Introversion/Extroversion, Time Stress, and Caffeine: Effect on Verbal Performance

Abstract. *Time pressure and caffeine differentially affected the performance of introverts on verbal ability tests similar to the Graduate Record Examination. With time pressure and 200 milligrams of caffeine, the performance of introverts fell by 0.63 standard deviation, but extroverts by 0.44 standard deviation.*

A classic, although widely challenged, finding in human and animal performance is that efficiency of performance is a curvilinear function of the stress induced by the task. Both high and low levels of stress are thought to be associated with inefficient performance, and moderate levels lead to optimum performance (*1*). Many anecdotal examples can be found of performance decrements under high stress, usually that associated with military combat or natural disasters (*2*), but it is difficult to find clear examples of decrements in performance for normal levels of stress (*3, 4*). Such decrements are usually open to the criticism that they occurred as a result of increases in distracting stimuli or because of contradictory task demands (*5*). The stress induced by taking an examination is usually assumed to be too little to lead to inefficient performance although performance on tests has occasionally been claimed to demonstrate curvilinear effects (*3, 6*). If performance on tests is curvilinearly related to stress, and if some individuals are more susceptible to this stress than others, then changes in the testing situation that lead to slight increases in stress should be beneficial for some individuals and harmful to others. In correlational terms, susceptibility to stress should be positively related to performance for low levels of stress, unrelated at moderate levels, and negatively related at high levels. We have found this to be the case.

We predicted that introverted individuals should be more susceptible to performance decrements under moderate levels of stress than should extroverted individuals. We expected that, with moderate increases in stress, introverts would decline in efficiency (and hence in performance) and extroverts would improve. That is, we expected the correlation between the introversion-extroversion dimension and performance to increase as stress was increased. This prediction derived from a theory of the behavioral and physiological differences between introverts and extroverts (*7*). In brief, this theory states that when variations in the environmental level of stimulation are controlled, introversion is positively correlated with cortical activation or arousal (*7*). Many of the behavioral correlates of introversion and extroversion reflect this differential arousal (*7, 8*). Other behaviors associated with introversion and extroversion are believed to be caused by homeostatic attempts to increase arousal (for example, by seeking stimulation) by under-aroused extroverts and to decrease arousal (for example, by avoiding stimulation) by over-aroused introverts (*9*). When proper controls are applied, psychophysiological studies of the differences between introverts and extroverts tend to substantiate this theory (*7–9*), although there is considerable question as to the unidimensionality of the introversion-extroversion construct (*10*).

We gave verbal ability tests under conditions presumed to differ in their arousing properties. The results are consistent with our predictions and indicate that the personality dimension of introversion-extroversion is related to test performance in a complex manner, and that certain testing conditions favor one end of the dimension while other conditions favor the opposing end.

We administered three equivalent tests of verbal ability (*11*) under three separate conditions to each of 101 undergraduate students. The forms and conditions were randomized for each subject (*12*). On one night the subjects were instructed to solve all 60 problems and to spend as much time as necessary. On another night, the subjects were allowed to spend only 10 minutes on the test, were told to work as quickly as possible, and were given two placebo pills which they were told contained 200 mg of either caffeine or lactose. The same procedure was followed on the third night, except that the pills actually contained 200 mg of caffeine (*13*). Subjects had been instructed not to consume any caffeine or other drugs for 6 hours preceeding each condition. They filled out the Eysenck Personality Inventory Form A (*14*) while waiting for the "caffeine" to take effect.

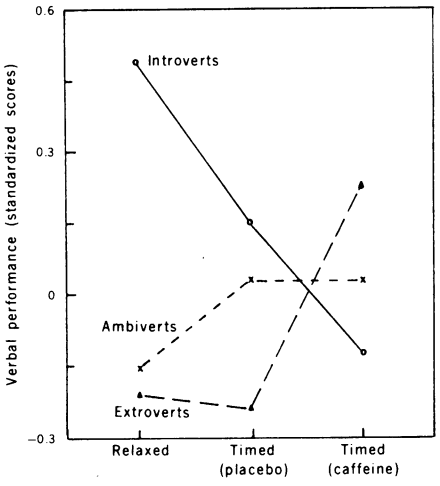

Fig. 1. Standardized performance scores (mean = 0, S.D. = 1) on practice verbal Graduate Record Examinations as function of introversion-extroversion, time pressure, and caffeine. The relaxed condition was standardized separately; the timed conditions were standardized together.

The correlations between number correct [corrected for guessing (*15*)] and the introversion-extroversion dimension were −.29 in the relaxed condition, −.18 under time pressure with placebos, and +.12 under time pressure with caffeine. Although the change in correlation from the relaxed to placebo conditions was not statistically significant, the change from placebo to caffeine conditions was (t-test of the difference between dependent correlations, $t = 3.38$, d.f. = 98, $P < .005$).

The distribution of introversion-extroversion scores can be divided into three groups, introverts, ambiverts, and extroverts (*14*) (Fig. 1). To allow for comparisons between scores achieved in different lengths of time, we converted all scores to standard scores. Scores from the relaxed condition were standardized separately, but means and variances from the two timed conditions were pooled before the scores were standardized. The appropriate correction for guessing (number correct − ¼ number incorrect) was applied to the scores before they were standardized (*16*).

The interaction between introversion-extroversion and situational stress (Fig. 1) is statistically significant (unweighted means analysis of variance, $F = 4.92$, d.f. = 4, 196, $P < .005$) (*17, 18*). In the two timed conditions, total performance can be separated into two components: speed (the number of problems attempted) and accuracy (the ratio of the number of problems correct to the number of problems attempted). The correlation between the introversion-extroversion dimension and speed did not increase significantly. For accuracy, however, there was a significant change in the correlation (from −.31 with placebos to +.02 with caffeine: $t = 3.15$, $P < .005$). For the grouped data, this indicated a decrease in accuracy from .69 to .63 for the introverts and an increase in accuracy from .60 to .64 for the extroverts. This implies that the locus of the effect is not merely a response style of trading off

speed for accuracy on the part of the introverts.

Before we generalize from these results, several limitations should be considered. (i) The relaxed condition allowed the subjects as much time as they required to complete the test. This is more generous than even normal "power" (untimed) instructions. (ii) The timed conditions were shorter than normally allowed on standard ability tests. (iii) The performance shift from relaxed to time stress is a relative shift (scores were standardized within condition); almost all subjects solved more problems in the power condition. In the timed conditions, however, the shift is absolute rather than relative; when treated with caffeine, introverts correctly answered fewer problems and extroverts more problems. (iv) Differences in performance in the relaxed condition could be a result of differences in arousal (our hypothesis) or represent different levels of involvement in the task. If introverts are assumed to be relatively more interested in intellectual problems, they might be expected to do better when allowed unlimited time. In the timed conditions, however, this explanation is less convincing. In the same testing session some subjects were administered placebo and others caffeine—a condition that diminishes the likelihood of differential susceptibility of introverts and extroverts to possible expectations of the experimenter.

Our effects are interactive ones and not main effects. Caffeine-induced stress neither raises nor lowers average performance but rather increases the performance for some individuals and decreases it for others. Similarly, across the two drug conditions, there was no net superiority for either introverts or extroverts. These findings suggest a paradigm for studying the effects on performance of stressors in conjunction with dimensions of personality. Specifically, this methodology overcomes many of the objections raised to previous studies of the curvilinear relationship between stress and performance (*5*).

WILLIAM REVELLE
PHYLLIS AMARAL
SUSAN TURRIFF

Department of Psychology,
Northwestern University,
Evanston, Illinois 60201

References and Notes

1. R. M. Yerkes and J. D. Dodson, *J. Comp. Neurol. Psychol.* **18**, 459 (1908); P. L. Broadhurst, *Acta Psychol.* **16**, 321 (1959); E. Duffy, *Activation and Behavior* (Wiley, New York, 1962).
2. R. B. Malmo, *On Emotions, Needs, and Our Archaic Brain* (Holt, Reinhart, and Winston, New York, 1962).
3. J. E. Hokanson and M. Burgess, *J. Abnorm. Soc. Psychol.* **68**, 698 (1964); R. T. Wilkinson, S. El-Beheri, C. C. Gieseking. *Psychophysiology* **9**, 529 (1972).
4. P. Patkai, *Int. J. Psychiatry Med.* **5**, 575 (1974).
5. R. Näätänen, in *Attention and Performance IV*, S. Kornblum, Ed. (Academic Press, New York, 1973), pp. 155–174.
6. J. W. Atkinson and J. O. Raynor, Eds., *Motivation and Achievement* (Winston, Washington, D.C., 1974); C. D. Spielberger and I. G. Saronson, Eds., *Stress and Anxiety* (Halsted, New York, 1975); E. Gaudry and C. D. Spielberger, Eds., *Anxiety and Educational Achievement* (Wiley, New York, 1971).
7. H. J. Eysenck, *Biological Basis of Personality* (Thomas, Springfield, Ill., 1967); J. A. Gray, in *Multivariate Analysis and Psychological Theory*, J. R. Royce, Ed. (Academic Press, New York, 1973).
8. G. S. Claridge, *Personality and Arousal* (Pergamon, Oxford, 1967); M. G. H. Coles, A. Gale, P. Kline, *Psychophysiology* **8**, 54 (1971); A. Crider and R. Lunn, *J. Exp. Res. Pers.* **5**, 145 (1971); R. B. Sloane, P. O. Davidson, R. W. Payne, *Arch. Gen. Psychiatry* **13**, 19 (1965).
9. H. J. Eysenck, in *Emotions—Their Parameters and Measurement*, L. Levi, Ed. (Raven, New York, 1975), pp. 439–467; F. Farley and S. V. J. Farley, *Consult. Psychol.* **31**, 215 (1967).
10. J. P. Guilford, *Psychol. Bull.* **82**, 802 (1975).
11. G. R. Gruber and E. C. Gruber, *Graduate Record Examination Aptitude Test: A Complete Review for the Verbal and Math Parts of the Test* (Simon & Schuster, New York, 1973). The first 60 questions (20 each of analogies, antonyms, and sentence completions) of practice tests 2, 3, and 4 were used.
12. There were no noticeable relationships between performance and the sequence of either the conditions or the tests. All sessions began at approximately 7 p.m. to control for possible diurnal effects [M. J. F. Blake, *Nature (London)* **215**, 896 (1967)].
13. Actually 400 mg of caffeine citrate was administered. This contained 200 mg of caffeine which is roughly equivalent to one and one-half to two cups of coffee [J. F. Greden, *Am. J. Psychiatry* **131**, 1089 (1974)].
14. H. J. Eysenck and S. B. Eysenck, *Eysenck Personality Inventory* (Educational and Industrial Testing Service, San Diego, 1964). The scores defining each group were 2 to 9 (introverts, $N = 27$), 10 to 15 (ambiverts, $N = 45$), and 16 to 21 (extroverts, $N = 29$). The mean extroversion score was 12.5 (S.D. = 4.5).
15. The correlations with number right (uncorrected) were −.28, −.13, and +.14.
16. The means before standardization were 37.3, 21.1, and 21.9 (S.D. = 8.6, 8.5, and 9.0) for the relaxed, placebo, and caffeine conditions, respectively.
17. Similar analyses were done with the neuroticism scale from the Eysenck Personality Inventory, but there were no significant effects.
18. A preliminary study with 60 subjects and 100 mg of caffeine had similar results. Introverts ($N = 18$) fell from +0.25 to −0.36 sigma units, while extroverts ($N = 11$) rose from +0.01 to +0.22. Ambiverts ($N = 31$) rose slightly from −0.2 to −0.16.
19. We thank J. Barry and L. Gourley for assistance in collecting the data for the pilot study and L. G. Humphreys, M. Humphreys, and two anonymous reviewers for helpful comments on an earlier draft of this paper.

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Two Functional Effects of Decreased Conductance EPSP's: Synaptic Augmentation and Increased Electrotonic Coupling

Abstract. *Three electronically coupled motor neurons, which mediate inking behavior in* Aplysia californica, *receive both increased and decreased conductance excitatory postsynaptic potentials (EPSP's). The increased conductance EPSP's reduce electrical coupling among the cells, whereas the decreased conductance EPSP's increase electrical coupling. The decreased conductance EPSP's also augment the action of a previously ineffective sensory input and this augmentation is enhanced by the increase in electrical coupling. Both effects combine to trigger a stereotypic behavioral response.*

Studies of vertebrate and invertebrate nerve cells indicate that different neurons receive and generate a variety of electrical and chemical synaptic actions. For example, excitatory chemical synaptic actions are usually mediated by an increased conductance to Na^+ and K^+ (*1*), but similar although slower synaptic excitation can be mediated by a decreased conductance to K^+ (*2*). Some insight into the functional role of the synaptic diversity of neurons can be gained by examining the synaptic actions of nerve cells in relation to behavior. We here compare the functional consequences of increased and decreased conductance synaptic excitation for three electrotonically coupled motor cells and the behavior which they mediate. We find that a synaptically activated increase in membrane conductance reduces electrotonic coupling [see also Spira and Bennett (*3*) and Kater (*4*)]. This synaptic input triggers a stereotypic inking response to a single strong, suprathreshold stimulus. The synaptically activated decrease in membrane conductance increases electrotonic coupling. In addition, it augments the action of a previously ineffective sensory input (*5*). Both effects combine to trigger inking in response to closely timed subthreshold stimuli.

In response to noxious stimuli, *Aplysia californica* exhibits an all-or-none stereotypic response in which copious amounts of dark purple ink are ejected from the mantle cavity (*6*). This response is mediated by three identified motor neurons located in the abdominal ganglion ($L14_A$, $L14_B$, and $L14_C$). The three motor neurons are silent, have a high resting potential (approximately −65 mv), and are electrotonically coupled to one another (see Fig. 2A). A single brief electrical stimulus to the connectives (nerve tracts that carry input to the abdominal ganglion from the head ganglia), or to peripheral nerves, produces similar synaptic responses in all three nerve