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Environmental/Ecological Psychology

Objective and Subjective Dimensions of Travel Impedance as Determinants of Commuting Stress[1]

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The stressful characteristics of commuting constraints are conceptualized in terms of both physical and perceptual conditions of travel impedance. This study develops and operationalizes the concept of subjective impedance, as a complement to our previously developed concept of impedance as a physically defined condition of commuting stress. The stress impacts of high-impedance commuting were examined in a study of 79 employees of two companies in the follow-up testing of a longitudinal study. Subjective impedance was overlapping but not isomorphic with physical impedance, and these two dimensions have differential relationships with health and well-being outcomes. The physical impedance construct received further confirmation in validational analyses and in predicted effects on various illness measures and job satisfaction. The newly constructed subjective impedance index was significantly related to evening home mood, residential satisfaction, and chest pain. Job change was also influenced primarily by commuting satisfaction. The results are discussed within an ecological framework emphasizing inter-domain transfer effects and situational moderators of commuting stress.

Traffic congestion is a major concern in urban areas, yet the private car remains the predominant mode of transportation for nearly 90% of the U.S. labor force. Transportation conditions are not merely matters of convenience, because they also have consequences for individual, family, and organiza-

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tional well-being. To the extent that automobile driving is stressful, chronic exposure to traffic congestion hypothetically impairs health, psychological adjustment, and work performance. Problems of transportation are highly salient in metropolitan areas and evoke strong visceral reactions among commuters.[3]

Our understanding of traffic congestion involves the concept of impedance, signifying a behavioral constraint on movement and goal attainment. As an aversive, frustrating condition, transportation impedance elevates arousal and elicits negative affect, thereby producing stress reactions that become relevant to choices of travel mode, residential location, and job location. Commuting stress is also an important issue at the aggregate level in terms of the transportation programs of work organizations and urban planning decisions.[4] Research in the areas of human factors engineering, public transit, environmental psychology, and community psychology pertaining to commuting stress was reviewed by Stokols and Novaco (1981) in shaping the ecological perspective that guides the present study.

Our previous work (Novaco, Stokols, Campbell, & Stokols, 1979; Stokols & Novaco, 1981; Stokols, Novaco, Stokols, & Campbell, 1978) has shown that the impedance characteristics of commuting are indeed stressful, as manifested by effects on blood pressure, tolerance for frustration, negative mood, and overall life satisfaction. We found that the transportation environment is reciprocally linked with characteristics of home and work environments, as well as with personality factors. Elements of residential choice and residential satisfaction, along with conditions of job involvement and job satisfaction, were related to how individuals experience their commute and how seemingly "low stress" personalities can be strongly affected by high-impedance commuting. These findings were interpreted from an ecological perspective on transportation stress, which identified various personal and contextual moderators of drivers' responses to their commutes (Stokols & Novaco, 1981).

We understand transportation stressors as conditions associated with various forms of travel and travel-related environments that constitute threats to physical and psychological well-being. Transportation stressors are broadly construed to include a diversity of travel conditions, such as traffic conges-

[3]In our own geographic area, traffic congestion, as calculated by the California Department of Transportation, has increased by a factor of 50 in Orange County since 1970 and has increased in Los Angeles County by 12–15% per 2-year interval since 1979. In the 1988 Orange County Survey, a telephone interview sampling of 1,000 residents, only 5% of those surveyed reported being satisfied with existing freeway conditions, which is down from 8% in 1987 and 32% in 1982. Nearly 50% of residents consider traffic congestion the county's most important problem (Baldassare, 1987; Baldassare & Katz, 1988).

[4]New legislation regarding air quality standards in Southern California requires companies with over 100 employees to initiate ride-sharing programs to alleviate traffic congestion.

tion, long commutes, air pollution, interpersonal conflict, and vehicle malfunctions. These conditions are thought to be products of personal, organizational, and community decision-making. The basic themes of our ecological perspective on transportation stress entail (a) concern with environment–behavior relationships at both the individual and the aggregate level for both transportation conditions and manifestations of well-being; (b) emphasis on reciprocal influences or interdependence among environments and their occupants; (c) recognition of processes of coping and adaptation to environmental demands; (d) attention to contextual conditions influencing behavior and well-being, including factors of personal, community, and societal relevance; (e) concern with the congruence between needs or goals and environmental affordances. These themes suggest a diversity of research questions on transportation that range considerably beyond the scope of the present study.

Themes b, c, and d are reflected in the present study. We view the transportation or commuting environment as a life domain reciprocally linked with the residential and occupational domains; thus we look for transactional influences between home, commuting, and job factors. We also assume that commuters make efforts to cope with transportation stressors, which may range from vehicle choice and travel schedule to residential change or job change. Cognitive coping may occur as well as or in lieu of such behavioral coping. Moreover, because commuting cognitions and behavior are embedded in overlapping and nested contexts at individual and aggregate levels, supplementary variables other than those in the proximal situation need to be incorporated. For example, we found that degree of choice exercised in selecting one's residence moderated stress reactions to commuting. Figure 1 depicts the general categories of variables encompassed by our ecological perspective on commuting stress.

The individual's daily commuting situation is embedded within his or her overall life situation, comprising the transportation, home, and work domains. The dotted lines in Figure 1 depict the notion that these major life domains and environmental settings are objectively linked in both space and time as part of the individual's daily activity system (Chapin, 1974; Magnusson, 1981; Michelson, 1985; Stokols & Novaco, 1981). These domains and settings also are linked psychologically as part of the individual's life space (Lewin, 1936). Thus, in our analysis of commuting stress, the individual's experience of subjective impedance, stress outcomes, and related coping efforts are jointly influenced by conditions and events within residential, transportation, and work domains.

Our previous research emphasized the *physical* parameters of travel impedance, particularly the spatial and temporal dimensions of commuting. Using a quasi-experimental approach, we constructed low-, medium-, and

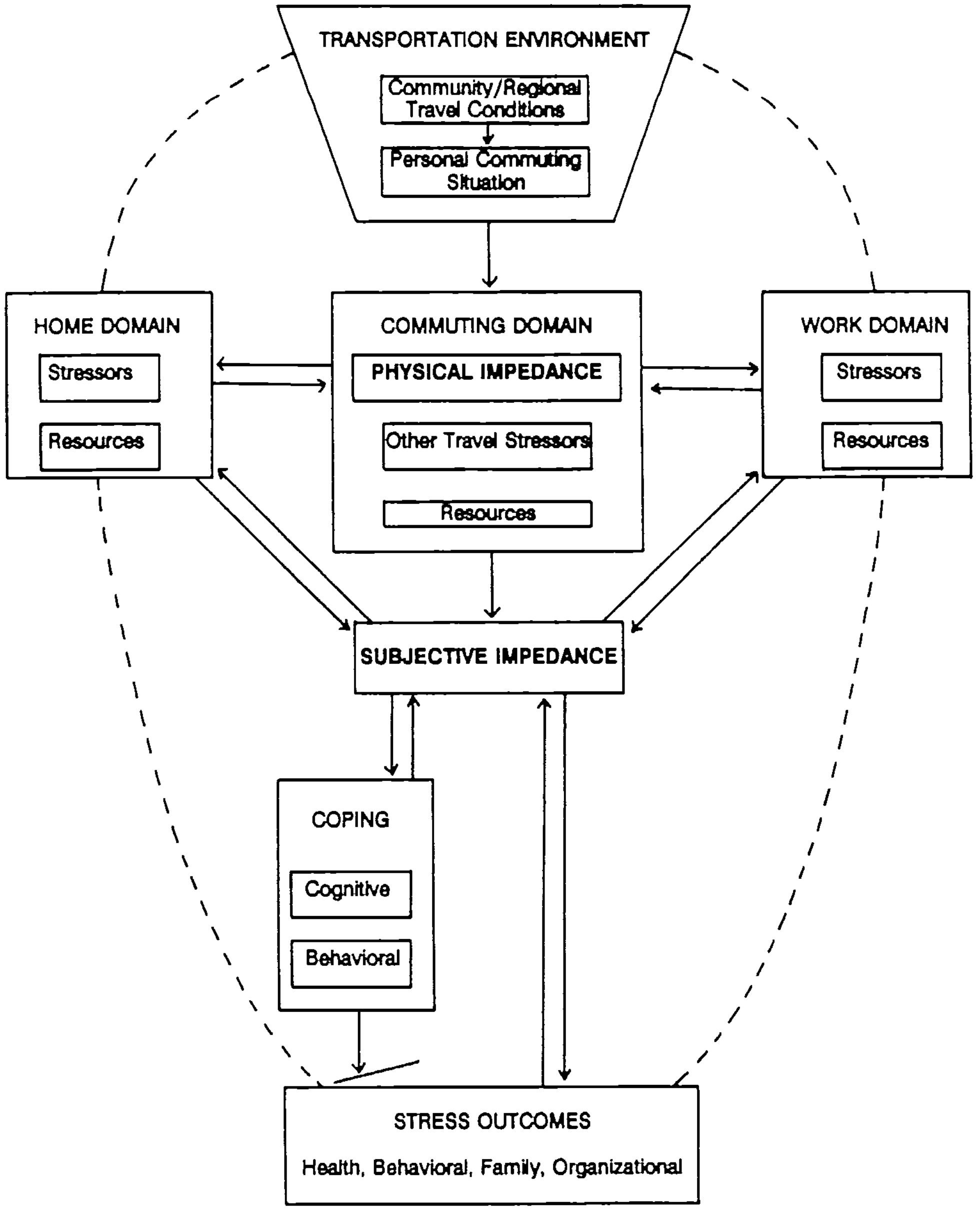

Fig. 1. Ecology of commuting stress.

high-impedance conditions based on the distributions of both commuting distance and time for employees at two local companies (procedural criteria are given subsequently). In addition to the ANOVA design with personality factors (Type-A coronary proneness; locus of control) as interactive variables, we used multiple regression designs to separately focus on the distance and time parameters as predictors of stress outcomes. Across various types of analyses, our operationalization of travel impedance was significantly validated. The stressor properties of travel impedance were evident in various ratings of aversiveness and traffic congestion obtained on questionnaires and daily commuting logs, increasing in negativity across levels of our quasi-experimental factor. Desire to change residence because of transportation conditions was related strongly to high impedance, as was actually having changed residential location. People formerly in long-distance conditions had moved to shorter distance conditions to reduce commuting strains. Moreover, many stress reaction outcomes were found for impedance exposure in significant effects obtained for blood pressure, negative mood, and tolerance for frustration. Corroborative results for the stress effects of impedance as a physical dimension of commuting were obtained by Schaeffer, Street, Singer, and Baum (1988) on blood pressure and proofreading measures.[5]

Although our initial studies of travel impedance sought to anchor the central concept in physical or objective terms, we always have recognized the value of perceptual or subjective dimensions. This dual phenomenological perspective has characterized our work (cf. Stokols & Novaco, 1981), as reflected in our use of measures regarding perception, satisfaction, and mood as *dependent* variables, along with physiological and performance indices. However, we have not as yet examined impedance as a *perceptual* phenomenon, which is the main focus of this study. We have used perceptual measures to validate our physically defined, quasi-experimental, impedance conditions and have obtained strong validation on multiple manipulation check indices (cf. Novaco et al., 1979; Stokols et al., 1978); yet impedance as a subjective experience may be independent of physical conditions. For example, the perceived aversiveness of noise does not necessarily match objective noise exposure, as complaints regarding airport noise are not reliably predicted by noise contour lines.

In keeping with a cognitivist tradition,[6] the perceived or subjective dimensions of travel impedance here receives our attention. An index of subjective

[5]Their impedance index was average speed, which we used previously (Novaco et al., 1979) as an alternative index but consider to be problematic because short-distance drivers spend a relatively higher proportion of their journey moving their car from stopped positions associated with maneuvering the vehicle at the beginning and ending of commutes—when the vehicle is nearly stationary or moving at a very low speed. Freeway travel, which is characteristic of long commutes, is in contrast defined as "congested" by highway engineers when driving speed is reduced below 35 m.p.h.—which is considerably faster than one backs out of driveways, enters a parking lot, etc. Because the low-speed conditions at the start and end of a commute constitute a higher proportion of the trip for short-distance travel, average speed is not a good index of impedance. Average speed increases as an artifact of commuting distance. Even in our low-impedance condition (distance = 2–7 miles), speed is correlated .31 with distance. Shaeffer et al. (1988) provided no information on distance.

[6]The importance of the perceiver's construction of the material world can be traced to the transcendental philosophy of Immanuel Kant (1981/1781) and to the writings of Roman Stoic philosophers more than a millennium and a half before him. Personality psychology, such as Kelly's (1955) personal construct theory and, before him, Murray's (1938) concepts of beta press (subjective construals) versus alpha press (objective characteristics) gave emphasis to the personal meaning of environmental conditions. Consequently, contemporary research on environmental cognition, with its heritage from Tolman, Lewin, and Piaget, has focused on the cognitive representation of the physical environment (Evans, 1980; Golledge, 1987). Lewin's (1951) field theory concepts of the psychological environment and the phenomenal field are important antecedents here. Within the stress field, of course, there has been an abundance of theory and research that was stimulated by Lazarus' (1966) conceptualization which emphasized *perceived* environmental demands and *perceived* ability to cope.

impedance is generated from a broad set of self-report items pertaining to perceived constraints in driving. This index is then examined for its relationship to adverse health and psychological outcomes, controlling for confounding influences.

The present investigation is a follow-up study of the initial sample, and seeks further validation of our impedance construct with regard to the quasi-experimental physical conditions, as well as the examination of the subjective impedance dimension. The additional construct validation questions concerned a more detailed assessment of the *constraining* properties of the commuting experience using previously unanalyzed data concerning the driver's perceptions about braking, the inability to avoid traffic, speed reduction, exposure to traffic control devices (stop lights; stop signs), and the proximity of other cars on the road. Here we also disaggregate the commute in terms of time and mileage spent on freeways (limited-access highways) versus surface street travel, examining these measures and exposure to road exchanges as auxiliary indices of physical impedance. Taylor and Pocock (1972) found in a study of public transit users in London that journeys involving multiple stages were associated with higher rates of absence from work. For our automobile commuters, a road exchange (switching from a surface street to a freeway or switching freeways) can be expected to be a node of congestion that heightens the stressfulness of the commute.

In addition to the validational analyses of constraint properties of the physical impedance conditions and the empirical generation of a subjective impedance index, this study investigates the health and emotional consequences of the impedance dimensions on previously unanalyzed data pertaining to illness, mood, and satisfaction. Both physical impedance and subjective impedance are hypothesized to have stress effects manifested on various illness measures, negative mood states, residential dissatisfaction, and job dissatisfaction. The tests of our hypotheses involve a variety of analytical designs which incorporate covariates to control for confounding variables.

METHOD

Subjects

Participants were recruited from a sample of 61 men and 39 women 18 months after they had participated in a previous study of work-related commuter stress (Novaco et al., 1979; Stokols et al., 1978). Initial efforts to contact respondents through their workplaces revealed that 31 of the original panel were no longer employed at the two Southern California manufacturing firms studied in the Phase 1 data collection. Further efforts succeeded in locating 13 additional members of the Phase 1 panel who had left the two companies. Thus, a total of 82 respondents were recontacted (49 men, 33 women), all of whom agreed to participate in the Phase 2 study. The initial sample of 100 participants was selected by the design criteria given below from a 25% volunteer pool generated by a solicitation sent to the 1,500 employees of the two companies. That is, 314 commuters volunteered for the initial study by returning a screening questionnaire, and 100 of them were selected by design criteria; 82 respondents were available to participate in the present follow-up.

Chi-square and one-way ANOVA analyses were performed on Phase 1 data to test for between-groups differences among the resulting three groups: (a) those who remained in their Phase 1 companies ($n = 69$), (b) those who had changed employers and were successfully contacted ($n = 13$), and (c) those who were never located ($n = 18$). No significant differences were observed between the groups on a variety of demographic measures, nor did the groups differ in self-reported satisfaction with job or residence. Accordingly, the 82 respondents successfully contacted were combined into a single Phase 2 sample. The data of 3 subjects were excluded from subsequent analyses due to extensive missing data, reducing the total sample of the current research to 79 (46 men, 33 women).

Design

Physical impedance (PI), established as a grouping condition in the initial study, was operationalized as a three-level factor generated from screening questionnaire data supplied by several hundred volunteers from the two companies. The quasi-experimental conditions of low, medium, and high impedance were composed of drivers in the bottom 25%, middle 30%, and upper 25%, respectively, for both the distributions of commuting distance and time. In addition to the distance and time criteria, subjects were initially selected only if they were solo drivers, did not drive on the job, had been on their particular commuting route for at least 8 months, and were not about to go on a vacation or to have recently returned from one.

In this follow-up study, distance and time again were used to define physical impedance levels based on the initial company distributions. As before, some volunteers who did not have correspondent positions on the two distributions (low/low, medium/medium, high/high) were included as subjects in regression analyses but excluded from the assessment of the three-level impedance factor. (The three-level grouping design was originally chosen to facilitate examination of interactions with upper and lower ranges of personality variables, such as Type A/Type B. Both the distance and the time distributions were used to select participants for the PI conditions (70 subjects). An additional 9 people who met our distance criteria in the low and medium conditions but who exceeded the time margins were included in the study and used in the regression analyses.) Thus, the *low PI* group comprised 19 persons who commuted less than 7.5 miles in less than 12.5 minutes; *medium PI* subjects were 24 persons whose commute was between 10 and 14 miles in 17 to 20 minutes; and *high PI* subjects were 27 persons traveling between 18 and 50 miles in 30–75 minutes. The commute times for the selection criteria were established by the trip *to* work because our initial study testings were done at the worksites, including arousal measures taken on arrival in the parking lot. If the evening commute times were used, no one would switch PI groups (distance is the same), although some would fall in the intermediate ranges. Furthermore, all subjects are used in the analyses of auxiliary PI indices: the number of road exchanges, the number of freeways, and the percentage of time and mileage spent on freeways.

Perceived or subjective impedance (SI) was first assessed in this follow-up study by 17 questionnaire items pertaining to subjective ratings of various constraints on movement associated with the morning and evening commutes. Factor analyses described below enabled us to partition the overall measure into four subscales; however, SI was ultimately indexed by the two strongest factors as explained below, and it was primarily used as a continuous variable in multiple regression analyses. SI was also operationalized in a few analyses as a two-level factor (low/high) by a median split on the index summary score when categorical variables were being analyzed.

Procedure

Eighteen months after the initial study, all subjects were sent a letter requesting their participation in this subsequent project. All those who could be located agreed to participate and were then sent a follow-up questionnaire, which was returned at a group meeting. The questionnaire partly contained various scales intended to provide validity checks on our operationalization of impedance as a condition of the physical environment. However, because these questionnaire items involved perceptions of the commuting experience they represented dimensions on which perceived impedance could be operationalized. In addition to the subjective ratings of impedance dimensions, the questionnaire contained new measures of physical aspects of the commute, various health measures, self-reports of coping behaviors associated with commuting, and some repeated measures of satisfaction, mood, and attitudes regarding transportation.

The physical aspects measures were the auxiliary PI indices mentioned earlier. The health measures included work absences due to illness, indexed by the number of illness occasions and by the number of sick days; overall occasions of colds or flu; and overall occasions of stress-related illness events, such as gastrointestinal problems, chest pain, headaches, and insomnia. The coping behavior measures are not reported here, except for job change which is included to illustrate components of our theoretical model.

The measures repeated from the initial study were in four basic categories: (a) personal and demographic items, including length of time at current residence and job, socioeconomic status, job position, type of car, and history of traffic accidents; (b) satisfaction with various life domains, including residential, employment, and commuting; (c) mood ratings pertaining to arrival at home from work; (d) health-related covariates; and (e) attitudes regarding environmental problems and transportation management strategies.

The repeated satisfaction measures pertaining to the commute, residence, and job involved seven-point scales for self-ratings. The commute ratings concerned the extent to which the subjects were inconvenienced by traffic congestion and their degree of satisfaction with their commute. The residential items included overall satisfaction, desire to relocate, residential crowding, degree of residential choice, and transportation factors as a reason for wanting to change residence. Job satisfaction was measured by five Likert items concerning dimensions of employment (e.g., feelings of accomplishment derived from the job; adequacy of current salary), which were summed for a composite score. The quality of the social and the physical environment at work was assessed by two sets of semantic differential scales.

The repeated mood measures were six semantic differential scales with bipolar anchors (viz., tense–relaxed, tired–energetic, friendly–irritable, happy–sad, carefree–burdened, intolerant–tolerant), referring to mood at home after the evening commute. The health-related covariates were the amount of alcohol, caffeine, and tobacco consumed per day, as well as exercise regimen, weight, and height. These variables, along with age and education were incorporated as covariates in various analyses.

Finally, in the measures repeated from the initial study, there were transproblems and transportation management strategies, but these data are not included in this report.

Further validation of the physical impedance conditions focused on the conjectured behavioral constraint properties.[7] That is, we sought manipulation checks beyond the simple "commuting satisfaction" and "traffic as an inconvenience" items used in the initial study by incorporating items reflecting the degree of perceived constraint. Items assessing the constraining properties of commuting included subjective ratings of speed

[7]We did attempt to index this behaviorally by measuring the amount of braking, but this effort failed because of difficulties in accessing the brake circuits in some automobiles and because our system, which used impulse counters, short-circuited the electrical systems of two vehicles. We could neither afford further electrical repair bills nor did this endear us to our subjects.

Table I. Subjective Impedance Subscales

Subscale	Loading
Evening commute congestion	Factor 1
Driving speed reduced by heavy traffic going home	.87
Unable to avoid heavy traffic on trip home	.72
Traffic jams make it necessary to reduce travel speed	.69
Presence of other cars to and from work	.68
Necessary to apply brakes while driving from work	.63
Traffic congestion is a frequent inconvenience	.61
Aversiveness of travel[a]	Factor 2
Rating of commute as slow-fast	.84
Rating of commute as stop-and-go-uninterrupted	.71
Satisfaction with the commute	.58
Rating of commute as unpleasant-pleasant	.57
Traffic accidents make it necessary to reduce speed	.57
Rating of commute as congested-uncongested	.49
Morning commute congestion	Factor 3
Driving speed reduced by heavy traffic to work	.81
Unable to avoid heavy traffic traveling to work	.73
Necessary to apply brakes while driving to work	.68
Surface street constraints	Factor 4
Travel speed reduced by traffic signals	.87
Travel speed reduced by stop signs	.87

[a]The Aversiveness of Travel subscale is reverse scored.

reduction due to traffic, the necessity of braking, interference from other cars, and exposure to stop signs and traffic signals. These validational items and others were also used to operationalize the newly created concept of impedance as subjectively experienced.

Subjective impedance was assessed by 17 items on the follow-up questionnaire. These items in shorthand form are presented in Table I, grouped according to subscales defined by factor analysis orthogonal rotation (Varimax). The factor loadings are contained in Table I; no factor item loaded above .40 on any other factor. These items represent all of the subjective ratings of travel constraints on our questionnaire, with the exception of one other item, "concern with collision from the rear," which was not associated empirically with any item grouping and was primarily related to owning a Pinto. This 18th item was therefore excluded from our SI analyses.

Because of the sample size and the absence of cross-validation, we only used factor analysis varimax rotation to establish subscales rather than to extract factors for the computation of factor scores. Thus, the collection of SI items was empirically partitioned into four subscales labeled "evening commute congestion," "aversiveness of travel," "morning commute congestion," and "surface street constraints." However, intercorrelational analyses of the subscales and obtained differences between afternoon versus morning commuting constraints led us to decide a priori to index SI by the evening commute and the aversiveness subscales.

Cross-correlation of the four subscales found that the surface street constraints subscale was uncorrelated with the evening commute congestion and aversiveness of travel subscales and only slightly correlated ($r = .19$) with the morning commute congestion subscale. It was therefore dropped from our attempts to index subjective impedance. The other three subscales are significantly correlated, with the strongest association ($r = .71$) being between evening congestion and aversiveness of travel. The morning congestion subscale correlates $r = .54$ and .55 with the other two, respectively. These three subscales have the following internal reliabilities (alpha): evening congestion, (.89), aversiveness of travel, (.83), and morning congestion, (.75). Because the morning congestion subscale is only moderately correlated with the other subscales and because of the highly significant effects for afternoon versus morning constraints reflected in the "necessity for braking" analyses reported below, we decided to index SI by aggregating only the evening congestion and the aversiveness of travel subscales. This aggregate index had an internal reliability (alpha) = .91. The a priori decision on the SI index was thus made for parsimony on the basis of these empirical relationships.

RESULTS

Subsample Comparisons

There were no significant differences between the two companies with regard to any of the physical impedance or perceived impedance operational variables, nor for the subsidiary impedance indices of percentage of time and mileage on freeways. Neither were there company differences in attitudes toward transportation issues, at either the initial or follow-up testings. Further, the companies did not differ in their retention of employees at this follow-up testing, being virtually identical at 68% of the original sample. Therefore, the companies were combined for all of the impedance analyses.

There are, however, differences between companies in the proportion of males and females, $\chi^2(1) = 23.1, p < .001$, as the sample from the aerospace firm had significantly more males and fewer females than did the pharmaceutical firm sample. Those from the aerospace firm also were older (42.7 vs. 35.0 years), $F(1, 75) = 9.94, p < .002$, and had greater length of employment (80.3 vs. 36.7 months), $F(1, 77) = 14.18, p < .001$. The company samples did not differ with regard to their years of education or length of time at their home residence.

Comparative analyses also were conducted with regard to those subjects who were included in this follow-up testing versus those who were not available because of relocation (i.e., nonincluded relocators); and for all those included in the present follow-up, differences were tested with regard to whether they remained in the same company or had changed jobs. No differences were found for any of these comparisons with regard to company, age, sex, marital status, length of employment (initial testing), or length of time at residence.

Impedance Physically Defined

Transportation Environment

The physical conditions of low, medium, and high impedance, as defined by the distance and time parameters, differ significantly with regard to commuting route properties that subsequently will be shown to be related to stress effects. Although our conditions are not really equidistant, we test for linear effects in the analyses because we assume PI to be linear and because we expect the effects of our conditions to be so ordered. Indeed, there are linear increases according to impedance level (from low to high) for the number of freeways traveled ($\bar{X}$ = 0.5, 1.2, and 2.4), $F(2, 65) = 18.0$, $p < .001$; the number of road exchanges ($\bar{X}$ = 1.0, 1.8, and 2.2), $F(2, 67) = 8.55$, $p < .005$; percentage of miles on freeways ($\bar{X}$ = 25.1, 64.1, and 82.1), $F(2, 61) = 16.02$, $p < .001$; and percentage of time on freeways ($\bar{X}$ = 19.8, 65.8, and 73.2), $F(2, 60) = 15.85$, $p < .001$. Clearly, then, the high physical impedance commute is associated with freeway travel, as the long-distance commuter cannot efficiently take surface streets. Although this is hardly a revelation, these various indices of freeway travel are associated with stress that is linked with perceived impedance (shown in Table V).

Important differences emerged between the morning and evening commutes. In a repeated measures ANOVA for time of day, the "necessity for braking" increased significantly from morning to evening, $F(1, 66) = 21.41$, $p < .001$. The effect occurred across impedance groups, especially in the medium and high conditions. This greater degree of braking on the evening commute is congruent with archival measures of traffic congestion to be discussed later and points to residential domain outcomes which are seen in conjunction with subjective impedance factors. As noted earlier, this afternoon versus morning difference influenced our indexing of SI.

These physical characteristics of the transportation environment and the personal commuting situation, according to our model, should generate degrees of subjectively experienced constraint that correspond to our PI conditions.

Physical Impedance and Subjectively Experienced Constraints

In the construct validation analyses, increasing levels of impedance, physically defined, were associated with greater amounts of travel constraint and aversiveness. Table II presents the significant results for exposure to traffic jams, being slowed by traffic accidents, driving speed reduced by heavy traffic going home, satisfaction with the commute, and traffic congestion as a frequent inconvenience. Each of these variables shows significant linear change from low to high impedance. Marginally significant trends also were obtained for ratings of the commute on "slow–fast," $F(2, 66) = 2.95$, $p < .06$, and "inability to avoid heavy traffic on the commute home," $F(2, 66) = 2.54$, $p < .09$. Moreover, as another reflection of constraint, significant effects were found regarding the rated availability of transportation alternatives, $F(2, 66) = 3.50$, $p < .04$, which decrease from low to high impedance ($\bar{X} = 3.3$, 3.1, and 2.0, respectively). High-impedance drivers perceive fewer commuting alternatives.

While ratings of dissatisfaction with commuting, speed reductions due to traffic, and exposure to traffic jams clearly are greater for the high-impedance commuter (who characteristically travels via freeways), there also

Table II. Travel Constraints as a Function of Physical Impedance Conditions[a]

Measure of travel constraint	Physical impedance condition: Low	Medium	High	F	p
Traffic jams	3.4 (2.0)	4.8 (2.0)	5.9 (1.8)	6.24	.02
Traffic accidents (slowed by)	1.4 (1.0)	2.3 (1.5)	2.8 (1.6)	9.69	.002
Speed reduced on evening commute	3.7 (1.6)	5.2 (1.6)	5.6 (1.7)	11.67	.001
Commuting satisfaction	5.6 (1.2)	4.4 (1.9)	4.1 (1.6)	7.79	.007
Traffic congestion as frequent inconvenience	4.4 (2.1)	5.1 (2.0)	5.6 (1.5)	3.87	.05

[a]Each of the travel constraint measures involves ratings performed on 7-point scales. Standard deviations are given in parentheses. The ANOVA was a test for linearity.

are constraints on surface streets, and these are inversely related to our physical impedance conditions. Significant differences across impedance groups occurred in ratings of travel speed reduction due to traffic signals ($\bar{X}$ = 4.5, 4.2, and 2.9), $F(2, 67) = 3.99$, $p < .02$, and stop signs ($\bar{X}$ = 3.2, 3.3, and 2.0), $F(2, 67) = 3.71$, $p < .03$, as such constraints are not salient for the long-distance drivers.

Health Impacts

The stress impacts of travel impedance previously found for blood pressure, mood at work, and frustration tolerance in the initial study were replicated for health effects in this follow-up. Occasions of work absence due to illness were significantly different across the physical impedance conditions, with more illness occasions for medium- and high-impedance commuters ($\bar{X}$ = 1.6, 4.3, and 3.2). Controlling for age, smoking, weight, and alcohol consumption as covariates, the impedance effect is significant, $F(2, 58) = 3.17$, $p < .05$, but note that the means are not linear. Analyses of covariance with these same control variables also were performed on reported number of sick days (transformed to square root scores because of variance heterogeneity), but the significant effect ($p < .05$) obtained without the covariates was not found when the control variables were included ($p < .11$). Exploring the possibility of gender influences, no main effects or interactions with impedance were found for gender on these health measures.

In addition to the ANOVAs on our quasi-experimental conditions by which impedance is physically defined, the auxiliary indices of physical impedance were examined in regression analyses computed with all subjects ($N = 79$), including those who were not in the quasi-experimental groupings. Correlations for the satisfaction (commuting, job, and residence) measures and several illness measures are presented in Table III, and the alpha level was set at .01 to curtail Type 1 errors. The number of freeways on the commute is significantly related to commuting satisfaction ($r = -.51$), days of absence from work due to illness ($r = .37$), and overall occasions of colds or flu ($r = .30$). The number of road exchanges also was significantly correlated with work-absence sick days ($r = .47$) and overall occasions of colds or flu ($r = .51$). This finding for road exchanges corroborates for driving what Taylor and Pocock (1972) found for stages of the trip for public transit commuters. Regarding the percentage of the commute spent on freeways, the % miles and % time indices were inversely related to commuting satisfaction ($r = -.48$ and $-.49$, respectively) and to job satisfaction ($r = -.35$ and $-.30$, respectively), but did not attain significance for the illness measures.

Table III. Satisfaction and Illness Measures Correlated with Auxiliary Indices of Physical Impedance[a]

Commute characteristics	Satisfaction measures: Commuting	Satisfaction measures: Job	Satisfaction measures: Residence	Illness measures: Work-absence illness occasions	Illness measures: Work-absence sick days	Illness measures: Occasions of colds/flu
No. of freeways	−.51[c]	−.06	−.03	.14	.37[c]	.30[b]
No. of road exchanges	−.10	−.20	−.11	.01	.47[c]	.51[c]
% miles on freeways	−.48[c]	−.35[c]	−.10	.24	.22	.23
% time on freeways	−.49[c]	−.30[b]	−.17	.25	.23	.25

[a]These analyses included all of the subjects (N = 79), not just those in the quasi-experimental impedance conditions.
[b]Correlation coefficient significance, $p < .01$.
[c]Correlation coefficient significance, $p < .001$.

Multiple regression analyses were performed for the PI auxiliary indices on the health measures, with the covariates of age, weight, smoking, and alcohol entered on the first step. Analyses were performed for the illness indices in Table III that had significant simple correlations with the dependent measure, and we report effects for significant changes in r^2 above that produced by the covariates. There are significant effects for work-absence sick days and for overall occasions of colds or flu, with only marginal effects for work-absence illness occasions.

The regressions for freeways and road exchanges on work-absence sick days produce significant changes in r^2 (.11), $F(6, 63) = 4.02$, $p < .02$, over that associated with the covariates alone, which do not produce a significant regression effect themselves. In a stepwise analysis of the auxiliary PI indices and SI, without the covariates (which were selected a priori but are uncorrelated with illness days), road exchanges enters first, $F(1, 70) = 20.07$, $p < .001$, accounting for 23% of the variance for illness days. Similarly, with regard to overall occasions of colds or flu, road exchanges enters on the first step and accounts for 28% of the variation, with no other variable improving on the significance of the regression. The number of freeways traveled also produces a significant change in the r^2 (.06) for colds or flu over the effect of the covariates, $F(5, 66) = 3.95$, $p < .05$. Percent-time on freeways as well adds significantly to the change in r^2 (.09), $F(5, 62) = 5.76$, $p < .01$, over the effect of the covariates.

Considering that negative health effects, which we here attribute to commuting stress from travel impedance, might alternatively be thought to result from lowered health maintenance behaviors (preempted by commuting time), analyses of variance were performed on weekly hours of physical exercise. Controlling for age as a covariate, the results are significant, $F(2, 59) = 3.65$, $p < .04$; however, the effect is due to linear *increases* in exercise hours with increasing levels of impedance ($\overline{X} = 2.2$, 4.9 and 6.5). High-impedance commuters do the most physical exercise, so the illness effects cannot be attributed to a lessened exercise regimen. Perhaps physical exercise was even used as a coping strategy for dealing with the stress of commuting. In addition, we also found that coffee consumption decreased linearly, $F(1, 66) = 5.76$, $p < .02$, with increasing levels of impedance ($\overline{X} = 4.1$, 3.3, and 2.4), again indicating that the stress effects found for high-impedance commuters are not due to deficiencies in health maintenance.

Cross-Domain Effects: Work and Home

As our model indicates, the commuting domain is reciprocally linked with the work and residential domains for both physical and subjective impedance. However, analyses of variance for the PI conditions were not significant for job domain variables. Two auxiliary PI indices did have significant regression effects for job satisfaction, controlling for job months, the physical environment at work, and social relationships at work by entering these variables on the first step of the analysis. Percent-miles on freeways has a significant effect after the three covariates have been entered, r^2 change = .12, $F(4, 67) = 12.84$, $p < .001$. Percent-time on freeways also predicts significantly with the covariates controlled, r^2 change = .09, $F(4, 67) = 8.91$, $p < .004$.

No effects were found for the PI conditions or for any of the auxiliary environmental indices on residential satisfaction, desire to move, residential choice, or for mood on arrival home from work. This absence of effects for physical impedance on residential domain variables stands in contrast to the significant effects found for subjective impedance reported below.

Subjective Impedance

Relationship to Physical Impedance

As indicated earlier, subjective impedance (SI) is indexed by the evening congestion and the aversiveness subscales. The interrelationship between SI and PI is one of partial independence. Linear increases in SI occur across increasing levels of PI, $F(1, 64) = 7.59$, $p < .008$, although the medium and high PI groups do not differ significantly ($\overline{X}_{SI}$ = 38.9, 48.8, and 50.2). Both the evening congestion ($p < .02$) and the aversiveness ($p < .007$) components are significant. The overlapping but not isomorphic indexing of impedance can be seen better in cross-tabulation analyses in which the SI distribution was bifurcated by a median split, thus creating low SI and high SI groups. The cross-tabulated frequencies of these low/high SI categories with the low/medium/high PI conditions are presented in Table IV. Indeed, the $\chi^2(2, N = 69) = 8.76$, $p < .01$, is significant, but one can see that there are four high SI subjects in the low PI condition and 9 low SI in the high PI condition. The medium PI condition is near evenly distributed. The non-

Table IV. Cross-Tabulation of Subjective Impedance with Conditions of Physical Impedance[a]

	Physical impedance (PI)		
Subjective impedance (SI)	Low	Medium	High
Low	14	10	9
High	4	13	17

[a]The SI groups are defined by a median split on the aggregated "evening congestion" and "aversiveness" subscales. The cross-tabulation is significant, $\chi^2(2) = 8.76$, $p < .01$.

correspondence between the physical index and the subjective index hypothetically reflects variations in the cognitive appraisal of commuting conditions, but it may also reflect a less than optimal measurement of these two constructs.

Regarding the evening congestion and the aversiveness components of SI, there are slight variations in the cell distributions, but both are significant ($p < .02$). In the high PI condition, the cell frequencies are more strongly distributed toward high SI for aversiveness (8 low, 18 high) than for evening congestion (11 low, 15 high). The morning congestion subscale, which was excluded a priori from the SI index, was not significant in the above ANOVA or cross-tabulation analyses.

Potential confoundings with SI were examined by performing analyses of variance and cross-tabulations, using the aggregate index for SI and the low/high SI categories, respectively. No significant effects were found for company, gender, marital status, age, education, job months, residential months, or stressful life events. Neither were there any confounding effects with these variables on the component subscales.

Cross-Domain Effects: Home and Work

The main analyses of SI were conducted as multiple regressions with various control variables entered on the first step. Preceding the multiple regressions, simple correlations were computed for SI and its component subscales, which are presented in Table V along with significance levels (alpha set at .01). Table V is given to succinctly report the zero-order correlational effects which guided the multiple regression analyses. It can be seen that SI is strongly associated with freeway commuting and with several residential variables. The principal dependent measure effect of SI is on mood at home in the evening. The higher the degree of subjective impedance, the more negative the mood (tense, irritable, tired, sad, burdened, and intolerant).

Further analyses on evening home mood involved several sets of multiple regressions, the most central of which are presented in Table IV. It can be seen that, controlling for three key residential variables (residential satisfaction, residential choice, and desire to move) and three job variables (job satisfaction, work physical environment, and work social relationships), SI significantly adds (r^2 change = .16) to the prediction of home mood, $F(7, 66) = 12.72$, $p < .001$. Very similar effects result when either the residential covariates or the job covariates are entered by themselves (for SI, the change in r^2 is .15 over the residential covariates and .14 over the job covariates). Both the evening congestion ($r = -.33$) and the aversiveness ($r = -.35$) components influence the home mood outcomes.

Table V. Correlations of Subjective Impedance (SI) and Component Subscales with Travel, Residential, Job, and Health Measures[a]

Measure	Subjective impedance		
	SI index	Evening congestion	Aversiveness
Travel			
Road exchanges	.13	.10	.16
No. of freeways	.45[c]	.36[c]	.52[c]
% miles on freeways	.43[c]	.37[c]	.47[c]
% time on freeways	.46[c]	.41[c]	.50[c]
Route months	.20	.20	.14
Route choice	−.24	−.19	−.29[b]
Car choice	−.21	−.20	−.15
Residental			
Residential satisfaction	−.30[b]	−.26[b]	−.26[b]
Desire to move	.27[b]	.22	.26[b]
Residential choice	−.35[c]	−.28[b]	−.35[c]
Residential crowding	.17	.11	.20
Residential months	.08	.08	.02
Job			
Job satisfaction	−.09	−.07	−.08
Work physical environment	.13	.11	.09
Work social environment	.22	.19	.25[b]
Health			
Illness work absences	.17	.12	.23
Sick days (work)	.11	.10	.12
Occasions colds/flu	.14	.11	.16
Occasions headache	.19	.16	.20
Occasions chest pain	.28[b]	.33[b]	.15
Mood, home evening	−.37[c]	−.33[c]	−.35[c]

[a]The analyses were performed on the full sample (N = 79).
[b]$p < .01$.
[c]$p < .001$.

In view of the relationship of SI to the physical impedance indices (Table V) the strength of the SI effects on home mood was examined in a multiple regression analysis with number of freeways, road exchanges, distance, and percent-time on freeways, along with SI. Among these variables, SI is the only significant predictor of home mood. Controlling for the physical impedance variables, SI produces a significant change in r^2, $F(5, 62) = 27.22$, $p < .001$.

Regressions of SI on residential satisfaction and on job satisfaction did not produce significant effects over the covariates. The analyses of residential satisfaction and a parallel variable, desire to move, were performed with residential months, residential crowding, and residential choice as covariates. In these analyses, residential choice (the degree of choice exercised in selecting the residence) accounts for too large a proportion of the variance

Table VI. Mood at Home in the Evening Regressed on Subjective Impedance Controlling for Residential and Job Variables[a]

Predictor	Step	Multiple R	Cumulative r^2	r^2 change	Simple r	Beta	Test of r^2 change
Work social relationships	1				.002	.107	
Residential satisfaction	1				−.061	−.074	
Work physical environment	1				−.125	−.049	
Residential choice	1				.007	.079	
Job satisfaction	1				−.107	−.102	
Desire to move	1	.156	.024	.024	.076	.074	
Subjective impedance	2	.426	.182	.158	−.351	−.445	$F(7, 66) = 12.72$[b]

[a]The home mood measure is a summary index of ratings on six bipolar scales. When SI enters the regression equation its effect is significant, $F(4, 69) = 3.30, p < .02$.
[b]$p < .001$.

(22% for residential satisfaction; 18% for desire to move) for SI to have predictive value. Without residential choice in the equation, SI does have significant r^2 change effects in a stepwise model for both residential satisfaction (r^2 change = .089), $F(3, 73) = 7.33, p < .01$, and for desire to move (r^2 change = .053), $F(3, 73) = 4.51, p < .04$. Since there were no significant correlations with residential satisfaction for physical indices (see Table III), no multiple regressions were run with those variables.

Similarly, the analyses of job satisfaction were conducted with job months, work physical environment, and work social relationships as covariates. The relationship of SI to job satisfaction is not significant, and the only effect occurs for work physical environment (r^2 change = .201). Thus, job satisfaction was affected by physical impedance but not subjective impedance, whereas the reverse was the case for the home mood effects. However, the job satisfaction measure was obtained at this follow-up testing point, and some job change did occur in the sample. Indeed, we did find job change related to subjectively experienced distress about commuting.

Commuting and Job Change

Because the SI variables were constructed for this follow-up study and were not part of our initial testing, we cannot fully test for SI effects on job change, which can be viewed as a coping behavior in our model. However, the repeated satisfaction measures do enable us to test for relationships, and there are significant effects for subjective commuting variables related to job change. A repeated measures ANOVA performed on the satisfaction with commute variable found a significant Group × Time interaction, $F(1, 74) = 26.89, p < .001$. The means and standard deviations are shown in Table

Table VII. Commuting, Job, and Residential Satisfaction as a Function of Job Change[a]

		Satisfaction measures					
		Commuting		Job		Residential	
Employment	*n*	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Changed	11	4.4_a (1.5)	$6.1_{a,b}$ (1.2)	14.6 (2.5)	16.4 (4.1)	4.8 (2.3)	5.1 (1.8)
Unchanged	67	5.4 (1.3)	4.5_b (1.7)	16.6 (3.3)	15.8 (4.2)	5.3 (1.3)	5.3 (1.3)

[a]Job change refers to shifting employment to a different company between the Time 1 initial testing and the Time 2 follow-up. Standard deviations are given in parentheses below the means. The repeated measures interaction is significant for the commuting measure ($p < .001$), and the means sharing the same subscript differ significantly from each other ($p < .01$) based on Scheffé a posteriori comparisons. There are no significant effects for the job or residential satisfaction measures.

VII. We then analyzed for significant differences between the four commuting satisfaction means by Scheffé's method for a posteriori comparisons, using the mean square error term from the repeated measures ANOVA and setting the alpha level at .01. Although our theory arguably allows us to perform a priori tests, this conservative procedure was used because of the relatively small number of job changers and the desire to minimize Type 1 error from performing many statistical tests. The results of the Scheffé posthoc comparisons given in Table VII are that the job changers increase significantly in commuting satisfaction from Time 1 to Time 2, and at the Time 2 testing, they are significantly higher in commuting satisfaction than those who did not change jobs. Several subjects explicitly wrote that they changed jobs because of the aversiveness of the commute. In contrast to these effects for commuting satisfaction, there were no significant effects for residential satisfaction or job satisfaction associated with job change, although the job satisfaction Groups × Time interaction approaches significance ($p < .06$).

It thus appears that change of employment was primarily associated with *commuting* satisfaction, which also increased significantly after the job change, while, for those who did not change jobs, commuting satisfaction decreased. Although the number of job changers is relatively small, this coherent set of highly significant differences in the means for commuting satisfaction supports our proposition of the reciprocal relationship between the job domain and the commuting domain.[8] These job change results also indicate that subjectively experienced impedance activates coping which can modify the work domain and (personal) transportation environment conditions.

Health Outcomes

For the analyses of physical health measures, the covariates of age, weight, smoking, and alcohol were entered on the first step, followed by SI. The analyses of work-absence illness occasions found that the regression was significant when SI is in the equation with the covariates, $F(5, 66) = 2.43$, $p < .04$, but SI did not produce a significant change in r^2. Neither work-absence sick days nor overall occasions of colds or flu were affected by SI, however, there were effects on one stress-related illness measure.

[8]Consistent with these findings for job change and commuting satisfaction, the feasibility of changing where one works increased significantly from low to high physical impedance at the Time 2 testing, $F(1, 64) = 4.36$, $p < .04$, as tested for linearity ($\bar{X} = 2.2$, 2.9, and 3.3, on a 7-point scale). Parallel to the commuting satisfaction effects, ratings of "traffic congestion as a frequent inconvenience" had a near significant Job Change × Time interaction, $F(1, 73) = 3.65$, $p < .06$, as those who changed jobs were slightly lower at follow-up ($T_1 = 4.8$, $T_2 = 4.6$), whereas those who remained at the same place of employment increased significantly ($T_1 = 4.0$, $T_2 = 5.1$), $t(64) = 4.99$, $p < .001$.

Subjective impedance did have a significant association with occurrences of chest pain. Because the distribution on this variable is skewed, this relationship was examined with different analytic methods. Reports of chest pain were given by 7 of 79 subjects, 3 of whom reported either two or three occasions. Converting the chest pain measure to a dichotomous variable and cross-tabulating it with the median split bifurcation of SI results in a highly significant association, χ^2 (1, N = 77) = 11.02, $p < .001$. *All* of those reporting chest pain are high SI commuters. A multiple regression was then performed on this dichotomized measure of chest pain, testing SI as the predictor and controlling for age, since this was the only covariate that correlated (r = .21) with the dependent measure. The regression approached significance on the first step when age was entered and then attained significance with SI, $F(2, 71) = 4.52$, $p <$ 02, which also produced a significant change of .07 in r^2, $F = 5.56$, $p < .02$. The multiple R for the equation with age and SI is .336. None of the physical impedance indices were correlated with chest pain nor was there an association found for the three-level PI factor.

Further exploration of the association between SI and chest pain found that the effect is being driven by the evening congestion component (r = .35), as the aversiveness component is uncorrelated (r = .07). This also indicates that the association is not artifactually due to complaint tendencies. Substituting the evening congestion subscale in the equation for SI with age results in a stronger regression effect, $F = 6.95$, $p < .002$, and raises the multiple R to .400.

Summary of PI and SI Effects

Summarizing the main findings on stress outcome measures for SI, significant effects were obtained for mood at home in the evening and with reports of chest pain but not with other health measures. In analyses of residential satisfaction and job satisfaction, SI did not have significant regression effects when other domain-related measures were covaried. Additionally, job change was associated with commuting satisfaction, which is a subjective commuting stress measure. Alternatively, the PI indices were significantly related to job satisfaction, illness work absences, and overall occasions of colds or flu, but not to chest pain, home mood, or residential satisfaction.

DISCUSSION

Travel impedance is both a physical and a perceptual phenomenon. We have found that the objective and the subjective dimensions of impedance are overlapping but not isomorphic conditions which have differential stress effects. The physical or objective conditions were found to have adverse effects on physical health and on job satisfaction, whereas the perceived or subjective condition was most strongly associated with residential impacts, especially evening home mood. However, there was no simple channeling of effects from type of impedance to type of outcome. Health and work effects occurred for subjective as well as physical impedance variables—the SI index was significantly associated with reports of chest pain, and commuting satisfaction (a subjective measure) was strongly related to job change.

Our previously developed concept of impedance as physically defined received further validation in this study and was found to have a number of health consequences that add to our earlier findings on arousal, task performance, and mood on arrival at work. The results for work-absence illness occasions, sick days, and job satisfaction obtained for the PI conditions and the auxiliary indices would seem highly relevant to employer concerns about the well-being and productivity of the workers. Our finding that job change in this sample was primarily related to commuting satisfaction, both before and after the change of employment, lends further support to this theme.

The subjective impedance concept, which follows from psychological traditions in stress research, received sufficient support to be pursued in further research. The robust effects of the SI index on evening home mood (after controlling for physical impedance and for several residential and job variables), corroborated our hypotheses, but SI was not predictive of residential satisfaction or job satisfaction, nor was it related to illness measures other than reports of chest pain. While both the evening congestion and the aversiveness components influenced the home mood effects, only the former produced the effects on chest pain. Further research must address whether the general absence of health effects for SI is a construct validity weakness or a result of measurement imperfections in prediction and/or criterion variables.

The non-isomorphism of the PI and SI conditions reflected in the cross-tabulation in Table IV suggests the operation of moderator variables associated with cognitive appraisal and/or stress-mitigating environmental factors. For example, a preliminary analysis indicates that the degree of choice exercised in buying the car is inversely related to SI ($r = -.21$, $p < .03$), and so is the degree of choice in commuting route ($r = -.24$, $p < .02$) and residential choice ($r = -.35$, $p < .001$). These three choice variables in a stepwise multiple regression on SI, each add significantly to the regression, producing a multiple $R = .463$, $F(3, 71) = 6.45$, $p < .001$. Degree of choice, personality factors that we have previously studied (Type A and locus of control), features of the car, and various characteristics of the residential and job environments need to be investigated as moderators of impedance.

However, imperfections in our measurement of SI and in the PI conditions must also be addressed in future research. The SI subscales require cross-validation, and the definition of the PI conditions must now take into account the higher levels of constraint on the evening commute.

Unidentified moderator variables may be obscuring the effects of SI on home or work domain outcomes. For example, although SI was significantly related to residential satisfaction and desire to move, its predictive value did not exceed that achieved by residential choice, a variable we previously found to be related to task performance measures and to commuting satisfaction (Novaco et al., 1979; Stokols & Novaco, 1981). This and other covariate effects underline the importance of controlling for confounding factors in analyses of transportation stressors.

The reciprocal links between the residential, commuting, and occupational domains that are hypothesized by our ecological perspective are confirmed here in the significant effects obtained for the impedance variables on the job and residential outcomes, as well as with the effects of job change on commuting satisfaction. Here we have not addressed the reciprocal impacts of residential variables on commuting stress, which will be examined in a subsequent paper on moderators of impedance. However, our findings indicate that the study of the stressful aspects of commuting will profit from the analysis of *interdomain transfer effects,* whereby the psychological consequences of environmental conditions in one life domain (home, commuting, work, or recreational) transfer to another, either positively or negatively. This idea was implied in our earlier work (Stokols & Novaco, 1981) but is made more explicit by the present model. The concept of transfer effects across life domains bears similarity to Zillmann's concept of "excitation transfer" (Zillmann, 1971, 1983; Zillmann & Bryant, 1974) which he used to explain heightened proclivities to respond aggressively in successive situations.

We have found previously that the arousal-inducing and mood-affecting consequences of the commute to work carried over to our midmorning testings. We also found that contextual factors, such as job involvement and degree of residential choice, moderated the stress impacts of commuting and that these moderating factors were linked to personality variables. Here we have found that perceived impedance in commuting transfers to negative mood states at home in the evening, controlling for strong moderating variables of the residential environment, as well as work environment variables. Similarly, the relationship between commuting satisfaction and job change, the finding of a negative impact on job satisfaction associated with percentage of time and miles on freeways, and the illness work-absence effects related to physical impedance factors can be viewed as negative transfers from the commuting to the occupational domain.

Our findings suggest that both commuters and work organizations are sustaining hidden costs associated with high-impedance commuting. Such indirect costs of employee transportation might be manifested in illness-related absence from work, disability claims, and reduced levels of employee productivity and morale. In Southern California, freeway travel has become increasingly congested, with very little new capacity in roadways to absorb continued growth; and our results indicate that stress effects are strongly associated with freeway travel and with road exchanges. Yet the private car remains the predominant mode of commuting, as it is for nearly 90% of the U.S. labor force. Despite increasing congestion and the decline in satisfaction with regional freeways (see Fotenote 3), it is still the case that 86% of the resident workers in Orange County commute to work by driving alone. Oddly enough, this increased from the 82% rate found 5 years before (Baldassare, 1987). This high percentage of drive-alone commuting, consistent with national patterns, reflects the lack of motivation for car-pooling due to the convenience and relative economy of the private automobile (Teal, 1987). Recent legislation regarding air quality standards is mandating ride-sharing programs, and we have some new research underway to examine alternative modes of commuting and mode shift effects on performance and health.

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