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Traffic Congestion, Type A Behavior, and Stress

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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 that impedes one's movement between two or more points. Sixty-one male and 39 female 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 enroute 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.

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, 1977; 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, Lundberg, & Frankenhaeuser, in press).

The current 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 that may exert pervasive effects on their lives. Traffic situations (especially during rush hour) are potentially stressful be-

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cause of 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 (Simonson, Baker, Burns, Keiper, Schmitt, & Stackhouse, 1968; Taggart, Gibbon, & Somerville, 1969; Hunt & May, Note 1), 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 (a) to develop a conceptualization of traffic congestion and its impact on people over extended periods, (b) to establish measurement criteria for operationalizing this conceptual framework, and (c) 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 that impedes one's movement between two or more points. The degree of *impedance* 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 (Appley & 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; Glass, Singer, & Pennebaker, 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 they become more impatient and irritated when they are delayed by co-workers on joint decision-making tasks (Glass, Snyder, & Hollis, 1974). Also relevant to the present study is the finding by Dembroski, MacDougall, and Shields (1977) 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:

1. 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.

2. 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 the Glass et al. (1974) delayed response task, an activity that 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 1,500 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. A response rate of only 25% raises the possibility of selection bias. Specifically, our sample may overrepresent 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.

From the initial group of volunteers, 100 persons were selected on the basis of the following criteria: (a) the average distance and duration of their daily commute to and from work, (b) their time of arrival at work, and (c) 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 8 months. The mean number of months on route was 39.14; the range was between 8 and 86 months, with 92% of the sample having traveled the same route for a year or more. 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 the following three major impedance groups were derived: (a) 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 min. on the road in either direction. (b) 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 17–20 min. on the road each way. (c) 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 min. 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 noncorrespondent rankings with regard to the time and distance distributions. These persons were assigned to two additional groups: (d) low distance–medium time ($n = 6$) and (e) 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 (see 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: (a) a weighted scoring system developed by Jenkins et al. in research with a large sample of adult males ($Mdn = .0$); (b) 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 ($Mdn = 8.0$); and (c) 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 weighted scoring system ($Mdn = 1.8$). There has been some controversy as to which of the first two procedures is most valid (cf. Glass, 1977), and we introduce 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 five 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 or she completed five daily commuting logs pertaining to the actual distances and times traveled each day and to the 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. Measures of blood pressure and heart rate were used to assess the possible physiological effects of routine exposure to traffic constraints. The use of these measures is justified on the basis of earlier research indicating a positive relationship between exposure to environmental demands and elevated levels of physiological arousal (cf. Forsyth, 1974; Gutmann & Benson, 1971; McGinn, Harburg, Julius, & McLeod, 1964; Rule & Nesdale, 1976).

On Tuesday and Thursday of the testing week, participants reported to a company conference room approximately 1.5 hours after arriving at work. 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 (1961). 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 pens or retracing a line. This task has been employed by Glass and 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-sec 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 sec 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 used to assess subjects' (a) perception of traffic congestion, (b) physiological arousal, (c) task performance, and (d) 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 computed on the basis of the ratings obtained between Monday and 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 (a) the five daily arousal scores, (b) the Monday, Wednesday, and Friday (arrival time) scores, and (c) the Tuesday and Thursday (midmorning) scores. The midmorning scores were used as baseline measures of subjects' physiological arousal because they were obtained in a setting unrelated to the transportation environment.

The principal measures of task performance were (a) the number of attempts made by each subject on Feather's (1961) insoluble puzzles, (b) the number of boxes correctly completed on the Digit Symbol Task, and (c) the number of symbols recalled in the Digit Symbol task.

Participants' mood was assessed daily by means of nine 5-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 was obtained from the background and personality questionnaires administered to subjects. The background questionnaire included items relating to the following six categories: (a) demographic data (e.g., marital status, education, and socioeconomic status); (b) 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); (c) 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, and desire to change current residence because of transportation-related problems); (d) health-related variables (e.g., weight, cigarette, coffee, and alcohol consumption, health problems, and medication); (e) job satisfaction and ratings of the physical and social environment at work; and (f) attitudes concerning environmental problems and transportation management plans.

All subjects completed the following personality scales in addition to the JAS: Rotter's (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 × 3 (A–B × Impedance) multivariate analyses of variance (MANOVAS) were performed on the major clusters of dependent variables.[1] Also, univariate analyses of variance were performed on certain measures derived from the background and personality inventories. All of the reported MANOVAS and ANOVAS used 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 × 3 (A–B × 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, $F(8, 104) = 3.29$, $p < .002$. Significant univariate effects were also obtained, indicating that subjects in the high- and medium-impedance conditions generally reported higher levels of morning congestion, $F(2, 55) = 4.35$, $p < .018$, afternoon congestion, $F(2, 55) = 7.27$, $p < .002$, congestion-related inconvenience, $F(2, 55) = 4.35$, $p < .018$, and lower levels of commuting satisfaction, $F(2, 55) = 5.92$, $p < .004$, than did those in the low-impedance groups (see Table 1).

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 6 months preceding this study) than had those in the high-impedance groups, χ^2 (5) = 12.92, $p < .024$, and that *no* subjects in the former two groups indicated a desire to change residence because of commuting problems whereas 52% of those in the high-impedance groups expressed this desire, χ^2 (5) = 27.64, $p < .001$.

Internal validity of the research design was further assessed by examining the orthogonality of the A–B and impedance factors as

[1] These analyses were computed using Cramer's (Note 2) "MANOVA" program. MANOVA uses 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.

Table 1
Mean Levels of Subjective Congestion and Satisfaction with the Commuting Process

Impedance condition	n	Subjective congestion for week (a.m.)		Subjective congestion for week (p.m.)		Traffic congestion as a frequent inconvenience		Satisfaction with the commute	
		M	SD	M	SD	M	SD	M	SD
Low									
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									
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									
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 9-point semantic differential scales. The traffic congestion and commuting satisfaction items are 7-point scales. Larger means indicate higher scores on the attribute listed.

well as the possible confounding of these factors with socioeconomic status, educational level, and sex. A 2 × 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. Moreover, no significant effects attributable to A–B, impedance, or the interaction of these factors were evident in a 2 × 3 ANOVA performed on socioeconomic status 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-impedance (84%) conditions, $\chi^2(5) = 10.69$, $p < .06$.

Effects of Experimental Factors

Experimental hypotheses were assessed through a series of 2 × 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 used covariates to control for individual differences on nonexperimental dimensions. Relevant covariates were selected on both theoretical and empirical grounds. For each dependent variable of interest, a set of potentially relevant covariates were designated. Those measures from among this set that were significantly correlated with the dependent variables were incorporated as covariates in the MANOVA tests. Age, weight, and number of months en 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 × Impedance MANOVAS were performed on males only ($n = 46$) as well as on the combined-sex sample ($n = 64$) to control for the possible effects of sex differences on our findings.[2] 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

[2] Male-specific analyses were performed rather than a Sex × Impedance × 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.

Table 2
Mean Mood for the Week

Impedance condition	*n*	Tense *M*	Tense *SD*	Irritable *M*	Irritable *SD*	Nervous *M*	Nervous *SD*	Impatient *M*	Impatient *SD*
Low									
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									
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									
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 5-point Likert scales. Larger means indicate higher scores on the attribute listed.

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 was 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 pérformance 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 four-item cluster of annoyance variables, $F(8, 106) = 1.95$, $p < .06$. Univariate tests indicated that high-impedance subjects rated themselves as more tense, $F(2, 56) = 4.77$, $p < .01$, and nervous, $F(2, 56) = 4.01$, $p < .02$, than did low-impedance individuals (see Table 2). 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, $r(62) = .26$, $p < .01$; for distance and diastolic pressure, $r(62) = .25$, $p < .02$). Certain of these correlations become more robust when the entire sample (all five impedance groups, $N = 100$) is used in the analyses (see Table 3).

Analyses of items pertaining to certain as-

Table 3
Pearson Correlation Coefficients for Blood Pressure and Commuting Indices

Index	Pressure Systolic	Pressure Diastolic
Distance (in miles)	.26* .25**	.25* .25**
Duration (in min.)	.24* .17*	.18 .14
Speed (in miles/min.)	.22* .29**	.26* .33***
Months on commute	.14 .19*	.27* .28**

Note. Numbers in first entry in each column are based on $n = 64$. Numbers in second entry in each column are based on $N = 100$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

pects 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 ($M = 41.4$ mph) than did those in the medium- ($M = 36.0$ mph) or low- ($M = 27.0$ mph) impedance groups, $F(2, 57) = 20.90$, $p < .001$. In addition, medium-impedance subjects had spent more months on their current commute ($M = 51.84$) than had low- ($M = 31.25$) or high-impedance ($M = 38.51$) individuals, $F(2, 56) = 6.44$, $p < .003$.

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 4). 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 nontransformed scores are analyzed.

A 2 × 3 MANOVA performed on Digit Symbol transcription and memory scores revealed a significant A–B multivariate effect, $F(2, 44) = 5.43$, $p < .008$.[3] 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 ($M = 37.73$ mph) than did Type Bs ($M = 33.10$ mph), $F(1, 57) = 4.60$, $p < .036$. Also, the Type As spent significantly less time on the road ($M = 25.84$ min.) than did the Type Bs ($M = 26.50$ min.), $F(1, 57) = 5.68$, $p < .02$, while average commuting distance 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 ($M = 46.00$) than had Type Bs ($M = 33.88$), $F(1,56) = 9.02$, $p < .004$. In addition, Type As reported having had a greater degree of choice in selecting their current residence than did Type Bs, $F(1, 56) = 4.18$, $p < .04$.

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 5 days of testing were analyzed in terms of a 2 × 3 MANOVA. Multivariate effects were nonsignificant although a significant A–B × Impedance univariate effect on systolic pressure was found, $F(2, 55) = 3.34$, $p < .04$, 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 4). A similar pattern of means was obtained for diastolic pressure, but the interaction effect did not reach significance ($p < .14$).

Among males only, the multivariate interaction effect was significant, $F(2, 36) = 3.53$, $p < .04$, with the pattern of means for systolic and diastolic pressure corresponding to that obtained in the combined-sex sample. For the male subsample, however, the univariate interaction effect on diastolic pressure was significant, $F(1, 37) = 7.26$, $p <$

[3] As reflected in the degrees of freedom for these analyses, Digit Symbol data were not available for all subjects.

Table 4
Mean Blood Pressure and Task Performance Levels

Impedance condition	n	Pressure: Systolic *M*	Pressure: Systolic *SD*	Pressure: Diastolic *M*	Pressure: Diastolic *SD*	Attempts on Puzzle 1 (insoluble) *M*	Attempts on Puzzle 1 (insoluble) *SD*	Attempts on Puzzles 1 and 3 (insoluble) *M*	Attempts on Puzzles 1 and 3 (insoluble) *SD*	Digit Symbol transcription *M*	Digit Symbol transcription *SD*	Digit Symbol recall *M*	Digit Symbol recall *SD*
Low													
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	2.36
		11.06	.54	8.36	.20	1.99	.69	2.51	.65	8.03	.99	2.43	.53
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	1.99
		11.13	.67	8.73	.57	1.89	.50	2.39	.33	7.43	.89	2.57	.41
Medium													
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	1.10
		11.65	.32	8.97	.37	1.82	1.01	2.47	.88	8.17	.51	2.60	.22
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	1.93
		11.23	.73	8.68	.50	2.34	.47	2.71	.38	7.24	1.06	2.40	.41
High													
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	1.67
		11.22	.36	8.74	.41	2.27	.63	2.85	.34	7.97	.81	2.20	.40
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	1.49
		11.78	.48	9.05	.46	1.46	.88	2.06	.77	7.39	.46	2.58	.29

Note. $n = 53$ for analyses of Digit Symbol performance scores. Numbers in second entry in each column 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.

.01, 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.

The results reported for the weekly blood pressure scores were consistent with those obtained in separate analyses of the arrival-time and midmorning scores. The lack of significant differences between these indices of blood pressure may be attributable to the cumulative effects of transportation conditions on baseline (chronic) as well as on traffic-specific indices of arousal. A greater number and variety of baseline measures (e.g., blood pressure readings taken at home prior to departure for work) must be obtained in future studies to provide a clearer assessment of the relationship between chronic and commuting-specific measures of arousal.

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 4). A significant A–B × Impedance effect was found in separate ANOVAS performed on subjects' attempts to solve Puzzle 1, $F(2, 56) = 4.78$, $p < .01$, 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.

Additional ANOVAS performed on demographic and personality variables revealed significant A–B × Impedance effects on car size and the "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 conditions, $F(2, 56) = 8.90$, $p < .001$. 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, $F(2, 53) = 2.72$, $p < .07$. Among males only, the interaction effect on driving habits was more pronounced, $F(2, 38) = 3.46$, $p < .04$.

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 were 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. (Data pertinent to this issue are being gathered in a follow-up phase of the present project.) 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 3).

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 3).

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 Type A behavior (cf. Bortner & Rosenman, 1967; Glass, 1977; Glass et al., 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).[4]

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 nonsignificant A–B differences among low-impedance subjects).[5]

A 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 had 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 con-

[4] The correlation between A–B and internal–external scores, however, was nonsignificant. For a further discussion of the interrelations among personal control, impedance, and stress, see Novaco, Stokols, Campbell, and Stokols (in press).

[5] The significant interaction on systolic pressure must be interpreted cautiously in view of the nonsignificant multivariate interaction on blood pressure ($p < .13$). The possibility 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 in light of the significant multivariate interaction effect obtained with the all-male sample.

ditions). 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 en route and time-urgent driving scores among high-impedance Bs, $r(8) = .79$, $p < .001$.

The above interpretations, while intriguing, remain speculative due to the restrospective nature of our research design. This point is illustrated by the significant A–B × Impedance interaction effect on car size that parallels the obtained pattern of means for blood pressure and puzzle task performance. In this case, we cannot 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 from other vehicles), or if they purchased them 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, $r(94) = -.22$, $p < .019$.

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, while providing preliminary support for the conceptualization of traffic congestion as an environmental stressor, the present research suggests directions for developing more refined assessments of impedance. Specifically, it will be important in future research to (a) develop behavioral criteria of impedance (e.g., frequency of braking during the commute); (b) monitor commuters' behavior and physiology while they are traveling as well as after they have completed the commute; and (c) determine whether the effects of travel conditions on arousal and task performance are accompanied by behavioral adaptations (e.g., change of residence, participation in carpools, purchase of a more luxurious car) or by long-term decrements in health status to the extent that such coping strategies are not used. Finally, the results of this study offer partial construct validation of the coronary-prone behavior pattern and suggest its importance in mediating the impact of traffic conditions on commuters.

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