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Abstract

A quasi-experimental study was conducted to assess the effects of routine exposure to traffic congestion on the mood, physiology, and task performance of automobile commuters. Traffic congestion was conceptualized as an environmental stressor which impedes one's movement between two or more points. Industrial employees were assigned to low, medium, or high impedance groups on the basis of the distance and duration of their commute and were classified as either Type A or Type B on a measure of coronary-prone behavior. As expected, subjective reports of traffic congestion and annoyance were greater among high and medium impedance commuters than among low impedance individuals. Also, commuting distance, commuting time, travel speed, and number of months on route were significantly correlated with systolic and diastolic blood pressure. Contrary to prediction, medium impedance As and high impedance Bs exhibited the highest levels of systolic blood pressure and the lowest levels of frustration tolerance among all experimental groups. The results were discussed in terms of the degree of congruity between commuters' expectancies and experiences of travel constraints.

Traffic Congestion, Type-A Behavior, and Stress

In recent years, behavioral scientists have devoted increasing attention to the urban environment and its impact on people (Fischer, 1976; Glass & Singer, 1972; Michelson, 1976; Milgram, 1970; Proshansky, Ittelson & Rivlin, 1976). A sizable body of research now exists on the behavioral and health consequences of exposure to numerous urban settings, including high-rise apartment buildings (Cohen, Glass & Singer, 1973; Newman, 1973), crowded markets and department stores (Langer & Saegert, 1976; Saegert, Mackintosh & West, 1975), and noisy neighborhoods (Damon, 1977; Weinstein, 1976). Despite the rapid accumulation of this research, certain facets of the urban environment and their effects on people have received little empirical attention. Among the most important of these is the impact of transportation conditions on human well-being (Singer, Lundburg, & Frankenhaeuser, in press).

The reported study examines the cumulative effects of traffic congestion on the mood, physiology, and task performance of automobile commuters. The investigation of people's reactions to traffic congestion is important for several reasons. First, urban commuters spend a sizable proportion of their days traveling between home and work (Catanese, 1972), making the transportation environment one which may exert pervasive effects on their lives. Traffic situations (especially during rush hour) are potentially stressful due to the delays they impose and the hostility they sometimes provoke (Turner, Layton, & Simons, 1975). Recent research on behavioral "aftereffects" of environmental stressors (Glass & Singer, 1972; Sherrod, 1974) suggests that the emotional demands of driving may result not only in impaired road performance, but also in emotional and behavioral deficits upon arrival at home or at work. Furthermore, the systematic assessment of traffic congestion and its effects on commuters might provide an empirical basis for developing community interventions (e.g, municipal and corporate promotion of ride-sharing programs) aimed at reducing transportation-related stress as well as air pollution and energy consumption.

Earlier experiments, focusing on the consequences of short-term exposure to either simulated or actual road situations, found that driving behavior is often accompanied by elevated heart rate (Hunt & May, Note 1; Simonson, Baker, Burns, Keiper, Schmitt, & Stackhouse, 1968; Taggart, Gibbon, & Somerville, 1969), skin conductance (Heimstra, 1970; Hulbert, 1957), and catecholamine secretion (Bellet, Roman, & Kostis, 1969). Although these studies clearly document the physiological arousal sometimes associated with driving, they provide no direct evidence regarding the psychological, physical, and behavioral residues of long-term exposure to traffic congestion.

The major goals of the present study were (1) to develop a conceptualization of traffic congestion and its impact on people over extended periods; (2) to establish measurement criteria for operationalizing this conceptual framework; and (3) to test certain hypotheses derived from the framework within the context of a field experiment.

The conceptual analysis tested in this study construes traffic congestion as an environmental stressor; specifically, as a behavioral constraint which impedes one's movement between two or more points. The degree of <u>impedance</u> encountered by travelers can be indexed in terms of at least two situational parameters: (a) the distance traveled between origin and destination, and (b) the amount of time spent in transit between these points. Hypothetically, the greatest degree of impedance from traffic congestion would result from traveling large distances slowly, whereas the least amount of impedance would arise from traveling small distances in a short amount of time.

Several areas of research, especially those pertaining to human aggression (cf. Donnerstein & Wilson, 1976; Rule & Nesdale, 1976) and crowding (cf. Altman, 1975; Baum & Epstein, in press; Stokols, 1976; Sundstrom, in press), indicate that environmental constraints can induce both physiological stress and performance deficits. Interactionist theories of stress (Apply & Trumbull, 1967; Glass & Singer, 1972; Lazarus & Launier, in press; McGrath, 1976), however, suggest that commuters' reactions to traffic congestion will not be uniform and will be mediated by several personal and social variables.

One personality dimension that would seem particularly important in affecting response to traffic congestion is the coronary-prone behavior pattern (Rosenman, Friedman, Strauss, Wurm, Jenkins & Messinger, 1966). This behavioral syndrome (Type A) is characterized by extremes of competitiveness, impatience, and job-involvement. Type A behavior has been found to be highly predictive of coronary heart disease while its counterpart, Type B behavior (noncompetitive, patient, relaxed) is much less likely to be associated with heart disease (Rosenman, Brand, Jenkins, Friedman, Strauss & Wurm, 1975; Zyzanski & Jenkins, 1970).

The reactions of Type A and Type B individuals to environmental stressors has been examined in a recent series of experiments conducted by Glass and his colleagues (Glass, 1977). Among the findings from this research are that Type A persons typically strive harder than Type Bs to avoid loss of control over their environment, though in highly uncontrollable situations, the former relinquish their efforts to reassert control more readily than the latter (Krantz, Glass & Snyder, 1974). Moreover, time-urgent As evidence greater tension and hyperactivity than Bs while performing tasks requiring a low rate of response for reinforcement, and become more impatient and irritated when they are delayed by coworkers on joint decision-making tasks (Glass, Snyder & Hollis, 1974). Also relevant to the present study is the finding by Dembroski, MacDougall & Shields (in press) that Type As manifest significantly greater increases than Bs in both heart rate and systolic blood pressure on reaction time tasks requiring rapid and accurate performance.

On the basis of the above-mentioned research and our conceptualization of traffic congestion, the following experimental hypotheses were formulated:

H1: Commuters exposed to high levels of impedance over a prolonged period will exhibit significantly greater physiological arousal, task performance deficits, perceptions of congestion, and feelings of annoyance than will those exposed to moderate or low levels of impedance.

H2: The pattern of results predicted by Hypothesis 1 will be qualified by a significant statistical interaction between the impedance and A-B factors. Among high and medium impedance subjects, greater stress will be manifested by Type A persons than by Type Bs, whereas the response differences between As and Bs within the low impedance conditions are expected to be statistically insignificant.

The second hypothesis assumes that driving under high impedance conditions is partially analogous to Glass, Snyder & Hollis' (1974) delayed response task, an activity which would potentiate greater frustration and impatience among As than among Bs.

Method

Subjects

Participants were paid volunteers recruited from the employee rosters of two large industrial firms in Irvine, California. All employees of these companies (about 1500 persons) were contacted by letter and asked to indicate their willingness to participate in a research project on "Commuting Patterns, Health, and Performance." Approximately 25% of those initially contacted volunteered for the study by returning a preliminary screening questionnaire.[1] From this group, 100 persons were selected on the basis of the following criteria: (1) the average distance and duration of their daily commute to and from work; (2) their time of arrival at work; and (3) the number of months during which they had traveled their current commuting route. The final sample consisted of 61 males and 39 females, all of whom were on the day shift and had traveled the same route for more than eight months.[2] The mean age of the sample was 36.8 years; mean educational level was 14.4 years. Occupational status of participants ranged from manufacturing to executive roles. Respondents were selected for the distance and time of their commute by the procedure outlined below.

Procedure

Selection of subjects for experimental groups. On the basis of information obtained from the screening questionnaire, the boundary criteria for three major impedance groups were derived.[3] Low impedance subjects were those falling within the bottom 25% of the distributions of commuting distance and time. This group was comprised of 27 persons who traveled less than 7.5 miles between home and workplace and spent less than 12.5 minutes on the road in either direction. Medium impedance subjects fell into the middle 30% on the time and distance distributions and consisted of 22 persons traveling between 10 and 14 miles and spending approximately 17 to 20 minutes on the road each way. High impedance subjects fell into the top 25% of the distance and time distributions and consisted of 36 persons traveling between 18 and 50 miles and spending from 30 to 75 minutes on the commute.

The above impedance groups included only those persons having correspondent positions along the distance and time distributions (i.e., low/low, medium/medium, high/high). A subset of the experimental sample, however, displayed non-correspondent rankings with regard to the time and distance distributions. These persons were assigned to two additional groups: low distance/medium time (n=6) and medium distance/high time (n=9). Data from these groups were combined with those from the other three groups for certain correlational analyses, as described below.

Participants were informed of their selection by mail and were requested to complete a series of background and personality questionnaires. Included in this set of measures was the Jenkins Activity Survey for Health

Prediction (JAS), a measure of the coronary-prone behavior pattern (Jenkins, Zyzanski & Rosenman, 1971; Zyzanski & Jenkins, 1970). Within each of the three main impedance groups, subjects were classified as either Type A or Type B on the basis of their JAS scores. Three scoring procedures were used for the classification of subjects in this study: (1) a weighted scoring system developed by Jenkins, et al., (1971) in research with a large sample of adult males median = 0.0; (2) a unit-scoring system developed by Krantz et al. (1974) in which A-B classification is based on a median derived from the particular group under study (median = 8.0); and (3) a procedure developed by the present authors in which a median split for the experimental sample is performed on the JAS scores computed by Jenkins et al.'s (1971) weighted scoring system (median = 1.8). There has been some controversy as to which of the first two procedures is most valid (cf., Glass, 1977), and we introduced the third as another alternative. Therefore, to provide a more rigorous classification of subjects than is permitted by using any of these procedures independently, only those persons who were consistently identified as either Type A or B across all three classification procedures were included in the experimental design ($n = 75$ for all impedance groups; $n = 64$ for low, medium, and high impedance groups).

Testing procedure. Subjects were contacted by phone to schedule their participation times. Each subject participated in the study for one week. During this time, he/she completed five daily commuting logs pertaining to the actual distances and times traveled each day, and to subjective impressions of the journey (e.g., perceived congestion, air quality, and temperature inside the vehicle). These logs were completed on arrival at work and at home for the morning and afternoon commutes, respectively.

Upon arrival at work on Monday, Wednesday, and Friday, employees drove to a testing station located in the parking lot of their company. There, each person's systolic and diastolic blood pressure were recorded using a Physiometrics SR-2 automatic blood pressure recorder. Heart rate was also measured by means of a cardiotachometer attached to the blood pressure recorder.

On Tuesday and Thursday of the testing week, participants reported to a company conference room approximately 1½ hours after arriving at work. Here, measures of blood pressure, heart rate, and mood were again obtained. Subsequently, one or two brief tasks were administered to assess the cumulative effects of impedance on tolerance-for-frustration and psychomotor performance.

During the Tuesday session, subjects performed the "perceptual reasoning" test developed by Feather (1965). The test consists of four puzzles, two of which are insoluble (puzzles 1 and 3) and two that are soluble (puzzles 2 and 4). Subjects were asked to trace the lines of a diagram without lifting their pen or retracing a line. This task has been employed by Glass & Singer (1972) as a measure of frustration tolerance and has been found to be sensitive to the aftereffects of environmental stressors.

During the Thursday session, subjects performed the digit symbol task from the Wechsler Adult Intelligence Scale (Wechsler, 1958). The task is a measure of psychomotor speed and concentration in which persons are required to copy the symbols associated with a line of digits into rows of boxes over a 90-second period. Performance on this task has been found to decrease under high levels of emotional arousal (cf. Doob & Kirshenbaum, 1973). Immediately after performing this task, subjects were administered a memory test in which they were given 30 seconds to recall the symbols associated with the nine digits of the Wechsler task.

Upon completion of the study, all subjects were provided with a summary of their daily blood pressure and heart rate readings, a report of the experimental hypotheses, and a detailed explanation of the research procedures. All individuals were paid $10.00 for their participation in the study.

Major dependent measures and statistical analyses. Four basic sets of measures were utilized to assess subjects' (1) perception of traffic congestion, (2) physiological arousal, (3) task performance, and (4) mood.

The degree of congestion was assessed by means of a 9-point bipolar scale included in the daily travel log. Subjects completed this scale both in the morning and evening upon arrival at work and at home. For each subject, mean levels of perceived congestion for the morning and evening journeys were completed on the basis of the ratings obtained between Monday through Friday. These summary scores, along with two 7-point scales on the background questionnaire assessing the extent to which subjects were inconvenienced by traffic congestion and satisfied with their commute, constituted the main checks on our conceptualization and measurement of impedance.

Physiological arousal was indexed in terms of systolic blood pressure, diastolic blood pressure, and heart rate, all of which were measured on each day of the testing period as described above. For each physiological measure, three means were computed based on (1) the five daily arousal scores, (2) the Monday, Wednesday, and Friday (arrival time) scores, and (3) the Tuesday and Thursday (mid-morning) scores.

The principal measures of task performance were (1) the number of attempts made by each subject on Feather's (1961) insoluble puzzles, (2) the number of boxes correctly completed on the digit symbol task and (3) the number of symbols recalled in the digit-symbol memory task.

Participants' mood was assessed daily by means of 9 five-point Likert scales. These scales pertained to how friendly, tense, alert, irritated, carefree, nervous, cheerful, impatient, and energetic subjects felt on each day of the testing period. Means were computed based on each subject's responses to all nine mood scales. Also, the four scales pertaining to subjective annoyance (tense, irritated, nervous, impatient) were analyzed separately as a multivariate cluster.

In addition to these four major clusters of dependent variables, a variety of other measures were obtained from the background and personality questionnaires administered to subjects. The background questionnaire included items relating to the following six categories: (1) demographic data (e.g., marital status, education and socioeconomic status); (2) aspects of the journey to work (e.g., size of car ranging from sports models to full size sedans, number of months on commute, average speed while traveling to work defined as the ratio of commuting distance/commuting time); (3) residential location (e.g., length of time at current residence, degree of choice in deciding where to live, frequency of earlier moves undertaken to shorten commuting distance, desire to change current residence due to transportation-related problems); (4) health-related variables (e.g., weight, cigarette, coffee, and alcohol consumption, health problems and medication); (5) job satisfaction and ratings of the physical and social environment at work; and (6) attitudes concerning environmental problems and transportation management plans.

All subjects completed the following personality scales in addition to the JAS: Rotter (1966) Internal-External Locus of Control Scale, The Novaco Anger Inventory (Novaco, 1975) and the Driving Habits Questionnaire developed by the present authors. The latter instrument is designed to measure time-urgent behavior as manifested in driving habits.

Pearson correlations among the above-mentioned variables were computed, based on the data obtained from all 100 subjects in the experimental design. Subsequently, a series of 2 x 3 (A-B by Impedance) multivariate analyses of variance (MANOVA) were performed on the major clusters of dependent variables.[4] Also univariate analyses of variance were performed on certain measures derived from the background and personality inventories. All of the reported MANOVAs and ANOVAs utilized data from only those 64 subjects (46 males, 18 females) included in the low, medium and high impedance groups.

Results

Checks on Internal Validity

A basic assumption underlying the present study was that commuters who traveled greater distances and spent more time on the road between home and work would experience higher levels of traffic congestion. Support for this assumption was obtained in a 2 x 3 (A-B x impedance) MANOVA performed on a cluster of four self-report items pertaining to congestion and commuting satisfaction. Results indicated a significant multivariate effect attributable to the impedance factor, $\underline{F}$ (8,104) = 3.29, $\underline{p} < .002$. Significant univariate effects were also obtained, indicating that subjects in the high and medium impedance conditions generally reported higher levels of morning congestion, $\underline{F}$ (2,55) = 4.35, $\underline{p} < .018$, afternoon congestion, $\underline{F}$ (2,55) = 7.27, $\underline{p} < .002$, congestion-related inconvenience, $\underline{F}$ (2,55) = 4.35, $\underline{p} < .018$, and lower levels of commuting satisfaction, F (2,55) = 5.92, $\underline{p} < .004$, than did those in the low impedance groups (see Table 1).[5]

The conceptualization of congestion in terms of distance and time parameters received further support in analyses of two additional questionnaire items. The first item pertained to whether or not subjects had ever changed their residence to shorten the distance of their commute. The second item related to whether or not subjects desired to move from their current residence due to commuting-related problems. Chi square analyses on both of the items were significant, indicating that more subjects in the low and medium impedance conditions had relocated their residence to reduce commuting distance at some point in their working careers (though not within the six months preceding this study) than had those in the high impedance groups, $\chi^2(5)$ 12.92, $\underline{p} < .024$, and that <u>no</u> subjects in the former two groups indicated a desire to change residence due to commuting problems whereas 52% of those in the high impedance groups expressed this desire, $\chi^2(5) = 27.64$, $\underline{p} < .001$ (see Table 2).

Internal validity of the research design was further assessed by examining the orthogonality of the A-B and impedance factors, as well as the possible confounding of these factors with socioeconomic status, educational level, and sex. A 2 x 3 ANOVA revealed the lack of a significant impedance effect on subjects' A-B scores (ascertained via the JAS), suggesting that the behavior type and impedance factors are independent.[6] Moreover, no significant effects attributable to A-B, impedance, or the interaction of these factors were evident in a 2 x 3 ANOVA performed on SES scores. However, Type-A individuals reported higher levels of education than Type Bs, as reflected in a marginally significant A-B effect on education scores, $F\ (1,57) = 3.24$, $p < .08$. Also, an analysis of sex composition across experimental groups indicated that the percentage of males and females was approximately equal (48% males) in the low impedance conditions but that males were more prevalent within the medium (83%) and high (84%) impedance conditions, $\chi^2(5) = 10.69$, $p < .06$.

Effects of Experimental Factors

Experimental hypotheses were assessed through a series of 2 x 3 MANOVAs performed on the dependent variable clusters relating to subjects' mood, physiology, and task performance. Also, univariate tests were performed on a number of demographic and personality measures. All analyses of physiological and task performance data utilized covariates to control for individual differences on non-experimental dimensions. Relevant covariates were selected on both theoretical and empirical grounds. For each dependent variable of interest, a set of potentially relevant covariates was designated. Those measures from among this set which were significantly correlated with the dependent variables were incorporated as covariates in the MANOVA tests. Age, weight, and number of months on route were entered as covariates in analyses of systolic and diastolic pressure whereas age and cigarette consumption were used in the analysis of heart rate. Also, age and educational level served as covariates in all analyses of the task performance data.

The A-B x impedance MANOVAs were performed on males only (n = 46) as well as one the combined-sex sample (n = 64) to control for the possible effects of sex differences on our findings.[7] These analyses seemed warranted for two reasons. First, the JAS (Jenkins et al., 1971) has been validated on males only and the possibility exists that this instrument provides a less reliable assessment of Type-A tendencies among females than among males (Zyzanski, Note 3). Second, the distribution of subjects across impedance conditions were skewed (with a higher percentage of males in the medium and high impedance conditions), introducing the possibility that effects of the impedance factor might be confounded with sex differences. Actually, the effects of impedance and A-B (on perceived congestion, mood, arousal, and performance) proved to be quite consistent across the all-male and combined samples. The results reported below, therefore, are based on the collapsed sample of males and females except where specific departures between the male and combined-sex samples are noted.

Main effects of the impedance factor. The first experimental hypothesis predicted that high impedance subjects would manifest greater arousal, task performance deficits, and self-reported annoyance than their medium or low impedance counterparts. Partial support for this hypothesis was evidenced by the multivariate effect of impedance on the 4-item cluster of annoyance variables, $\underline{F}$ (8,106) = 1.95, $\underline{p}$ < .06. Univariate tests indicated that high-impedance subjects rated themselves as more tense, $\underline{F}$ (2,56) = 4.77, $\underline{p}$ < .012, and nervous, $\underline{F}$(2,56) = 4.01, $\underline{p}$ < .024, than did low-impedance individuals (see Table 3). No impedance main effects were obtained in the analyses of physiological and task performance data. Correlational analyses indicated, however, that higher levels of commuting distance, time, speed and months on the commute were significantly correlated with increased systolic and diastolic blood pressure (e.g., for distance and systolic pressure, $\underline{r}$(62) = .26, $\underline{p}$ < .019; for distance and diastolic pressure, $\underline{r}$(62) = .25, $\underline{p}$ < .023). Certain of these correlations become more robust when the entire sample (all five impedance groups, n = 100) is used in the analyses (see Table 4).

Analyses of items pertaining to certain aspects of the commute did reveal significant impedance main effects. First, although high impedance subjects reported higher levels of congestion, they tended to travel at higher average speeds ($\overline{X}_H$ = 41.4 MPH) than did those in the medium ($\overline{X}_M$ = 36.0 MPH) or low ($\overline{X}_L$ = 27.0 MPH) impedance groups, $\underline{F}$ (2,57) = 20.90, $\underline{p}$ < .001. In addition, medium impedance subjects had spent more months on their current commute ($\overline{X}_M$ = 51.84) than had low ($\overline{X}_L$ = 31.25) or high impedance ($\overline{X}_H$ = 38.51) individuals, $\underline{F}$ (2,56) = 6.44, $\underline{p}$ < .003.

Main effects of Type-A behavior pattern. Main effects attributable to behavior type, though not initially predicted, were found in analyses of task performance data and on items regarding certain aspects of the commute.

Before presenting these findings, it should be noted that preliminary inspection of several task performance and arousal measures revealed heterogeneity of variance across experimental groups (see Table 5). In such cases, square root and logarithmic transformations were performed to determine which procedure was most effective in reducing heterogeneity of variance. As a result, square root transformations were employed in all analyses of digit-symbol task performance and of systolic and diastolic blood pressure, whereas logarithmic transformations were used in analyses of insoluble puzzle scores. Significant experimental effects reported for these variables are based on transformed scores though in all cases, the effects remain significant when non-transformed scores are analyzed.

A 2 x 3 MANOVA performed on digit symbol transcription and memory scores revealed a significant A-B multivariate effect, $F\ (2,44) = 5.43$, $p < .008$. A significant univariate effect on transcription scores indicated that Type A subjects were more proficient at the digit symbol copying task than were Type Bs, $F\ (1,45) = 6.95$, $p < .001$. A-B differences were not significant on the memory scores, however.

Significant A-B main effects also were obtained on several indices pertaining to characteristics of the commute. Type As traveled at significantly higher speeds ($\overline{X}_A$ = 37.73 MPH) than did Type Bs ($\overline{X}_B$ = 33.10 MPH),

$\underline{F}$ (1,57) = 4.60, $\underline{p} < .036$. Also, the former groups spent significantly less time on the road ($\overline{X}_A$ = 25.84 min.) than did the latter ($\overline{X}_B$ = 26.50 min.), $\underline{F}$ (1,57) = 5.68, $\underline{p} < .02$, while average commuting distances did not vary significantly between the A and B groups.

An analysis of commuters' months on their route indicated Type As had traveled their current commute for more months ($\overline{X}_A$ = 46.60) than had Type Bs ($\overline{X}_B$ = 33.88), $\underline{F}$ (1,56) = 9.02, $\underline{p} < .004$. In addition, Type As reported having had a greater degree of choice in selecting their current residence than did Type Bs, $\underline{F}$ (1,56) = 4.18, $\underline{p} < .046$.

Interactive effects of A-B and impedance factors. The second experimental hypothesis predicted that among high impedance subjects, Type As would exhibit greater stress than Type Bs. Analyses revealed several statistical interactions of A-B and impedance but, as reported below, the direction of these effects diverged from the predicted pattern of means.

Mean levels of systolic and diastolic blood pressure for the five days of testing were analyzed in terms of a 2 x 3 MANOVA.[8] Multivariate effects were nonsignificant although a significant AB x impedance univariate effect on systolic pressure was found, $\underline{F}$ (2,55) = 3.34, $\underline{p} < .043$, indicating that high impedance Bs displayed higher systolic pressure than medium or low impedance Bs, but that medium impedance As showed higher systolic pressure than did low or high impedance As (see Table 5). A similar pattern of means was obtained for diastolic pressure but the interaction effect did not reach significance ($\underline{p} < .14$).

Among males only, the multivariate interaction effect was significant, F(2,36) = 3.53, $\underline{p} < .04$, with the pattern of means for systolic and diastolic pressure corrresponding to that obtained in the combined-sex sample.

For the male subsample, however, the univariate interaction effect on diastolic pressure was significant, $F(1,37) = 7.26$, $p < .011$, while the comparable effect on systolic pressure was not ($p < .15$). No effects of the experimental factors on heart rate were found either among the male or combined-sex samples.

Analyses of the tolerance-for-frustration means (attempts to solve insoluble puzzles) revealed a pattern similar to that obtained in the analyses of systolic blood pressure (see Table 5). A significant A-B x impedance effect was found in separate ANOVAs performed on subjects' attempts to solve puzzle 1, F $(2,56) = 4.78$, $p < .012$, and on their total attempts to solve puzzles 1 and 3, F $(2,56) = 5.02$, $p < .01$, indicating that tolerance-for-frustration was lowest among high impedance Bs and highest among high impedance As (see Table 4).[9]

Additional ANOVAs performed on demographic and personality variables revealed significant AB x impedance effects on car size and Driving Habits Questionnaire scores. Specifically, Type As drove smaller cars than Bs in the low and medium impedance conditions but this pattern was reversed for high impedance, F $(2,56) = 8.90$, $p < .001$. Also, Type As scored higher than Type Bs on a measure of time-urgent driving habits under low and medium impedance conditions, but this pattern was reversed for high impedance, F $(2,53) = 2.72$, $p < .075$. Among males only, the interaction effect on driving habits was more pronounced, $F(2,38) = 3.46$, $p < .042$.

Discussion

The experimental hypotheses were based on the crucial assumption that increased commuting distance and time would be associated with higher levels of self-reported traffic congestion. In support of this assumption, high and medium impedance subjects reported higher levels of traffic congestion on the way to and from work, were generally more inconvenienced by traffic congestion and less satisfied with their commute than were low impedance subjects. Taken together, these results lend support to our conceptualization and measurement of impedance.

The fact that average commuting speed increased significantly from the low to high impedance conditions, however, is not consistent with our conceptualization of impedance in terms of behavioral constraint. Also, the positive correlations between travel speed and systolic and diastolic blood pressure are inconsistent with the notion that traffic constraints are associated with greater frustration and arousal. How can these results be reconciled with the findings that high impedance subjects experienced greater levels of traffic congestion than did low impedance subjects?

First, it is possible that a larger portion of long distance commutes are spent on limited-access "freeways" than are shorter commutes. Thus, although long distance commuters may undergo as much (or more) exposure to traffic constraints as do short distance travelers in getting on and off freeways, the average rate of speed of the former group may be higher due to the greater proportion of time they spend on major highways relative to the time spent on surface streets. Furthermore, traveling at higher speeds particularly on crowded freeways may expose drivers to a higher rate and number of environmental demands (e.g., noise, vibration, increased risk of injury from traffic accidents) than are experienced at slower speeds.

These demands, when added to the constraints experienced on surface streets (e.g., traffic signals at busy intersections), may account for the positive correlations between speed and blood pressure reported earlier (see Table 4).

As our first hypothesis predicts, high impedance subjects reported greater annoyance upon arrival at work than did low impedance subjects. Also, the significant correlations between various commuting indices (i.e., distance, time, speed, months on the route) and blood pressure suggest that routine exposure to traffic congestion is associated with increased physiological arousal. In view of these correlations, however, it is surprising that the predicted main effects of impedance on measures of arousal and task performance were not found. The absence of these effects may be attributable to at least two factors. First, the interactive effects of A-B and impedance on physiological and task measures simply may have muted the independent effects of impedance on these variables. Second, impedance main effects on blood pressure and task performance might have been more apparent with a larger sample as suggested by the increased significance of the correlational findings when impedance groups 4 and 5 are included in the analyses (see Table 4).

The significant A-B main effects, though not predicted, are consistent with the data from earlier studies and provide some support for the construct validity of the coronary-prone behavior pattern. First, the findings that Type As reported higher levels of education and attained higher scores on the digit-symbol copying task (a task in which both speed and accuracy of performance are emphasized) parallel the findings of Glass and his colleagues (Glass, 1977) that As are more hard driving and achievement oriented than Bs. Also, the findings that As traveled at higher average speeds and spent less time on the road than Bs, together with the absence of a significant A-B effect on commuting distance, provide evidence for the time-urgency component of pattern-A behavior (cf., Bortner & Rosenman, 1967; Glass, 1977; Glass, Snyder & Hollis, 1974). Finally the fact that Type A commuters expressed a greater degree of choice in determining the location of their residence is consistent with the notion that As are characteristically more concerned than Bs with the maintenance of personal control over the environment (cf., Glass, 1977).[10]

Contrary to the first and second experimental hypotheses, we did not find that stress levels were greatest among Type As under high impedance conditions. Instead, the obtained interaction effects indicated that among medium impedance subjects, As exhibited higher systolic blood pressure and performance deficits on the puzzle task than did Bs but this pattern was reversed among high impedance subjects (with non-significant A-B differences among low impedance subjects).[11]

At least two interpretations of the unexpected patterning of blood pressure and puzzle task means can be ventured. The first is derived from Seligman's (1975) theory of learned helplessness and from the findings of Krantz, Glass & Snyder (1974; cf., Glass, 1977) that Type As are more susceptible than Bs to the experience of helplessness when exposed to prolonged or uncontrollable environmental stressors. To the extent that traffic congestion is experienced as an intense or uncontrollable stressor, high impedance As may eventually give up their attempts to exert control over traffic conditions and, consequently, manifest less physiological arousal than high impedance Bs. This interpretation of the blood pressure results, however, is contradicted by the finding that high impedance As were more persistent in their attempts to solve insoluble puzzles than either medium impedance As or high impedance Bs. Moreover, no significant A-B or A-B x impedance effects were found on subjects' ratings of the severity of traffic congestion.

An alternative and more plausible explanation of the arousal and task performance results is based on the assumption that commuting stress is mediated by a discrepancy between the commuter's expectations about and actual experience of travel constraints. Specifically, certain attributes of medium impedance As and high impedance Bs may have predisposed these groups to be especially sensitive to traffic conditions. Among the As, for example, more than 50% of the low and medium impedance subjects have changed residence at some point in their careers to shorten commuting distance while only 20% of the high impedance As had relocated for this reason. Thus, for medium impedance As who had relocated in the hope of reducing commuting problems yet were still experiencing intermediate levels of congestion, the discrepancy between actual and ideal commuting conditions may have been greater than for high or low impedance As (whose expectations about the commute were more congruent with actual travel conditions). Furthermore, As who are characteristically more impatient than Bs may accommodate more readily to long distance-high speed commutes than to medium distance-medium speed commutes. In effect, a greater degree of person-environment fit may prevail for the former group than for the latter.

A somewhat different set of circumstances may have increased the salience of traffic congestion among high impedance Bs. Commuters in this group reported the lowest level of residential choice among all participants in the study and, like other Type Bs, scored low on the JAS Job Involvement factor. Therefore, it seems reasonable to expect that these persons would find it difficult to cope with the demands of long distance commuting between work and residential settings that are viewed as uninvolving and constraining, respectively.

The potential impact of commuting demands on the behavior and personality of travelers is suggested by the finding that high impedance Bs manifested greater time urgency in their driving habits than did any of the Type As in our study. Evidence that this finding reflects the consequences of continued exposure to commuting pressures rather than the invalidity of the A-B construct is provided by the significant correlation between the number of months on route and time-urgent driving scores among high impedance Bs, $r(8) = .79$, $\underline{p} < .001$.

The above interpretations, while intriguing, remain speculative due to the retrospective nature of our research design. This point is illustrated by the significant A-B x impedance interaction effect on car size which parallels the obtained pattern of means for blood pressure and puzzle task performance. In this case, we can not determine whether medium impedance As and high impedance Bs purchased relatively small cars for reasons unrelated to commuting stress and, subsequently, were stressed by conditions within the vehicle (e.g., lack of space, reduced insulation for other vehicles); or as an unsuccessful coping strategy aimed at reducing their exposure to traffic congestion. Perhaps commuters who have been sensitized to the constraints of congestion purchase smaller cars with the expectation that they will be more maneuverable in congested situations. (Car size, in fact, was found to be inversely correlated with travel speed $\underline{r}(94) = -.22$, $\underline{p} < .019$.)

At least one other unexpected finding merits comment: i.e., the significant interaction effects on blood pressure and task performance were not accompanied by corresponding effects on subjects' mood and annoyance levels. The apparent discontinuity between perceptual and attitudinal measures, on the one hand, and physiological and task performances indices, on the other, is further reflected by the significant inverse correlations observed among many of these variables. For example, diastolic blood pressure was negatively correlated with perceived morning congestion, $\underline{r}(93) = -.21$, $\underline{p} < .023$. Also, while months on the route was positively correlated with diastolic blood pressure (see Table 4), it was negatively correlated with morning congestion, $\underline{r}(94) = -.20$, $\underline{p} < .026$, evening congestion, $\underline{r}(94) = -.15$, $\underline{p} < .08$, concern about the widespread useage of automobiles within the city, $\underline{r}(93) = -.21$, $p < .022$, and concern about air pollution $\underline{r}(93) = -.27$, $\underline{p} < .004$. While these correlations are not large, the <u>pattern</u> of findings suggests that increased physiological arousal resulting from commuting stess is accompanied by psychological adaptation to, and possibly even denial of, such stress.

On the whole, the findings from this study indicate that routine exposure to traffic congestion is associated with significant differences in the mood, physiology, and task performance of commuters. Moreover, the present research provides preliminary support for the conceptualization of traffic congestion as an environmental stressor and suggests directions for developing more refined assessments of impedance. Specifically, it will be important in future research to (1) develop behavioral criteria of impedance (e.g., frequency of braking during the commute); (2) monitor commuters' behavior and physiology while they are traveling, as well as after they have completed the commute; and (3) determine whether the effects of travel conditions on arousal and task performance are accompanied by behavioral adaptations (e.g., participation in carpools, residential relocation, purchase of a more luxurious car) or by long-term decrements in health status to the extent that such coping strategies are not utilized. Finally, the results of this study offer additional construct validation of the coronary-prone behavior pattern and suggest its importance in mediating the impact of traffic conditions on commuters.

Table 1

Mean Levels of Subjective Congestion and Satisfaction With the Commuting Process

Condition	n	Subjective congestion for week (a.m.) M	Subjective congestion for week (a.m.) SD	Subjective congestion for week (p.m.) M	Subjective congestion for week (p.m.) SD	Traffic congestion as a frequent inconvenience M	Traffic congestion as a frequent inconvenience SD	Satisfaction with the commute M	Satisfaction with the commute SD
Low Impedance									
Type A	10	3.23	2.09	3.62	1.86	3.80	2.10	5.60	1.35
Type B	10	2.82	1.68	3.36	1.20	2.50	1.18	5.90	1.20
Medium Impedance									
Type A	6	3.83	2.01	4.25	1.82	3.50	2.26	5.67	1.51
Type B	11	4.94	.78	6.11	1.82	4.18	1.72	5.55	1.29
High Impedance									
Type A	14	4.06	1.29	5.24	1.95	5.36	1.34	4.43	1.28
Type B	10	4.72	1.69	5.12	1.60	4.00	2.11	4.60	1.08

Note The subjective congestion items are nine-point semantic differential scales. The traffic congestion and commuting satisfaction items are seven-point scales. Larger means indicate higher scores on the attribute listed.

Table 2

Number of Persons Indicating a Desire to Change Their

Residence Due to Traffic-Related Problems[a]

Response	Impedance					
	Low		Medium		High	
	Type A	Type B	Type A	Type B	Type A	Type B
Yes	0	0	0	0	5	7
No	10	9	6	12	8	3

a. X^2 (5) = 27.64, $p < .001$

Table 3

Mean Mood For the Week

Condition	n	Tense M	Tense SD	Irritable M	Irritable SD	Nervous M	Nervous SD	Impatient M	Impatient SD
Low Impedance									
Type A	10	3.81	.72	4.60	.32	4.25	.42	4.44	.44
Type B	10	3.97	.52	4.52	.46	4.37	.53	4.42	.51
Medium Impedance									
Type A	6	4.48	.43	4.78	.20	4.35	.51	4.33	.47
Type B	11	4.03	.52	4.55	.43	4.36	.42	4.53	.45
High Impedance									
Type A	15	4.43	.71	4.73	.59	4.75	.71	4.55	.75
Type B	10	4.53	.65	4.61	.61	4.71	.53	4.54	.56

Note The mood items are five-point Likert scales. Larger means indicate higher scores on the attribute listed.

Table 4

Pearson Correlation Coefficients for Blood Pressure

And Commuting Indices

Commuting Indices \ Blood Pressure	Systolic pressure	Diastolic pressure
Distance (Miles)	.26* (.25**)	.25* (.25**)
Duration (Minutes)	.24* (.17*)	.18 (.14)
Speed (Mi/Min.)	.22* (.29**)	.26* (.33***)
Months on Commute	.14 (.19*)	.27* (.28**)

Note: n=64. Numbers in parentheses indicate correlation coefficients for N=100.

*** $p < .001$

** $p < .01$

* $p < .05$

Table 5

Mean Blood Pressure and Task Performance Levels

Condition	n	Systolic blood pressure M	Systolic blood pressure SD	Diastolic blood pressure M	Diastolic blood pressure SD	Attempts on puzzle 1 (insoluble) M	Attempts on puzzle 1 (insoluble) SD	Attempts on puzzles 1&3 (insoluble) M	Attempts on puzzles 1&3 (insoluble) SD	Digit Symbol Transcription M	Digit Symbol Transcription SD	Digit Symbol Recall M	Digit Symbol Recall SD
Low Impedance													
Type A	11	122.64	12.22	74.75	3.50	9.00	6.02	14.45	7.29	65.25	15.88	6.13	2.3
		(11.06)	(.54)	(8.36)	(.20)	(1.99)	(.69)	(2.51)	(.65)	(8.03)	(.99)	(2.43)	(.5
Type B	10	124.20	14.82	76.50	9.92	7.20	2.57	11.50	3.92	55.89	13.55	6.77	1.9
		(11.13)	(.67)	(8.73)	(.57)	(1.89)	(.50)	(2.39)	(.33)	(7.43)	(.89)	(2.57)	(.4
Medium Impedance													
Type A	6	135.83	7.47	80.50	6.72	9.67	10.07	15.33	9.73	67.00	8.46	6.80	1.1
		(11.65)	(.32)	(8.97)	(.37)	(1.82)	(1.01)	(2.47)	(.88)	(8.17)	(.51)	(2.60)	(.2
Type B	12	126.50	16.47	75.58	8.71	11.25	4.29	16.17	6.51	53.42	14.71	5.92	1.9
		(11.23)	(.73)	(8.68)	(.50)	(2.34)	(.47)	(2.71)	(.38)	(7.24)	(1.06)	(2.40)	(.4
High Impedance													
Type A	15	125.93	8.00	76.47	7.10	11.73	8.02	18.27	6.17	64.09	12.65	5.00	1.6
		(11.22)	(.36)	(8.74)	(.41)	(2.27)	(.63)	(2.85)	(.34)	(7.97)	(.81)	(2.20)	(.4
Type B	10	138.90	11.30	82.00	8.30	6.20	6.43	10.00	6.82	54.75	7.03	6.75	1.4
		(11.78)	(.48)	(9.05)	(.46)	(1.46)	(.88)	(2.06)	(.77)	(7.39)	(.46)	(2.58)	(.2

Note: n=53 for analyses of digit symbol performance scores. Numbers in parentheses are transformed means and standard deviations. Transformations of puzzle data are logarithmic. Transformations of blood pressure and digit data are based on the square root of the original means.

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Footnotes

[1]The fact that only 25% of those employees contacted volunteered to participate in the study raises the possibility of selection bias. Specifically, our sample may over-represent persons most bothered by traffic congestion and other commuting problems. However, the significant between-groups variation in reports of traffic congestion and commuting satisfaction (see Results section and Table 1) suggests that our sample incorporates a representative cross-section of respondents on these dimensions.

[2]The mean number of months on route for all subjects (N=100) was 39.14. The range of response on this item was between 8 and 86 months, with 92% of the sample reporting that they had traveled the same route for a year or more.

[3]Measures of distance and time were first obtained on the screening questionnaire and these measures were then verified by those obtained on daily commuting logs. Only in a few cases did the commuting log measures vary significantly (i.e., fall outside criterion boundaries) from the estimates on the screening questionnaire, and these cases were then dropped from the design. For the two companies participating in the study, distance and time parameters were virtually identical.

[4]These analyses were computed using Cramer's (Note 2) "MANOVA" program MANOVA utilizes a least-squares analysis and computes an exact solution when the distribution of subjects across experimental groups is unequal. The order of testing was adjusted to obtain unbiased estimates of main effects.

[5] As reflected in the degrees of freedom for certain analyses, reported results are based only on the responses of those subjects for whom relevant data were available.

[6] As expected, significant impedance main effects were found in analyses of subjects' commuting distance ($p < .001$) and commuting time ($p < .001$) scores, both of which served as criteria for assignment of subjects to impedance groups. Also, significant A-B main effects were found not only on subjects' A-B factor scores ($p < .001$) but also on three additional scores derived from the JAS, all of which reflect subtypes of the more general A-B behavior pattern: Speed and Impatience, Job Involvement, and Hard Driving ($p < .001$ for all scores).

[7] Male specific analyses were performed rather than a sex x impedance x A-B MANOVA since there were too few females in the medium and high impedance conditions to permit an assessment of the interactions among the three factors.

[8] Results reported for the weekly blood pressure scores were consistent with those obtained in separate analyses of the arrival-time and mid-morning scores. Also, no significant differences between arrival-time and mid-morning blood pressure were found.

[9] Analysis of the digit-symbol memory scores revealed a divergent pattern of means in which As performed worse than Bs under high impedance conditions but better than Bs under medium impedance conditions. This interaction effect is not significant with age and educational level entered as covariates ($p < .20$) but is significant with age and SES as covariates, F (2,45) = 3.15, $p < .05$.

[10] A 2 x 3 ANOVA performed on subjects' locus of control scores, however, revealed the lack of significant A-B, impedance, and A-B x impedance effects. Moreover, the correlation between A-B and I-E scores was non-significant. For a further discussion of the interrelations among personal control, impedance, and stress, see Novaco, Stokols, Campbell, and Stokols (Note 3).

[11] The significant interaction on systolic pressure must be interpreted cautiously in view of the non-significant multivariate interaction on blood pressure ($p < .13$). The possiblity remains that the univariate effect is the result of chance rather than treatment variation. The significant interaction on diastolic pressure among males, however, can be viewed more confidently as a reliable finding in light of the significant multivariate interaction effect obtained with the all-male sample.