

Environmental Stressor Effects on Creativity and Decision Making

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Abstract

What happens to higher cognitive processes when people are exposed long-term environmental stressors? To find out, 32 subjects were placed in a small, uncomfortable, and crowded chamber for either 24 or 48 hr. An additional 32 subjects served as controls in a non-stressful environment. All subjects were given a series of problem solving and decision making tasks at various times. Subjects showed a consistent decrease in creativity with increased exposure to environmental stressors. In contrast, the stressors had little effect on verbal problem solving ability, general intelligence, or decision-making strategy. Control subjects did not show systematic changes in any of the tasks. This pattern of results suggests that environmental stressors had little effect on well-structured tasks requiring clearly identified processing strategies. Larger effects were observed, however, for tasks calling for creative responses based on strategies that could not be identified in advance. The results have important implications for developing procedures for reducing stress effects. The paper ends with a discussion of the generality of results for tasks, subjects, and stressors.

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Introduction

Higher thinking processes require a variety of cognitive processing abilities, such as problem solving, creativity, memory, and decision making (Hogarth, 1987). Both psychological theory and common sense maintain that thinking ability may be impaired under highly stressful conditions. For instance, it has been hypothesized that individuals under stress will exhibit a narrowing of focus and stereotyped responding (Mandler, 1979, 1984). Such shifts would be incompatible with the cognitive processes necessary for effective high-level thinking (Halpern, 1989).

Early research on attention (Callaway & Dembo, 1958) and cue utilization (Easterbrook, 1959) suggests that one reaction to stress involves a narrowing of attention. Later research has focused on exploring the effects of time stress on various basic cognitive processes, such as attention and vigilance (e.g., Hockey, 1979). There has been little research, however, on the effect of environmental stressors on complex cognitive functioning.

The purpose of this research project is to evaluate the effects of environmental stressors on higher cognitive processing. Initially, subjects were given a series of simple and complex tasks to complete in a comfortable, non-stressful situation. They were then placed in a climate-controlled chamber characterized by noisy, uncomfortable, and crowded conditions. During their stay, subjects completed the same series of tasks to evaluate their cognitive ability. Comparisons can be made between the two conditions.

In addition, there was a control group that completed the tasks in a non-stressful environment. Thus, stress effects can be

evaluated by comparing experimental subjects to control subjects.

The research was guided by two central questions. First, do environmental stressors effect cognitive performance? It is possible that such external factors have little impact on cognitive functioning. Second, if there are stressor effects, are they greater in more complex tasks, such as decision making and creativity, than in simpler tasks? That is, are higher level processes more disrupted by stress effects than low-level processes?

The present study examined stressor effects in three ways. First, subjects' performance in each task was evaluated at successive time intervals – stressor effects should appear as a deterioration in behavior. Second, the results for tasks varying in complexity can be compared to determine if environmental stressors influence some behaviors more than others. Third, the performance of experimental subjects can be compared to non-stressed control subjects.

Method

Four groups of eight experimental subjects were placed in a small, crowded, uncomfortable chamber for 1 or 2 days. Nurses were present to monitor the subjects and to administer the research instruments. Subjects were given a series of cognitive tasks to perform at various times during their stay. Control subjects were treated similarly, except they were in a normal experimental room.

Environmental Chamber. A special chamber was constructed in the Institute for Environmental Research at Kansas State University. The chamber measured 12' by 9.6' and contained 2 bunk beds, a toilet, a storage cabinet, an exercise bicy-

cle, and a research table. There was about 10 square feet of open area per person. The chamber was climate controlled, with two levels of temperature (72°F/22°C, 86°F/30°C), two humidity levels (50% Rh, 86% Rh), and two duration levels (24 hr, 48 hr)¹.

The conditions in the chamber were characterized by: (1) Complete confinement during the duration of the study. (2) Normal sleep patterns were disrupted with a series of four-hr alternating work/rest schedules.² (3) During the awake periods, subjects were kept busy with a series of cognitive tasks involving memory, problem solving, attention, and decision making. (4) Participants were also required to ride a special exercise bicycle (which ran a ventilating fan) for two 15 min periods during each 24 hr period. (5) Normal eating habits, as well as personal hygiene patterns, were disrupted by the constraints of the chamber environment. According to subjects' postexperimental reports and the nurse-experimenters' observations, these conditions did create a very uncomfortable and stressful environment.

Subjects

Stress Group. The 16 women and 16 men in the stress group were obtained by distributing fliers to a variety of police, fire, and medical agencies in Riley County, Kansas.³ Each participant was given an initial physical examination by a registered nurse and required to fill out a detailed medical history. These results were reviewed by a physician; only those individuals the physician felt could handle the stress of the environmental chamber could take part. Subjects in the 24-hr tests were paid \$200 for their participation; those in the 48-hr group were paid \$350.

Two participants could not complete the experiment. One male in a 24-hr group reported feeling too claustrophobic and asked to leave. One female in a 48-hr group could not tolerate the heat and lack of sleep; she was removed from the chamber by the nurse-researchers. The data from these subjects were not used.

Control Group. The 16 men and 16 women in the control group were obtained from a newspaper advertisement. Twenty-one of the participants were students, with the remainder from the local community. The control subjects were paid \$20 for their time.

One male and one female had scores on the creativity test lower than the tabled norms. Therefore, control-group results are reported for 15 women and 15 men.

Experimenters

Two registered nurses were responsible for initial physical examinations of the stress group. They also administered the research instruments and monitored the subjects well being while in the chamber. One nurse was present in the chamber at all times; they alternated 12-hr shifts. They were paid for their time.

Two students connected with the project were the experimenters for the control groups. They ran the control subjects in a manner parallel to the experimental session. They were paid for their time.

Procedure

A common procedure was used for all tasks. Before entering the chamber, subjects went through the first version of the instruments under non-stressful conditions. Once in the chamber, they then

completed at least one and as many as three more versions of all instruments. The number of presentations of each task depended on the availability of alternative forms and total time in the chamber (24 or 48 hr). The different forms were randomly assigned for presentation at various times. The results reported here make clear how often each task was presented.

Control subjects completed the tasks under similar timing conditions. However, they were run in comfortable surroundings with normal sleep, eating, hygiene, etc.

Instruments

Ten cognitive tasks were used, ranging from attention and memory to problem solving and decision making. Six of the tasks are reported here; the results for the remainder were not different in any substantial way from these six. In addition, subject's performance on the exercise bicycle was monitored; those results are not relevant here.

Memory Recall. As a measure of memory performance, immediate and delayed recall tasks were used (Lindsay & Norman, 1977). Subjects heard a list of 18 words. Immediately after the presentation, they were asked to recall as many words as possible. Following an intervening task lasting 20 min, they were asked again to recall as many words as they could.

Various lists were used. One was presented before the experiment began and others were presented at varying times during subjects' stay in the chamber.

Anagram Solution. As a measure of verbal ability, subjects were asked to solve a set of anagrams (Feather, 1982). For example, they had to determine which word(s) could be made from a reordering

of the letters in "ONEASS" (the answer is below). The anagrams were chosen to be of about equal difficulty, with roughly 50% solution rates (Feather, 1965).

Various sets of anagrams were presented, the first in the prechamber session and the remainder during different times in the chamber. Subjects were given 30 sec to solve each of seven anagrams in a set. (The answer to the anagram is "SEASON.")

IQ Measure. Despite the controversy over their uses (and misuses), IQ tests provide a highly reliable measure of individual differences (Morris, 1988). However, IQ scores can be subject to various short-term and long-term environmental factors (Sternberg, 1986). To measure IQ, subjects were given several versions of a standardized test developed by Eysenck (1962).

Subjects had 30 min to complete booklets (labeled "puzzle solving") contained 40 questions each. An example of one of the questions is: "Insert the missing number: 4 9 17 35 ___ 139" (the answer is given below). Other question types involved odd-man out identifications, relationship between figures, missing words, and anagrams. Various versions were administered before and during the time in the chamber. IQ scores were estimated using norms developed by Eysenck (1962). (The answer is "69").

Creativity. The ability to generate novel solutions to problems is vital to effective thinking (Adams, 1986). Creativity was measured using the AC Test of Creative Ability (Industrial Relations Center, 1953, 1954). Two forms were administered, one in the prechamber session and one in the final part of subjects stay in the chamber. The test was designed to measure the quantity and quality of ideas people gener-

ate in work situations; this is better suited to the subjects' background than more academically oriented tests.

There were three sections in the instrument: In the first 20-min section, subjects were to list as many possible consequences of a work situation as they can, e.g., "In a final assembly department employing 16 women inspectors, only 7 come to work on a given day." Subjects were then to list all the consequences they could think of.

The second 10-min section required subjects to produce reasons why a particular work situation might be true, e.g., "April is the month when the fewest accidents of any kind occur in the U. S." They were to list all the reasons that it might be true.

In a third 15-min part on originality, subjects generated as many uses for five common objects (e.g., "a red brick") as they could. This is similar to the Unusual Uses test (Torrance, 1966).

Calibration. The ability to assess accurately the state of one's uncertainty can be measured by calibration. For a well-calibrated decision maker, the stated probabilities should match the observed proportion of events. Under stress, it might be expected that subjects' ability to assess probabilities would become less accurate. To determine calibration, subjects gave probability assessments for general knowledge questions; this task has been widely used in risk assessment research (e.g., Fischhoff, Slovic, & Lichtenstein, 1977).

Two versions of the calibration instrument were given to subjects, one in the prechamber session and one at the end of the stay in the chamber. These two versions have been established as equivalent in previous analyses (Slovic, 1983). Each version had 50 two-alternative questions such

as, "Which magazine had the largest circulation in 1970, Playboy or Time?" Subjects then gave probability assessments of being correct.

Impression Formation. One of the most frequently used tasks in social judgment research is impression formation. Subjects are asked to form an impression of a person described by several personality or character traits (e.g., Anderson, 1962). In the task used here, subjects evaluated job applicants described on realistic personnel forms; the task was developed by Nagy (1981) and Gaeth (1984).

Subjects assessed 32 hypothetical applicants for the job of computer programmer. Each applicant was described by two job relevant cues (years of relevant experience and recommendation of past employer) and three job irrelevant cues (age, gender, and physical attractiveness).⁴ Other items, such as phone, address, etc., were included as fillers to make the application form more realistic. The 32 cases were generated from a $2 \times 2 \times 2 \times 2 \times 2$, experience \times recommendations \times age \times gender \times attractiveness, factorial design. Subjects (unknowingly) judged all cases twice to estimate an error term for the Analysis of Variance. The subjects went through the task in the prechamber and in the chamber session.

Results and Discussion

The findings for various tasks were analyzed in two ways. First, results for each task were compared across different test administrations; this led to either a prechamber-chamber or prechamber-earlychamber-latechamber, within-group analyses. Second, experimental (chamber) subjects were compared to control (nonchamber) subjects; this led to a between-

group analysis. The general strategy will be illustrated for the memory recall task.

Memory Recall. As expected, experimental subjects remembered more words in the immediate recall condition (Mean = 10.6) than in the delayed recall condition (M = 3.0). Immediate recall was somewhat better in the prechamber session (M = 11.4) than in the chamber sessions (M = 10.3). Delayed recall also was better in the prechamber (M = 4.3) than in the chamber (M = 2.5).

Recall results for control subjects were comparable. For instance, immediate recall (M = 10.2) was superior to delayed recall (M = 3.2). Surprisingly, control subjects (like their experimental group counterparts) had higher recall scores in the first session (M = 4.0) than in the last three sessions (3.0).

Analyses of group x session interactions were significant for both immediate, $F(3,180) = 4.31$, and delayed recall, $F(3,180) = 2.80^5$. For immediate recall, experimental subjects showed a decline across sessions, with some improvement in the last session; control subjects showed a gradual increase across all four sessions. For delayed recall, experimental subjects had a steady decline across the first three sessions with an improvement in the last session; control subjects had a similar, but less pronounced pattern.

In all, recall scores were worse with exposure to environmental stressors. However, there are two factors to consider before drawing any conclusions. First, there is no consistent evidence that increased time in the chamber had an effect. Second, performance of control subjects shows the same pattern as the experimental subjects. Taken together, these findings provide

mixed evidence of environmental effects on recall.

Anagram Solution. The analyses showed no significant differences in any of the tests. In the prechamber session, for instance, the mean number of correctly solved anagrams was 4.5 for experimental subjects. In the chamber, the overall mean was not significantly different at 3.9. Moreover, the first and second chamber sessions were nearly identical (M = 3.8 and M = 4.0). Thus, the anagram task was not sensitive to environmental effects.

IQ Measure. As shown in Figure 1, there were sizable differences in mean IQ measures for experimental subjects across sessions, $F(3,177) = 48.12$. The prechamber results were lowest, with the middle session in the chamber yielding the highest values. The plot shows an inverted-U shape.

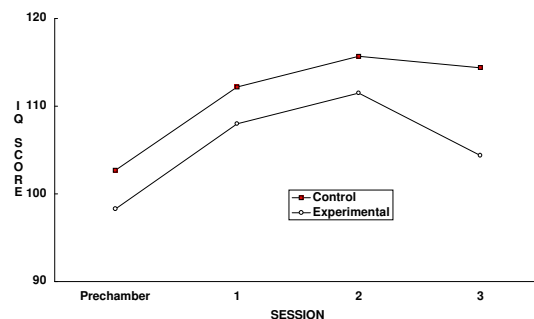


Figure 1. Mean IQ (puzzle solving) scores for experimental and control groups over four sessions.

Control subjects revealed a similar pattern, except for the last session. There was a significant groups x sessions interaction, $F(3,177) = 3.11$. Further analyses revealed the interaction was concentrated in the last session; with it removed, the interaction drops out, $F(2,118) < 1$. There was no apparent reason for the differences in the last session.

Although there were significant results, the pattern is not that expected from stressor effects for three reasons. First, performance improved from prechamber to experimental sessions; this may reflect learning, but is not indicative of stress. Second, the trend peaks during the middle session, not at the beginning or the end; this does not show the monotonic relationship expected from continued exposure to stressors. Finally, except for the final session, there is a constant difference between experimental and control subjects. Thus, the IQ measure does not show sensitivity to stressor effects.

Creativity. The mean creativity scores for experimental and control groups on the prechamber and chamber administrations of the creativity test appear in Figure 2. The experimental subjects show a sizable decline, whereas the control subjects are unchanged.

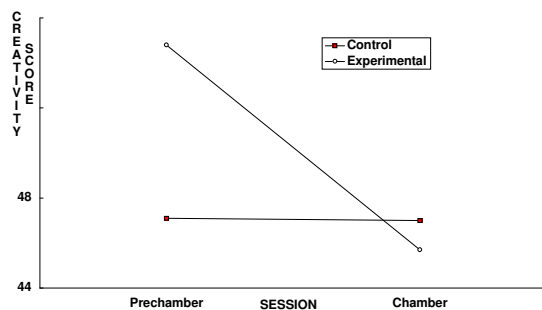


Figure 2. Mean creativity scores for experimental and control groups over two sessions.

Statistical tests revealed a significant groups \times session interaction, $F(1,58) = 19.94$. The decrease in experimental scores is significant, $t(58) = 6.51$, whereas control scores are not significantly different.

Three other analyses were conducted to determine the consistency of the results. First, the decline was examined for the four separate groups of experimental sub-

jects. A 4×2 , groups \times session, analysis of variance revealed a significant session main effect, $F(1,26) = 32.20$, but no group main effect or interaction. Thus, similar effects were observed in all experimental groups.

Second, separate t tests were conducted to examine the three parts of the creativity test. All parts showed significant decrements with stress, $t(29) = 5.11, 3.82,$ and 3.32 , respectively.

Third, changes for individual subjects were examined. For the experimental group, 24 of 30 subjects had a decrease in creativity, 4 increased, and 2 were unchanged. For the control group, 14 subjects decreased, 15 increased, and 1 was unchanged. The difference is significant, $\chi^2(2) = 9.33$.

The reliability of the creativity measure was examined by correlating the scores on the two forms of the test; the order of these forms was counterbalanced across sessions. The reliability coefficients for the parallel forms were $r(28) = .73$ and $.77$ for the experimental and control groups. These values are similar to that reported in the test manual ($r = .75$) for parallel forms. In addition, reliability was checked by having the tests scored by two independent raters; the intercorrelation was quite high, $r(58) = .99$.

The pattern of creativity scores reveals a clear stressor effect both in the prechamber-chamber decline and in the difference between experimental and control subjects. Interesting, experimental subjects started with higher scores than control subjects; in the second session, the two groups are nearly alike. Thus, performance of the more experienced experimental group falls to the level of inexperienced control group.

Calibration. The calibration scores for probability assessments were comparable to results obtained in prior studies (e.g., see Lichtenstein, Fischhoff, & Phillips, 1982). That is, subjects were overconfident in their estimates for items of moderate and high difficulty. There was no difference, however, between the prechamber and chamber conditions in the calibration scores for experimental subjects. Furthermore, the experimental and control subjects were not significantly different. Thus, the overconfidence in the calibration scores was not effected by stressors.

Impression Formation. The pattern of job-applicant evaluations was comparable to the results reported by Gaeth (1984) and Nagy (1981; also see Shanteau & Nagy, 1984). That is, subjects relied primarily on the job-relevant attributes of experience and past recommendations in making judgments. Less emphasis was placed on job-irrelevant attributes of age and gender. There was no evidence the pattern of results changed as a function of stress.

Comparisons between experimental and control subjects revealed minor differences not related to stress. For instance, controls placed more emphasis on the age attribute than experimental subjects. This may be due to the relative inexperience of control subjects in job hiring situations. While the implications of this effect are worth exploring for personnel hiring practices, there was no evidence of change as a function of environmental stressors. Thus, impression formation strategies were not influenced by stress.

General Discussion

The study produced two interesting results. The first involves the psychological effects that environmental stressors produced on creativity. The second involves the ab-

sence of stressor effects on other cognitive processes, particularly judgment and decision making. Each of these results will be discussed followed by comments on the generality of the present findings.

Stress and Creativity

The present results clearly show creativity is reduced in a stressful environment. Mean performance on the AC Test of Creativity revealed a significant decline for experimental subjects, whereas performance for control subjects was unchanged. Followup analyses confirmed the reliability of this trend, ie, similar decrements were observed in all three parts of the creativity instrument. Moreover, individual analyses showed that 80% of experimental subjects had declining creativity scores, whereas controls were evenly split between showing gains and declines. Thus, environmental stressors produced a consistent decrement in creativity scores.

One surprising result was that performance did not differ across the four experimental groups. It was expected that longer exposure to stressors (48 vs. 24 hr), higher humidity (86% Rh vs. 50% Rh), and greater heat (86°F/30°C vs. 72°F/22°C) would enhance stress effects. Although there were some trends in that direction, the results did not reach significance. More research is needed to determine if there is a temporal or climatic component to the observed effect.

The finding has both specific and broad implications for how people cope with stressful environments. Specifically, in emergency enclosures, such as storm shelters, responsible individuals could find their well-being dependent on creative responses to unexpected problems. Moreover, it seems likely that stress in an actual shelter might be greater than in this study.

If creativity is reduced under stress, then adaptive behaviors may be impaired.

It is important to consider the development of appropriate techniques for coping with these effects. It may be help, for instance, to warn individuals about the negative effects of environmentally-induced stress on creativity. Alternatively, people might “pre-think” solutions to difficult problems instead of relying on spontaneous answers; expert decision makers were observed by Shanteau (1992) using pre-thinking as a strategy to deal with difficult problems. In any case, the observed decrement in creativity has important implications for emergency behavior.

In a broader sense, the present results have implications for a variety of stressful environments. Although researchers have speculated about effects of environmental stressors such as noise, fatigue, and crowding on workplace behaviors (Ivancevich & Matson, 1980; Sharit & Salvendy, 1982), the effects on creativity remained unexplored. Yet, many jobs may call for creative responses in stressful situations.

Although the environmental research chamber used here may seem artificial, there are a variety of real-world settings that involve similar circumstances. Many workplaces are characterized by crowded, uncomfortable surroundings and workshifts that disrupt normal day-night sleep cycles. Indeed, the experimental subjects (police, nurses, and fire fighters) often work in such settings. It is notable, therefore, that stress effects were observed for these experienced subjects. Presumably less experienced subjects would be even more susceptible.

Other Psychological Processes

The behaviors analyzed in this study, excluding creativity, can be separated into two categories. The first involves verbal behavior in the memory recall, anagram, and written IQ tests. The second involves the decision making processes of probability calibration and impression formation. Despite the many differences between these two categories, minimal stressor effects were observed for both.

The failure to find stressor effects in verbal behaviors might be explained by the overlearning and highly repetitive practice associated with language. Any skill rehearsed as much as word usage may be more-or-less resistant to environmental influence. This is supported by the anecdotal observation of the nurse experimenters that subjects maintained their conversational styles in the chamber. Although often terse and showing signs of irritation, subjects could carry on normal discussions and express themselves even at the end of the session. This suggests that well practiced skills may be unaffected by environmental stressors.

The finding that decision making performance was not influence by environmental factors was more surprising. Judgment and decision making, along with creativity and problem solving, are usually classified as “higher cognitive processes” (Solso, 1991). These processes are the most complex and involve the highest levels of thought. Given the depth of cognitive analysis necessary, it seems reasonable that stressors might interfere with these processes.

Nonetheless, the present results show little impact of the stressors on the probability calibration and impression formation tasks. Both involve thought and analysis,

and take some time to complete. Like creativity, these decision making tasks call for multi-level cognitive processing. Then why did stressor effects appear for creativity and not for these tasks?

One possible answer is that both calibration and impression formation are repetitive tasks. Although the stimuli change from trial to trial, the response requirements are unchanged. Thus, once a subject adopts a decision strategy, it may be possible to keep applying that same strategy under stress. Indeed, the initial task presentation in the prechamber session may allow subjects to develop such a consistent strategy. This strategy can then be followed when the subject is faced with environmental stressors.

In contrast, the creativity instrument was the only task used here that is not repetitive. Not only are the various sections of the measure different, but the type of questions precludes developing a common strategy. This suggests that other non-repetitive tasks, including some decision problems, may be subject to stressor effects.

Generality

Consideration of the generality of present findings can be addressed at three levels: tasks, subjects, and stressors. Each of these deserves discussion.

Task Generality. The choice of specific tasks to represent cognitive domains is crucial. It is possible that different tasks could have produced different results. For instance, recognition memory might have shown a greater decrement under stress than recall. And there are a variety of other decision tasks that might have been chosen, such as gambling choices.

There were seven criteria used to select the tasks used here. First, each task had to be representative of the domain. Second, there had to be multiple versions available. Third, the results must be easy to score. Fourth, subjects' performance had to be measurable in quantitative terms. Fifth, the task should be understandable by the experimental subjects (who were older, less educated, but more experienced than college students). Sixth, the tasks as a set had to contain a balanced assortment of problem types. Lastly, there had to be a reasonable chance that stressor effects would emerge.

Given these constraints, many tasks were considered and rejected. Most were eliminated for failure to meet the criteria above. Others were eliminated because they needed special equipment that could not be maintained in the experimental chamber, such as computers.

Obviously, there is no way to know whether the observed results will generalize to other tasks. We do believe, however, the tasks are representative of various domains and tap into processes and strategies common to each domain. Therefore, we are comfortable that the tasks chosen have as good a chance as any to produce generalizable results.

Subject Generality. The sample of experimental subjects was selected from an unusual population. Police, fire fighters, and nurses are atypical subjects. They work in high stress occupations with relatively low pay and professional status. Except for nurses, they were not college educated and, as the IQ scores show, they have average intelligence. They also are older than the typical research subject, more likely to be married with children, and tend to live in less affluent areas of

town. In short, they are better described as “blue collar” than “white collar.”

We would argue that these subjects are closer to the larger population than the typical college students. More important, the experimental subjects were the most relevant for the research project. They are likely to have experienced and to be involved in environmental stressor situations. And given the nature of their occupations, other people depend on them to cope effectively with stress. Thus, their results are important for this project.

From another view, these subjects because of their background should be better able to handle environmental stressors. Using a “toughest case” logic, if these subjects show stress effects, then similar effects will probably be found for others. And it is likely that less experienced subjects would show even larger effects.

Perhaps it reflects the subjects’ experience that few of the tasks showed any stress effects. Most of their performance was more-or-less unchanged by continued environmental stressors. The subjects’ general ability to perform at a consistent level makes the stress effects that did occur notable.

Stressor Generality. There is another question of generality: Will the results here generalize to other types of stressors? In the present study, there were a variety of stress factors. These included the physical stressors of crowding and noise. There also were personal-state stressors of irritability and sleeplessness. Lastly, there were task-related stressors of time pressure (in most tasks) and performance anxiety.

Since many studies of stress use only one or two stressors, it is difficult to compare our results to other studies. Given the vari-

ety of stressors used here, it is not possible to say which stressor or combination of stressors had the greatest impact. It is also impossible to determine whether our specific findings will generalize to other situations. Clearly, more research is needed on the generality of effects observed with different stressors.

Footnotes

¹ Originally, the plan was to have eight groups of subjects in a 2 x 2 x 2, temperature x humidity x duration, design. However, the study was terminated after only four groups were run because of changes in funding priority by the project sponsor.

Separate analyses were conducted for each group. There were no consistent differences between the groups for any of the instruments reported here. Therefore, the results have been combined across the four groups.

² Only four bunk beds were available for sleeping. Therefore, separate work/rest schedules were constructed for the eight subjects. Half of them rested while the other half worked.

³ One of the goals of the Federal Emergency Management Agency, which supported this project, was to study how emergency personnel functioned in a highly confined environment. Therefore, it was necessary for the project to use subjects whose occupation and experience exposed them to environmental stressors.

⁴ Hiring laws in the U. S. and Kansas prohibit discrimination in employment on the basis of age or gender.

⁵ All significant effects reported at the .05 level.

Author Notes

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