It is further assumed that this optimal level of arousal varies as a function of task parameters such that this peak level is higher for easier rather than for harder tasks.

3. A third hypothesis is that there is a curvilinear relationship between arousal and hedonic tone. That is, there is a preferred or ideal level of arousal, and amounts of arousal either above or below that are not as pleasant as those at the optimal level.

With these three hypotheses it is possible to derive predictions about the performance of introverts and extraverts in arousing and nonarousing situations. That is, in a boring situation (e.g., a vigilance task with a low probability of signal occurrence), introverts should perform better than extraverts. This is predicted on the basis of the higher arousal of introverts than extraverts and the low arousal properties of the task. As the task becomes more arousing, however, introverts should quickly attain their optimum level of arousal (if they were not there already). As introverts pass through the descending side of the inverted-U curve, extraverts would most probably be ascending. Thus, for moderately arousing tasks, the performance of introverts and extraverts should not differ. As the task becomes even more arousing, the introverts should become overaroused and their performance should deteriorate. Extraverts, with initially low levels of arousal, on the other hand, should not attain their optimum level until well after the introverts are past theirs. Thus, with low levels of arousal introverts are expected to perform better than extraverts, and with high levels of arousal extraverts are expected to be superior to introverts. The findings of Revelle et al. (1976) support this prediction, assuming that time pressure is more arousing than no time pressure and that caffeine is more arousing than a placebo.

Additional support for the inverted-U prediction may be found in the work of Davies and Hockey (1966), who found that in a visual cancellation task, signal frequency and noise level interacted with introversion/extraversion. By assuming noisy conditions to be more arousing than quiet conditions, a high signal frequency to be more arousing than a low signal frequency, and introverts to be more aroused than extraverts, Davies and Hockey (1966) found it possible to order the visual cancellation scores of their subjects in a curvilinear order. The performance of extraverts improved with increases in either signal frequency or noise level, whereas the performance of introverts deteriorated when both noise and signal frequency were increased.

Further evidence for the inverted-U hypothesis of introversion/extraversion was reported by Corcoran (1972). Assuming that sleep deprivation leads to a lower arousal level, Corcoran found that although increasing sleep deprivation produced decrements in performance for extraverts, sleep deprivation actually led to improvements in the performance of introverts. The task was presumed to be quite arousing: Subjects were required to follow with a stylus a highly complex path around many holes in a drum revolving at high speed. To induce high arousal, errors were punished with 100-dB white noise. On this task, it was assumed that introverts were initially overaroused and extraverts were optimally aroused. Sleep deprivation was thought to bring the introverts down to more optimal arousal levels but to take the extraverts below their optimal point.

Another relationship that can be predicted from the arousal preference hypothesis is that extraverts should be stimulation seekers and introverts stimulation avoiders. Thus, we would expect extraverts to avoid vigilance-type tasks but to seek out and do well on those tasks that produce higher

arousal levels. Introverts, on the other hand, should seek out those tasks that induce lower levels of arousal and avoid those that produce high levels. These preferences, of course, are seen in our everyday stereotypes of introverts and extraverts, and can also be demonstrated in the laboratory. Thus, Elliot (1971) and Ludvigh and Happ (1974) have shown that extraverts prefer higher levels of auditory stimulation than do introverts. Similarly, Gale (1969) has shown that in an operant situation where an increase in visual stimulation was used as a reward, extraverts work harder than introverts. The greater caffeine preference of extraverts (Bartol, 1975) may be seen as their way of achieving a higher, and for them a more pleasant, level of arousal.

Limitations of the Arousal Theory

A difficulty with such a simple explanation of stimulation seeking is that it fails to take account of differences in stimulus value between self-paced and externally paced tasks. That is, is mountain climbing a highly arousing situation because of the high risk, or is it a relaxing avocation because of the self-paced nature of the task? This theory of stimulation seeking also fails to take account of individual differences in preferences and abilities. For example, is attending a dance arousing because of the social stimulation, or is it relaxing because you are a good dancer? These examples illustrate the difficulty in deciding which tasks or situations are most arousing. Clearly, more effort and thought are needed before arousal theory can predict situational preferences.

Yet another conceptual weakness in the theory as outlined is that differences in preferred level may or may not be correlated with differences in resting level. It is quite possible to construct a model in which preferred level and resting level are independent. This would lead to the prediction that high stimulation seekers are either those with low resting levels or high ideal levels, or both. The present theory does not predict the behavioral consequences of differences in ideal arousal level separate from differences in basal level.

A final problem with the theory as outlined above is the concept of arousal itself. What does it mean to say that someone is more aroused than someone else? Arousal is normally a within-subjects concept contrasting states of extreme sleepiness with extreme excitement. Within-subjects increases in arousal are associated with increases in heart rate, breathing rate, number of spontaneous galvanic skin responses (GSRs), increases in skin conductance, and increases in the dominant electroencephalogram (EEG) frequency. In addition to these psychophysiological indicators of arousal, it is possible to assess within-subjects differences by self-report (Kjellberg & Bohlin, 1974; Thayer, 1967). In fact, in one study, self reports of arousal were found to correlate more with the physiological indicators than any two indicators correlated with each other (Clements, Hafer, & Vermillion, 1976). What does it mean, however, to perform between-subjects comparisons using procedures validated within subjects? Is it even possible to consider between-subjects differences on the same dimension as within-subjects differences? That is, within subjects, a person is more aroused with a heart rate of 80 beats per minute (bpm) than with 60 bpm, but is someone with an 80-bpm rate more aroused than someone else is with a 60-bpm rate?

It is perhaps these difficulties that lead to the findings that although introverts and extraverts do not differ on self-report measures of arousal, introversion interacts with self-reported arousal on a measure of semantic memory retrieval (M. W. Eysenck, 1974). Similarly, in a study relating introversion/extraversion, skin conductance, and performance (Revelle, 1974), it was found that although neither skin conductance nor introversion was related to anagram performance, the interaction between introversion and skin conductance was significant. Introverts with low skin conductance performed better than introverts with high skin conductance, whereas extraverts with moderate levels of skin conductance did better than those with either lower or higher levels.

A final point about the utility of the curvilinear arousal–performance hypothesis is

that the curvilinear hypothesis serves as a description rather than an explanatory device. It does not provide an explanation for performance increments or decrements under increases in arousal. If on a particular task extraverts are observed to do better and introverts worse (with a moderate increase in stress), there is no guarantee that the same mechanism was responsible for both the increment and the decrement. It may be that one theory will be needed for the performance increments and a second for the performance decrements.

A similar point has been made by Poulton (1977) in his discussion of the performance changes induced by increases in ambient noise levels. Poulton proposes that the performance increases with noise are due to the arousing properties of noise but that the performance decrements are due to increases in the distracting effects of noise (masking of inner speech, etc.). Other critics of the inverted-U hypothesis (viz., Näätänen, 1973) also hold that decrements are due to distractions confounded with the increase in stress. Thus, noise (Davies & Hockey, 1966), the presence of others (Geen, 1973), or testlike versus relaxed conditions may be thought of as being more distracting than the control conditions.

Caffeine as a Stressor

A central point to our discussion of the effects of caffeine upon performance is the assumption that caffeine increases arousal. An excellent review of the effects of caffeine upon humans is that of Gilbert (1976), from which this section will borrow heavily. One of the best known behavioral effects of caffeine is, of course, that it delays the onset and reduces the quality of sleep. With awake subjects, caffeine facilitates performance on simple repetitive tasks (the facilitation occurs after many repetitions of the task), probably through its fatigue-alleviating properties. With chronically high doses, caffeine induces symptoms clinically indistinguishable from anxiety (Greden, 1974). Normal caffeine consumption also has been related to symptoms of anxiety among workers confronted with the stress of a factory closing (Cobb, 1969). For extraverts, caffeine has been shown to improve performance on a vigilance task by reducing the characteristic decline in performance as the work progresses (Keister & McLaughlin, 1972). With respect to psychophysiological measures, caffeine reduces the habituation rate of the GSR to auditory stimuli. Neurochemically, it is thought that the effect of caffeine is to inhibit the breakdown by phosphodiesterase of cyclic adenosine monophosphate (AMP), which results in higher cylic-AMP levels. A related phenomenon is that caffeine raises blood-sugar levels as well as the plasma level of free fatty acids. When taken orally, caffeine reaches peak plasma levels within 30 min. and remains in the blood stream with a half-life between 2 and 4 hr. A normal cup of coffee has been estimated to contain about 75 mg of caffeine, although some individuals consume cups with upwards of 300 mg of caffeine (Gilbert, Schwieder, Marshman, & Berg, 1976).

The effect of caffeine on performance appears to be interesting in its own right. Whether this effect is in any way similar to the effects of such presumed arousers as noise, social stimulation, or anxiety remains to be determined. That is, it remains to be determined whether caffeine and the other presumed arousers have the same behavioral effects. Beyond this, it also remains to be determined whether these effects are mediated by a common physiological mechanism. In our studies we specifically investigated the behavioral effects of caffeine. However, we believe that the assumption that the effect of caffeine and other stressors (e.g., noise, social stimulation, or anxiety) can be subsumed under a common construct (arousal) is theoretically fruitful.

The Measurement of Introversion/Extraversion

Some comments are also needed about the personality dimension of introversion/extraversion. In order to assess this dimension, subjects are asked to answer questions about their life-styles and behavioral tendencies. Do they like parties? Will they do anything on a dare? The items and the answers to

these items that define the introversion/extraversion scale have been selected primarily on the basis of psychometric criteria (Eysenck & Eysenck, 1969). Basically, a set of items were selected that correlated with each other and did not correlate with other items. There is some dispute whether by this criterion introversion/extraversion is one or two scales. Thus, Guilford (1975, 1977) and Carrigan (1960) have suggested that it is more useful to consider the subscales of impulsivity and sociability as separate constructs and not to combine them into the higher order factor of introversion/extraversion. See H. J. Eysenck (1977) for a rebuttal of this position.

While it is clear that there is a relationship between introversion/extraversion and arousal-related measures, it would be quite surprising if items selected on these psychometric criteria would prove to be the best predictors of performance in arousing situations. The assumption that we initially made in this series of experiments was that the dimension of introversion/extraversion was our best lead to individuals who will perform well or poorly under stress. In analyzing our results we looked at the introversion/extraversion scale as well as the two subscales of impulsivity and sociability. The object was to determine whether the introversion/extraversion scale or one of the two subscales would be the best predictor of performance increments and decrements under stress. The answer was complex and will be discussed in more detail later.

The First Replication

The first replication of the Revelle et al. (1976) study was undertaken as part of a doctoral dissertation at Northwestern University (Gilliland, 1977). The procedures employed by Gilliland will be described, and those aspects of the procedures that differed from the Revelle et al. study will be noted.

In the Gilliland experiment subjects served in a single, 2-hr. session as compared to three 1-hr. sessions in Revelle et al. The subjects were given one of two forms of the Graduate Record Examination (GRE) practice tests (see Gruber & Gruber, 1973; Revelle et al., 1976). Then, each subject was given one of three doses of caffeine adjusted according to the body weight of the subject: 0 mg/kg of body weight (the placebo condition), 2 mg/kg of body weight, or 4 mg/kg of body weight. Forty-five minutes after the administration of caffeine, the subjects were tested on an equivalent form of the GRE practice test. Both the pre- and the posttest were given under high time pressure (10 min.) to complete the test.

The data of principal interest in this study were the change scores (the difference in the number correct between pre- and posttests). Gilliland reports that there was a significant Extraversion × Drug Level interaction; however, the pattern of results was somewhat different than was expected. It had been anticipated from the inverted-U hypothesis that the administration of caffeine in either dose would harm the performance of introverts. The performance of extraverts was expected to be enhanced by the small dose but perhaps be harmed by the large dose. Contrary to those expectations, the performance of the introverts as dosage increased first became better (0 mg/kg to 2 mg/kg) and then became worse (2 mg/kg to 4 mg/kg). The performance of the extraverts steadily improved with increasing dosages of caffeine.

When the introversion/extraversion scale was broken down into the two subscales (impulsivity and sociability), it was apparent that most of the caffeine effects were due to the impulsivity scale. For low impulsives there was a significant quadratic trend as the performance of low impulsives first increased then decreased with an increasing dose of caffeine. For high impulsives there was a significant linear trend as the performance of those subjects increased steadily across the levels of the drug variable. The interaction of linear trends was statistically significant. The only significant effect on the sociability scale was the quadratic trend for low sociables. These subjects first increased then decreased across the levels of the drug variable. Gilliland concluded that his results supported the inverted-U hypothesis and the arousal interpretation of introversion/extraversion. His data did cast doubts,

however, upon the unitary nature of the construct.

Experiments 1–5

As a result of the Revelle et al. (1976) and Gilliland (1977) studies there seemed to be little doubt that there was an interaction between the personality dimension of introversion/extraversion and the dosage of caffeine. However, the exact form of the interaction was not clear, and it seemed possible that a task or an environmental variable (stage of practice, time of day, the use of a pretest, etc.) might be moderating this interaction. Furthermore, as a result of Gilliland's observation about the importance of the impulsivity subscale, it was not clear whether the entire introversion/extraversion scale or one of its components was responsible for this Drug × Personality interaction. This section of the article reports on the results from five experiments designed to look at some aspect of this interaction. Experiments 1 and 2 were relatively direct attempts to replicate the Revelle et al. experiment. Experiment 1 was a two-session experiment conducted in the morning. Experiment 2 was a single-session experiment using the pre- and posttest design previously used by Gilliland. Experiment 1 included only the timed placebo and caffeine conditions. Experiment 2 crossed time and relaxed conditions with the placebo caffeine manipulation. Experiments 3 and 4 looked at the effect of time of day as well as caffeine versus placebo. In Experiment 3, subjects were required to attend two sessions, one in the morning and the other in the evening. Experiment 4 differed from the preceding experiments in that a different cognitive task was used. Experiment 5 was a two-session experiment conducted in the evening. In Experiment 5, a variety of ability tests were administered in an attempt to assess the generality of the Revelle et al. findings.

Method

General Procedure

The subjects were asked not to take any caffeine (coffee, tea, cola, stay-awake pills) for 6 hr. prior to the experiment. The experiments were conducted in group sessions with between 2 and 12 subjects per session. The subjects were asked to sign a consent form indicating the possible side effects of caffeine, were screened for medical contraindications, and then were asked to drink a glass of Tang containing either caffeine or flat quinine water (to approximate the bitterness of the caffeine solution). After drinking the Tang, the subjects waited 30 min. before starting on the performance tasks. During this time the personality and behavioral questionnaires were administered. In some of the experiments (1, 2, and 5), an additional performance task was also included. The results from these additional tasks will not be discussed in this article.

Materials

The personality questionnaires included the following: (a) the Eysenck Personality Inventory (EPI), which includes 24 introversion/extraversion items, 24 stability/neuroticism items, and 9 lie items. (Within the introversion/extraversion scale there are subscales for sociability and impulsivity [see Table 1]); (b) an experimental version of the Eysenck Personality Questionnaire that contains scales for introversion/extraversion, stability/neuroticism, psychoticism, lie, and four different impulsivity scales;[1] (c) a questionnaire consisting of 92 items derived from the Sells, DeMaree, and Will (Note 1) study of the Guilford and Cattell personality inventories. Items were selected to measure impulsivity, activity, sociability, and anxiety. In addition, items concerning caffeine consumption, sleep and study habits, and how hard subjects tried in the experiment were included. A short adjective check list (Thayer, 1967) in which subjects report their current mood or feelings was also included. Not all of these additional questionnaires were given in every experiment. Where relevant, the exceptions will be noted. The standard performance task (used in three of the five experiments as well as in the Revelle et al. and Gilliland studies) is similar in format to the verbal form of the Graduate Record Exam. Two forms of the test were used. Each test consisted of 20 each of analogies, antonyms, and sentence completions. The questions were taken from Gruber and Gruber (1973). This test is referred to as the *practice GRE.*

Experiment 1

Subjects. The subjects were 108 students from the introductory psychology class at Northwestern University. They served in the experiment as part of a course requirement.

[1] This form was kindly provided by S. B. G. Eysenck.

Table 1
Impulsivity and Sociability Subscales of the EPI

Impulsivity scale[a]
Longs for excitement
Is usually carefree
Does not stop and think things over before doing anything
Generally does and says things quickly without stopping to think
Would do almost anything for a dare
Often does things on the spur of the moment
Often shouts back when shouted at
Likes doing things in which he/she has to act quickly
Is not slow and unhurried in movement
Sociability scale[b]
Does not feel shy when he/she wants to talk to an attractive stranger
Does not prefer reading to meeting people
Likes going out a lot
Does not prefer to have few but special friends
Can usually let him-/herself go and enjoy him-/herself at a lively party
Other people think of him/her as being very lively
Is not quiet when with other poeple
If there is something he/she wants to know about, he/she would not rather look it up in a book than talk to someone about it
Does not hate being with a crowd who plays jokes on one another
Likes talking to people so much that he/she would never miss a chance of talking to a stranger
Would be very unhappy if he/she could not see lots of people most of the time
Does not find it hard to really enjoy him-/herself at a lively party
Can easily get some life into a rather dull party

[a] Items 1, 3, 5, 8, 10, 13, 22, 39, and 41 are from the Eysenck Personality Inventory (EPI), Form A.
[b] Items 11, 15, 17, 20, 25, 27, 29, 32, 37, 44, 46, 51, and 53 are from the Eysenck Personality Inventory, Form A.

Design and procedure. Each subject was tested on 2 consecutive days at either 9:00 or 10:00 a.m. On Day 1, the subjects were randomly assigned to receive caffeine or placebo. On Day 2, subjects were switched to the alternative drug condition. That is, if they had received caffeine on Day 1, they received placebo on Day 2. The dosage of caffeine was 200 mg (400 mg of caffeine citrate). The performance task was the practice GRE. A different form of this test was used on each of the 2 days. Subjects were allowed 10 min. to answer the 60 questions.

Experiment 2

Subjects. The subjects were 90 students from the same source used in the previous experiment.

Design and procedure. Each subject served for one 1½-hr. session. The experimental sessions started at 10:00 a.m. Subjects were given 10 min. to complete a pretest on one of the two forms of the practice GRE prior to drinking the Tang solution. They then filled out the personality questionnaires for 30 min. before taking the second form of the practice GRE. In half of the experimental sessions the subjects were allowed 10 min. to complete the second test, and in the other half they were allowed 20 min. The dosage of caffeine was 200 mg.

Experiment 3

Subjects. The subjects were 157 students from the same source as used in previous experiments.

Design and procedure. Each subject served in two 1-hr. sessions. The sessions were held at 9:00 a.m. and 7:00 p.m. Approximately half of the subjects were first tested in the morning and then in the evening. The remaining subjects were first tested in the evening and then in the morning. Approximately 36 hr. separated the two sessions for a given subject. When signing up for the experiment, subjects had a choice of whether to serve first in the morning or evening. Subjects were randomly assigned to receive caffeine during the first session and placebo during the second or to receive placebo first and caffeine second. The combination of the two variables (drug and time of day) resulted in four between-subjects conditions with approximately equal numbers of subjects in each condition. The four conditions were (a) caffeine in the morning of Day 1 and placebo in the evening of Day 2, (b) placebo in the morning of Day 1 and caffeine in the evening of Day 2, (c) caffeine in the evening of Day 1 and placebo in the morning of Day 2, (d) placebo in the evening of Day 1 and caffeine in the morning of Day 2. The experimenter was blind to the drug manipulation. The dosage of caffeine was 200 mg.

Experiment 4

Subjects. The subjects were 153 students from the same source as the previous experiments.

Design and procedure. The subjects served in one 1-hr. session at either 9:00 a.m. or 7:00 p.m. They assigned themselves to either the morning or evening session when they signed up for the experiments. The subjects were unaware until they arrived for the experiment that they would be asked to take caffeine. Subjects were randomly assigned to either the caffeine or the placebo condition. The amount of caffeine was 200 mg. The experimenter was blind to the drug manipulation. The performance task was 68 4-choice analogy problems (*A:B::C:?*). Distractors were used in these problems that were related to or were strong associates of the *C* terms. For example, *Pig:Boar::Dog:?* was one of the problems. The correct answer was *Wolf* and one of the distractors was *Cat*. The subjects were given 5 min. to answer the analogy problems and were encouraged to answer as many problems as possible.

Experiment 5

Subjects. The subjects were 121 members of the Northwestern University community. They had been recruited through an advertisement in the student newspaper. They were each paid $2.50 an hour for participating in the experiment.

Design and procedure. Each subject served in two 1-hr. sessions at 7:00 p.m. The sessions for a given subject were held on consecutive days. Subjects were randomly assigned to receive caffeine on Day 1 and placebo on Day 2 or placebo on Day 1 and caffeine on Day 2. The experimenter was blind to the drug condition. Three new performance tasks were used for the first time. These were the verbal, quantitative, and abstract reasoning tests from the Differential Aptitude Test (DAT). One form of each test was used on Day 1, and the alternative form was used on Day 2. Subjects were allowed 10 min. to complete each of the three subtests of the DAT. There were 50 items on each form of the verbal reasoning and abstract reasoning tests and 40 items on each form of the quantitative reasoning test. The dosage was 4 mg/kg of body weight.

Results

Taken together, these five experiments, in addition to the two previously reported, show very consistent patterns for some variables. Before reporting the results from each experiment and discussing their implications, we think it is worthwhile to consider this overall pattern. In order to make this pattern as clear as possible, the median performance expressed in standard score units (standardized within experiments) for Experiments 1–5 plus Revelle et al. (1976) and Gilliland (1977) has been plotted in Figures 1–3. These figures show the median performance as a function of experimental conditions and the personality variables of impulsivity (Figure 1), sociability (Figure 2), and introversion/extraversion (Figure 3). It should be noted that impulsivity and sociability, although subscales of introversion/extraversion, do not include all of the items from the entire introversion/extraversion scale. Thus, the results from the introversion/extraversion scale are not simply the sum of the results from the impulsivity and sociability subscales. The experimental manipulations shown in Figures 1–3 are the drug condition (caffeine/placebo), the time of day when the subjects were tested (morning/evening), and the stage of practice (Day 1/Day 2).

The most striking results are for the impulsivity subscale on Day 1. There is a crossover interaction in the morning (Figure 1, Panel a) and this interaction reverses in the evening (Figure 1, Panel b). That is, although low impulsives performed more poorly with than without caffeine in the morning of Day 1, they performed better with than without caffeine in the evening. The opposite is true for high impulsives, who were helped by caffeine in the morning and hindered by it in the evening. For impulsivity, the effects on Day 2 are not large, and in the evening the pattern of who is helped and who is hindered reverses from Day 1 to Day 2 (Figure 1, Panels b and d).

The results using the sociability subscale are in many ways dissimilar to the results using the impulsivity subscale. Compare the results in the morning for impulsivity and sociability (Figure 1, Panel a vs. Figure 2, Panel a, and Figure 1, Panel c vs. Figure 2, Panel c). For sociability, the Day 2 results are the most striking. In the morning, low sociables were helped by caffeine whereas high sociables were hindered (Figure 2, Panel c). This pattern reverses in the evening, where low sociables were hindered and high sociables helped by caffeine (Fig-

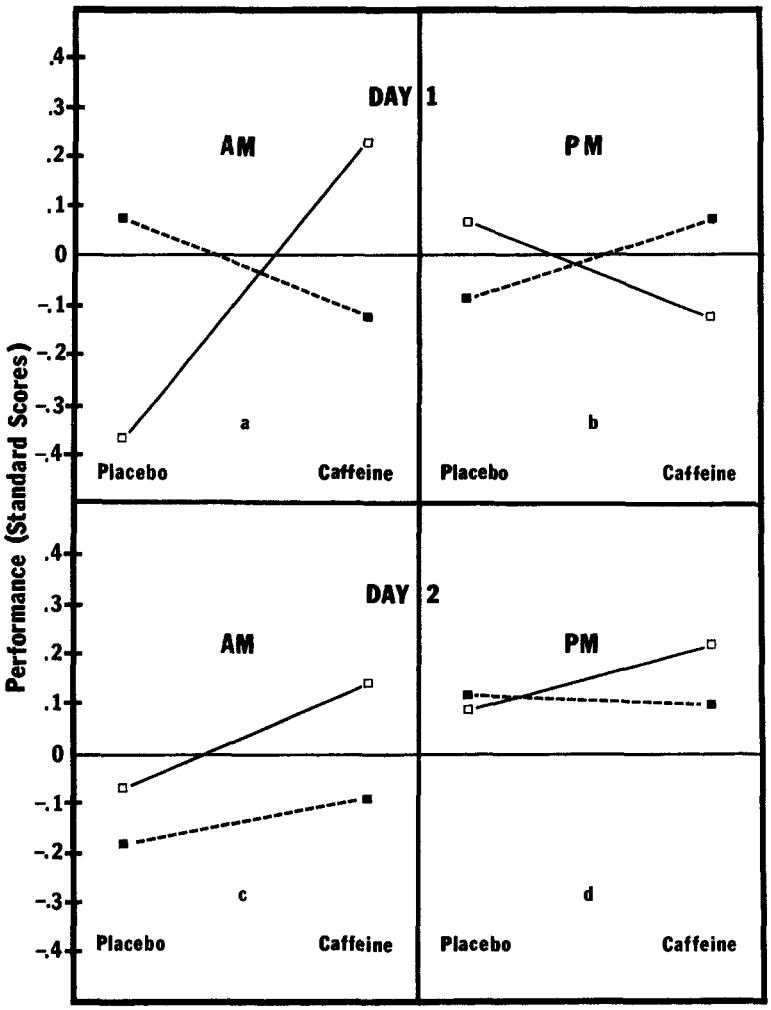

Figure 1. Median performance (in standard scores) as a function of impulsivity, placebo or caffeine, time of day, and experiment duration for Revelle et al. (1976), Gilliland (1977), and Experiments 1–5. (Low impulsives ■ - - - - ■ ; high impulsives □——□.)

ure 2, Panel d). Again note that in the evening there is a reversal in the pattern of who is helped and who is hindered by caffeine between Day 1 and Day 2 (Figure 2, Panels b and d).

Using the entire introversion/extraversion scale (Figure 3) appears to add nothing and may even detract from the effects noted for the subscales of impulsivity and sociability. In fact, the Day 1 effects for impulsivity are eliminated when the entire introversion/extraversion scale is used (Figure 1, Panel a vs. Figure 3, Panel a, and Figure 1, Panel b vs. Figure 3, Panel b).

In the remainder of the results section, the data from individual experiments will be reported. Because the interactive effects of drug and personality are larger and more consistent for the subscales of impulsivity and sociability than they are for the introversion/extraversion scale, only the results from these subscales will be reported.

Experiment 1

Experiment 1 was a 2-day, crossover design conducted in the morning. The variables were Day 1 versus Day 2 (day) and

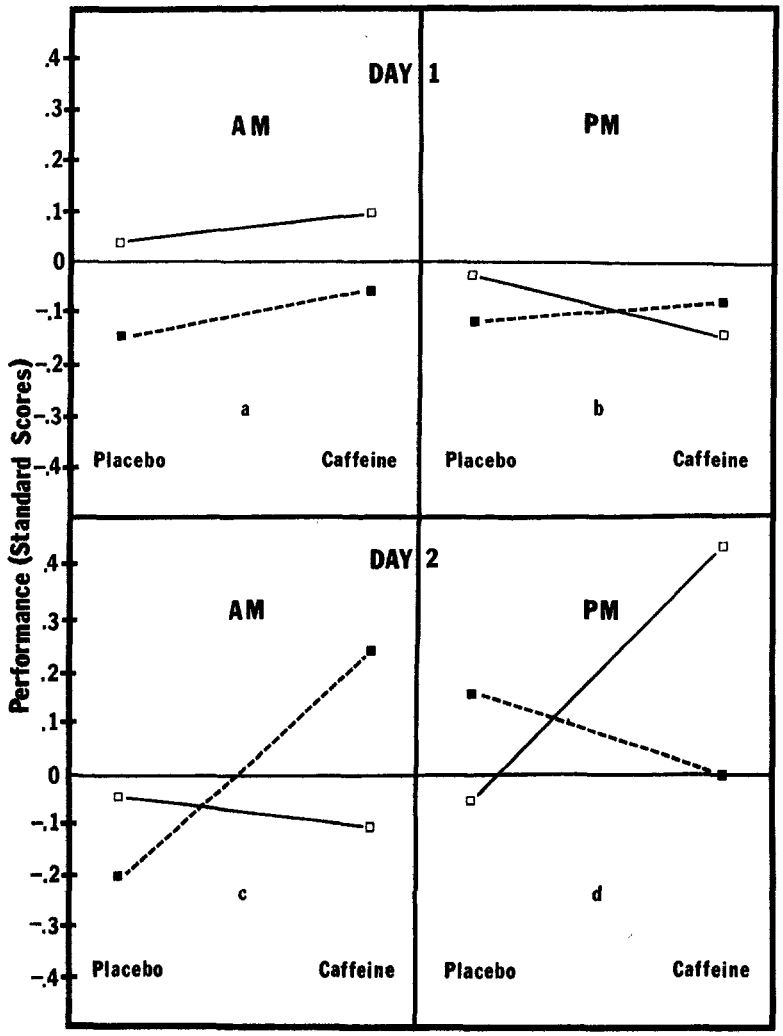

Figure 2. Median performance (in standard scores) as a function of sociability, placebo or caffeine, time of day, and experiment duration for Revelle et al. (1976), Gilliland (1977), and Experiments 1–5. (Low sociables ■ - - - - ■ ; high sociables □——□.)

caffeine versus placebo (drug). In addition, the subjects were divided into groups of high and low impulsives and high and low sociables. In this and all subsequent experiments these groups were determined by taking a median split of the scores on the impulsivity and sociability scales from the EPI. The results for both the impulsivity and sociability dimensions are given in Table 2. The entries in Table 2 are the mean number correct out of the 60 items on the test. On Day 1, low impulsives and low sociables appear to have been hindered by the administration of caffeine, down 1.39 and 1.60 points, respectively. In contrast to this decline, high impulsives and high sociables appear to have improved with the administration of caffeine, up 1.81 and 2.34 points, respectively. On Day 2, all subjects appear to have done better with caffeine. Statistical analysis partially confirms the differential effect of caffeine on Day 1 and Day 2. The Impulsivity × Drug × Day interaction was not significant,[2] $F(1, 104)$

[2] The level of significance chosen for these experiments was $p \leq .05$.

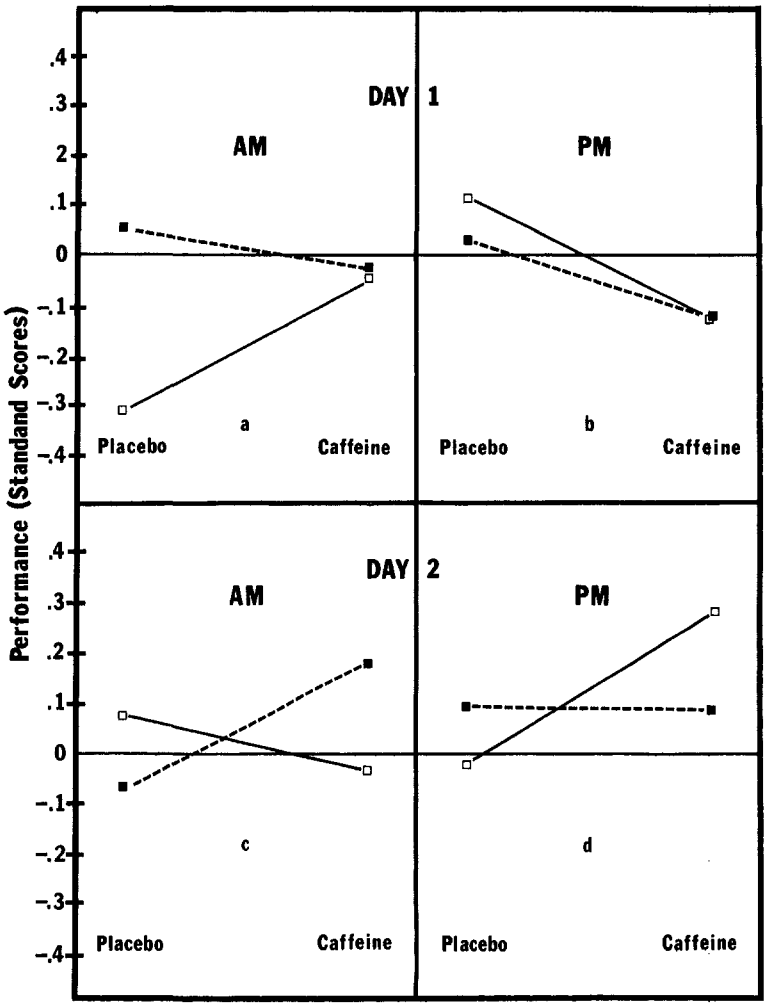

Figure 3. Median performance (in standard scores) as a function of introversion/extraversion, placebo or caffeine, time of day, and experiment duration for Revelle et al. (1976), Gilliland (1977), and Experiments 1–5. (Introverts ■ - - - - ■ ; extraverts □———□.)

= 2.86, $MS_e = 16.37$. However, the Sociability × Drug × Day interaction was significant, $F(1, 104) = 8.17$, $MS_e = 16.66$. There was also a significant improvement from Day 1 to Day 2, $F(1, 104) = 4.94$. Thus, this experiment showed that stage of practice was moderating the Personality × Drug interaction. In addition, the crossover interaction between impulsivity and drug was clearly shown to occur in the morning of Day 1 (see Figure 1, Panel a).

Experiment 2

Experiment 2 consisted of a single experimental session in which both a pre-and a postdrug performance measure were obtained. The variables were drug and time allowed to take the test (pacing). The results are shown in Table 3 for both the pre- and the posttest as a function of drug, pacing, and the personality variables of impulsivity and sociability. On the pretest there was a tendency for low impulsives and

Table 2
Mean Number Correct for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 1

Personality dimension	Day 1				Day 2			
	Placebo		Caffeine		Placebo		Caffeine	
	M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity								
Low	22.68	22	21.29	24	21.38	24	23.50	22
High	19.09	33	20.90	29	20.93	29	22.48	33
Sociability								
Low	21.48	25	19.88	24	20.71	24	23.80	25
High	19.73	30	22.07	29	21.48	29	22.13	30

low sociables who were to be given caffeine to do worse than those who were to be given placebos. Also high impulsives and high sociables who were to be given caffeine did better than those who were to be given placebos. However, neither the Impulsivity × Drug interaction nor the Sociability × Drug interaction was significant, $F(1, 86) = 2.25$, $MS_e = 41.37$, and $F(1, 86) = 3.05$, $MS_e = 39.71$, respectively. None of the other interactions or main effects was significant on the pretest. Although the Personality × Drug interactions were not significant on the pretest, it should be noted that the pattern on the pretest was the same as the pattern on the posttest. To some extent, then, the pattern on the posttest may have resulted from the fortuitous assignment of subjects to conditions.

On the posttest, as expected, the subjects in the relaxed conditions did substantially better than subjects in the timed conditions. However, the pattern of results was the same for the relaxed and timed conditions. Neither the Impulsivity × Drug × Pacing interaction, $F(1, 82) = .26$, $MS_e = 77.45$, nor the Sociability × Drug × Pacing interaction, $F(1, 82) = .25$, $MS_e = 88.26$, was significant. The Impulsivity × Drug interaction was not significant, $F(1, 82) = 2.18$,

Table 3
Mean Number Correct for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 2

Personality dimension	Test	Pacing							
		Relaxed				Timed			
		Placebo		Caffeine		Placebo		Caffeine	
		M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity	Pretest								
Low		21.82	11	20.15	13	18.44	9	17.53	15
High		16.62	13	20.25	12	19.10	10	20.29	7
Impulsivity	Posttest								
Low		36.09		34.54		20.67		19.00	
High		31.31		37.33		21.60		23.57	
Sociability	Pretest								
Low		22.73	11	20.12	17	19.89	9	18.38	13
High		15.85	13	20.38	8	17.80	10	18.44	9
Sociability	Posttest								
Low		36.27		35.53		21.22		19.54	
High		31.15		36.63		21.10		21.78	

Table 4
Mean Number Correct for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 3

Personality dimension	Time of day	Day 1				Day 2			
		Placebo		Caffeine		Placebo		Caffeine	
		M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity	AM								
Low		24.05	20	20.10	20	19.00	18	17.92	13
High		18.79	19	23.28	18	21.13	24	22.44	25
Impulsivity	PM								
Low		19.00	13	22.23	18	21.25	20	24.50	20
High		22.12	25	21.83	24	23.06	18	21.68	19
Sociability	AM								
Low		23.04	26	23.35	20	19.45	20	22.35	20
High		18.38	13	19.67	18	20.91	22	19.28	18
Sociability	PM								
Low		21.30	20	20.85	20	22.95	20	23.69	26
High		20.78	18	23.14	22	21.17	18	22.00	13

Note. AM = morning; PM = evening.

nor was the Sociability × Drug interaction, $F(1, 82) = 1.25$. Although the interactions between personality and drug condition were not significant, the pattern was the same as in the first experiment, and, for impulsivity, the same as in Figure 1, Panel a. That is, low impulsives and low sociables did worse with than without caffeine, whereas high impulsives and high sociables did better with than without caffeine. However, when change scores are calculated (the posttest mean minus the pretest mean), only the impulsives in the timed condition show this pattern. In change scores, the low impulsives in the timed condition did .75 points worse with than without caffeine, and the high impulsives did .59 points better with than without caffeine. The change scores for the relaxed condition showed that high impulsives were helped more by caffeine than were low impulsives, but the crossover pattern was not present. The low impulsives did .67 points better with than without caffeine, and the high impulsives did 2.75 points better with than without caffeine. For the sociability dimension, no discernable pattern was present in the change scores. In the timed condition, the low sociables did .25 points worse with than without caffeine, and the high sociables did .06 points worse with than without caffeine. In the relaxed condition, the low sociables did 2.04 points better with than without caffeine, and the high sociables did 1.12 points better with than without caffeine.

Experiment 3

Like Experiment 1, Experiment 3 was a 2-day, crossover design. In addition to the day and drug variables, Experiment 3 included a time of day variable. All subjects were tested in both the morning and evening. The mean number correct as a function of personality, day, drug, and time of day is shown in Table 4.

The most important result from this experiment was the demonstration that time of day was affecting the Personality × Drug interaction. The Impulsivity × Drug × Time of Day interaction was significant, $F(1, 149) = 27.99$, $MS_e = 15.38$. In the morning, the low impulsives did 2.52 points worse with than without caffeine, whereas the high impulsives did 2.90 points better with than without caffeine. In the evening, this pattern reverses, with low impulsives doing 3.29 points better with than without caffeine while high impulsives were doing .83 points worse with than without caffeine.

With respect to the sociability dimension, there was also a significant three-way interaction with the drug and time of day variables, $F(1, 149) = 5.43$, $MS_e = 15.33$. In the morning, the low sociables did 1.61 points better with than without caffeine, whereas high sociables did .17 points worse with than without caffeine. In the evening, the pattern changed as low sociables did only .95 points better with than without caffeine, and high sociables did 1.60 points better with than without caffeine.

As will be noted later, Day 2 performance in this experiment did not conform to the pattern found in the other studies. Because of the possibility that switching both the drug condition and the time of day on these subjects may have affected the Day 2 results, the Day 1 results were analyzed by themselves. This analysis confirmed the Impulsivity × Drug × Time of Day interaction, $F(1, 149) = 6.58$, $MS_e = 52.33$. In the morning, the low impulsives did 3.95 points worse with than without caffeine, whereas the high impulsives did 4.49 points better with than without caffeine. In the evening, this pattern was reversed as the low impulsives did 3.33 points better with than without caffeine, and the high impulsives did .29 points worse with than without caffeine. The pattern here is the same as the median pattern shown in Figure 1, Panels a and b. However, the Sociability × Drug × Time of Day interaction was not confirmed, $F(1, 149) = .16$, $MS_e = 50.54$. Furthermore, the Day 1 sociability pattern is not the same as the Day 1 impulsivity pattern, as it was for both days combined. In the morning of Day 1, both the low and high sociables did better with than without caffeine (.31 and 1.29 points, respectively). In the evening, the low sociables did .45 points worse with than without caffeine, whereas the high sociables did 2.36 points better with than without caffeine.

Experiment 4

In Experiment 4, the subjects themselves chose whether to be tested in the morning or evening. The dependent variable was the number correct on a 68-item analogies test. The results as a function of personality, drug, and time of day are given in Table 5. The interaction of Impulsivity × Drug × Time of Day was not significant, $F(1, 136) = 3.86$, $MS_e = 112.18$. However, the pattern of results was the same as the median pattern in Figure 1, Panels a and b. In the morning, low impulsives did 2.74 points worse with than without caffeine, and high impulsives did 8.46 points better with than without caffeine. This pattern was reversed in the evening, when low impulsives did 2.17 points better with than without caffeine, and high impulsives did .98 points worse with than without caffeine.

The triple interaction with sociability, drug, and time of day was not significant ($F < 1$). However, the Sociability × Drug interaction was significant, $F(1, 136) = 12.14$, $MS_e = 107.15$. These results differ from the impulsivity results in this experiment and from the sociability results in the previous experiment. In the morning, the low sociables did 9.19 points better with than without caffeine, and the high sociables did 5.30 points worse with than without caffeine. In the evening, the low sociables did 6.93 points better with than without caffeine, and the high sociables did 3.28 points worse with than without caffeine.

One possible explanation for the difference with the previous study could be in the amount of caffeine consumed prior to participation in this study. In Experiment 4, we had been primarily concerned with the characteristics of the subjects who would and would not take caffeine and who would select themselves for the morning or evening sessions (these results will be discussed later). For this reason, the subjects in Experiment 4 were not warned about the caffeine manipulation, and as a consequence, they were not told to abstain from caffeine for 6 hours prior to participating. If prior caffeine consumption was varying with time of day or with the sociability dimension, this might account for these discrepant results. Unfortunately, due to experimenter error a caffeine consumption questionnaire was not administered in Experiment 4, so this speculation cannot be verified.

Table 5
Mean Number Correct for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 4

Personality dimension	Morning				Evening			
	Placebo		Caffeine		Placebo		Caffeine	
	M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity								
Low	37.90	21	35.16	19	40.29	17	42.46	28
High	32.71	14	41.17	12	39.33	15	38.35	17
Sociability								
Low	33.35	20	42.54	13	36.92	13	43.85	20
High	39.13	15	33.83	18	41.84	19	38.56	25

Experiment 5

Experiment 5 was a 2-day experiment conducted in the evenings. Subjects served in both the placebo and caffeine conditions. The performance tasks were the verbal reasoning, numerical ability, and abstract reasoning subtests of the DAT. The numbers correct on each test as a function of personality, drug condition, and day are given in Table 6. The maximum numbers correct on the verbal, quantitative, and abstract tests are 50, 40, and 50, respectively. The experiment confirmed the findings of Experiments 1 and 3 in showing that the Impulsivity × Caffeine interaction is moderated by stage of practice. For the verbal, numerical ability, and abstract reasoning tests, the Impulsivity × Drug × Day interactions were significant, $F(1, 117) = 30.32$, $MS_e = 8.75$; $F(1, 117) = 4.73$, $MS_e = 7.56$; and $F(1, 117) =$

Table 6
Mean Number Correct for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 5

Personality dimension	DAT subtest	Day 1				Day 2			
		Placebo		Caffeine		Placebo		Caffeine	
		M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity	Verbal								
Low		33.79	28	37.70	30	36.70	30	34.57	28
High		35.66	32	34.48	31	33.74	31	34.91	32
Impulsivity	Quantitative								
Low		18.86		20.10		22.77		22.04	
High		20.75		19.77		22.68		22.81	
Impulsivity	Abstract								
Low		28.39		30.50		33.80		33.04	
High		30.75		29.45		32.19		34.50	
Sociability	Verbal								
Low		34.07	28	37.42	31	36.35	31	33.71	28
High		35.41	32	34.67	30	34.00	30	35.66	32
Sociability	Quantitative								
Low		18.21		20.84		22.35		20.29	
High		21.31		19.00		23.10		24.34	
Sociability	Abstract								
Low		27.14		30.10		33.97		31.46	
High		31.84		29.83		31.97		35.88	

Note. DAT = Differential Aptitude Test.

13.57, $MS_e = 11.67$, respectively. Moreover, the pattern for all three tests was the same as the median pattern in Figure 1, Panels b and d. On Day 1, the low impulsives did better with than without caffeine, and the high impulsives were worse with than without caffeine. On Day 2, this pattern reversed, so that the low impulsives did worse with than without caffeine, and the high impulsives did better with than without caffeine.

With respect to the sociability dimension, the effects were in the same direction as they were with the impulsivity dimension. For the verbal reasoning, numerical ability, and abstract reasoning tests, the Sociability × Drug × Day interaction was significant, $F(1, 117) = 29.91$, $MS_e = 8.88$; $F(1, 117) = 35.82$, $MS_e = 7.15$; and $F(1, 117) = 42.41$, $MS_e = 11.54$, respectively. The Day 2 pattern for all three tests was the same as the median pattern shown in Figure 2, Panel d. In addition, for both the numerical ability and the abstract reasoning tests, there was a significant improvement from Day 1 to Day 2, $F(1, 117) = 60.61$, and $F(1, 117) = 67.50$, respectively. The effect of days was not significant for the verbal reasoning test, $F(1, 117) = 1.45$.

Personality Variables

Experiment 4 was designed to answer questions about whether the traits of impulsivity and sociability were related to subject's decisions to participate in these studies. In this experiment subjects were allowed to sign up for either a morning or an evening session, and a roughly constant number were allowed to sign up each week during the academic term. In Table 7, the mean impulsivity and sociability scores are shown as a function of the time of day, time during the term, and drug condition. The impulsivity and sociability scores are from the EPI, which was administered after the drug or placebo was given to the subjects and before the performance test. For the impulsivity scores, neither time of day, $F(1, 127) = .02$; drug condition, $F(1, 127) = .25$, $MS_e = 2.62$; nor any of the other main effects or interactions were significant. For the sociability scores the interaction between drug and time during the term was significant, $F(3, 135) = 6.63$, $MS_e = 6.38$. None of the other interactions and none of the main effects were significant.

This interaction between drug condition and time during the term was surprising and somewhat disconcerting. We had thought that subjects with different personality characteristics might be signing up for the experiment at different times during the term or might be selecting themselves for the morning or evening sessions. However, we had not anticipated any effects due to the administration of caffeine. The finding was disconcerting, because any effect of drug condition on the personality scores would lead to interpretive problems. The issue here concerns the direction of causation. Is a stable personality trait causing the effects, or are the personality scores we are obtaining simply another manifestation of the basic effect? To investigate further the effect of drug on personality, the results from the other four experiments were analyzed. In these analyses the dependent measures were the impulsivity and sociability scores from the EPI. In the 2-day experiments, the EPI results are from Day 1. The independent variables were drug condition and time during the term (except for Experiment 5, which did not involve introductory psychology students). In addition, for Experiment 3, the time of the Day 1 testing session was included as a variable. In none of these experiments was the main effect of drug condition, or any of the interactions involving the drug condition, significant. For Experiments 1 and 2, the main effect of time during the term was significant for impulsivity, $F(3, 99) = 3.98$, $MS_e = 2.92$, and $F(3, 82) = 3.75$, $MS_e = 3.00$, respectively.

Thus, there is no evidence that caffeine affected the impulsivity scores. For each of Experiments 1–5 the mean score for the caffeine condition minus the score for the placebo condition was .01, .07, −.07, −.12, and −.09, respectively. For the sociability scores, the significant interaction found in Experiment 4 was not found in the other experiments. Furthermore, the pattern of results in these experiments did not resemble

Table 7
Impulsivity and Sociability Scores for Experiment 4 as a Function of Time in Term, Time of Day, and Drug Condition

Time of day and drug condition	Time in term (in quarters) 1st Score	1st *n*	2nd Score	2nd *n*	3rd Score	3rd *n*	4th Score	4th *n*	*M*
				Impulsivity					
Morning									
Placebo	4.64	11	4.00	8	2.83	6	4.30	10	4.09
Caffeine	3.45	11	3.50	6	4.43	7	4.71	7	3.97
Evening									
Placebo	4.00	7	4.20	10	5.00	10	3.60	5	4.31
Caffeine	3.57	7	3.58	12	4.25	12	4.79	14	4.13
				Sociability					
Morning									
Placebo	7.73	11	8.38	8	4.83	6	7.40	10	7.29
Caffeine	6.82	11	6.83	6	8.14	7	8.00	7	7.39
Evening									
Placebo	7.00	7	8.50	10	7.00	10	6.00	5	7.31
Caffeine	7.29	7	5.42	12	8.33	12	9.21	14	7.67

the Experiment 4 pattern. The differences in the sociability scores between the caffeine and placebo conditions were .23, −.21, .70, .25, and .24, for Experiments 1–5, respectively. The slight trend here (four out of five studies in the same direction), along with the significant interaction found in one out of five experiments, suggests at most a small effect of caffeine on sociability scores.

The next issue was whether there were any differences between the experiments in terms of subject characteristics. In Table 8 the mean impulsivity and sociability scores, the standard deviations of these scores, the reliability of the impulsivity and sociability scales, and the intercorrelation between these scales is given for Experiments 1–5. The differences between the experiments in these statistics are relatively small and appear to be largely unrelated to the magnitude of the observed effects. However, there was a difference between the reliabilities for the impulsivity and sociability scales. For all five experiments the impulsivity scale had a lower reliability than did the sociability scale. The median reliabilities were .48 and .71 for impulsivity and sociability, respectively. The median correlation, .25, between impulsivity and sociability was not very large and suggests that impulsivity and sociability need not always be considered as components of a higher order introversion/extraversion factor. (See also Revelle & Rocklin, 1979).

Table 8
Means, Standard Deviations, Reliabilities (α), and Intercorrelations of Impulsivity and Sociability Scales

Scale	Experiment 1	2	3	4	5
Impulsivity					
M	3.94	4.04	3.82	4.13	4.45
SD	1.79	1.86	1.79	1.63	1.82
α	.48	.49	.44	.38	.51
Sociability					
M	7.51	6.97	7.80	7.45	7.44
SD	2.68	2.85	2.77	2.70	2.56
α	.72	.74	.68	.71	.69
Sociability × Impulsivity	.25	.33	.31	.24	.25

Discussion

Consistencies Between Experiments

To facilitate comparisons between these five experiments and the two experiments previously conducted in our laboratory

(Gilliland, 1977; Revelle et al., 1976), data from all seven experiments have been combined into two tables. Table 9 summarizes the effects of caffeine on low and high impulsives. For each experiment, individual scores were first converted to standard scores using the within-cell error term. The average standard score in the placebo conditions was then subtracted from the average standard score in the caffeine condition. For Experiment 2, differences between the standardized change scores in the timed conditions are reported. For the Gilliland experiment, standardized change scores in the placebo and the 4 mg/kg of body weight conditions are reported. For the Revelle et al. experiment, the data from the timed conditions are reported, and the results from Days 2 and 3 are combined and reported in the Day 2 column. The pattern in the morning of Day 1 is especially clear. In each of the five studies conducted in the morning, the low impulsives were hindered and the high impulsives were helped by caffeine. The median loss (in standard deviations) was .22 for the low impulsives, and the median gain was .58 for the high impulsives. The pattern in the evening of Day 1 is also fairly clear. In Experiments 3 and 4 and for all three subtests used in Experiment 5, the low impulsives were helped by the administration of caffeine and the high impulsives were hindered. The only exception to this Day 1 pattern is the Revelle et al. study, in which low impulsives were slightly hurt by caffeine. However, in this study the high impulsives were hindered more by caffeine than were the low impulsives. Across all of these studies and tests, the median improvement for low impulsives was .27, and the median loss for high impulsives was .15.

Overall, the prevailing pattern for the impulsivity dimension on Day 1 in the morning was reversed in the evening. Low impulsives were hindered by caffeine in the morning and helped in the evening. High impulsives were helped by caffeine in the morning and hindered in the evening. Experiment 3 showed that this reversal in the Impulsivity × Drug interaction was not the result of different subjects selecting themselves for the morning and evening experiments, as this interaction was significant on Day 1. In Experiment 3, subjects were required to sign up for both an evening and a morning session. It seems highly unlikely that subjects who signed up to serve in the morning of Day 1 and the evening of Day 2 would differ from those who signed up to serve in the evening of Day 1 and the morning of Day 2. The results of Experiment 4 also support the conclusion that time of day was affecting the Impulsivity × Drug interaction. In that experiment, subjects had an opportunity to sign up for either a morning or an evening session. With respect to the person-

Table 9
Standard Score Differences Between the Caffeine and Placebo Conditions as a Function of Impulsivity for Revelle et al. (1976), Gilliland (1977), and Experiments 1–5

	Day 1				Day 2			
	AM impulsivity		PM impulsivity		AM impulsivity		PM impulsivity	
Experiment	Low	High	Low	High	Low	High	Low	High
Revelle et al.	—	—	−.11	−.96	—	—	−.05	−.79
Gilliland	−.16	.55	—	—	—	—	—	—
1	−.22	.28	—	—	.33	.24	—	—
2	−.12	.09	—	—	—	—	—	—
3	−.55	.62	.46	−.04	−.15	.18	.45	−.19
4	−.26	.80	.20	−.09	—	—	—	—
5 (Verbal)	—	—	.53	−.16	—	—	−.29	.16
5 (Numerical)	—	—	.18	−.14	—	—	−.10	.02
5 (Abstract)	—	—	.33	−.20	—	—	−.11	.36

Note. AM = morning; PM = evening.

Table 10
Standard Score Differences Between the Caffeine and Placebo Conditions as a Function of Sociability for Revelle et al. (1976), Gilliland (1977), and Experiments 1–5

	Day 1				Day 2			
	AM sociability		PM sociability		AM sociability		PM sociability	
Experiment	Low	High	Low	High	Low	High	Low	High
Revelle et al.	—	—	−.66	−.58	—	—	−.05	1.02
Gilliland	.24	.03	—	—	—	—	—	—
1	−.28	.36	—	—	.48	.10	—	—
2	−.03	−.01	—	—	—	—	—	—
3	.04	.18	−.06	.32	.40	−.22	.10	.11
4	.89	−.51	.67	−.32	—	—	—	—
5 (Verbal)	—	—	.52	−.11	—	—	−.41	.26
5 (Numerical)	—	—	.38	−.33	—	—	−.30	.18
5 (Abstract)	—	—	.47	−.32	—	—	−.39	.61

Note. AM = morning; PM = evening.

ality dimensions being considered here (impulsivity and sociability), there were only minor differences between the morning and evening subjects, though there was some evidence for selection effects as a function of time during the term. This suggests that the sign-up procedures used in most of these experiments (except for Experiment 5 and Revelle et al., 1976) did not produce strong selection effects.

Stage of practice clearly affected the Impulsivity × Drug interaction. In Experiment 5, this interaction was significant for all three tests. It was also significant for Revelle et al. (1976), $F(2, 188) = 3.95$, $MS_e = 83.73$. However, the nature of the change from Day 1 to Day 2 is not readily apparent.

Table 10 summarizes the effects of caffeine on high and low sociables. As in Table 9, the entries in Table 10 are the differences between the caffeine and placebo conditions in standard scores. Unlike the impulsivity results the sociability results are not consistent on the first day of testing. This is true for both the morning and evening sessions. As with impulsivity, there was a clear effect of stage of practice. The Sociability × Drug × Day interaction was significant in Experiment 1 and for all three tests in Experiment 5. For Revelle et al. (1976), however, this interaction was not significant, $F(2, 188) = 1.26$, $MS_e = 82.63$.

Probably the only way to make sense out of the Day 2 results for both impulsivity (Table 9) and sociability (Table 10) is to ignore the results of the third experiment. This was the only experiment without a significant Personality × Drug × Day interaction. Perhaps this was due to the design of the experiment, which provided for a switch in both the drug and the time of day conditions from Day 1 to Day 2. Ignoring Experiment 3, on the second day of testing, impulsivity and sociability seem to have affected performance in a similar manner. All subjects appeared to do better when given caffeine in the morning. In the evening, low impulsives and low sociables did worse when given caffeine, whereas high impulsives and high sociables did better when given caffeine. This finding was reported by Revelle et al. (1976) and appears in retrospect to be due to the fact that their subjects were given three testing sessions. That is, the results from Sessions 2 and 3 overshadowed the results from Session 1.

When the results from Day 2 are considered, it should be remembered that all of the multiday experiments involved a crossover design. That is, subjects who served in the caffeine condition on Day 1 were given placebos on Day 2, and subjects who were given placebos on Day 1 were given caffeine on Day 2. This design is inappropriate if

there was differential transfer from the Day 1 conditions. Before we draw any strong conclusions from the Day 2 results, it will be necessary to make use of a complete design in which some subjects do not receive both caffeine and placebo.

Arousal Theory of Introversion/Extraversion Revisited

Given the consistent patterns in the data, it is appropriate to ask how well they fit the arousal theory of introversion/extraversion. In order to fit an arousal model to these data we are making the following assumptions:

1. The administration of caffeine increases arousal;
2. If a performance decrement results from the administration of moderate doses of caffeine, then the subjects must have been initially optimally aroused or overaroused;
3. If a performance increment results from the administration of caffeine, then the subjects must have been initially underaroused.

In addition to these assumptions, the simple model outlined in the introduction hypothesized that introverts are more aroused than extraverts. With respect to the impulsivity subscale, this model fits the morning data: Caffeine hurt the performance of presumably highly aroused low impulsives and helped the performance of presumably less than optimally aroused high impulsives. This traditional model is unable, however, to explain the results in the evening of Day 1, the interaction between morning and evening, or the interaction between Day 1 and Day 2. A more plausible model that fits our Day 1 data and that follows from the research by Blake and his associates (Blake, 1967, 1971; Blake & Corcoran, 1972) is that high and low impulsives differed not so much in their overall arousal but in the phase of their diurnal arousal rhythms. Blake (1967, 1971) demonstrated that the body temperature of introverts both rises to its highest value and falls off from this peak several hours before that of extraverts. If we can assume that Blake's finding applies to the impulsivity dimension, then the Day 1 results support a modified arousal theory: Low impulsives achieve their peak arousal level earlier in the day than do high impulsives. This modified formulation suggests that in the morning, the low impulsives are optimally aroused without caffeine but that caffeine makes them too aroused and induces decrements in performance. High impulsives, on the other hand, are below their optimal level and become more aroused and more efficient with caffeine. In the evening, however, the arousal model only fits if the assumption is made that the low impulsives are now suboptimally aroused (on the down limb of their diurnal arousal curve) while the high impulsives are optimally aroused without caffeine. This follows from our assumption and the results, which showed that in the evening, the low impulsives were helped by caffeine, whereas the high impulsives were hindered by caffeine.

The impulsivity data from Day 2 in the morning are not consistent enough to be interpreted (perhaps due to the change in both the time and drug condition in Experiment 3). The evening data, however, are consistent enough to attempt to fit the modified arousal model. In order for the modified arousal model to fit the Day 2 evening data, it is necessary to make two post hoc assumptions. First, the high impulsive subjects must be assumed to have had a lower level of arousal in the evening of Day 2 than they had in the evening of Day 1. Perhaps they had habituated to the experimental situation and no longer found it particularly arousing. Second, the low impulsives must be assumed to have had a higher level of arousal in the evening of Day 2 than they had in the evening of Day 1. Perhaps they had experienced higher levels of discomfort than did the high impulsives during the Day 1 testing session. Because of this higher level of discomfort on Day 1, they might have been more apprehensive and thus more aroused during the Day 2 testing session. With these additional assumptions, the modified arousal model can fit the evening data on Day 2. That is, the low impulsives are now optimally aroused without caffeine and overaroused with caffeine, whereas the high impulsives are suboptimally aroused without caffeine and optimally aroused with

caffeine. This account of the Day 2 results is highly speculative and is without independent evidence supporting the two post hoc assumptions. Such evidence would consist of a demonstration that physiological or self-report indicators of arousal increased from Day 1 to Day 2 for low impulsives and decreased for high impulsives.

The lack of a consistent pattern on Day 1 for the sociability dimension negates the possibility of fitting an arousal curve to these sociability data. By the second day, however, the pattern does suggest that in the evening, low sociables were optimally aroused without caffeine and overaroused by the administration of caffeine, whereas the high sociables were suboptimally aroused without and optimally aroused with caffeine. It is interesting to note that although the impulsivity and sociability scales have different patterns on Day 1, they have converged into the classic introversion/extraversion interpretation by the evening of Day 2. That is, it appears as if introverts (low impulsives, low sociables) were optimally aroused without and overaroused with caffeine, whereas extraverts (high impulsive, high sociable) were underaroused without and optimally aroused with caffeine. These differences between Day 1 and Day 2 suggest that it is important to consider impulsivity and sociability separately as well as in combination at the higher order factor of introversion/extraversion. It is unfortunate that much previous research has not been broken down with respect to these two primary dimensions.

It is particularly unfortunate that the work relating personality to differences in the diurnal rhythm of arousal has not made this distinction between impulsivity and sociability. Blake's initial finding (1967) and subsequent studies with Corcoran (Blake & Corcoran, 1972) made use of the Heron (1956) scale of introversion/extraversion, which has both impulsivity and sociability components in unspecified amounts. Similarly, Patkai (1971) reported differences in the diurnal rhythm of adrenaline secretion in its relation to introversion/extraversion as assessed by the Maudsley Personality Inventory (Eysenck, 1959), an early form of the EPI. Finally, Folkard (1976) related differences in introversion/extraversion assessed with the EPI to the diurnal rhythm of pain sensitivity. Since none of these studies examined phase differences in terms of either impulsivity or sociability, it is impossible to conclude with certainty that impulsivity is the important component. However, on the basis of their findings, taken together with ours, which show that impulsivity interacts with time of day and sociability does not, we suggest that impulsivity and not sociability is related to the diurnal rhythm of arousal.

The complex pattern of results involving personality, time of day, stage of practice, and performance should be taken as neither confirming nor disconfirming arousal models. With some additional assumptions, an arousal model can be fit to these data. Alternative versions of arousal models that we have not explored may also fit these data. What the data do show, however, is that replicable results can be obtained, at least on Day 1. The stability of these results should permit the formulation and testing of more precise arousal models. Finally, these results show that the situation with respect to arousal manipulations is more complex than has generally been recognized. This point has been made quite well by Gale (1977) in his discussion of the determinants of arousal and its relationship to vigilance. Gale lists nine potential sources of arousal in experimental situations: (a) arousal due to stable individual differences; (b) arousal due to biological rhythms such as the menstrual and diurnal cycles; (c) arousal due to subject recruitment effects; (d) arousal due to experimenter–subject rapport and subject understanding of the purpose and conventions of the task; (e) arousal due to task mastery and choice of a proper strategy; (f) arousal due to task-specific effects (e.g., some tasks such as ours probably are arousal-inducing by themselves, whereas others, such as vigilance, are thought to be the opposite); (g) arousal due to situational effects of the experiment (e.g., group versus individual sessions, pleasant versus noxious environmental conditions); (h) arousal due

to feedback on how well the subject is doing; and (i) arousal due to extrinsic and intrinsic motivational characteristics of the subject and the experimental procedure.

In our studies we have found several of these sources of arousal to be important. Obviously the most important conceptually is the effect of stable individual differences in arousal. This effect was initially under investigation and is fundamental to the Eysenckian model. However, our data do not support the existence of such stable individual differences, but rather suggest that stable differences in the phase of the diurnal rhythm have an effect on the relationships between personality, stress, and performance. The previous interpretation of time of day results (e.g., Colquhoun & Corcoran, 1964) has been that introverts, who are normally more aroused than extraverts, become overaroused as the day progresses, and thus their performance deteriorates. However, our data, in conjunction with the earlier studies by Blake (1967) and Blake and Corcoran (1972) imply that this is not the case. Rather, they suggest that introverts, or specifically low impulsives, are more aroused than high impulsives early in the day and less aroused later in the day due to an earlier peaking of their diurnal arousal rhythm. If the low impulsives had been overaroused as Colquhoun and Corcoran (1964) suggested, the administration of caffeine should have further increased arousal and thus hurt performance. Since caffeine helped the performance of low impulsives, we conclude that they were underaroused.

In addition to differences in arousal between subjects, our studies also demonstrate the importance of several more of the determinants of arousal listed by Gale. It is quite likely that taking a test similar to the Graduate Record Examination is a very arousing manipulation for undergraduates. This is probably a more arousing task for this type of subject than it would be for many others. It is also possible that the arousal value of the task changes from Day 1 to Day 2. As a final point, it should be noted that the experimenter needs to control and preferably manipulate all of these possible sources of arousal in order to understand the relationship between arousal and performance. Individual differences must be taken into consideration, because there appears to be no main effect associated with caffeine and there may be few main effects associated with other arousal manipulations. In addition, we would not have observed a Personality × Caffeine interaction if we had collapsed the morning and evening conditions. It appears that the standard experimental practice of testing subjects at various times during the day may have prevented other investigators from finding these interactive effects between personality and manipulated arousal. The administration of caffeine (assuming that this increases arousal) is what permits us to determine whether the poor performance of introverts in the evening is due to underarousal or overarousal. Finally, stage of practice and/or degree of adaptation to the experimental setting must be considered in any analysis of the effects of arousal on performance.

Processes Underlying Performance Changes

Our experiments had been designed to replicate, extend, and test the generality of the Revelle et al. (1976) findings but not to elucidate the processes responsible for the performance increments and decrements. However, it is still possible to draw some tentative conclusions about these processes. The principle question about the process is whether it is peripheral or central. Although we cannot answer this question in general, it appears possible to eliminate a variety of peripheral processes, thereby lending some support to the idea that the changes are due to some fundamental change in the efficiency with which information is processed.

Distraction as an explanation for the performance decrements can probably be rejected. Some of our subjects reported gastric disturbances after taking caffeine, so a distraction effect seemed possible. However, the complex and apparently stable pattern of effects observed on Day 1 seems to rule out distraction as a general explanation. Individuals similar to those helped by caffeine in the morning were hindered by it in the

evening, and individuals similar to those who were hindered in the morning were helped in the evening. It is unlikely that a person who was susceptible to caffeine-induced gastric upsets, or any other form of caffeine-induced distraction, at one time of day would be helped by caffeine at another time of day. Furthermore, most of the subject reports that we got did not suggest that our subjects were particularly aware of the drug condition, at least on the first day of the experiment. Related to the distraction hypothesis is the possibility that our subjects differed in terms of their normal caffeine intake. Thus, those who showed improvements with caffeine might have been suffering from caffeine withdrawal symptoms (they had been asked not to take caffeine for 6 hours prior to the experiment). Those who showed decrements with caffeine might have been unaccustomed to caffeine and they might have suffered from gastric upsets, distraction effects, and so on. Again, the complex pattern of results on Day 1 does not support this explanation. In addition, when self-reports of caffeine consumption are examined, the amount of caffeine consumed appears to be small, suggesting that there would be little effect of caffeine withdrawal (see Gilbert, 1976). There was also no noticeable relationship with the personality variables except in Experiment 5. Subjects were asked to report average daily consumption of caffeine-containing substances such as coffee, tea, colas, stay-awake pills, and the like. Their responses were converted to cups of coffee equivalent (weighting tea and colas as .5 cups of coffee and stay-awake pills as 1.25 cups; see Gilbert, 1976). Subjects, whether high or low in impulsivity, reported drinking the equivalent of slightly more than 1.5 cups of coffee a day. The only exception to this finding was Experiment 5, where the high impulsives reported drinking 2.2 cups and the lows 1.5 cups per day. The difference was significant, $F(1, 119) = 7.34$, $MS_e = 2.35$. It is important to point out that the subjects in this experiment were somewhat older (mean age 19.5 years) than were the subjects in the other experiments (mean age = 18.8). It thus seems possible that in this population, differential caffeine consumption as a function of personality develops after a few years at college (see Bartol, 1975).

Another explanation that can probably be eliminated is some change in the willingness of the subjects to guess. Again, the complex pattern of results rules out any simple relationship between caffeine and willingness to guess. In addition, an examination of the number of overt errors did not reveal a consistent relationship between this statistic and the number correct. If changes in guessing were responsible for changes in the number correct, a positive correlation would be expected. With respect to the impulsivity dimension over all five experiments, there were 15 occasions when the number correct was greater for the subjects given caffeine than for those not given caffeine. In 8 of these 15 occasions, the number of errors was also greater for those given caffeine. There were 17 occasions when the number correct was less for the subjects given caffeine than for those not given caffeine. On 8 of these 17 occasions, the number of errors was greater for those given caffeine. The time of day effect and the stage of practice effect also appear to be largely unrelated to the changes in the error scores (The error data for Experiments 1–5 are given in the Appendix, Tables A1–A5.)

It also seemed possible that a change in some general test-taking strategy such as skipping the hard questions to answer the easy questions might be responsible for these results. However, finding the same basic results for tests that vary widely in difficulty and for varying degrees of time pressure does not support such an explanation. The analogies test used in Experiment 4 does not contain difficult items, as our subjects would be correct almost 100% of the time without the extreme time pressure employed (5 min. to answer 68 questions). The DAT subtests were also substantially easier for our subjects than were the practice GREs. Experiment 2, however, contained the only condition approaching the time pressure of a standard power test (20 min. to answer 60 questions). The pattern of

results in the posttest data for this condition was the same as in the other experiments. However, the change scores suggest that the Personality × Drug interaction may be attenuated at the slower rate.

Obviously, we have not eliminated all possible peripheral or strategic explanations for the observed increments and decrements. However, the stability of the effects (especially the Day 1 effects) over the range of cognitive tasks employed suggests that we are dealing with something more basic or fundamental. There is evidence from other experiments on introversion/extraversion and arousal that response competition may be involved (see Broen & Storms, 1961; M. W. Eysenck, 1976). There is also evidence supporting some disturbance in encoding processes (Hamilton, Hockey, & Quinn, 1972; Schwartz, 1975). Either of these notions might provide the basis for an explanation of our results. Easterbrook's (1959) suggestion that arousal leads to a narrowing of attention is harder to reconcile with these results on forced-choice tests. Possibly, narrowing of attention could be equated with inflexible encoding. Alternatively, narrowing of attention could result from inability to rapidly switch attention from one task to another. This in turn could result from some general deficit in working memory operations.

Implications for Personality Theory and Research

These findings regarding the relationship between personality differences and performance in stressful situations are relevant to the current controversy in personality theory with respect to the consistency, stability, and utility of traits (e.g., Block, 1977; Bowers, 1973; Mischel, 1968, 1973, 1977). The lack of a main effect for traits implies that a simple model of trait consistency is inadequate. The complex pattern of interactions with time of day could be taken as showing that traits are not very useful predictors of performance. This, however, would be a mistake, because the effects of caffeine, time of day, and stage of practice would not have been apparent without the inclusion of the individual differences variable. With the appropriate individual differences variable included, relative changes in cognitive performance greater than one standard deviation are observed.

In addition, these findings are relevant to the interactionist position that traits are only important in the way they interact with situational variables. Our results clearly show that the effects of impulsivity and sociability depend on situational determinants of arousal. However, the process of teasing out the Trait × Situation interactions has been greatly aided by our theoretical framework (the curvilinearity assumption and the assumption about stable individual differences in some aspect of arousal). It seems as if much of the current emphasis on Trait × Situation interactions ignores this point about the usefulness of theory in directing the search for the Trait × Situation interaction.

Also, it should be noted that our results suggest that the classic formulation of introversion/extraversion (Eysenck, 1967) needs to be reconsidered. On the first day in our studies, the two components of introversion/extraversion function in such a different fashion as to make the analysis of the secondary factor of introversion/extraversion of dubious value. This emphasizes the importance of suggestions by Gray (1973) and Schalling (1978) to look at impulsivity and sociability separately. It is possible, however, that in repeated-day studies, the functional independence of these two subscales is reduced. This needs to be explored in further investigations. It is also clear that on Day 1, the interpretation of main effect differences in arousal between high and low impulsives is incorrect. The more compelling explanation, compatible with our results and the earlier results of Blake (1967), Folkard (1976), and Patkai (1971), is that low impulsives reach their peak of arousal earlier in the day than do high impulsives. The result is that low impulsives are more aroused in the morning and less aroused in the evening than are high impulsives.

However, it is also important to point out that the meaning of impulsivity, as used in

this article, is not completely clear. We started this series of studies with the belief that introversion/extraversion was the best lead to follow in trying to understand individual differences in susceptibility to stress. We now feel that a subcomponent of this dimension, impulsivity, is a better lead. But impulsivity as we have measured it is clearly a complex construct. The nine-item impulsivity subscale of the EPI introversion/extraversion scale is not a psychometrically pure measure of anything. It includes items about not stopping to think, doing things on the spur of the moment, personal tempo, and risk-taking behavior. It is possible that this scale is a complex blend of different constructs, but it is also clear that there is enough in common in these items to produce the consistent pattern of results that we have observed in our studies. Clearly, further psychometric and experimental work refining the construct of impulsivity is in order.

Finally, our results suggest that the debate between Eysenck, on the one hand, and Cattell and Guilford, on the other, as to the importance of introversion/extraversion in a multivariate theory of personality cannot be resolved by factor analysis alone, but needs to take into account the results of carefully planned and executed experimental studies.

Conclusions

The most important conclusion from this series of studies is that it is possible to show reliable performance increments and decrements as a function of how people respond about their preferences and activities on a paper-and-pencil test and the administration of caffeine. The stable pattern of results from the first day allows us to specify those conditions in which we expect certain subjects to do well or badly under caffeine-induced stress. In the morning, low impulsives are hindered by the administration of caffeine, whereas high impulsives are helped by it. In the evening, low impulsives are helped by caffeine, whereas high impulsives are hindered by it. The results from the second day are not as powerful or as easily understandable. It is clear that something is happening between Day 1 and Day 2, but we are not able to specify what is accounting for the effect.

A second conclusion is that arousal theory can be profitably applied to our results. It should be reiterated, however, that by this we do not mean that introversion/extraversion has a main effect on arousal. It seems as if the relationship between personality and arousal is one of phase differences in the diurnal rhythm rather than a difference in chronic arousal, as was previously postulated.

Although we are unable to specify any particular cognitive process that could account for our effects, we have eliminated a variety of peripheral or strategic explanations. The complex pattern of interactions involving time of day and caffeine-induced stress certainly eliminates motivation and ability and probably eliminates distraction as possible explanations for the personality effects. Looking for some basic change in the efficiency with which information is processed seems worthwhile.

Reference Note

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Appendix

Table A1
Mean Number of Errors for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 1

Personailty dimension	Day 1				Day 2			
	M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity								
Low	8.05	22	8.17	24	8.17	24	8.14	22
High	8.21	33	8.79	29	9.62	29	7.12	33
Sociability								
Low	8.28	25	8.42	24	8.21	24	8.00	25
High	8.03	30	8.59	29	9.59	29	7.13	34

Note. Results are shown as a function of days and drug conditions. MS_e for impulsivity = 12.73 and for sociability = 12.78.

Table A2
Mean Number of Errors for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 2

Personality dimension	Pacing							
	Relaxed				Timed			
	Placebo		Caffeine		Placebo		Caffeine	
	M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity Pretest								
Low	6.18	11	8.08	13	6.44	9	6.60	15
High	8.08	13	9.00	12	6.70	10	5.86	7
Impulsivity Posttest								
Low	12.18	11	12.85	13	7.11	9	6.60	15
High	14.15	13	13.33	12	8.80	10	5.43	7
Sociability Pretest								
Low	6.45	11	8.76	17	5.67	9	6.46	13
High	7.85	13	8.00	8	7.40	10	6.22	9
Sociability Posttest								
Low	11.55	11	12.94	17	7.22	9	6.31	13
High	14.69	13	13.38	8	8.30	10	6.11	9

Note. Data are presented both as a function of pre- and posttest and as a function of drug condition and pacing. MS_e for the pretest was 6.91 for impulsivity and 6.76 for sociability. MS_e for the relaxed posttest was 27.02 for impulsivity and 26.23 for sociability. MS_e for the timed posttest was 8.70 for impulsivity and 8.95 for sociability.

Table A3
Mean Number of Errors for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 3

Personality dimension	Time of day	Day 1				Day 2			
		Placebo		Caffeine		Placebo		Caffeine	
		M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity	AM								
Low		7.50	20	8.25	20	7.94	18	7.69	13
High		8.63	19	11.94	18	8.29	24	8.44	25
Impulsivity	PM								
Low		7.46	13	8.33	18	6.70	20	10.05	20
High		7.68	25	9.71	24	8.72	18	8.89	19
Sociability	AM								
Low		7.42	26	9.75	20	6.95	20	7.20	20
High		9.31	13	10.28	18	9.23	22	9.28	18
Sociability	PM								
Low		7.55	20	8.05	20	7.60	20	9.46	26
High		7.67	12	10.09	22	7.72	18	9.54	13

Note. Results are shown as a function of day, time of day, and drug condition. AM = morning; PM = evening. MS_e between subjects was 21.61 for impulsivity and 21.85 for sociability. MS_e within subjects was 9.43 for impulsivity and 9.51 for sociability.

Table A4
Mean Number of Errors for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 4

Personality dimension	Morning				Evening			
	Placebo		Caffeine		Placebo		Caffeine	
	M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity								
Low	.62	21	2.37	19	3.12	17	.89	28
High	1.00	14	1.42	12	1.20	15	2.94	17
Sociability								
Low	.80	20	1.77	13	1.23	13	1.90	20
High	.73	15	2.17	18	2.89	19	1.48	25

Note. Results are shown as a function of drug condition and time of day. MS_e for impulsivity was 14.53 and 14.95 for sociability.

Table A5
Mean Number of Errors for Median Splits on the Impulsivity and Sociability Dimensions for Experiment 5

Personality dimension	Subtest	Day 1				Day 2			
		Placebo		Caffeine		Placebo		Caffeine	
		M	*n*	*M*	*n*	*M*	*n*	*M*	*n*
Impulsivity	Verbal								
Low		3.57	28	3.97	30	6.17	30	5.86	28
High		4.13	32	3.74	31	5.90	31	6.75	32
Impulsivity	Quantitative								
Low		4.18		4.37		3.97		3.32	
High		3.63		3.26		2.81		4.53	
Impulsivity	Abstract								
Low		3.50		5.50		4.97		2.61	
High		3.47		3.03		2.61		3.22	
Sociability	Verbal								
Low		3.68	28	4.65	31	6.65	31	5.39	28
High		4.03	32	3.03	30	5.40	30	7.16	32
Sociability	Quantitative								
Low		3.57		4.13		4.26		4.11	
High		4.16		3.47		2.47		3.82	
Sociability	Abstract								
Low		3.32		5.29		4.26		2.89	
High		3.63		3.17		3.27		2.97	

Note. Results are shown as a function of days, drug condition, and subtest of the Differential Aptitude Test. MS_e within subjects for verbal, quantitative and spatial for impulsivity were 6.01, 6.26 and 6.60, respectively. For sociability, these MS_es were 5.88, 6.33, and 6.54, respectively. The MS_es between subjects for impulsivity for these three tests were 24.76, 14.02, and 40.72, respectively. The MS_es between subjects for sociability were 24.09, 13.98, and 41.61, respectively.

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