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Transportation, Stress, and Community Psychology[1]

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Conditions of transportation were investigated as sources of psychological stress as they affect the physiology, task performance, and mood of commuters. Participants in the study were 100 employees of industrial firms. Traffic congestion was construed as a behavioral constraint in terms of the concept of impedance which is defined by the parameters of distance and time. It was expected that the effects of impedance would be mediated by personality factors, such as locus of control. Multivariate tests of the internal validity of the impedance factor were significant. However, significant main effects for impedance were obtained only for mood and residential adaptation. The predicted interactions of impedance with locus of control were obtained across task performance indices. In multiple regression analyses, the distance and speed of the commute to work were found to account for significant proportions of variation in blood pressure, while several indices of personal control had significant regression effects on the task measures. The implications of the results for research in community psychology are discussed.

The technological progression in transportation from horses to streetcars to automobiles has encouraged land-use patterns that necessitate greater mobility of community members and has generated social and economic problems in

urban communities (Schaeffer & Schlar, 1975). Curiously, however, problems related to transportation have eluded the attention of community psychologists. Seymour Sarason (1974) has remarked, "I have never met a psychologist or psychiatrist with a 'community' orientation who was even interested in the problem of public transportation or who understood its differential relationship to various groups in the community" (pp. 147-148). In fact three recent community psychology texts (Bloom, 1977; Heller & Monahan, 1977; Rappaport, 1977) do not contain a single reference or index for transportation.

Transportation resources are prime determinants of the physical, economic, and social characteristics of urban communities. Early social ecologists (Burgess, 1926) recognized that the shape of urban areas is determined by their facilities to transport goods and to provide mobility for residents. Accessibility is a central characteristic of cities. Consequently, the economic base, patterns of residential location, and social relationships in an urban area are closely intertwined with transportation resources.

Community psychologists could select from among several avenues of investigation in the area of transportation. For example, one might choose to study the effects of differential mobility across various age and socioeconomic groups, in that excessive reliance on the automobile may be having adverse effects on the young, the poor, and the elderly. Another approach might be for the community psychologist as social planner to study the process whereby community values could be incorporated into transportation planning (Catalano & Monahan, 1976; Olson, 1969). Alternatively, experimental projects might investigate public attitudes towards mass transit and ride-sharing and examine the effectiveness of various strategies for increasing ridership on mass transit services (Deslauriers & Everett, 1977; Everett, Hayward, & Meyers, 1974; Horowitz & Sheth, 1976).

The line of investigation adopted by the present authors follows from our interest in human stress and adaptation. The point of departure was our belief that routine exposure to the demands of long-distance commuting may have a cumulative impact on personal health, psychological adjustment, job performance, and family relationships. The traffic congestion typically associated with automobile travel between residential and work settings is viewed as a naturalistic stressor that is hypothesized to have adverse effects over time. Traffic congestion is a salient feature of urbanization, although congestion as a hindrance to mobility is not unique to automobile travel, having also occurred with horse-drawn vehicles in ancient Rome and in 19th century European and American cities (Smerk, 1974).

While it is characteristic of modern societies that urban growth increases the distance and length of time traveled by people between residential and work settings (Catanese, 1972), the impact of commuting to work on personal health and behavior has only recently received experimental attention (Singer, Lundberg,

& Frankenhauser, 1977; Taylor & Pocock, 1972). There has been an abundance of research on human factors in traffic safety (e.g., Forbes, 1972) and on the effects of driving on particular physiological responses, such as heart rate and hormone secretion. However, a conspicuous shortcoming of the existing research on transportation effects (except for Singer et al., 1977) is the absence of a theoretical framework.

The theoretical model that guides our research is based on perspectives of psychological stress (Appley & Trumbull, 1967; Lazarus, 1966) which are interactionist in nature. That is, the approach to environment—behavior relationships within this orientation emphasizes mutually influenced processes between environment and behavior and assumes that environmental influences will be mediated by cognitive, personality, and social psychological factors. Consequently, we expect that the effect of traffic congestion on urban commuters will vary as a function of identifiable psychological factors associated with how stress is experienced.

Stress is a hypothetical state of imbalance between environmental demands and the response capabilities of the person or system to cope with these demands (McGrath, 1970; Mechanic, 1968). *Stressors* are aversive events or elements in various environmental fields that disturb the organism's equilibrium, interfere with its performance, or even threaten its survival. *Stress reactions* are the adverse health and behavioral consequences of the failure to cope with environmental demands. We assume that stressors, as environmental demands, do not have a uniform effect on individuals and that their impact is mediated by psychological processes.

Conditions of transportation are well-suited for an ecological analysis of stress. Traffic congestion, mode of transportation, residential choice, job satisfaction, and a host of other environmental and personality variables may have an aggregate adverse effect on commuters. As a particular stress agent, traffic congestion can be viewed as a behavioral constraint that impedes one's movement between two points. Traffic congestion also operates as a frustration by blocking goal-directed behavior, such as getting to work on time. Extensive research has demonstrated that behavioral constraints and frustrations induce a variety of physiological and behavioral imbalances. Adverse physiological and behavioral effects of such constraints have been found in research on crowding (Altman, 1975; Stokols, 1976; Sundstrom, in press) and on human aggression (Berkowitz, 1969; Buss, 1963; Hokanson & Burgess, 1962).

We have construed traffic congestion as a stressor in terms of the concept of *impedance*. The degree of impedance is defined by two basic physical parameters: (a) the distance traveled between origin and destination, and (b) the amount of time spent in transit between these points. Consequently, the greatest impedance would result from traveling long distances slowly, and the least impedance would occur when short distances are traveled in a small amount

of time. The degree of stress that a commuter experiences on a route of particular impedance is hypothesized to be mediated by a host of factors which we have attempted either to control experimentally or to measure systematically.

Personal control has been recognized as an important mediator of stress. Recent research on human stress has found that the individual's perception of control over aversive events significantly influences stress reactions (Averill, 1973; Glass & Singer, 1972; Lefcourt, 1973). Various forms of decisional, cognitive, and behavioral control over aversive events can ameliorate the stress impact of those events (cf. Averill, 1973).

With respect to commuting, various elements of control bear upon the commuter's experience of stress. For example, the degree of choice involved in the selection of one's residence may mediate the effects of commuting. A high-impedance commute may be more stressful when residential location has occurred under low choice (e.g., being the only place one could afford) than under high choice conditions (e.g., selecting the house because of its value as an investment). In addition, the type or size of car and the resources within the vehicle that enable the commuter to control features of its environment (such as space, seating comfort, insulation from noise, air conditioning, and music) may also influence the degree of stress that is experienced.

The generalized expectation for control over situational events has received extensive attention as a personality variable (Phares, 1977; Rotter, 1966, 1975). In Rotter's theory, the concept of locus of control refers to a generalized expectancy concerning whether or not persons perceive themselves to have power over what happens to them. This concept is represented in terms of the now familiar dimension that is called "internal–external control." Internal control refers to the perception that positive and/or negative events are a consequence of one's own behavior and are thus under personal control. External control refers to the perception that events in certain situations are independent of one's own behavior and are therefore beyond personal control (Lefcourt, 1966).

Hypothetically, belief in personal control as a generalized expectancy will influence how a person is affected by and copes with stress, provided that the investigation controls other essential factors in Rotter's theory, namely, experience in the situation and reinforcement value (cf. Rotter, 1975). When in an aversive situation where reinforcement is independent of their behavior, internals will be in a situation of incongruity between their generalized expectations for control and the locus of control for that particular situation. As a consequence, internals should experience greater arousal than externals and be more persistent in trying to escape from the situation. Houston (1972) has found that internals increased significantly more in heart rate than did externals under threat of shock, whether or not there was incongruity between general and situational expectations for control. He attributed the internals' higher arousal to greater efforts expended to exert control in the experimental task. Pertinent to the task situation of the present project, it has been found that internals exhibit higher performance than do externals in a test situation where

successful performance is contingent on one's own efforts, i.e., a situation of congruity between general and situational expectations for internal control (Houston, 1972; Rotter & Mulry, 1965).

The present study is an investigation of the transportation environment as a potential field of stress and attempts to examine how various forms of control and expectations for control influence stress reactions as measured by various physiological, behavioral, and self-report indices. The objectives of the study were to test the operationalization of our concept of impedance and its differential effects on commuters and to examine the extent to which stress reactions were mediated by personal control factors.

The investigation was conducted with the employees of two Irvine, California industrial firms. Impedance was defined as a three-level factor (low, medium, high) based on the joint distributions of distance and time of commute. While the results reported here consist of a subset of the data obtained, their focus is on the extent to which impedance is mediated by various personal control dimensions. In this regard, the following hypotheses were set forth:

1. Routine exposure to high levels of impedance in commuting to work will result in higher perceptions of congestion, higher levels of physiological arousal, greater task performance deficits, and greater disturbances in mood than will exposure to lower impedance conditions. This hypothesis predicts significant main effects for impedance.

2. The distance and time parameters of the impedance concept will independently account for significant proportions of variation in the various stress outcome measures. This hypothesis predicts significant linear regressions for distance and time.

3. The impedance conditions will have differential effects for internal vs. external locus of control subjects. Internals will experience greater arousal under high impedance than will externals. However, on the task measures, high-impedance internals will have a higher level of task performance than will externals, since the test situation will combine high arousal with tasks for which outcome is contingent on performance. This hypothesis predicts significant interactions between impedance and locus of control.

4. The set of personal control indices (I-E total, residential choice, and type of car) will account for significant proportions of variation in the various stress outcome measures. This hypothesis predicts significant linear regressions for the personal control indices.

METHOD

Subjects

Participants in the study were 100 employees of two Irvine Industrial Area companies. One firm manufactured ophthalmic products, and the other manufac-

tured aerospace parts. There were no significant differences in the socioeconomic status of the subjects as a function of companies, and participants ranged in occupational levels from basic manufacturing to executive. Subjects consisted of 61 males and 39 females, having a mean age of 36.8 years, and a mean educational level of 14.4 years. They were selected for the distance and time of their commute by the procedure given below for the impedance design. Subjects were also selected for the criteria of (a) having been on their particular commuting route for a least 6 months, (b) being on the day shift, and (c) not having recently returned from or being about to go on vacation. Subjects were paid $10 for their voluntary participation in the study.

The initial contact with subjects was made through the cooperation of the personnel departments of their respective companies. A general mailing was distributed to all company employees (about 1,500 persons) and approximately 25% of those initially contacted agreed to participate by returning a preliminary screening questionnaire.[3] When the selection criteria were applied to this pool of subjects, about one-third were selected for the impedance design.

Experimental Factors

The impedance variable is a three-level factor defined in terms of distance and time. High-impedance subjects were those commuters in the top 25% of the distributions for both distance and time of travel to work. Medium-impedance subjects were in the middle 30% of these distributions, and low-impedance subjects were in the bottom 25%. The correlation of distance and time was $r = .93$ for the selected sample. For the two companies, the distance and time parameters were virtually identical. The criteria were as follows: low impedance = 1.0–7.5 miles, 2–12 minutes; medium impedance = 10–14 miles, 17–30 minutes; high impedance = 18–50 miles, 30–75 minutes. Measures of distance and time were first obtained on a screening questionnaire, and these measures were then verified by entries on the daily commuting logs. Only in a few cases did the commuting log entries vary significantly (i.e., fall outside criterion boundaries) from the estimates on the screening questionnaire, and these cases were then excluded.

The above three impedance groups consisted only of those participants having corresponding positions on the distance and time distributions (i.e., low/low, middle/middle, high/high). A total of 85 subjects were in these con-

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[3] 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 overrepresent persons most bothered by traffic congestion and other commuting problems. However, the significant between-groups variation in reports of congestion and commuting satisfaction reflected in Table I of our results suggests that our sample incorporates a cross-section of respondents on these dimensions.

ditions. Data from an additional 15 subjects in two additional groups (low distance/middle time and middle distance/high time) were not used in the impedance design analyses but were utilized in the multiple regression analyses which tested the separate effects of the physical parameters and personal control indices on the dependent measures. These additional subjects were included in order to increase the sample size for the regression analyses which separately examined the predictive contributions of distance and time.

Subjects within each of the three main impedance groups were blocked on their generalized expectations for control as either internals or externals. A median split was performed on the total scores for the Rotter I-E scale to create this classification. The distribution has a median of 7.88, and subjects with scores of 8 or above were classified as externals. There were no significant differences between internals and externals within impedance levels on either the distance or time of their commute. In each impedance cell, less than half of a standard deviation separates the internal and external means for distance, and the time means are virtually identical. Thus, the impedance and the locus of control dimensions can be treated as orthogonal.

Procedure

The selected participants were informed of their selection for the study by a personal letter. Included with this notification was a background questionnaire to obtain data on demographic variables, perceptions of commuting, personal health, various aspects of the residential and job environments, and attitudes toward transportation management plans.

On each day of a work week, participants completed a travel log, recording the mileage and time at the beginning and end of their trips to and from work. Subjective evaluations of traffic congestion were also obtained on the daily logs. On those days for which a log was kept, measures of physiology and mood were obtained immediately upon arrival at work on 3 days and after 1 hour at work on the other 2 days. On Monday, Wednesday, and Friday, participants drove to a prearranged station located in the parking lot of their company. Blood pressure and heart rate were taken immediately after they got out of their car, following which they were asked to rate their mood on nine affective dimensions that pertain to stress. Systolic and diastolic blood pressure were recorded by a Physiometrics SR 2 automatic blood pressure recorder.[4] Heart rate was ob-

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[4] The Physiometrics SR 2 records pressure by means of infrasonic pulse detection through a sensitive transducer built into a cuff bladder. The cuff is inflated at a standard rate by an automatic pump. The transducer detects low-frequency vibrations in the arterial wall which are transformed to a galvanometer pen that inscribes pressure readings on a calibrated cardboard disk. An automatic circuit adjusts sensitivity, and cuff deflation is manually regulated to achieve a standard rate of deflation of 3-5 mm per beat. This instrument has many advantages over the traditional auscultation methods, particularly in noisy environments.

tained by means of a cardiotachometer component to the Physiometrics SR 2 which displays heart rate on the deflation cycle of blood pressure recording.

On Tuesday and Thursday, task performance was assessed in addition to physiology and mood. The testing sessions were held within a building of the company in groups of 8 to 10 subjects. In the first session, subjects were administered the Feather (1961) "perceptual reasoning" test. This is a task that was developed by Feather in his studies of persistence and most recently has received use by Glass and Singer (1972) as a measure of frustration tolerance. Most important, this task has been shown by the latter authors to be sensitive to the aftereffects of environmental stressors. The task consists of four puzzles. Puzzle 1 and 3 are insoluble, while Puzzles 2 and 4 are soluble. The subject's task is to trace the lines of a diagram without lifting the pen or retracing a line. The stress measure is the number of attempts at each of the insoluble puzzles.

In the second testing session, the digit symbol task from the Wechsler Adult Intelligence Scale was administered. For this task, the subject must copy into rows of boxes the symbols associated with a line of digits and must do so with speed and accuracy for a 90-second period. The digit symbol test measures psychomotor speed and concentration (Wechsler, 1958) and is appropriate as an index of stress effects. Immediately after the digit symbol test, subjects were given an incidental memory test. They were given 30 seconds to recall the symbols associated with the nine digits of the Wechsler task.

Dependent Measures[5]

The principal dependent variables used for the present paper consist of four basic sets of indices: (a) self-ratings of traffic congestion, (b) physiological measures, (c) task performance measures, and (d) self-ratings of mood. There are multiple variables within each set, and multivariate analyses are performed in testing the experimental hypotheses.

For many of the dependent measures, analysis of variance were performed using covariates to remove variation due to nonhypothesized factors. We arrived at a determination of proper covariates by selecting from an intercorrelational analysis those personal attribute dimensions having a significant correlation with the dependent measure of interest and that when added as a covariate resulted in a significant F ratio for its effect. For systolic and diastolic blood pressure, age and weight were used as covariates. For heart rate, cigarette consumption and use of medication were added to age and weight. Age and educational level were used as covariates for the task performance measures.

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[5] Due to the large number of measures obtained, there are missing data on some subjects. This is reflected in the degrees of freedom for certain analyses.

In addition to the basic covariates, a set of residential and employment covariates were used to control for reward value in tests of the locus of control factor, as Rotter's (1966) theory specifies.[6] The employment covariates (job satisfaction and ratings of the work environment) did not have significant effects, whereas the residential covariates (residential choice and residential satisfaction) did have significant covariate effects and are reported below.

RESULTS

Internal Validity Analyses

The three levels of the impedance factor were construed to represent increasing conditions of traffic congestion. Four self-report measures of congestion and commuting satisfaction obtained on two different instruments (travel logs and background questionnaires) separated by a 1-month interval were used to evaluate the assumed relationship between impedance levels and perceived congestion. Descriptive statistics for their four indices are presented in Table I. A multivariate analysis of variance (MANOVA) was performed on these four indices to test for an impedance effect, and the results were significant, multivariate $F(8, 158) = 3.35, p < .001$. Univariate analyses were significant for each of the four indices: morning congestion, $F(2, 82) = 3.48, p < .035$, and afternoon congestion, $F(2, 82) = 5.54, p < .006$, on the travel logs, and for the traffic congestion, $F(2, 82) = 4.69, p < .01$, and the commuting satisfaction ratings, $F(2, 82) = 8.06, p < .001$, on the background questionnaire. Each of the congestion measures increase going from the low to the middle to the high condition, providing a clear indication that our grouping of subjects on the basis of impedance was meaningful.

As a further test of the impedance effect, several backgroun questionnaire items were analyzed to examine the impact that the demands of commuting exerted on residential choice and relocation. Two items for which the respondents checked "yes" or "no" inquired as to whether they had ever moved their residence to shorten the distance of their commute or to reduce exposure to traffic congestion. Chi-square analyses were performed on these data across

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[6] Rotter's social learning theory states that behavior potential is a function of the expectation that the behavior will result in reinforcement in a particular situation and the value of the reinforcement. The expectancy in a particular situation is a function of specific expectancies and generalized expectancies. Locus of control is a generalized expectancy. However, on the basis of theory, predictions about behavior as a function of locus of control must take reinforcement value into account. Our indices of residential and employment covariates are intended to accomplish this, as these factors may affect how the commuter experiences the travel between home and work. The specific expectancy in the commuting situation was controlled by the selection criterion of length of time on route.

Table I. Means Ratings of Congestion Across Levels of Impedance[a]

Impedance	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	27	3.24	1.90	3.70	1.69	3.19	1.90	5.74	1.26
Medium	22	4.24	1.72	5.13	2.19	3.82	2.17	5.68	1.25
High	36	4.32	1.57	5.19	1.84	4.69	1.86	4.53	1.46

[a] All items are 7-point semantic differential scales. Larger means indicate higher scores on the attribute listed. Impedance effects are significant at $p < .04$ for subjective congestion (a.m.) and at $p < .01$ for all other indices listed. The multivariate effect is significant at $p < .001$.

the three impedance conditions. The results were significant for the "shorten distance" item, $\chi^2 = 15.10$, $df = 2$, $p = .0005$, as 44.4% in the low impedance condition, 63.6% in the middle impedance condition, and 14.3% in the high impedance condition indicated that they had changed their residence for this reason. Similar effects were obtained for the "reduce exposure to congestion" item, $\chi^2 = 8.56$, $df = 2$, $p = .01$, as 33.3% low impedance, 40.9% middle impedance, and 8.65% high impedance subjects reported having changed their residence in this regard. These data indicate that commuters have made efforts to adapt to the demands of transportation by relocating. However, vis-à-vis the stress hypothesis of the study, it should be recognized that all subjects had been on their particular commuting route for a minimum of 8 months prior to the collection of stress measures. In fact, 92% had been on that route for a year or more.

Table II. Number of Persons Designating Transportation Conditions as a Reason for Wanting to Change Residence[a]

Response	Impedance		
	Low	Medium	High
Yes	0 (0%)	0 (0%)	15 (42.9%)
No	27 (100%)	22 (100%)	20 (57.1%)

[a] $\chi^2_{(2)} = 25.57$, $p < .0001$.

Table III. Negative Affect Mood Ratings as a Function of Impedance Conditions[a]

Impedance condition	Tense		Irritable		Nervous		Impatient	
	M	SD	M	SD	M	SD	M	SD
Low	3.87	.663	4.55	.386	4.33	.446	4.27	.660
Medium	4.10	.574	4.67	.373	4.33	.533	4.51	.449
High	4.40	.621	4.69	.531	4.66	.582	4.52	.648

[a] The multivariate effect for impedance is significant at $p < .05$. Univariate effects are significant for tense $p < .01$ and for nervous $p < .05$. Effects for irritable and impatient are interactive with locus of control (cf. text).

Table data in Table II provide a strong illustration of the impedance effect. These are the results of the coding of an open-ended item on the background questionnaire, for which the subject was asked, "If you do want to move from where you live, what would be your reason?" If the respondent gave anything pertaining to transportation or commuting as a reason for wanting to move, the response was coded "yes." A chi-square analysis was significant, $\chi^2 = 25.57$, $df = 2$, $p < .0001$. Strikingly, no subject in the low impedance or middle impedance conditions designated transportation reasons for wanting to change residence, while 42.9% of high impedance subjects did so.

Stress Measures and Impedance[7]

The experimental hypotheses were evaluated by a series of 2×3 MANOVAs with covariates performed on sets of stress measures. The dependent variable clusters consisted of indices on physiology, task performance, and mood. Except for negative mood, main effects for impedance were not obtained on the stress measures.

The mood data are presented in Table III. Of the nine affect dimensions on the mood scale, four of these are negative in tone (viz. tense, irritable, nervous, and impatient) and, in this regard, can be viewed as stress outcome indices. While the between-group differences for the impedance conditions were small, the means for each negative affect increase from the low to the high impedance condition. A MANOVA analysis on these four indices resulted in a significant impedance main effect, multivariate $F(8, 144) = 2.01$, $p < .05$. In the univariate analyses, the impedance effect was significant for tense, $F(2, 75) = 5.87, p <$

[7] The focus of our report with regard to locus of control is concerned with the interaction of this personality factor with impedance. Hence, attention is not given to locus of control main effects. It can be noted that no significant multivariate main effects were obtained for I-E on the mood, physiological, or task measure clusters. Significant univariate effects did result for I-E on impatient ($p < .03$) and on digit recall ($p < .02$). Internals had higher means on both variables.

.004, and for nervous, $F(2, 75) = 3.81, p < .03$. The effects for irritable and for impatient were interactive with locus of control and are described below. There were no significant effects on any of the positive mood dimensions.

Table IV contains the results of the impedance factor crossed with the locus of control dimension for the physiological and task measures. Although systolic and diastolic pressure did increase from the low to the high impedance conditions and the blood pressure means were higher for internals, main effects were not significant when weight was controlled as a covariate. In the multiple regression analyses below, it was found that weight accounts for 25% of the variance in systolic pressure and 16% of the variance in diastolic pressure.

As anticipated, the stress effects were interactive. A MANOVA analysis performed on systolic pressure, diastolic pressure, and heart rate was significant, multivariate $F(6, 142) = 3.98, p < .001$, controlling for age and weight. A significant interaction between impedance and locus of control was obtained for diastolic pressure, $F(2, 68) = 3.71, p = .029$, controlling for age, weight, and the residential covariates. But in a pattern which differs from that for diastolic pressure, there was a significant interaction for heart rate, $F(2, 65) = 4.02$, $p = .023$, controlling for age, cigarettes, and medication, plus the residential covariates. In the middle impedance condition, internals are higher than externals on both heart rate and diastolic pressure. For low impedance, internals have higher heart rate ($p < .05$), but externals have higher diastolic pressure (ns). In contrast, for high impedance, externals have higher heart rate than internals ($p < .06$), but diastolic pressure is similar for internals and externals.

The task data were predominantly in the predicted direction with internals having the higher performance scores in the middle and high impedance conditions (except for digit symbol in the middle cell) and externals having higher performance scores in the low impedance condition. The multivariate analysis of the interaction approached significance, $F(6, 118) = 2.01, p < .07$ controlling for age and education.[8] Univariate effects were significant for Puzzles 1 and 3, $F(2, 72) = 4.16, p = .020$, and were also significant ($p < .03$) when residential covariates were used. The digit recall interaction approached significance, $F(2, 54) = 2.71, p = .075$, when the residential variables were added to the basic covariates.

It was hoped that between-group differences in physiological patterns for blood pressure and heart rate could be explained on the basis of differences in affect (i.e., blood pressure increases might be associated with anger-like moods and heart rate increases with anxiety-like moods). However, this did not obtain. The MANOVA test of the impedance X locus of control interaction was sig-

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[8] The Puzzle 1 index was removed from the MANOVA tests, since it is a linear determinant of the Puzzle 1 and 3 index, and it therefore would confound the multivariate test of task performance.

Table IV. Mean for Indices of Stress Reactions Across Levels of Impedance for Internals and Externals[a]

Impedance condition	Systolic BP		Diastolic BP		Heart Rate		Puzzle 1		Puzzles 1 & 3		Digit symbol task		Digit symbol recall	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Low														
Internal	124.85 (124.14)	16.32	73.00 (71.03)	7.93	85.23 (83.45)	11.74	7.92 (8.33)	5.34	11.92 (12.52)	5.30	57.64 (59.05)	16.72	6.54 (6.82)	2.58
External	119.07 (121.13)	9.51	75.93 (77.34)	6.70	80.57 (81.59)	7.25	11.93 (11.46)	7.29	18.21 (17.47)	8.54	65.50 (62.82)	10.62	6.92 (6.69)	1.38
Medium														
Internal	127.33 (124.35)	16.91	77.50 (75.97)	9.14	83.50 (83.89)	11.18	10.75 (11.16)	5.06	17.92 (18.56)	8.90	54.33 (55.61)	13.63	6.42 (6.53)	2.06
External	123.50 (126.87)	10.13	73.37 (74.25)	5.63	75.12 (76.22)	8.13	7.62 (7.52)	5.85	11.25 (11.07)	4.92	63.75 (62.64)	11.72	5.50 (5.40)	1.85
High														
Internal	130.39 (127.66)	11.15	77.44 (77.25)	7.22	75.33 (77.99)	9.20	9.94 (9.78)	7.10	15.17 (14.92)	7.38	61.28 (60.80)	9.21	7.07 (6.98)	1.54
External	123.25 (125.65)	14.04	76.25 (77.54)	9.04	84.94 (81.66)	12.05	9.00 (9.01)	7.49	15.06 (15.11)	6.26	58.64 (60.08)	13.95	4.82 (4.86)	2.14

[a]Multivariate effect for impedance × I–E interaction for physiological measures is significant at $p < .001$ and approaches significance for the task measures at $p < .07$. Univariate tests of the interaction were significant for diastolic pressure ($p < .03$), heart rate ($p < .03$), Puzzles 1 & 3 ($p < .02$), and approaches significance for digit recall ($p < .08$). Means adjusted for covariates are in parentheses.

nificant, $F(8, 144)$ 2, 31, $p < .02$, and the univariate analyses revealed significant interaction effects for irritable, $F(2, 74) = 4.06$, $p = .021$, and for impatient, $F(2, 74) = 5.60$, $p = .005$, but not for tense or for nervous ($p = .124$). The interaction resulted from opposite patterns for internals and externals in the middle condition relative to the low and high conditions. While the internals are less irritable and impatient, the externals are more irritable and impatient in the middle condition, and it is in this condition where the blood pressure and heart rate effects correspond (i.e., internals are higher on both measures).

Multiple Regressions with the Physical Parameters

The analysis of transportation conditions in terms of impedance has used the physical parameters of distance and time. In an effort to determine the relative contribution of distance, time, and speed $(D/T)^9$ to the stress outcome criteria, multiple regression analyses were conducted. In addition, the mediating effect of several indices of personal control were also evaluated by including them in the regression equations.

In the regression analyses, for each dependent measure, basic covariates were entered on Step 1, as given below. Then, in a stepwise procedure, the personal control variables of I-E total score, type of car, and residential choice were entered along with one of the physical commuting parameters. Thus, separate analyses were performed for distance, time, and speed, each clustered with the personal control indices, and in each analysis, controlling for the basic covariates. This procedure thus involved 21 prediction equations (7 dependent measures and 3 physical parameters). For blood pressure, the covariates are age and weight; for heart rate, the covariates are age, cigarettes, and medication; for the task measures, the covariates are age and education. Table V illustrates the results of one such analysis, which includes speed (D/T) as the physical parameter in the prediction equation for systolic pressure.

In the regression analyses for heart rate, there were no significant univariate effects beyond those obtained for the covariates of age ($r = .210$), cigarettes ($r = .518$), and medication ($r = .304$), which together account for 32% of the variance in heart rate (multiple $r = .564$). None of the physical parameters or personal control indices added significantly to the prediction of heart rate once age, cigarettes, and medication were controlled.

For systolic and diastolic blood pressure, significant effects were obtained for the physical parameters, except time, and for the personal control variables, particularly the locus of control index. The multivariate F's were highly significant ($p < .001$) following the inclusion of either distance or speed and the

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[9] The speed index was added since it could provide additional information on how the stress effects of commuting might be conceptualized and since it is easily computed from the distance and time measures.

Table V. Multiple Regression Effects for Systolic Blood Pressure as a Function of Speed and Personal Control Indices[a]

Predictor variable	Step	Multiple r	Cumulative r^2	Simple r	Beta	Reliability of regression
Age	1	.184	.034	.184	.04	$F(2, 87)$ = ns
Weight	1	.536	.287	.530	.442	$F(2, 87)$ = 23.06, $p < .001$
Speed (D/T)	2	.579	.336	.286	.200	$F(3, 86)$ = 5.14, $p < .01$
I-E total	3	.602	.362	−.356	−.177	$F(4, 85)$ = 3.49, $p < .02$
Car type	4	.612	.374	−.095		
Residential choice	5	.620	.385	−.058		

[a] Multivariate $F(4, 85)$ = 12.05, $p < .001$. The multivariate F pertains to the significance of the prediction equation at the last step when a significant univariate F was obtained in the stepwise procedure. The F ratios reported in the "reliability of regression" column refer to the univariate relationships to the criterion measure when the last significant univarite effect was obtained. The *beta* weights reported are standardized coefficients, and the multiple r's are adjusted for the number of factors in the equation.

locus of control index after the convariates (cf. Table V). Of the physical parameters, time is the least potent predictor, and speed is the most powerful. In fact, significant relationships were not obtained for time regressed on either systolic (r = .169) or diastolic (r = .143) pressure. When time is used in combination with distance in the speed index, it does improve upon the effects obtained for distance alone. Distance effects were significant for systolic pressure, $F(3, 86)$ = 5.16, $p < 01$, and for diastolic pressure, $F(3, 86)$ = 5.93, $p < .01$. Significant speed effects were obtained for systolic pressure, $F(3, 86)$ = 5.14, $p < .01$, and for diastolic pressure, $F(3, 86)$ = 10.03, $p < .001$. Increase in distance and speed are associated with increases in blood pressure.

The locus of control index had significant regression effects on systolic pressure when entered with distance ($p < .01$) and with speed ($p < .05$) as internality is associated with higher blood pressure. No significant effects were obtained for car type or for residential choice. No personal control index had significant regression effects on diastolic pressure. When time is used as the physical parameter in the prediction equation, the effect for car type approaches significance, $F(3, 86)$ = 2.46, $p < .10$, on diastolic pressure.

Regression effects on the task performance variables were found for the personal control indices but not for the physical parameters. Distance, time, and speed are all last to enter the stepwise analysis.[10] The effects for these variables, as well as their overall effects on the prediction equation are interchangeable.

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[10] For the covariates, age had a significant regression on each of the task measures: Puzzle 1, $F(2, 87)$ = 4.17, $p < .025$; Puzzles 1 and 3, $F(2, 87)$ = 4.94, $p < .01$; digit task, $F(2, 87)$ = 4.64, $p < .025$; and especially digit symbol recall, $F(2, 87)$ = 11.33, $p < .001$, as older subjects had lower performance scores. Education had a significant regression only on digit task, $F(2, 87)$ = 5.82, $p < .01$, with higher education associated with better performance.

Each of the personal control indices had significant regression effects on task measures. Car type was significant for Puzzle 1, $F(3, 86) = 8.18, p < .01$, and for Puzzles 1 and 3, $F(3, 86) = 7.83, p < .01$, as commuters who drive larger cars demonstrated greater tolerance for frustration. A higher degree of residential choice was also associated with greater frustration tolerance ($p < .08$) and had a significant positive regression on digit symbol recall, $F(3, 76) = 6.95, p < .005$. The I-E total score was significant for digit task, $F(3, 86) = 3.26, p < .05$, and for digit symbol recall, $F(4, 75) = 3.77, p < .01$, as internals demonstrated higher performance. With respect to the regression effects obtained for car type and residential choice, these results are not attributable to socioeconomic status, as SES was not found to have significant effects on the task measures.

DISCUSSION

Commuting on congested roadways has provoked the ire of automobile drivers and hopefully will receive attention from community psychologists as a problem pertaining to stress and adaptation. The present study has demonstrated that transportation conditions, construed in terms of our concept of impedance, significantly affect commuters perception of congestion, their physiological arousal, task performance, and negative affect. However, consistent with an interactionist perspective of human stress, the impact of the stressors associated with transportation was mediated by personality and social psychological factors, here studied as dimensions of personal control. We have also found the coronary-prone behavior pattern to be a significant mediational factor (Stokols, Novaco, Stokols, & Campbell, 1978).

Our investigation was based on the assumption that the selection of subjects according to graduating blocks of the distance and time parameters of commuting would reflect increasing levels of constraint associated with transportation. Consistent across a number of self-report measures, higher levels of impedance resulted in the reporting of higher degrees of traffic congestion, greater inconvenience, less satisfaction with commuting, and a greater desire to change residence. These findings support the validity of the impedance concept and its operations. Additional support for the impedance conditions as a stress dimension was obtained on the residential relocation variables.

Of the four research hypotheses, the strongest confirmation was found for Hypothesis 3 which predicted significant interactions of impedance with locus of control. Significant multivariate effects for this interaction were found for physiology and mood and approached significance on task performance. Increases in impedance generally resulted in higher arousal, and, consistent with previous research (Houston, 1972; Rotter & Mulry, 1965), internals exhibited better task performance than did externals in a test situation where successful performance

was contingent on one's own efforts. Unpredicted interactions between impedance and locus of control, for which we have no plausible explanation, were obtained on the negative mood indices.

Hypothesis 2, which predicted significant linear regressions for the distance and time parameters on the stress measures, received partial support. Time did not have significant regression effects for any dependent measures above the variance accounted for by the covariates in the prediction equations except when used in combination with distance as the speed index. Distance and speed had significant effects for both systolic and diastolic blood pressure, but not for heart rate or for the task measures. The effects for speed were stronger than were those obtained for distance. Since there are increased attentional and performance demands when an automobile is driven faster and since human factors research on driving (Forbes, 1973) has shown faster speed to increase arousal, the factor of "average speed of commute" merits attention in future research.

The personal control indices of locus of control, residential choice, and type of car were predicted in Hypothesis 4 to have significant regression effects. Significant effects were obtained for locus of control on systolic and diastolic blood pressure. For the task measures, significant effects were obtained for car type on the puzzle tasks, for residential choice on the digit task and Puzzle 1, and for locus of control on the digit task. Thus, Hypothesis 4 also received partial confirmation.

Only a small degree of confirmation was obtained for Hypothesis 1, which predicted significant main effects for impedance. Impedance main effects were found for negative mood and for the residential adaptation indices but not for arousal or for the task performance measures. This was surprising, given that the manipulation checks on the commuting ratings were strong and were consistent across several indices obtained at different points in time and in different forms. While systolic and diastolic blood pressures generally increased with rising levels of impedance, heart rate decreased for internals and followed a J-shaped pattern for externals. Main effects were not obtained for the task measures, but this was possibly the result of the significant interactions for impedance with locus of control.

The heart rate data are indeed puzzling. We cannot account for the decrease in heart rate for internals across impedance levels. Except for the high impedance cell, externals also decrease in heart rate (the cigarette consumption for high impedance externals was $\bar{X} = 14.00$ per day vs. 1.94 per day for high impedance internals). It was thought that the higher heart rates in the low impedance conditions might be the result of being more rushed to get to work. Commuters living closer to work might leave themselves a smaller margin for arrival and be more hurried, resulting in higher heart rates. However the weekly ratings of "feeling rushed to get to work" did not support this conjecture ($\bar{X} = 2.5$ low impedance, 3.45 medium impedance, and 3.42 high impedance). Feeling rushed increased linearly for internals and was curvilinear for externals. The fact that

heart rate also tended to have inverse correlations with negative mood (especially tense, $r = -.37$, and nervous, $r = -.32$, for internals) cannot be explained. A continuous monitoring of physiological measures during the entire commute, rather than discrete measures at the end of the trip, will be attempted in future studies to provide a more precise analysis of arousal effects. Previous investigations of human performance during automobile driving have found decreases in heart rate during travel (Laurell & Lisper, 1976; Lisper, Laurell, & Stening, 1973).

Whether we have most usefully operationalized the impedance concept is an open question. Although we have used the term *impedance* to meae a behavioral constraint, we have not operationalized that concept behaviorally. Consequently, observed stress effects might be due to properties of the distance- and time-defined impedance conditions other than this proposed behavior-constraining characteristic. Future investigations will incorporate behavioral indices (e.g., measures of braking) in the definition and/or validation of impedance conditions.

The distance and time parameters do appear to be predictors of the stress effects associated with commuting to work. Yet, in the absence of a strong array of impedance main effects, alternative strategies for indexing these parameters should be explored. The narrow spread between the three conditions on distance and time may have attenuated the effects due to impedance. Perhaps more extreme cutting scores on the distance and time parameters would generate stronger effects. However, our efforts to control for extraneous influences (time on route, work shift, vacation schedule, etc.) rapidly reduced the size of the subject sample. Consequently, more extreme criteria will require a larger subject pool.

The present project has indicated an important area for research in community psychology. If community psychology is to proclaim that it is concerned with the study of environmental forces which impact on the adjustment of persons and communities, it must do more to investigate areas like transportation and other aspects on the physical environment that influence health and behavior. Heller and Monahan (1977) give a useful presentation of such research domains in their chapter on social settings. It has been suggested here that conceptions of human stress and adaptation can serve as valuable models within which such research can be conducted.

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