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~~Before we~~ can progress further toward the development of a more general theory of stress and performance in work environments, requires the ~~we need to determine~~ whether diverse stressors produce different types of stress (strain) responses in addition to the different levels of response that have been frequently observed. In the present experiment, four stressor conditions are systematically compared in their effects on blood pressure and heart rate responses. It was found that three stressor environments which differed from each other on a number of variables but had a social setting in common produced diverse degrees but similar kinds of blood pressure and heart rate responses. Different kinds of stressor responses were obtained in a non-social (video game) hand-eye coordination task. It is suggested that if future research extends this finding to the stressor-performance relationship, theories of stress and performance will have to consider complex interactions among a number of relevant variables.

Differential Effects of Four Stressors on Blood Pressure and Heart Rate

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It has been widely recognized that stress,* particularly at excessive levels, may contribute to decrements in human task performance. Unfortunately, detrimental stress levels frequently do exist in work environments. Improving performance and satisfaction of the work force are linked to the development of environments which do not contain excessive stressor conditions. To

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*For the purpose of this paper, the word "stressor" will be used to describe stimulus conditions impinging on a person. The physiological effects of excessive stressor levels will be considered as "strain." The resulting conscious experience will be considered "stress." Subsequent performance will describe the level and quality of work during a stress experience. Distinctions will also be made between kind and degree of response to stressors. For example, if stressor "A" would result in a 10% increase in heart rate and a 20% increase in systolic and diastolic blood pressure, while stressor "B" produces a 15% increase in HR and a 30% increase in SBP and DBP, the effects will be considered different in degree. If, on the other hand, stressor "C" results in a 30% increase in SBP and a 10% decrease in DBP and HR, we will speak of differences in the kind of effect. Similar relationships can be drawn for the effects of various stressors on measures of performance.

develop better, more pleasant and more effective work environments, we need to learn more about stressors and their effects than we know to date. It is especially necessary to know whether different forms of stressors in the work environment (e.g., social stressors vs. task-related stressors) operate in the same or in differential fashion to produce important physiological responses (strain) and subsequent changes in performance and satisfaction. Do stressors differ only in the degree of strain and stress experience (and performance change) which they produce, or do they differ in the characteristic kind of physiological response and the type of performance change as well? If we wish to generate an overall theory of stress, if we wish to make relatively simple predictions about the stressor to performance relationship, then a single stress response in working human beings would certainly be welcome. If, on the other hand, stressors differ not only in the degree but also in the kind of effect they have on physiological responses and subsequent performance, or if different stressors interact with specific tasks in unique ways to modify physiological status and subsequent response, then we will have to engage in considerably more effort to learn when and where we need to intervene to optimize task performance and satisfaction. In the present paper, the relationship between various stressor conditions and physiological activity (strain) as measured via increases and decreases of blood pressure and heart rate will be considered. The employed stressor conditions will vary in level and will be both social and non-social. The selected stressor conditions will be manipulated in an experimental setting and will be similar to stressors experienced in work environments.

We know that stressor conditions which impinge upon persons act upon their cardiovascular systems. Indices of these effects are measurements of systolic blood pressure, diastolic blood pressure and heart rate. As a first approximation, simultaneous increases in blood pressure (particularly systolic) and heart rate are typically interpreted as indicants of sympathetic arousal due to stressor conditions. Diastolic blood pressure increases (without parallel systolic elevation) in the presence of relatively constant or decreasing heart rate have been considered an effect of increased peripheral resistance (vasomotor tone), representing a somewhat different kind of strain response to potentially different kinds of stressors. If this is so, then the measurement of heart rate and pressor responses is the most convenient non-invasive indicator of kind and degree of experienced stress. As a result, this form of measurement is quite useful to determine whether different degrees and kinds of stressor conditions have similar or diverse effects on human physiological status and, potentially, on subsequent work performance. It would be particularly useful to determine whether different stressors merely produce different degrees of physiological strain, or whether they result in diverse kinds of strain responses as well. If there is little commonality in the hemodynamic responses to work environment related stressors and tasks, then little commonality of subsequent performance across the various stressor conditions might be expected and diverse procedures for reducing stressor conditions in the work environment may be required.

Previous research on the effects of stressor conditions on hemodynamic responsivity has not been very systematic in nature. Different researchers have typically employed different kinds of subjects, diverse tasks and varying environments to obtain single or few measures of cardiovascular response. Such research suggests that physiologic reactivity to diverse stressor conditions may or may not be different in degree and type. The majority of researchers have obtained data suggesting that blood pressure and heart rate tend to become elevated with stress experience (e.g., Andrien and Hansson, 1981; Bassan, Marcus and Ganz, 1980; Bonelli, Hörtnagl, Brücke, Lochs and Kaik, 1979; Roscoe, 1978; Rush, Shepherd, Webb and Vanhoutte, 1981; Sime, Buel and Eliot, 1980). Stressor tasks utilized in such research efforts have varied widely, e.g., from landing aircraft to performing mental arithmetic. Despite the good number of research efforts reporting similar or equivalent results, some researchers have obtained data that appear to be inconsistent with the more general find of similar degrees of physiological response to diverse stressors. For example, Danner, Endert, Koster and Dunning (1981) found that students about to take a medical school examination did present with elevated diastolic blood pressure, unchanged systolic blood pressure and decreased heart rate. Cacioppo and Sandman (1978) presented their subjects with cognitive tasks (arithmetic, string memorization and anagrams) and with an unpleasant visual task (watching slides of an autopsy). While heart rate showed an increase in the cognitive tasks, it decreased upon presentation of the autopsy slides.

Differences in cardiovascular reactivity may lead us to search for potential differences among stressors as they affect human physiologic responsivity or as they interact with tasks, environments and social settings to produce specific responses. Such an explanation would suggest that differential physiological responses (e.g., peripheral vascular resistance vs. increase in heart rate or output) would be due to specific stressor types which would need to be identified. However, one may also propose a quite different set of reasons for the divergent data mentioned above. The obtained discrepancies might, for example, be due to individual differences, i.e., the type of persons represented in the samples of specific researchers. Considerable data on differences among individuals of diverse characteristics to (equally diverse) stressors have been collected. For example, Vossel and Laux (1978) have shown that persons adapt to stressors, even if previously presented in a different mode, and will show less physiological arousal (cardiovascular responsivity) to subsequent stressors. Other researchers have demonstrated that a number of cognitive styles affect the degree to which altered cardiovascular hemodynamics are obtained (e.g., Gaines, Smith and Skolnik, 1977; Kelsall and Strongman, 1978; Streufert, Streufert, Dembroski and MacDougall, 1979; Woods, 1977). Attempts have been made to relate certain personality variables to cardiovascular arousal as well (e.g., Hinton and Craske, 1977; VanImschoot, Liesse, Mertens and Lauwers, 1978). The large volume of research on the Type A coronary prone behavior individual and his/her exaggerated reactivity is now very well known (e.g., Dembroski, Weiss, and Shields, 1978). Elevated cardiovascular responsivity to certain stressors may also be aggravated by specific work or job characteristics. Sime et al. (1980), for example, report data indicating that blood pressure was considerably higher for executives as compared to non-executives in their sample. Finally, cardiovascular hemodynamics may be affected by recently taken medication, particularly beta blockers, and other drugs used to decrease the autonomic neural effects on the cardiovascular system. Specifically, heart rate elevations to stress appear to be diminished or eliminated while elevations in blood pressure often persist (e.g., Bonelli, et al. 1979; Dunn, Lorimer and Lawrie, 1979; Heidbrenner, Pagel, Röckel and Heidland, 1978; Nakano, Gillespie and Hollister, 1978).

While the data indicating discrepant types of responsivity to diverse stressor conditions are suggestive, they are hardly conclusive. As long as data are obtained with diverse tasks, different subject populations, diverse experimental settings and somewhat varying measurement techniques, one cannot be certain that those studies reporting disparate physiologic types of responsivity are reliable and valid, especially in the face of the larger number of research efforts that have reported differences in degree, but not in kind of responsivity. Moreover, we cannot be certain that the obtained differences in the kind of physiological reponse stem from settings that are even remotely related to standard work environments. A reliable test of the question as to whether different stressor conditions will produce physiological (here, cardiovascular) responsivity which varies not only in degree but also in kind requires that measurement methods and external environment are held constant, and that responsivity to a number of different stressors is obtained from the same group of subjects, performing tasks that are similar to tasks that may occur in work environments. Some initial efforts in this direction (although often not particularly relevant to work environments) have been reported. For example, Andrien and Hansson (1981) exposed their subjects to both cold pressor and arithmetic tasks. While they obtained increased blood pressure in both tasks, only heart rate increased on the arithmetic task. Rush et al. (1981) measured cardiovascular reactivity during physical exercise and mental stress with essentially similar results. Light and Obrist (1980), on the other hand, found that persons reacting with specific arousal in one task would react similarly in other tasks. As already mentioned, Cacioppo and Sandman (1978) obtained diverse arousal measures in unpleasant visual as compared to unpleasant cognitive tasks. Discrepancies of this nature have led some researchers to conclude that effects of stressors are highly specific and depend on the kind of stressor and the kind of task (Lulofs, Wennekens and VanHoutem, 1981) employed and may function via totally different hemodynamic mechanisms (Andrien and Hansson, 1981).*

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*Researchers concerned with hormonal responses (e.g., Frankenhäuser, 1975; Frankenhäuser, vonWright, Collins, vonWright, Sedvall and Swahn, 1976) have obtained data that would argue at least in part for non-uniformity of the human stress reaction as well (c.f. also Singer, 1980).

The obtained discrepancies, however, have typically arisen from extremely discrepant task environments or from stressors that show so little commonality with each other that they would rarely occur in the same work environment. The research reported by Andrien and Hansson (1981), for example, employed a physical stress task (immersion of a hand in cold water) and a cognitive task. One of the tasks utilized by Cacioppo and Sandman (1978) was not a task in the normal sense at all: subjects were exposed to unfamiliar, unpleasant visual stimuli. In other words, the question of whether tasks at moderate to severe stressor levels which occur in normal work environments would result not only in changes in the degree, but also in changes in the kind of cardiovascular responsivity to the diverse stressors, remains at least partially open. What appears to be needed is research which systematically compares several stressor types which are potentially relevant to work environments across the same subjects, holding all other variables constant. This research was designed to approach that problem in a systematic fashion. Subjects are exposed to a pleasant social interaction, a stressful social interaction, a rest period in the presence of another person, and task performance and rest periods while alone. Pressor*and heart rate responses to these conditions are measured for the same persons across stressor conditions and compared to baseline. The relationship between stressors and performance, and strain and performance (and satisfaction) will be explored in subsequent research.

* Pressor response refers to systolic and diastolic blood pressure measurement via a self inflating cuff placed on either arm.

METHOD

Stressor Conditions

Five different stressor conditions were employed. They were selected to differ in the degree of potential stress, in the social vs. non-social environment in which they occurred, and in the kind of behavior/performance that was required. All stressors were selected to allow precise control of experimental manipulation, yet to have similarity to work environments with which they might be compared. The following conditions were utilized:

Non-social baseline: resting alone, probably not unlike the coffee break taken in a private setting. The following four conditions were compared to this condition; differences are expressed as delta values which are used as the basis for data analysis (see below).

Social baseline: resting in the presence of another person, probably not unlike the coffee break taken with others present but without interaction with them.

Complexity interview: a task in which a social interchange on non-self selected topics occurs, yet in a pleasant, open interpersonal atmosphere. The complexity interview is based on the sentence completion task on which extensive validity and reliability data, as well as administrative requirements, are available.

Type A interview: a task in which social interchange on non-self selected topics occurs, yet in an unpleasant, challenging interpersonal atmosphere, not unlike the interaction with a somewhat hostile demanding boss. Again, extensive reliability and validity data as well as administration requirements are available.

Video game task: a non-social, task-oriented setting in which the person is working alone against different levels of experimentally scaled and controlled challenges, experiencing both potential success and failure in the task setting. The task is similar to many hand-eye coordination tasks found in work environments.

The following section will discuss how these tasks were employed in the research.

Procedure

Twenty-six adult male paid volunteers with a median age of 50.5 (range 24 to 71) participated as individuals in a series of tasks. Total time spent in the experimental setting was approximately four hours per person. Upon arrival at the laboratory, each subject was individually briefed about the forthcoming events. His signature on a consent form was obtained. Subjects were then taken to one of two identical experimental rooms. For one-half of the subjects (n=13) the experimental procedure began when the experimenter attached a blood pressure cuff to the dominant arm. The cuff allowed the experimenter to measure systolic blood pressure, diastolic blood pressure and heart rate at two-minute intervals.*

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*Measurements were taken automatically by a Vitastat 900D and recorded on tape. Alarms were sounded when blood pressure would exceed 200 mm Hg systolic. Two successive readings at this level were considered dangerous and would have resulted in excluding the subject from further participation in the research. No such readings were, however, obtained.

The experimenter then sat at a desk across from the subject and asked a number of biographic questions. Responses to the questions were recorded by the experimenter on a data sheet. Upon completion of the biographic questionnaire, the subject was asked to sit back and relax for a few minutes. The experimenter remained in the room and quietly worked on organizing a set of papers.

Complexity Interview

After approximately six minutes, the experimenter handed the subject a set of cards. Each card contained the stem of a sentence (e.g., When someone competes with me. . . .). The subject was asked to complete the sentence and add several additional sentences on the same topic. After the subject completed his responses to the card, the experimenter asked several non-leading, non-directive questions, encouraging the subject to continue his statements on the topic at hand. When the subject's repertoire of responses to each topic was exhausted, he was asked to go on to the following card. A total of 12 cards was presented. The procedure represents an interview version of the sentence completion test (Schroder and Streufert, 1963); Schroder, Driver and Streufert, 1967) designed to measure cognitive complexity. The behavior and responses to the experimenter allowed the subjects to "open up" and present their significant thoughts and feelings to another person. Responses of the subjects were recorded on videotape for future analysis. Physiological measurement procedures during this and other parts of the research will be discussed below in the section on measurement.

Type A Interview

Following the complexity interview, the original experimenter left the room and a second experimenter entered and administered the Type A Structured Interview developed by Rosenman and Friedman (c.f. Rosenman, 1978) to measure coronary prone behavior. The interview represents a standardized social challenge situation considered by many to exemplify severe social stress. The responses of subjects were again videotaped. After completion of the interview, the blood pressure cuff was removed from the subject's arm to allow him the freedom to write. The subject was then asked to respond to a paper-and-pencil questionnaire (of no interest to this paper).

Collection of Non-social Baseline Data

Upon completion of the questionnaire, the subject was escorted to another (identical) experimental room. The blood pressure/heart rate cuff was attached to the non-dominant arm and the subject was instructed to watch a video screen. After the experimenter left the room, videotaped instructions for a video game (similar to Pac Man) were presented on the screen. Instructions were detailed enough to allow all subjects, including those who had no previous experience with video games, to understand the task. The task itself was selected for its general interest across divergent groups of potential subjects and because it did not rely on considerable previous experience with video games. Once the subject had completed watching the instructions, he was asked to sit back and relax for a few minutes while a kaleidoscopic display of colors slowly unfolded on the video screen in front of him. Subjects spent several minutes watching the kaleidoscope.

Hand-eye Coordination Task

The video game began with a practice period with a slow speed and low difficulty level, allowing even the uninitiated to perform better than the supposed "average performance score" obtained at first play by "most persons." Following the practice period, subjects rated the difficulty level of the task on a seven-point scale and then sat back (as instructed) to once more relax for a few minutes. Ratings and relaxation periods were introduced following each of the five game periods. The four game periods following the practice period were systematically varied in difficulty level (in random order) from relatively easy (little or no stress) to very difficult (moderately high stress). Perceptions of difficulty matched the experimentally introduced difficulty levels. Even those unfamiliar with video games found the easy task level to be very easy and even those who reported considerable experience with video games found the most difficult task level to be very difficult. None of the subjects reached the supposed "average score obtained by most players" at the most difficult task level. At the completion of the video game hand-eye coordination task, subjects were again asked to sit back and relax for a few minutes. Finally, the experimenter reentered the room, removed the blood-pressure/heart-rate cuff and instructed the subject to complete another paper-and-pencil questionnaire. Following the completion of that questionnaire, subjects were debriefed, paid and released.

The task sequence described above held for one-half (n=13) of the subjects. The remaining thirteen subjects were exposed to the experimental procedure in the inverse order (paper-and-pencil questionnaire followed by video-game, questionnaire, Type A interview, complexity interview, and biographic questions, with rest periods appropriately interspersed).

Measurement

Measurements of systolic blood pressure, diastolic blood pressure and heart rate were taken throughout the sequence of tasks at two-minute intervals (except when subjects were working on questionnaires). Measurements for the rest period between the biographical and the complexity interview (here called social baseline), for the Complexity Interview, the Type A interview, and the four (non-practice) playing periods of the game were employed as the units of analysis for this research. Measurements during these task conditions were limited to four measurements with two-minute intervals to limit the compression of subjects' arms. Measurements for each of the task conditions were averaged to obtain a single score and compared with non-social baseline values (obtained while subjects were watching the kaleidoscopic pictures* on the T.V. screen). Discrepancies between the four task levels and the resting levels were expressed as mean delta values.

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*Non-social baseline levels were also obtained at the end of the experimental sessions (again in a non-social setting) and for the resting periods between the game periods. Data analysis indicated no difference in systolic and diastolic blood pressure or heart rate for these various non-social baseline conditions.

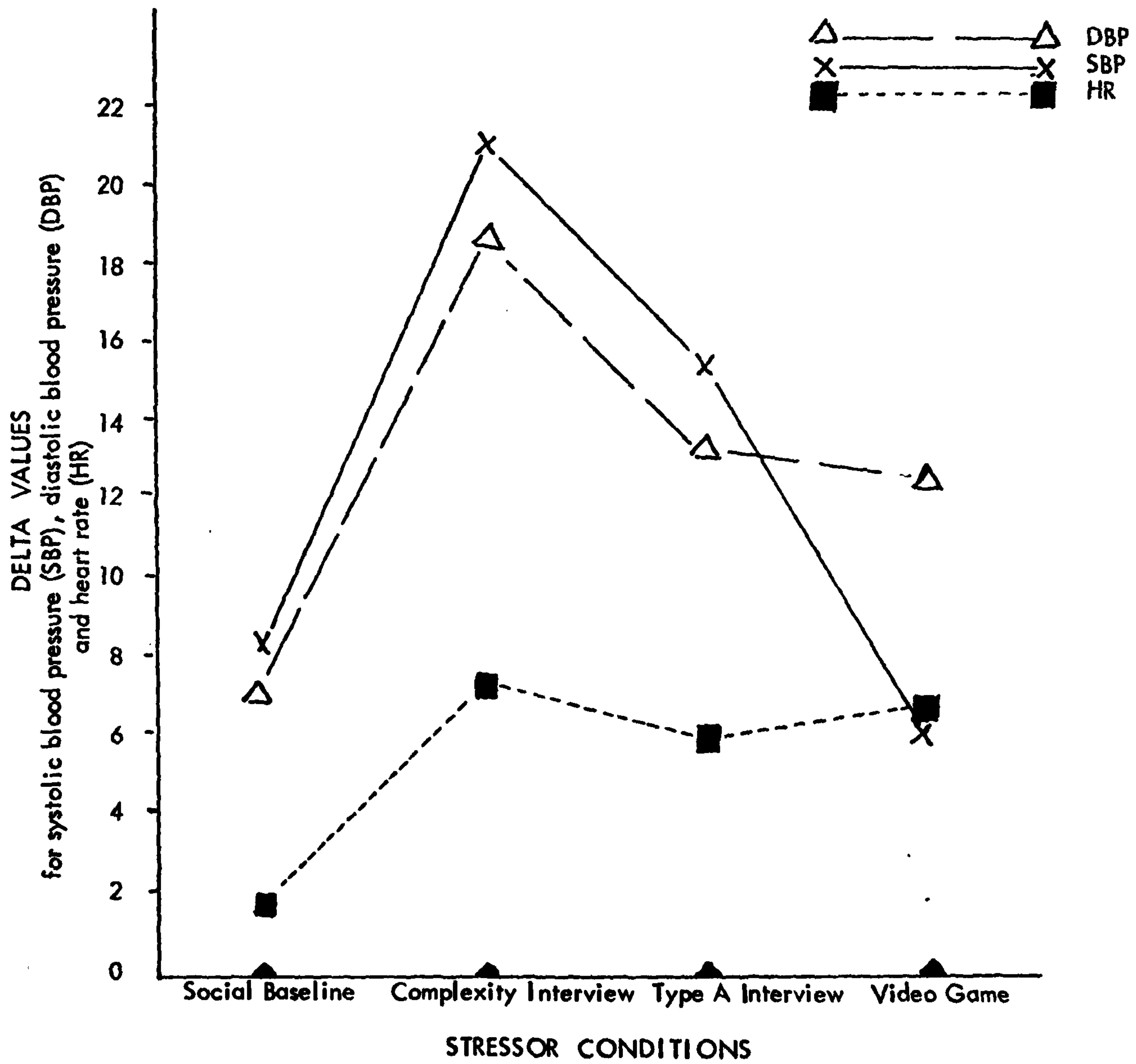
RESULTS AND DISCUSSION

Delta values for systolic blood pressure, diastolic blood pressure and heart rate discrepancies from non-social baseline values were calculated for mean levels obtained during the complexity interview, the Type A interview, the video game (hand-eye coordination) task and the social baseline measure. Data analysis was based on these delta values. Primary data analysis utilized Analysis of Variance techniques for overall and partial comparison among the measures. Secondary data analysis employed measures of correlation to relate blood pressure to heart rate (see below).

The main concern of the analysis and interpretation will be on elevations of systolic and diastolic blood pressure measurements since these two measures may respond differently to different stressors and may indicate differential response tendencies. Parallel elevations of systolic and diastolic blood pressure across tasks will be considered evidence for similar responsivity to stressors across different stressor environments. Parallel elevations (delta values) of different magnitudes in response to different stressors will be viewed as reflections of diverse degrees of strain. Interactions of the four stressor environments with the two measures of blood pressure will be considered evidence for differential types of strain responses to different stressor conditions.

An Analysis of Variance (2x4, entirely within) for systolic and diastolic blood pressure deltas comparing the effects of four stressor conditions [(1) social baseline; (2) the Complexity Interview, a low external stress social situation allowing the subject to verbally "open up;" (3) the Type A interview, a high externally produced social stress situation created by a challenging and somewhat hostile experimenter; and (4) four levels of the video game varying from low to high task stress] resulted in a highly significant F ratio for stressor conditions ($F=26.52$, 3/75 df, $p < .001$) and a significant blood pressure by stressor conditions interaction ($F=4.44$, 3/75 df, $p < .01$). The significant main effect for stressor conditions reflects the diverse levels of blood pressure increases produced by the four experimental treatments. The absence of a significant main effect for blood pressure deltas ($F < 1.0$) suggests that elevations in systolic and diastolic blood pressure occurred, in general, to about the same degree. Particularly interesting, however, is the significant interaction between blood pressure and stressor conditions. While individual comparisons among the three measures taken in social settings (social baseline, Type A interview and Complexity interview) did not produce significant interaction terms, all three produced significant interaction F ratios when singly compared with blood pressure elevations during the video games. As shown in Figure 1, systolic and diastolic blood pressure elevations differed only slightly (with diastolic elevations insignificantly higher) for the three measures taken in social settings. Quite different measurements were obtained, however, during the game, the only non-social stressor condition: delta systolic blood pressure with a mean elevation of 6.4 mm Hg remained

Figure 1. Effects of four stressor conditions on elevations of systolic blood pressure, diastolic blood pressure and heart rate above non-social base line.



relatively low, while delta diastolic blood pressure with a mean elevation of 12.7 mm Hg was relatively high and quite similar to the level obtained for that measure during the Type A interview (13.4 mm Hg).

Another finding of interest is the discrepancy between blood pressure elevations obtained during the Complexity Interview as compared to the measures from the Type A interview. On first consideration, one might expect that higher arousal levels should be obtained from the Type A setting: confrontation from a challenging and hostile experimenter - not unlike a somewhat unpleasant interaction with a demanding and disapproving boss - should be more stressful than the pleasant, non-directive interaction with the interviewer in the Complexity Interview. A closer look at the topics discussed in the Complexity Interview, however, may clarify why significantly higher arousal levels were obtained in that interview as compared to the Type A interview ($p < .02$ for systolic and $p < .002$ for diastolic blood pressure). The sentence stems employed in the Complexity Interview suggest problems, uncertainties and challenges of the past to which the subject responds in a permissive atmosphere. Many of the subjects apparently had never been able to express their feelings about some of these past (and some present) problems they had experienced, and not only relived these experiences cognitively, but often allowed themselves to experience the difficulties and problems for the first time.* In other words, while there was no

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*An example may be a subject who emphasized, after completion of the Complexity Interview, that he had never told anyone about any of the thoughts he expressed. He followed that statement with the concern that his wife or anyone else he knew might find out what he said. He was, of course, assured that no one would.

externally induced stressor present at the time of the Complexity Interview, subjects apparently utilized the stems and the permissive environment to generate their own internal stressors and attempted to deal with them in that setting.

If it is argued that an increase in systolic blood pressure associated with an increase in heart rate reflects sympathetic arousal, then correlations of some size should be expected between those two measures and between their delta values. Correlations do, however, depend on the distributions of the samples. The fact that we are dealing with comparisons between mean values and that a few subjects were taking beta blockers should diminish the expected correlations somewhat. More important, however, could be an individual difference variable: some persons apparently experience a decrease in heart rate with at least some stressor conditions (e.g., Danner et al., 1981). A check on the sample distributions obtained in this research showed that delta values for systolic and diastolic blood pressure distributed around a single median across the various stressor conditions while heart rate deltas produced a bimodal distribution. Slightly less than half of the subjects fit well into a distribution ranging from a decrease in heart rate of -8 to an increase of +3, while the remainder of the subjects distributed themselves in the range of +4 to +25 beats per minute. Such a bimodal distribution would make a high correlation between systolic blood pressure and heart rate quite unlikely. In fact, correlations obtained were only +.23 between systolic blood pressure and heart rate in the Complexity Interview, +.20 for the Type A interview and

+.16 for the video game. Heart rate and systolic blood pressure for the social baseline condition appeared uncorrelated. Diastolic blood pressure correlated positively with heart rate for the Complexity Interview (+.23) and the Type A interview (+.36), but negatively for the video game (-.21). While the correlation levels generally were quite low and positive, the striking departure from the typical results occurred again in the video game setting. This negative correlation, together with the finding that parallel increases in both blood pressure measures and in heart rate occurred for the social stressor conditions, while elevations in heart rate and diastolic blood pressure were associated with lower levels of systolic blood pressure in the non-social video game task, suggests that the different stressor conditions did indeed produce physiological strain levels of different degree <u>and</u> different kind. While the hemodynamic changes to the social stressor conditions can be primarily related to elevated cardiac functioning, the strain produced by the video game task may be more general in nature: vasomotor tone (peripheral resistance) was likely affected as well. It is quite possible that other measures of the more general response, e.g., measures of perspiration, may also have distinguished between the social stressor conditions and the non-social stressor task, had they been employed in this research.

The data obtained in this research confirm the suggestions made by those authors who view different stressor conditions as productive of not only diverse degrees, but also diverse kinds of physiological arousal. Since the stressor conditions utilized in this research effort are not unlike situations that persons experience in normal work environments, our concerns with finding a general theory of stressor effects upon at least physiological arousal in the work environment become more complicated. Obviously, this research effort has not yet related physiological arousal (here blood pressure and heart rate) differences to task performance. It can probably be assumed that performance would be differentially affected by diverse physiological arousal characteristics just as physiological responsivity is differentially affected by diverse stressors. Nonetheless, further research must investigate the correctness of such an assumption. If it is confirmed, we will most likely have to build a theory relating stressors to performance in work environments which considers complex interactions among types and levels of stressors, individual difference variables, situational variables, and task requirements. Such a theory is not likely to emerge without considerable programmatic experimentation.

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