Journal of Environmental Psychology (1998) **18**, 113–139
© 1998 Academic Press
Article No. ps980086
0272-4944/98/020113+28$30.00/0

Journal of ENVIRONMENTAL PSYCHOLOGY

THE VIEW FROM THE ROAD: IMPLICATIONS FOR STRESS RECOVERY AND IMMUNIZATION

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Abstract

A considerable body of folklore and scientific research alludes to the efficacy of the vernacular environment to influence both aesthetic experience and general well-being. To examine explicitly whether stress recovery and/or immunization varies as a function of the roadside environment, 160 college-age participants, both male and female, viewed one of four different video-taped simulated drives through outdoor environments immediately following and preceding mildly stressful events. Overall, it was anticipated that participants who viewed artifact-dominated drives, relative to participants who viewed nature-dominated drives, would show greater autonomic activity indicative of stress (e.g. elevated blood pressure and electrodermal activity), as well as show altered somatic activity indicative of greater negative affect (e.g. elevated electromyographic (EMG) activity over the brow region and decreased activity over the cheek region). In addition, it was expected that participants who viewed nature-dominated drives would experience quicker recovery from stress and greater immunization to subsequent stress than participants who viewed artifact-dominated drives. The overall pattern of results is consistent with both hypotheses and the findings are interpreted to support postulating a sympathetic-specific mechanism that underlies the effect of nature on stress recovery and immunization.

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Introduction

A noted Italian Renaissance architect, Leon Alberti, wrote that roads should be made 'rich with pleasant scenery' (*De re Aedificatoria*, 1485). Quoted in Lay's (1992, p. 314) comprehensive history of the world's roadways, an account that begins with the first human footpaths and includes extended treatises on such topics as the relative merits of macadam and asphalt, this statement by Alberti is the first mention made of roadside aesthetics. Though there is early evidence of great ancient road builders planting trees along the side of the road (e.g. in China during the Qin and Han dynasties, and along the Great Royal Road in India during the 4th century BC), such plantings usually served utilitarian or religious purposes (Lay, 1992). The tree-lined boulevard, an aesthetic amenity that became very popular in 19th century Europe, also has its roots in the Italian Renaissance in the form of the garden *allée*, an elongated style of landscape garden, typified by shady tree-lined pathways and used for upper-class promenades (Lawrence, 1988). Influenced in part by European landscape designs and the Victorian romantic ideal of a rural life, the F.L. Olmsteds (father and son) and Calvert Vaux developed a roadway design featuring wide grassy center medians, and thereby popularized parkways in the United States (Lay, 1992). Thus, the publication of Alberti's 'Ten Books of Architecture' near the start of the Renaissance serves as a watershed event in the history of roadside aesthetics.

In the more recent history of road design, landscape architects have exerted an important influence on the quality of roadsides. In the early development of roads for automobile travel in this country, a concern for roadside aesthetics was considered one of the four main functions of the landscape engineer (Gubbels, 1938) and figured prominently in principles for good design (McCluskey, 1985). Statements like the following were not uncommon:

> The best road between A and B is the road that is economical, safe and interesting. It has been estimated

> that sixty-five percent of highway traffic is for pleasure, and pleasure comes from variety. What does the autoist care whether the measured distance from A to B is forty miles or forty-three miles? If the three extra miles will enable him to catch a long, vista of a distant stream, see from a hilltop a broad valley where cattle, horses and sheep are grazing, see farmers mowing hay or turning dark sod, or find his road ahead bending mysteriously under the arch of an overhanging tree, he will not begrudge the few minutes they cost him. (Gubbels, 1938, p. 7).

This quote and the associated historical sketch illustrate several points. First, an historical concern for roadside aesthetics can be fairly well documented among professional designers. This is perhaps surprising, given the current state of most urban freeway roadsides, where landscaping has played a relatively minor role (Rottinghaus, 1973; Lay, 1992). This situation may be explained in part by the second point: the development of design principles for roadside aesthetics and their consistent application has occurred primarily on rural highways, where the development of the surrounding right of way could be planned rather than retrofitted to an existing urban environment (Hornbeck & Okerlund, 1972; McCluskey, 1985; Lay, 1992). There is some irony here, because the greatest volumes of traffic are in urban areas and on commuter roads that lead into urban areas, and thus the greatest potential impact of roadside aesthetics is on those roads where landscape planning has been a minor consideration. A third point is that the desirability or benefits of aesthetic roadsides are presumed by designers (e.g. Gubbels, 1938; Rottinghaus, 1973; McCluskey, 1985) and legislators (e.g. Metheny, 1967) alike, without reference to supporting behavioral evidence other than estimated statistics on the popularity of pleasure driving.

In the research to be reported here, we are concerned with the potential impact of roadside quality on motorists in more quotidian driving circumstances, such as the commute to and from work. Licensed drivers in the U.S. drive 13,000 miles per year, on average (ULS Report, May 1995), 66 per cent of which is nonpleasure driving (Jervis, 1973). Not only is automobile commuting categorized as non pleasure driving, it is distinctly unpleasant for many commuters (Novaco *et al.*, 1979), and commuting in general is associated with negative worker morale (Koslowski & Krausz, 1993) and can produce potentially harmful physiological effects (Schaeffer *et al.*, 1988). Thus, to the extent that roadside quality affects motorists, the potential health and quality of life impacts of those effects are substantial. Unfortunately, research to date on the quality of roadside environments does not clearly delineate the nature or extent of such effects (Schauman *et al.*, 1992). Although there was early concern with roadside quality, effort and expense on aesthetics was often justified in terms of safety (Gubbels, 1938; Hornbeck *et al.*, 1969) though we have found no empirical evidence to support this rationale.

To clearly establish that the quality of roadside environments has the potential to influence health and quality of life, we will selectively review research in three areas: where people look when they drive, stress effects associated with driving and other forms of commuting, and the perceived quality and potential impact of roadside environments on motorists. In the research on where people look, we will be concerned primarily with evidence pertaining to the extent to which motorists attend to elements of the roadside environment. Next we will be concerned with why it matters where people look. In this section we will examine research on commuter stress, which will help to establish the potential mitigating influence of roadside environments that are perceived to be aesthetically pleasing or stress-reducing. We will then review research on the perception of roadside environments, focusing on those elements associated with perceived quality or aesthetics, especially as they relate to the oft-hypothesized stress-reducing qualities of nature-dominated environments. To anticipate, we will conclude that motorists most likely do devote some of their attention to roadside environments, that they have definite opinions about the nature and quality of those environments, and that the well-documented stress associated with driving and other forms of commuting may possibly be mitigated by aesthetically preferred, stress-reducing roadside environments dominated by nature.

To cast this research in terms introduced 50 years ago by Kurt Lewin (1946) and others, this work constitutes diagnostic social action research. Lewin defined action research as '…comparative research on conditions and effects of various forms of social action, and research leading to social action'. Diagnosis, or scientific fact-finding, was distinguished from the study of general laws of social behavior, and was considered crucial to the 'social engineer', who could not apply the general laws without some knowledge of the 'specific character of the situation at hand'. Thus, with this study we are finding facts relevant to the specific situation of automobile commuting, which may ultimately lead to social action in the urban planning and transportation planning policy arenas.

Where do motorists look?

The literature on where people look when they drive is dominated by ergonomic studies employing eye-tracking devices to help assess the perceptual, attentional and judgment conditions associated with driving. For instance, a well-established finding in the literature is that 'perceptual narrowing' occurs for drivers as the demands of driving increase. With increasing demand (e.g. greater speed, increased traffic) the physical range of fixations narrows and the length of fixations increases (Mourant & Rockwell, 1970; Ceder, 1977; Miura, 1987). Not too surprisingly, the results from many such studies confirm that traffic, the road ahead and traffic signals and signs account for a large percentage of motorists' eye fixations (Carr & Schissler, 1969; Mourant & Rockwell, 1970; Ceder, 1977; Hughes & Cole, 1988; Miura, 1987). Unfortunately, in studies where the focus is on the attentional demands of driving, even tentative inferences about the extent to which attention is devoted to the roadside are often unwarranted, and where it is possible to draw tentative inferences, it is usually impossible to determine the specific content of off-road fixations (*cf.* Mourant *et al.*, 1969; Blaauw & Riemersma, 1975; Hughes & Cole, 1988). Despite these limitations, it is clear from this literature that at least some attention is devoted to roadside elements when people drive. This conclusion is warranted in part because of the repeated findings of significant proportions of eye-fixation records to spatial regions that are unrelated to driving. This conclusion is also consistent with theoretical models that have been developed to account for drivers' attention and eye-scanning patterns (Senders *et al.*, 1967; Ceder, 1977). The typical drive scenario that emerges from the theoretical and empirical literature is one in which some central, task-relevant region is the focus of attention (in driving, usually the focus of expansion[1]), with occasional attentional forays directed to nontask-relevant aspects of the environment.

If some significant proportion of off-road eye fixations are to nontask-relevant aspects of the roadside environment, what is the nature of the roadside elements that are fixated? Several eye movement studies that have included retrospective surveys of motorists' perceptions to compare recollections to real-time fixations are instructive. Carr and Schissler (1969) for instance, solicited free-recall from local commuters, and from drivers and passengers who were unfamiliar with a 4·5 mile drive into Boston. When asked to recall the highpoints of their journey in as much detail as they wished, the items recalled by drivers who were unfamiliar with the route were more likely to be driving-related than were the items recalled by the other groups. The drivers who were familiar with the route (i.e. the commuters) and the unfamiliar passengers were more apt to recall off-road elements including large buildings, historical sites and residential areas, with relatively little mention of driving-related items.

These findings are notable for two reasons. First, the self-report data corroborate the perceptual narrowing phenomenon reported in numerous eye movement studies: those participants in the most demanding situation, the unfamiliar drivers, recalled relatively little information from off-road, task-irrelevant areas of the driving environment. Second, among the commuters and passengers, those in the less demanding situation, there was no mention made of natural environment elements (parks, rivers), though the route they drove crosses at least two major rivers that could have been mentioned. It is not clear why natural elements were not mentioned, but it may be that parks and other natural amenities do not constitute easily named entities, and thus may be under-represented on a verbal recall task.

In Carr and Schissler's study, then, there may well have been items, including natural environment elements, that were fixated but not recalled. Luoma (1988), for instance, has reported data where traffic control signs (various crosswalk indicators) and roadside advertisements were clearly fixated but not recalled. Numerous studies conducted in Europe have shown that anywhere from 20 per cent to 80 per cent of drivers cannot recall traffic signs immediately after passing them (Johansson & Rumar, 1966; Johansson & Backlund, 1970; Drory & Shinar, 1982; Milosevic & Gajic, 1986). Despite this poor recall, at least one study suggests that drivers do respond to traffic signs, and thus must perceive them however minimally. Summala and Hietamäki (1984) observed over 2100 Finnish drivers in seven conditions, six different sign configurations and a no-sign control condition. All participants decelerated through the observation point, located on a curve at the crest of a hill, though participants in four of the six sign conditions decelerated significantly more than those in the control condition, and those signs that specifically required a reduction in speed elicited the greatest deceleration. Recall data were not solicited, but the behavior of these drivers seems to have been more heavily influenced by the presence of road signs than one would expect from the recall data reported in previous studies which indicate that typical recall of roadside signs is about 50 per cent or less (Johansson & Rumar, 1966; Johansson & Backlund, 1970; Drory & Shinar, 1982).

The relative inadequacy of verbal recall instruments as a measure of roadside perceptions and the potential influence of roadside environments can also be seen in a study of the perception of roadside art (McGill & Korn, 1982). Participants with varying familiarity with the study area were driven through a neighborhood on a set route and asked to recall what they could, while other participants familiar with the area recalled what they could of the route without benefit of the drive. Across participants, businesses (by name or type) were by far the most frequently recalled items (55% of all items), with the next most frequent categories being buildings (8%) and streets (7%). Spontaneous references to roadside art (three murals along the route) accounted for less than 5% of the responses, as did recall of a large park that bordered a quarter mile of the 1·7-mile (2·4 km) route. Participants were also given a recognition test of their memory for the roadside environment. Under these conditions, an average of 58 per cent of the participants remembered the murals, while two pictures of entrances to the park were recognized by 81 per cent and 89 per cent of the participants, respectively. The recognition 'hit rate' for businesses, the most frequently recalled items along the route, was only 65 per cent . Thus, though the art and natural roadside elements were not widely recalled, the ease with which they were recognized implies that most people perceived these items during the drives.

Why does it matter where motorists look?

Aesthetic benefits

Though we can render no clear picture of where off-road glances of motorists fall given the available data, there is good evidence that people do discriminate among different types of roadsides, and that they have opinions about roadside attractiveness. In a factor analytic study of Dutch roadways represented by photographs, Riemersma (1988) reported that motorists categorize roads based on two major dimensions: various aspects of safety, and the urban/rural character of the road. In particular, among the items that loaded heavily on the urban/rural factor were 'greenery' and 'many trees', which loaded positively, and 'urban character' and 'many buildings', which loaded negatively. Though these perceived distinctions did not closely correspond to official government road classifications, they did accurately reflect objective physical characteristics of the roads that were judged.

One aspect of the perceived distinction between the urban and rural character of roadways is likely the scenic quality or attractiveness of the roadsides. This can be inferred from a consideration of Riemersma's (1988) data in the context of perceived environmental quality studies, which indicate that people visually prefer natural[2] environments over more urbanized environments (see Parsons, 1991*a*). The opposite loadings of trees and greenery vs urban character and buildings on the same factor could well reflect differing opinions about the scenic quality of these types of environments, given that safety and other road-related variables loaded on two other independent factors. Such a difference in preferences would be consistent, as well, with years of social commentary railing against the 'visual blight' of urban and suburban development in the U.S. (Blake, 1964; Nairn, 1965; Lewis *et al.*, 1973). Despite these views, there is relatively little empirical data on the scenic quality of roadside environments, though the evidence is consistent with the view that roadside development often negatively influences scenic quality.

Evans and Wood (1980) for instance, investigated the effects of increasing developments on a scenic highway corridor using simulated drives. A 12-mile section of the highway was represented by 100 color slides taken from the driver's perspective, a methodological approach that previously has been validated for the representation of scenic road corridors in forest areas (Schroeder & Daniel, 1980). Separate groups rated an undeveloped scenic corridor, the same corridor with minimal development, and the same corridor with substantial development. Both affect-laden (beautiful/ugly) and more cognitively oriented (simple/complex) judgments were elicited, and findings indicated that as development along the corridor increased, the highway was rated as less valuable, useful, pleasant, beautiful and scenically attractive, and more cluttered. These variables accounted for over 40 per cent of the variance in participants' ratings. There were no perceived differences in the complexity, hazardousness, orderliness or roughness of the simulated drives.

In a similar study, Winkel *et al.* (1970) focused more closely on several specific types of elements associated with roadside development. Two simulated drives (commercial and landscaped) were presented to separate groups through the use of black and white photographs. When utility poles and overhead wires were removed from the commercial drive, the roadside environment was perceived to be more personal, much simpler and much more effective. Participants assigned to the landscaped route condition responded in essentially the same fashion, but only when utility poles, overhead wires, billboards and other signs were removed. Subsequent interviews revealed that these participants would have responded positively to the removal of the utility poles and overhead wires alone were it not for the fact that their removal served to accentuate the remaining billboards and signs, which they did not like. This last finding is consistent with earlier research establishing that people respond negatively to billboards (MacGillivary, 1969). Findings from this same study indicate that there is a negative, monotonic relationship between billboards and roadside aesthetics such that as the density of billboards increases, visual preference ratings of the roadside decrease. Thus, studies looking at specific elements of commercial strip development, as well as those focusing more generally on the overall amount of development, suggest that development negatively impacts roadside aesthetics.

While these studies reflect attitudes about and preferences for roadside environments, there is evidence that driving behavior can be influenced by aesthetics as well. Ulrich (1974) interviewed 48 drivers in a suburban Ann Arbor (MI) neighborhood regarding route choices for shopping trips to a nearby shopping center. All participants lived in an area with similarly easy access to two parallel roads to the shopping center: a scenic but slower Parkway route, and a faster nonscenic Expressway route. Respondents reported that over half of their trips to the shopping center were on the Parkway, despite the fact that the trips were nonrecreational, and that the Parkway required more stops and took longer to traverse. When in a hurry, most respondents preferred the faster Expressway, while the Parkway was preferred when drivers were not in a hurry. The Parkway was also associated with feelings of relaxation and the desire to view nature, findings that were likely due partially to the slower speeds on the Parkway, but which may also be attributable partially to the attractiveness of the natural surroundings. This latter possibility is an important point, because it suggests a possible mechanism by which roadside environments can positively influence the health and quality of life of urban commuters (see discussion below).

Health consequences

Research on the stress associated with driving can be broadly divided into two categories, those studies focused specifically on the task of driving, and those studies more generally concerned with the commuting or transportation goals of drivers and/or passengers.[3] Researchers have been investigating the health effects of driving as a task for over 30 years, establishing that driving can be a stressful activity, especially under demanding driving conditions (Simonson *et al.*, 1968; Littler *et al.*, 1973). Increases in electrodermal activity over resting levels indicate that driving elicits activation of the sympathetic nervous system (Taylor, 1964). Elevations in catecholamines and corticosteroids during ordinary driving (Bellet *et al.*, 1969) suggest the involvement of both sympathoadrenal medullary and adrenocortical stress response systems, though several studies have failed to show corticosteroid increases for professional truck drivers (e.g. Cullen *et al.*, 1979; Vivoli *et al.*, 1993). Cardiovascular changes are evident as well, including increases in heart rate, heart rate variability and blood pressure among healthy drivers (Wyss, 1970; Littler *et al.*, 1973) and ischemic depression of the T-wave and the S-T segment of the cardiac waveform among drivers with coronary heart disease (Bellet *et al.*, 1969; Taggart *et al.*, 1969). These same cardiac abnormalities can also be seen in healthy drivers when the driving distances involved are long (several hundred miles or more; Burns *et al.*, 1966). Demanding driving conditions tend to exacerbate these effects, with on-ramps, off-ramps and roundabouts increasing heart rates relative to straight road sections (Rutley & Mace, 1972) for instance, and with the sharpness of curves having a positive relationship to electrodermal activity (Babkov, 1975).

Despite these well-documented physiological responses to driving (see Sadalla & Hauser, 1991, for a comprehensive review) relatively little research has been done to establish a link between such changes and the health of drivers. A series of studies on Dutch bus drivers by Mulders and his colleagues offers the strongest support (Mulders *et al.*, 1982, 1988). Urinary catecholamines were examined for two groups of drivers, those with high and those with low rates of illness absenteeism. Both groups showed elevated levels of catecholamines after a period of work relative to resting levels. The high absenteeism group, however, showed significantly higher levels of epinephrine and norepinephrine after the work period than the low absenteeism group, though the resting catecholamine levels of the two groups did not differ. These findings have been replicated and extended in subsequent research to include a third group of drivers whose illness absenteeism fell between that of the high and low absenteeism groups; their catecholamine levels followed the same pattern. While these studies suggest that stress-related endocrine responding of bus drivers during their shift is associated with their health status, the generalizability of these findings to more ordinary driving situations is unclear given the additional time and social interaction pressures inherent in driving a bus (see Evans & Carrère, 1991).

Apart from the task of driving *per se*, several researchers have found that commuting is a stressful activity, having negative health and quality of life consequences both for those who drive to work (Novaco *et al.*, 1979) and for those who use other forms of transportation (Singer *et al.*, 1978; Takano, 1983). These and other studies have reported increased blood pressure associated with longer or more difficult morning commutes (Stokols & Novaco, 1981; Schaeffer *et al.*, 1988). Lowered job satisfaction (Novaco *et al.*, 1990; Koslowski & Krausz, 1993), higher illness absenteeism (Taylor & Pocock, 1972; Novaco *et al.*, 1990) and lower performance scores on various cognitive tasks (Novaco *et al.*, 1979; Schaeffer *et al.*, 1988) have also been reported for those with longer or more difficult commutes. These findings are fairly robust, having been corroborated across several research groups using different methods to characterize the difficulty of commuting (distance, time, distance and time, multi-stage nature of the commute, etc.). Novaco, Stokols and their colleagues have introduced the term 'physical impedance' to refer to any physical constraints to travel that might interfere with commuting (see Stokols & Novaco, 1981, for a review) such as traffic congestion. More recently they have suggested that 'subjective impedance' be used to refer to commuters' perceptions of the extent to which physical constraints to travel actually interfere with their commute to or from work, and a pair of studies has indicated that this distinction is important. Independent of effects associated with physical impedance, subjective impedance is associated with negative moods at home following evening commutes and participants with high subjective impedance scores are also generally more likely to report chest pains (Novaco *et al.*, 1990; Novaco *et al.*, 1991).

Given the stressful nature of driving and commuting, it is surprising that research in these areas is devoted almost exclusively to establishing the fact and delineating the quality of travel-related stress. Relatively little research has been concerned with potential mitigating factors, and what research there is has focused on social or person-centered variables, such as how problems at home or on the job can contribute to driving stress and the influences of drivers' cognitive appraisals and trait anxiety levels (see Gulian *et al.*, 1989, for a review of this work). We have found no research that examines the possible mitigating effects of roadside environments on travel-related stress, which is the primary purpose of this study.

While there is no direct evidence regarding the stress-reducing effects of roadside environments, there is evidence that outdoor environments can differentially affect recovery from stress in nontravel contexts. Ulrich *et al.* (1991) monitored psychological and physiological recovery from a mild laboratory stressor under varying environmental conditions. Those participants who viewed videotaped surrogates of environments dominated by natural vegetation recovered more completely and quickly than those who viewed video tapes of artifact-dominated urban environments. Earlier research suggests that such effects may have important health consequences (Ulrich, 1984). Recovering hospital patients, appropriately matched for age, gender, socio-economic status, pre-surgical health status etc., used fewer and less potent analgesics and left the hospital sooner if their hospital room looked out on a small wooded area as opposed to another part of the hospital building. Others have reported similar psychological and physiological restoration effects attributable to interactions with natural environments (e.g. Parsons, 1991*b*; Hartig, 1993), and Hartig *et al.* (1991) have speculated that the obverse may be true as well, suggesting that exposures to stress-reducing natural environments may gird one for encounters with future stressors (an 'immunization' effect). The focus among these researchers on the distinction between natural and urban or artifact-dominated environments derives from habitat selection theory (Orians & Heerwagen, 1992) and other evolutionary theories (e.g. Ulrich, 1983; Kaplan & Kaplan, 1989) that suppose genetic predispositions to visually prefer and feel more comfortable in environments that approximate those of human speciation, arguing that such environments afford long-term survivability. Thus, *caeteris paribus*, these theories predict that natural environments should be visually preferred and more calming than their artifact-dominated counterparts, and among natural environments, those that more closely approximate supportive African savannas (the environments of our speciation) should be preferred most of all.

Research hypotheses

In summary, these findings indicate that visual exposure to natural environments can be stress-reducing, and they suggest the possibility that roadside environments dominated by natural elements can mitigate travel-related stress. The tenability of this inference is bolstered by the substantial evidence that some portion of motorists' attention is likely to be devoted to nontask-oriented aspects of the travel environment, that motorists are aware of the environments they travel through, that they have definite opinions about the attractiveness of those areas and that their behavior can be influenced by the scenic quality of the environments through which they drive. Based on this evidence we derived two major hypotheses. First, we expected that participants who viewed artifact-dominated roadside environments, as compared to participants who viewed nature-dominated roadside environments, would show greater autonomic activity indicative of stress (e.g. elevated blood pressure and electrodermal activity), as well as show altered somatic activity indicative of greater negative affect (e.g. elevated EMG activity over the brow region and decreased activity over the cheek region). Second, we expected that a nature-dominated 'drive' would both facilitate recovery from stress, as well as ameliorate the negative consequences of a future stressor, as compared to an artifact-dominated 'drive'.

Though this is a laboratory study, our research perspective is, as indicated above, action-oriented, so we have taken great care to foster the ecological validity of this research. First, and most importantly, we have constructed video-taped environmental surrogates that constitute a fairly subtle distinction between artifact-dominated and nature-dominated roadside environments (see details in the Method section below). This was done to more closely approximate the typical suburb-to-city commuting environment, where completely naturally vegetated roadsides are unlikely. Thus, the nature-dominated environments used in this study were not wholly natural, but included a mixture of naturally vegetated roadsides and those that showed some light commercial development. Second, because the nature of the stress that might be encountered in commuting and pre-commuting environments (i.e. rushing to get ready to leave prior to the morning commute, and stressors encountered on the job prior to the evening commute) is likely to be varied, we included passive and active stressor exemplars, as this particular distinction has come to be important in the psychophysiological literature (e.g. Tomaka *et al.*, 1993). Though we expected these stressor types to elicit qualitatively distinct responding, we did not expect this manipulation to interact with the environmental drives. That is, we expected differential recovery rates as a function of roadside environments, regardless of the nature of the stressor experienced prior to the drive. Finally, in an effort to more carefully explore the distinction between artifact-dominated and nature-dominated environments, we have included golf courses among our nature-dominated roadside environments. The categorization and psychological import of golf courses is an interesting question because golf courses are immediately recognizable as largely (or wholly) contrived environments, yet they are completely composed of natural elements. To the extent that these environments elicit restoration and/or immunization effects similar to those predicted for nature-dominated environments in general, we can surmise that content *per se* contributes more to perceived environmental categorization and the psychological import of golf courses than does configurational provenance.

Support for these hypotheses would have both theory-oriented and action-oriented implications. With respect to evolutionary theories relevant to environmental restoration, evidence that relatively superficial environmental transactions (restricted visual access from a moving vehicle) are sufficient to influence stress-related physiological responding would suggest that the class of phenomena that need to be accounted for is fairly broad. And, support for these hypotheses would also contribute important information about 'the specific character' of the commuting situation that could usefully inform social action and policy regarding the design of travel environments.

Method

Overview

The experiment consisted of four distinct phases. Following a short baseline period, all participants experienced a mild stressor (Stressor1), then viewed a short video tape of drives through one of four different outdoor environments (Drive), and finally experienced a second and qualitatively different stressor (Stressor2). The stressors differed according to whether they required passive (viewing a video tape) or active (serial addition) engagement of the participants, and their presentation order was counterbalanced across participants. The battery of physiological measures reflecting both autonomic and somatic activity was obtained continuously throughout the experiment.

Research participants

One hundred and seventy-six undergraduate students with no known neurological or health disorders served as research participants. One hundred and fifty research participants received credit toward fulfilling a course requirement and 26 were paid \$20 for their participation. The data from 16 research participants were lost due to either equipment failure or experimenter error, resulting in a final participant pool of 79 women and 81 men. The self-reported average age, height, and weight of the women and men was 20·2 years, 64·3 inches (1·63 m), 129·0 lb (58·6 kg) and 19·7 years, 70·6 inches (1·79 m), 171·9 lb (78·1 kg), respectively.

Apparatus and recordings

Three channels of facial electromyographic (EMG) activity (*corrugator supercilii*, *zygomaticus major*, and *orbicularis oris* muscle regions), three channels of autonomic activity (electrocardiogram, blood pressure, and skin conductance), and two channels of electrooculographic (EOG) activity (vertical and horizontal) were recorded. Each channel was calibrated using external reference signals generated with a Coulbourn^{TM} Biosystem Calibrator placed in the experimental room and connected to the biosensor junction box located immediately behind the participant's chair.

The facial EMG, EOG and electrocardiogram (ECG) signals were relayed to wide-band general-purpose AC-coupled amplifiers. The facial EMG signals were band-pass filtered (4–650 Hz, 6 dB/octave rolloff) prior to full-wave rectification and smoothing using precision integrators (Paynter filters) with time constants of 25 ms. Each facial EMG channel was calibrated using a 100-µV, 100-Hz square wave signal and the system gain was set to ×5000. The EOG signals were band-pass filtered (0·01–20 Hz, 6 dB/octave rolloff) and each channel was calibrated using 1-mV, 1-Hz square wave signal and the system gain was set to ×1000. The ECG signal was bandpass filtered (1–150 Hz, 24 dB/octave and 36 dB/octave rolloff, respectively) and this channel was calibrated using a 1-mV, 1-Hz simulated cardiac waveform. The system gain was set to ×1000.

The blood pressure waveform was recorded using a Cortronics^{TM} 7000 pressure monitor, which was factory calibrated to cover the range from 0 to 250 mmHg. The output from this unit is a continuous analog voltage proportional to the pressure waveform (20 mV/mmHg). Skin conductance was measured with a Coulbourn^{TM} Isolated Skin Conductance Module (Model #S71-22) using a precision DC excitation voltage of 0·5 V and set to transduce both phasic and tonic changes in electrodermal activity. The module was factory calibrated to produce a continuous analog voltage proportional to changes in skin conductance (1000 mV/µS). With the exception of the EOG and ECG signals, all signals were passed through anti-aliasing filters (4 Hz, 36 dB/octave) prior to sampling via a laboratory computer. Each channel was digitized (16-bit) at a rate of 200 Hz and stored for subsequent data reduction and analysis. In parallel with the data acquisition system, skin conductance and any two other physiological signals were displayed on a 3-channel oscilloscope throughout the experiment.

Details concerning biosensor preparation and placement for each physiological measure are listed below. Unless otherwise indicated, all biosensor impedances were measured using a Grass^{TM} impedance meter registering kΩ at 30 Hz and a hypoallergenic, high conductivity gel was used as the biosensor electrolyte.

Iso-ground. The left ear-lobe was wiped clean with isopropyl alcohol, and a pair of gold-cup biosensors filled with gel was attached using a spring-clip holder.

Skin conductance. The skin surface directly over the thenar and hypothenar eminence of the right hand served as the recording sites. Before attachment of the biosensors, the research participant's hands were washed with nonabrasive, pH-balanced soap and thoroughly dried with paper towels. Two large Ag/AgCl surface biosensors (13 mm i.d.) were filled with 0·05 M NaCl Unibase paste (Fowles *et al.*, 1981) and attached to the skin surface with disposable, double-sided adhesive collars.

Electrooculogram.[4] To record vertical EOG one biosensor was placed on the skin surface approximately 1·5 cm below the bottom right eyelid and the other biosensor was placed approximately 1 cm above the right eyebrow. To record horizontal EOG, biosensors were placed approximately 1·5 cm caudal to the ectocanthions. Prior to attachment, the research participants were asked to sit up and look straight ahead. With their eyes in this position, an imaginary line drawn between the two vertical EOG biosensors would bisect the right pupil, and an imaginary line drawn between the two horizontal EOG biosensors would bisect the pupils of the left and right eyes. Each site was abraded with a disposable pad impregnated with an alcohol pumice suspension and then wiped clean with isopropyl alcohol. Two pairs of miniature Ag/AgCl surface biosensors (4 mm i.d.) were filled with hypoallergenic, high conductivity gel and attached to these sites with disposable, double-sided adhesive collars.

Facial electromyogram. Facial EMG activity was recorded from sensors placed over the left *corrugator supercilii*, left *zygomaticus major*, and the left *orbicularis oris* muscle regions (hereafter referred to as the Brow, Cheek, and Mouth regions, respectively). One pair of standard 4-mm Ag/AgCl miniature biosensors was used for each EMG muscle region. Skin preparation for each of the muscle recording sites was the same. Dead skin and oil were removed from each area by rubbing lightly with a disposable abrasive pad, followed by an abrasive skin gel applied with a cotton-tipped applicator. After abrasion, the skin was wiped clean with isopropyl alcohol. Each pair of biosensors was filled with gel and attached to the skin surface with disposable, double-sided adhesive collars. EMG recordings were bipolar with an inter-sensor distance of approximately 1 cm, center-to-center. Biosensor impedances for the three muscle channels averaged 6·9, 5·4, and 6·9 kΩ, respectively.

Heart rate. To record the electrocardiogram (ECG) a sternal placement on the right collar bone and an axillary placement on the left lowest rib was used. Before attachment, recording sites were mildly abraded with a disposable abrasive pad and wiped clean with isopropyl alcohol. Two miniature Ag/AgCl surface biosensors (4 mm i.d.) were filled with gel and attached with disposable, double-sided adhesive collars to the placement sites.

Blood pressure. Blood pressure was recorded with an osculatory cuff placed over the brachial artery of the left arm. The cuff was connected to a Cortronics^{TM} 7000 Pressure Monitor which maintained the cuff pressure at a level of 19–20 mmHg, after an initial 2-min calibration period, and provided a continuous analog readout of the blood pressure waveform.

Task and stimuli

Presentation media. All video stimuli were presented via a video projection system in the semi-darkened experimental room. This system projected a 4×6 ft (1·2×1·8 m) image onto a reflective white screen approximately 15 ft (4·5 m) in front of the participant. All audio stimuli were presented via a surround-sound stereo system that was adjusted to a comfortable listening level.

Passive stressor. The passive stressor was a 12-min black and white movie about the prevention of workplace accidents (Gorman, 1956). The movie contains simulations of injuries and accidents that can occur in woodshops as a result of carelessness or disregard for safety regulations, and has been used extensively as an effective yet mild laboratory stressor (e.g. Lazarus *et al*., 1962).

Active stressor. The active stressor was an audiotaped version of the Paced Auditory Serial-Addition Task (PASAT). In a typical administration of the PASAT a series of single-digit numbers is read aloud to the participant. The participant's task is to add every two digits in the given series together and say the sum of these two digits aloud. The PASAT has been used as a measure of the rate of information processing, concentration and attention span, and participants performing the PASAT find the task to be mildly stressful and anxiety-producing (Roman *et al.*, 1991).

In the present study, the pre-recorded 12-min audio tape of the PASAT consisted of a male voice reading one practice series containing 35 randomly presented, single-digit numbers and four subsequent series, each with 50 randomly presented, single-digit numbers. Each series differed in the digit presentation rate, varying between the clearly achievable and nearly impossible (i.e. 20 and 48 per min) with a constant inter-series interval of 23 s.

Roadside environments. Raw footage. Surrogate 'drives' through four distinct types of roadside environments were made using a Hi-8 mm video-camera (SONY TR101). Scenes for the Forest/Rural drives were video-taped along farm-to-market roads and state highways in central and east Texas, and these roadside environments were dominated by natural vegetation. Scenes for the remaining three drives were video-taped in and around the cities of Austin, Dallas, and Houston, Texas. The Urban drives were video-taped in areas dominated by human artifacts, primarily commercial buildings, proprietary signs

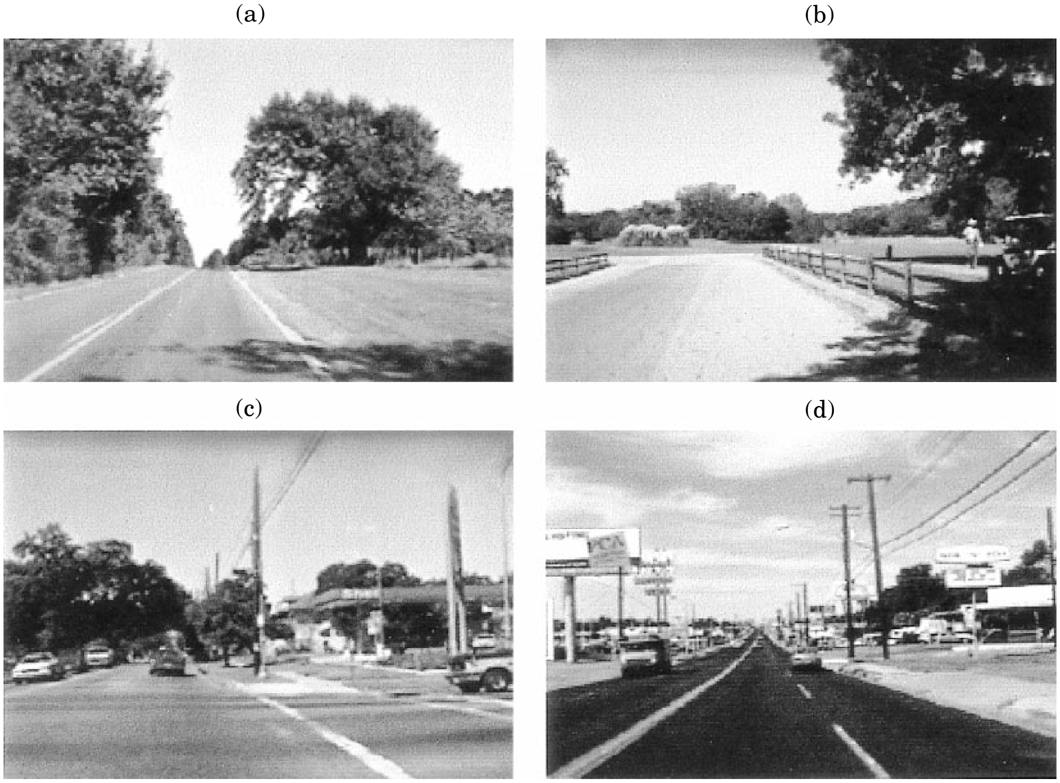

FIGURE 1. Representative scenes from the four environmental 'Drives.' Panels (a)–(d) show the Forest, Golf, Mixed and Urban drives, respectively.

and billboards. Scenes for the Golf drive were videotaped along golf courses and these roadsides typically consisted of a golf course on one side and well-vegetated residential areas on the other. The final category of surrogate drives was a Mixed drive, which was composed of scenes from areas where light development is allowed in residential neighborhoods. The roadsides in these scenes are fairly heavily vegetated, though commercial buildings, signs and other artifacts are clearly visible in each scene. Example scenes from roads in each of the four conditions are presented in Figure 1.

Production methods. Field procedures for all environments were the same. The camera was mounted on a steadicam (Steadicam Jr$^{\text{TM}}$), a gyroscopic balance device that greatly reduces the high frequency jitter associated with hand-held videography. The video was shot looking straight ahead from the center position of a mini-van (in between the driver and front passenger seats), and framed to exclude both the interior and exterior of the vehicle. Travel was between 20–35 m.p.h. (32–56 k.p.h.) primarily on two-lane roads.

Field video was dubbed to BetacamSP and 1-inch tape formats for editing, and master tapes were produced on BetacamSP. Each drive was 10 min long, and consisted of ten 20–40-s segments representative of the appropriate roadside condition randomly mixed with ten 20–40-s segments from the Mixed condition. This was true of the Mixed condition as well, producing a tape where all 20 segments were mixed residential and light development areas. To minimize order effects, each tape was constructed twice for each condition, yielding two 10-min taped drives per condition. These orders were counterbalanced across subjects within each condition. Each 10-min tape in a given random order was preceded by a 20-s preliminary scene from the Mixed condition, and a 1-s dissolve was used as a transition between segments. Starts and stops were eliminated from the raw footage, providing for smooth transitions from movement on one road to movement on the next road. BetacamSP master tapes of each drive were dubbed to Super-VHS tapes for final presentation.

Design and procedure

The full experimental design consisted of three between-subject factors and two within-subject factors. The between-subject factors were Sex (Men, Women), Roadside Environment (Forest, Golf, Mixed, Urban), and Stressor Order (Passive Stressor

First, Active Stressor First). The two within-subject factors were Phase (Stressor1, Drive, Stressor2) and Epoch (4). Participants were randomly assigned to conditions resulting in no fewer than eight and no more than 12 participants in each of the 16 cells defined by the between-subject factors.

Participants were tested individually in a large carpeted sound-attenuated room with a minimum of visible equipment. Each complete experimental session lasted approximately 2·5 h. Upon arrival at the laboratory, the participant was taken to a preparation area and provided with an explanation for and description of the study. Participants were told the purpose of the study was to measure involuntary neural activity while performing a variety of information processing tasks. Following a thorough explanation of the procedure, participants signed an informed consent document and completed a questionnaire regarding general health and drug usage. After all biosensors were properly affixed, the participant was taken to the experiment room and seated in a large reclining chair. The biosensor leads were then inserted into a junction box connected to a Grass^{TM} Model 12 Neurodata System and a Coulbourn^{TM} Modular Instrument System housed in an adjacent room, and a blood pressure cuff was placed on the participant's left arm and calibrated. Each physiological signal was then inspected on an oscilloscope for artifacts. If all the signals appeared artifact-free the participant was asked to sit quietly for 5 min while baseline recordings were taken.

Immediately following the baseline period, participants were given instructions for the first task. Before experiencing the passive stressor they were told that they would be watching a film on the prevention of workplace accidents and should pay attention to the screen for the entire film. Before experiencing the active stressor they were told they would be doing a mental arithmetic task and would hear a series of single-digit numbers read aloud on audio tape. The participant's task was to add each digit heard to the number before it and say the answer aloud. The participant was reminded that the goal was not to keep a total sum, but to add every two numbers together. It was explained that there would be one practice series with 35 numbers followed by four experimental series each comprising 50 numbers. The participants were instructed to do their best on each trial and if they happened to miss or forget a number to begin adding with the next pair of numbers they heard. After the first stressor, participants were given the following instructions for viewing the simulated 'drives':

> For the next task, you will see a videotape of various short scenes that you might see from your car while driving through several urban and rural environments. This tape lasts about ten minutes and for its duration it is important that you pay attention to the screen and imagine that you are an occupant of the car.

After watching one of four environmental 'drives', instructions were given for the succeeding stressor period. Immediately following the second stressor, all participants filled out a short questionnaire regarding previous golfing experience and familiarity with the stimuli, and listed the places they had lived prior to college. During both stressor and recovery periods participants remained alone in the experiment room. Throughout the experiment, an intercom system permitted audio communication between the experimenter and the participant and a hidden video camera allowed the experimenter to see the participant.

Data reduction

Each phase of the experiment was divided into four nonoverlapping consecutive epochs of different absolute lengths. The baseline period (5 min) was divided into 1·25-min epochs, the Passive stressor period (12 min) was divided into 3-min epochs, the Active stressor period (10 min) was divided into four trials of differing length, and the 'Drive' period (10 min) was divided into 2·5-min epochs.

Prior to statistical analysis, the physiological measures were systematically examined for artifacts, outliers and violations of normality. Artifacts were excluded from the data prior to data reduction. Two measures, average skin conductance level (SCL_A) and skin conductance response magnitude (SCR_M) were extracted from the skin conductance data. SCL_A was computed as the simple average within each epoch and SCR_M was computed as the average amplitude of skin conductance responses greater than 0·1 μS within each epoch. The time between r-spikes was extracted from the ECG signal and the resulting interbeat intervals (IBI) were then averaged within each epoch. After computing epoch means for all measures the data were again visually inspected. Histograms, as well as plots of means vs standard deviations, revealed that the EMG and skin conductance data were not normally distributed. For normalization, a $\log_{10}$ transform was applied to the EMG data and a square root transform was applied to the skin conductance data. Unless otherwise indicated, all physiological data from each subject are expressed as difference scores[5] and, for all statistical tests, alpha was set at $p \leq 0{\cdot}05$ and the Greenhouse–Geiser correction applied where appropriate.

Results

Manipulation checks

Baseline values. Descriptive statistics on the physiological measures during the baseline period are presented in Table 1. All of the values are within normal ranges for this age group and consistent with prior research.

Random assignment. The three self-report and seven physiological variables were examined to see if initial differences existed among the groups despite random assignment. In terms of prior golfing experience, nearly half (46·3%) of the participants reported playing golf at least once, with nearly twice as many men as women reporting having done so (60·3% vs 34·2%; χ^2 (1)=5·41). However, participants in each of the Roadside Environment conditions had equivalent golfing experience *so defined* (χ^2(3)=1·39, N.S.). In terms of prior familiarity, 34 per cent of the participants reported at least some familiarity with the environmental scenes. However, participants in each of the conditions defined by the Sex and Roadside Environment factors were equivalent in terms of prior familiarity, χ^2(1)=0·92, N.S. and χ^2(3)=3·40, N.S., respectively. Finally, 61 per cent of the participants reported spending more than one-half their lives living in urban areas.[6] As above, participants in each of the conditions defined by the Sex and Roadside Environment factors were equivalent in terms of the number growing up in predominantly urban areas, χ^2(1)=0·00, N.S. and χ^2(3)=2·25, N.S., respectively.

Eight separate four-way between-subject analyses of variance (ANOVAs) were conducted to examine whether any baseline physiological differences existed between the groups. With just two exceptions, all *F* values were nonsignificant. Women, on average, showed both significantly higher levels of activity over the Brow region (11·08 vs 7·73 μV) and significantly lower SBP (100·39 vs 110·69 mmHg) than men; *F*(1,144)=8·96 and *F*(1,128)=29·08, respectively. In sum, essentially no baseline differences were observed among the four roadside environment conditions on any of the physiological measurements.

Stress response

The active and passive stressors used in this experiment were intended to elicit qualitatively different stress responses. To examine the effectiveness of the stressors eight separate mixed-model repeated measures ANOVAs were conducted. The statistical model was composed of the factors of Sex (Men, Women), Stressor Order (Passive Stressor First, Active Stressor First), Stressor Period (First, Second) and Epoch (4). The data for each participant were expressed as difference scores from their average baseline.

Cardiovascular measures. For DBP, the only significant main effect was for Epoch, *F*(3,423)=11·82. This main effect, as well as a significant Stressor Order × Stressor Period effect, *F*(1,141)=7·13, were qualified by the three-way interaction of these factors, *F*(3,423)=26·32. In addition, the Epoch × Sex effect was also significant, *F*(3,423)=4·23. A very similar pattern emerged in regard to SBP, with significant effects for Epoch, *F*(3,408)=12·42, Stressor Order × Stressor Period × Epoch, *F*(3,408)=27·18,

TABLE 1
Baseline values for physiological measures

Dependent variable	Units	Mean	95% Lower	95% Upper	Minimum	Maximum	*n*
Zygomaticus major	μV	1·104	1·049	1·269	0·045	10·927	158
Corrugator supercilii	μV	9·233	8·191	10·408	0·136	66·930	160
Orbicularis oris	μV	3·839	3·304	4·462	0·107	22·407	159
Inter-beat interval	ms	841·128	819·096	863·160	593·443	1517·810	156
Diastolic blood pressure	mmHg	64·592	63·288	65·896	42·989	90·519	148
Systolic blood pressure	mmHg	105·401	103·365	107·438	76·733	146·741	144
Skin conductance level	μS	3·877	3·476	4·299	0·418	16·529	157
Skin conductance response	μS	0·123	0·093	0·157	0·000	1·446	157

Note. The summary statistics for the EMG and skin conductance variables were first computed on the transformed variables and then transformed back into their original units.

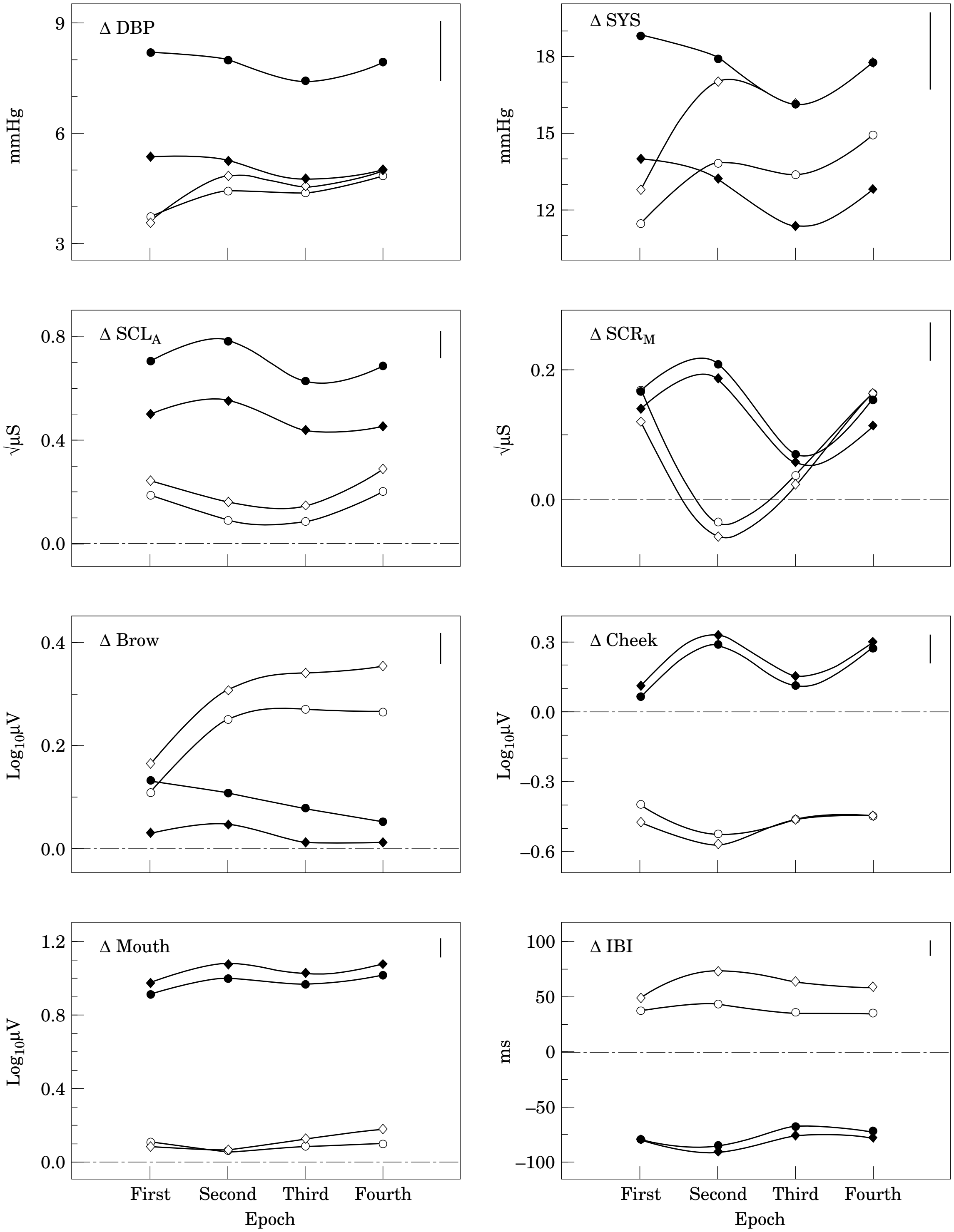

FIGURE 2. Relative changes in physiological activity as a function of Time, Stressor and Order. The data represent mean values across subjects based on arithmetic differences from idiographic baselines. The vertical black line in the upper right corner of each panel represents one-half the average 95% confidence interval for the data displayed in the respective panel. (○) passive first; (●) active first; (◇) passive second; (◆) active second.

and Epoch × Sex, $F(3,408)=4{\cdot}45$. The Stressor Order × Stressor Period × Epoch interaction for both DBP and SBP is displayed in the top panels of Figure 2. Two features are clearly revealed in these panels. First, the response to the active stressor was an immediate increase followed by a decline over time, whereas the response to the passive stressor was a more gradual increase over time. Second, the group who received the active stressor first and the passive stressor second were more responsive than the group who received the passive stressor first and the active stressor second. An inspection of the means and confidence intervals reveals that the Epoch × Sex effect was due primarily to men being slightly more responsive than women during the final epoch in terms of both DBP (6·14 vs 5·24 mmHg) and SBP (16·50 vs 15·08 mmHg).

As with DBP, there were significant IBI effects for Epoch, $F(3,441)=3{\cdot}65$, and Stressor Order × Stressor Period, $F(1,147)=641{\cdot}81$, qualified by the three-way interaction of these factors, $F(3,441)=22{\cdot}49$. There were also significant effects for Stressor Order × Epoch, $F(3,411)=4{\cdot}54$, and Stressor Order × Stressor Period × Sex, $F(1,147)=8{\cdot}82$. The Stressor Order × Stressor Period × Epoch interaction is displayed in the bottom right panel of Figure 2. Two features are readily apparent. First, the responses to the active and passive stressors were of opposite sign; that is, the response to the active stressor was a relatively immediate and sustained decrease in IBI (increased heart rate) and the response to the passive stressor was a relatively immediate and sustained increase in IBI (decreased heart rate). Second, the participants who received the passive stressor second were more responsive than the group who received the passive stressor first. An inspection of the means and confidence intervals revealed that the Stressor Order × Stressor Period × Sex effect was due primarily to men being more responsive than women to the active stressor (−102·73 vs −69·91 ms).

Skin conductance. Significant effects for Stressor Order × Stressor Period, Epoch and Stressor Order × Stressor Period × Epoch emerged for both SCL_A and SCR_M. The respective fiducial values for SCL_A were $F(1,153)=154{\cdot}36$, $F(3,439)=14{\cdot}64$, and $F(3,459)=19{\cdot}96$, and the respective values for SCR_M were $F(1,153)=13{\cdot}66$, $F(3,429)=45{\cdot}48$, and $F(3,459)=69{\cdot}01$. The Stressor Order × Stressor Period × Epoch interaction for both SCL_A and SCR_M is displayed in the second row of Figure 2. The left panel shows that the SCL_A response was greater to the active stressor than to the passive stressor and that the response was greatest when the active stressor was presented first. The right panel shows a less clear but similar pattern for SCR_M.

Facial EMG. The effects of Stressor Order × Stressor Period, Epoch and Stressor Order × Stressor Period × Epoch emerged as significant for the activity recorded over all three facial muscle regions. The respective fiducial values were $F(1,155)=95{\cdot}48$, $F(3,465)=38{\cdot}86$ and $F(3,486)=102{\cdot}03$ for the Brow region; $F(1,153)=426{\cdot}18$, $F(3,459)=17{\cdot}67$ and $F(3,459)=51{\cdot}19$ for the Cheek region; and $F(1,154)=1156{\cdot}76$, $F(3,462)=9{\cdot}91$ and $F(3,462)=7{\cdot}79$ for the Mouth region. The Stressor Order × Stressor Period × Epoch interaction for all three muscle regions is displayed in the third and fourth rows of Figure 2. It is clear from these panels that the passive stressor, relative to the active stressor, led to a sustained increase in the Brow region, a concomitant decrease in activity in the Cheek region and a relative absence of activity in the Mouth region.[7] In addition, a Stressor Order × Sex × Stressor Period interaction emerged as significant for the Brow region, $F(1,155)=18{\cdot}21$. An inspection of the means and confidence intervals revealed that this interaction was due primarily to women being both more responsive than men to the passive stressor (0·327 vs 0·188 $\log_{10}\mu V$), and less responsive than men to the active stressor (0·037 vs 0·074 $\log_{10}\mu V$).

Environments

As mentioned previously, we hypothesized that participants who viewed artifact-dominated roadside environments, relative to participants who viewed nature-dominated roadside environments, would show greater autonomic activity indicative of stress (e.g. elevated blood pressure and skin conductance), as well as show altered somatic activity indicative of greater negative affect (e.g. elevated EMG activity over the Brow region and decreased activity over the Cheek region). The general statistical model comprised the factors of Sex (2), Roadside Environment (4) and Epoch (4), and each participant's data was expressed as the difference from their average baseline. To assess this hypothesis specifically we constructed a planned contrast in which we compared the responses, during the Drive phase, of the participants assigned to the nature-dominated conditions (Forest, Golf) to those in the artifact-dominated conditions (Mixed, Urban). The contrast weights were 0·75 (Urban), 0·25 (Mixed), −0·25 (Golf) and −0·75 (Forest).[8] If the general ANOVA suggested a possible Sex by Roadside Environment interaction ($p \leq 0{\cdot}1$) then the contrast was applied separately to the data from the men and women participants.

Cardiovascular measures. The overall ANOVAs revealed reliable main effects for neither Sex nor

Roadside Environment for any of the cardiovascular measures. However, clear main effects for Epoch were found for all three cardiovascular measures. Both DBP and SBP were elevated during the first epoch (9·44 and 2·77 mmHg, respectively) and increased even further during the latter three epochs (11·72, 11·84, 11·85 and 3·41, 3·43, 3·37 mmHg, respectively), F(3,417)=12·77 and F(3,402)=11·67, whereas IBIs were longer during the first epoch (22·53 ms) and returned to baseline values during the latter three epochs (2·20, −2·92, 1·89 ms), F(3,432)=33·7. More relevant to the issues under consideration were significant Sex by Roadside Environment for SBP, F(3,134)=3·35, and Epoch by Roadside Environment interactions for both DBP, F(9,417)=2·19, and SBP, F(9,402)=2·08. Finally, the main effects for Epoch were further qualified by the presence of significant interactions of Epoch with Sex for both DBP, F(3,417)=3·58, and SBP, F(3,402)=4·01.

No clear evidence emerged for our prediction of systematic changes in the cardiovascular system in response to artifact-dominated vs nature-dominated roadside environments. As can be seen in the lower right panel of Figure 3, there was no evidence for this effect with regard to IBIs, F(1,144)=0·41, N.S., and for either men or women with regard to either SBP, F(1,134)=0·26, N.S., and F(1,134)=1·29, N.S., or DBP, F(1,139)=0·16, N.S., and F(1,139)=0·27, N.S.. As Figure 3 shows, the observed significant effects are due primarily to the fact that men were relatively more responsive to the Golf and Mixed roadside environments, whereas women were relatively more responsive to the Forest and Urban environments. Also, men generally showed increasing blood pressures throughout the drive relative to women. Finally, participants in the Golf condition showed minimal changes throughout the drive relative to participants in the other Roadside Environment conditions. The ranges across epochs for the respective difference scores (mmHg) for DBP were: Golf (0·4), Forest (0·67), Urban (0·58) and Mixed (1·38); and for SBP were: Golf (1·69), Forest (2·31), Urban (2·16) and Mixed (5·82).

Skin conductance. The general ANOVA model revealed Epoch effects for both SCL_A and SCR_M. Average skin conductance levels were elevated during the first epoch (0·164 √µS) and then fell throughout the remaining epochs (0·008, -0·06, and −0·09 √µS), F(3,447)=62·22. Average skin conductance response magnitude was suppressed during the first epoch (−0·084 √µS), continued to fall during the second epoch (−0·102 √µS), and began to rise toward baseline during the third (-0·04 √µS) and fourth (−0·045 √µS) epochs, F(3,447)=2·85. Finally, the Roadside Environment factor was significant, F(3,149)=2·93, and Games–Howel pairwise tests revealed that SCL_A was higher in the Urban condition than in any of the other conditions and that the SCL_A was higher in the Golf condition than in the Mixed condition.

Evidence was found for our prediction of increased skin conductance activity in response to artifact-dominated relative to nature-dominated roadside environments. Specifically, the predicted effect emerged as marginally significant with regard to SCL_A, F(1,149)=3·19, p=0·07, although there was no evidence for this effect with regard to SCR_M, F(1,149)=0·68, N.S.. As can be seen in the middle upper left panel of Figure 3, the ordering of the means followed our prediction for three out of the four conditions. Contrary to expectation, the Mixed condition led to the lowest SCL_A.

Facial EMG. The general ANOVA model revealed reliable Epoch and Sex effects for the Brow region only. Activity over this area increased during the first epoch (0·082 $\log_{10}$µV), and was further increased throughout the latter three epochs (0·166, 0·179, and 0·159 $\log_{10}$µV), F(3,456)=30·29. Women also had higher levels of overall activity than men (0·218 vs 0·077 $\log_{10}$ µV), F(1,152)=16·46 (see Figure 3).

As can be seen in the lower middle panels of Figure 3, no consistent evidence emerged for our prediction of elevated EMG activity over the Brow region and decreased activity over the cheek region in response to artifact-dominated relative to nature-dominated roadside environments. Contrary to expectation, participants actually showed elevated activity over the Brow region in response to the nature-dominated roadside environments, F(1,152)=4·07. No specific predictions were made for EMG activity over the Mouth region.

Recovery

We hypothesized that participants who viewed nature-dominated roadside environments, relative to participants who viewed artifact-dominated roadside environments, would show both quicker and more complete recovery from induced stress. The data were re-expressed in the following manner to derive these two dependent variables: first, only participants who showed at least a five per cent increase (relative to the grand average) during the stressor for a particular measure were included in the analy-

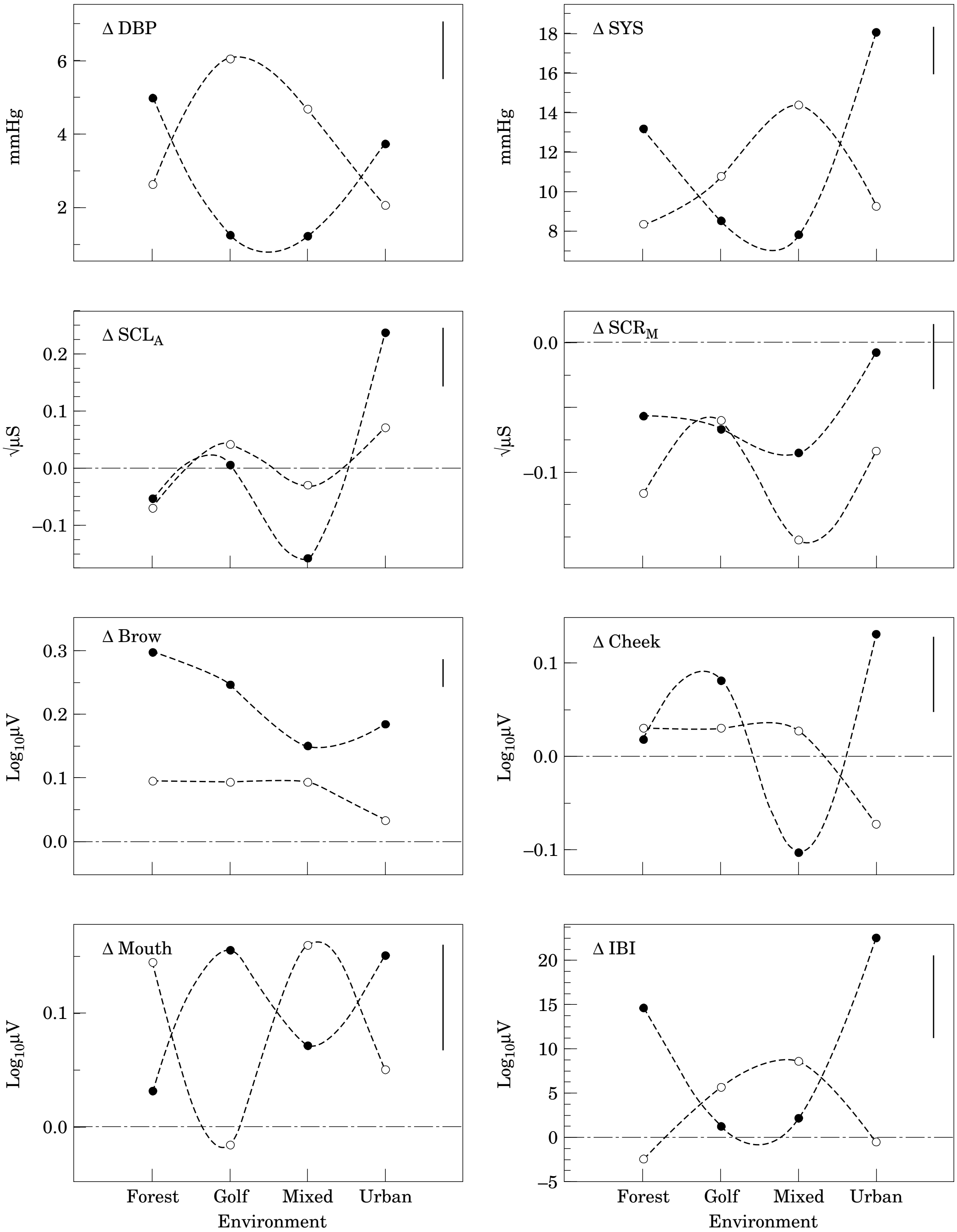

FIGURE 3. Relative changes in physiological activity as a function Roadside Environment and Sex. The data represent mean values across subjects based on arithmetic differences from idiographic baselines. The vertical black line in the upper right corner of each panel represents one-half the average 95% confidence interval for the data displayed in the respective panel. (○) men; (●) women.

sis.[9] Second, the raw values were converted to percentage change scores according to the formula, (Data-Baseline) ÷ Maximum response during the stressor. Finally, the speed of recovery was operationalized as the epoch in which these scores either first crossed or were equal to zero,[10] and the completeness of recovery was operationalized as the actual scores at this point of recovery. The general statistical model comprised the factors Sex (2), Stressor Type (2) and Roadside Environment (4).[11] As before, we constructed a planned contrast in which we compared the responses, during the Drive phase, of the participants assigned to the nature-dominated conditions (Forest, Golf) to those in the artifact-dominated conditions (Mixed, Urban). The contrast weights were 0·75 (Urban), 0·25 (Mixed), −0·25 (Golf), and −0·75 (Forest).

Cardiovascular measures. The general ANOVA revealed a small set of reliable effects. First, DBPs returned nearer to baseline levels following the passive as opposed to the active stressor (15·7% vs 53·7%, respectively), $F(1,78)=5·73$. Second, with regard to SBP, men recovered both more quickly and more completely than women following the passive stressor (1·6 vs 2·56 and 12·84% vs 51·2%, respectively), $F(1,112)=8·26$ and $F(1,112)=6·67$. Third, with regard to SBP, participants in the Forest and Mixed conditions recovered more completely, following the passive stressor, than did participants in the Golf and Urban conditions (17·34% and 8·99% vs 59·65% and 60·73%, respectively), $F(3,112)=2·75$. Fourth, also with regard to SBP, participants in the Golf condition recovered more quickly than participants in the Urban condition following the passive stressor (1·63 vs 2·53); however, participants in the Golf condition recovered less quickly than participants in the Urban condition following the active stressor (2·53 vs 1·63), $F(3,112)=3·04$. Fifth, with regard to IBI, participants recovered more quickly following the active than the passive stressor (2·14% vs 2·79%), $F(1,103)=10·53$, and those in the Urban condition exhibited incomplete recovery following the passive stressor relative to those in the Golf condition (20% vs −30%), $F(3,103)=4·55$.

Skin conductance. No statistically reliable effects were found with regard to SCL_A. However, significant main effects for Roadside Environment were found for SCR_M for both speed and completeness of recovery, $F(3,109)=3·46$, and $F(3,109)=3·57$. Games–Howell pairwise follow-up tests revealed that participants in the Urban condition took significantly longer to recover than did participants in the Mixed condition (2·09 vs 1·33) and a weighted contrast revealed that the main effect for the completeness of recovery was due primarily to the participants in the Golf condition recovering more completely than participants in all other conditions (−192·20% vs −68·33%), $F(1,109)=10·11$.

Facial EMG. With regard to activity in the Brow region, no statistically reliably effects were found involving the Roadside Environment factor. However, with regard to speed of recovery, men recovered more quickly than women (1·14 vs 1·98), $F(1,110)=9·64$, and all participants recovered more quickly following the passive as opposed to the active stressor (1·52 vs 1·89), $F(1,110)=3·81$. Concerning completeness of recovery, men recovered more completely than women (−26·99% vs 36·39%), $F(1,110)=12·62$; however, this was qualified by a significant Sex by Stressor interaction, $F(1,110)=4·44$. Both of these effects are due primarily to women showing little evidence of recovery following the active stressor (i.e. 76·26%) and participants in the other conditions showing strong evidence of complete recovery.

A priori analyses. Limited evidence emerged for our prediction that participants who viewed nature-dominated roadside environments, relative to participants who viewed artifact-dominated roadside environments, would show both quicker and more complete recovery from stress. As can be seen in Figures 4 and 5, none of the measures showed the entire trend; however, the planned contrast was significant for SCR_M, $F(1,109)=4·85$. As can be seen in the middle right panel of Figure 4, the ordering of the means followed our prediction for three out of the four conditions. Contrary to expectation, the Golf condition led to the lowest SCR_M.

Immunization

We hypothesized that viewing nature-dominated roadside environments, relative to artifact-dominated roadside environments, would ameliorate the negative consequences of a future stressor. Our operationalization of these consequences was slightly different for the passive and active stressors. For both stressors, we examined the maximum response during the second stressor; however, for the active stressor we also examined both the average percentage of addition problems actually attempted as well as the average per cent correct relative to the number attempted. Consequently, the general statistical model for the analysis of the maximum response comprised the factors of Sex (2), Stressor Type (2) and Roadside Environment (4), while the model for the analysis of both per cent attempted and per cent correct, being limited to the active stressor, did not include the stressor factor. As before, we constructed a planned contrast in which

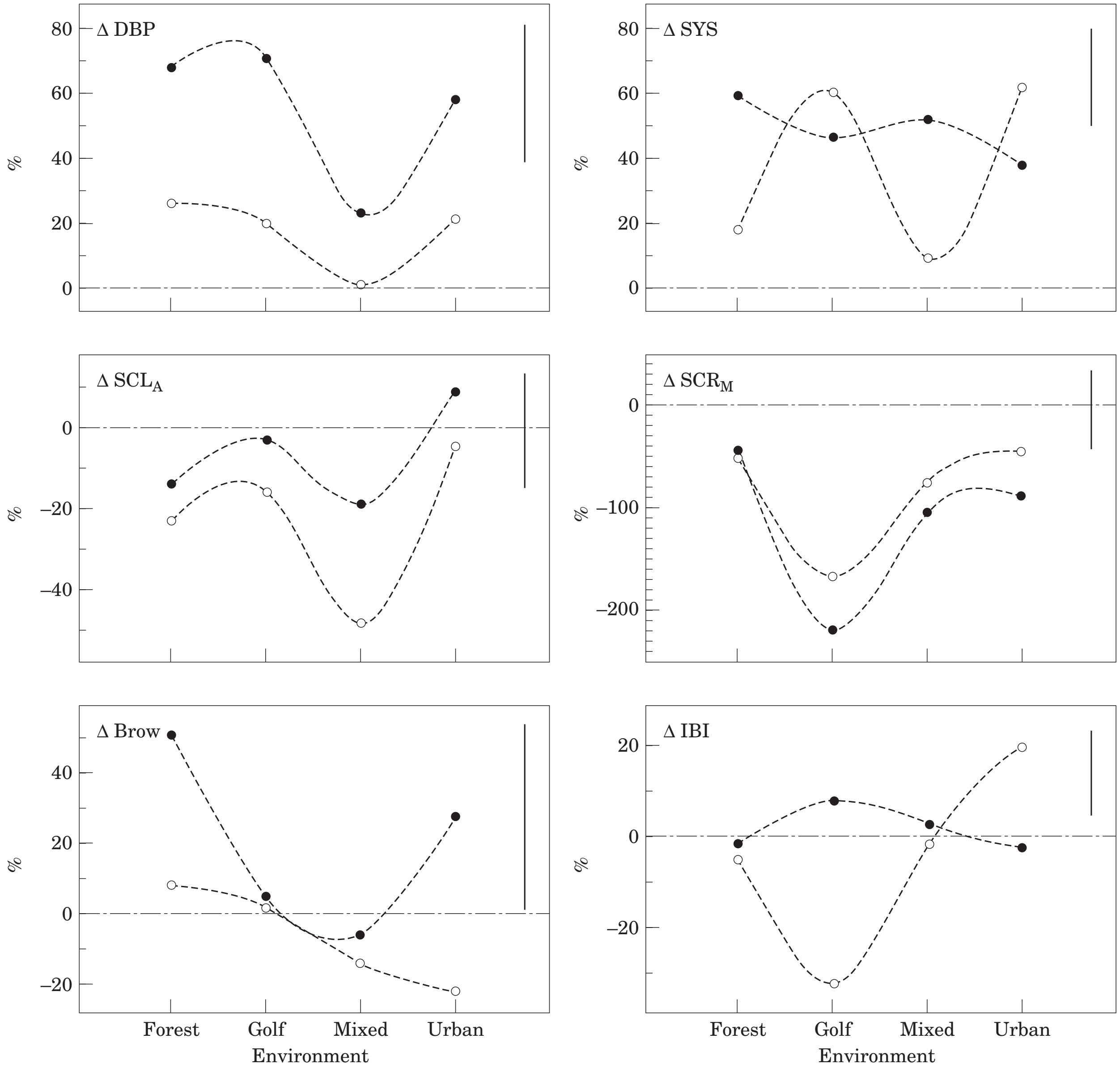

FIGURE 4. Completeness of recovery as a function of Roadside Environment and Stressor Type. Completeness of recovery is defined as the value at which the per cent change scores first crossed or were equal to zero. The data represent mean values across subjects. The vertical black line in the upper right corner of each panel represents one-half the average 95% confidence interval for the data displayed in the respective panel. (○) passive; (●) active.

we compared the Drive phase responses of the participants assigned to the nature-dominated conditions (Forest, Golf) to those in the artifact-dominated conditions (Mixed, Urban). The contrast weights were 0·75 (Urban), 0·25 (Mixed), −0·25 (Golf), and −0·75 (Forest).

Cardiovascular measures. No effects were significant for DBP. However, a significant Sex by Stressor Type interaction did emerge for SBP, $F(3,137)=6{\cdot}58$. As Figure 6 shows, women were somewhat more reactive to the active stressor than the passive stressor, whereas men were much more reactive to the passive than to the active stressor. For IBI, a marginally significant main effect for Sex, $F(1,135)=4{\cdot}61$, $p=0{\cdot}03$, and a highly significant main effect for Stressor Type, $F(1,135)=327{\cdot}29$, were observed. These were qualified, however, by a marginally significant Sex by Stressor Type interaction, $F(1,135)=4{\cdot}79$, $p=0{\cdot}03$. As can be seen in Figure 6, men and women responded similarly to the passive stressor, but the men showed significantly greater cardiac acceleration to the active stressor than did the women.

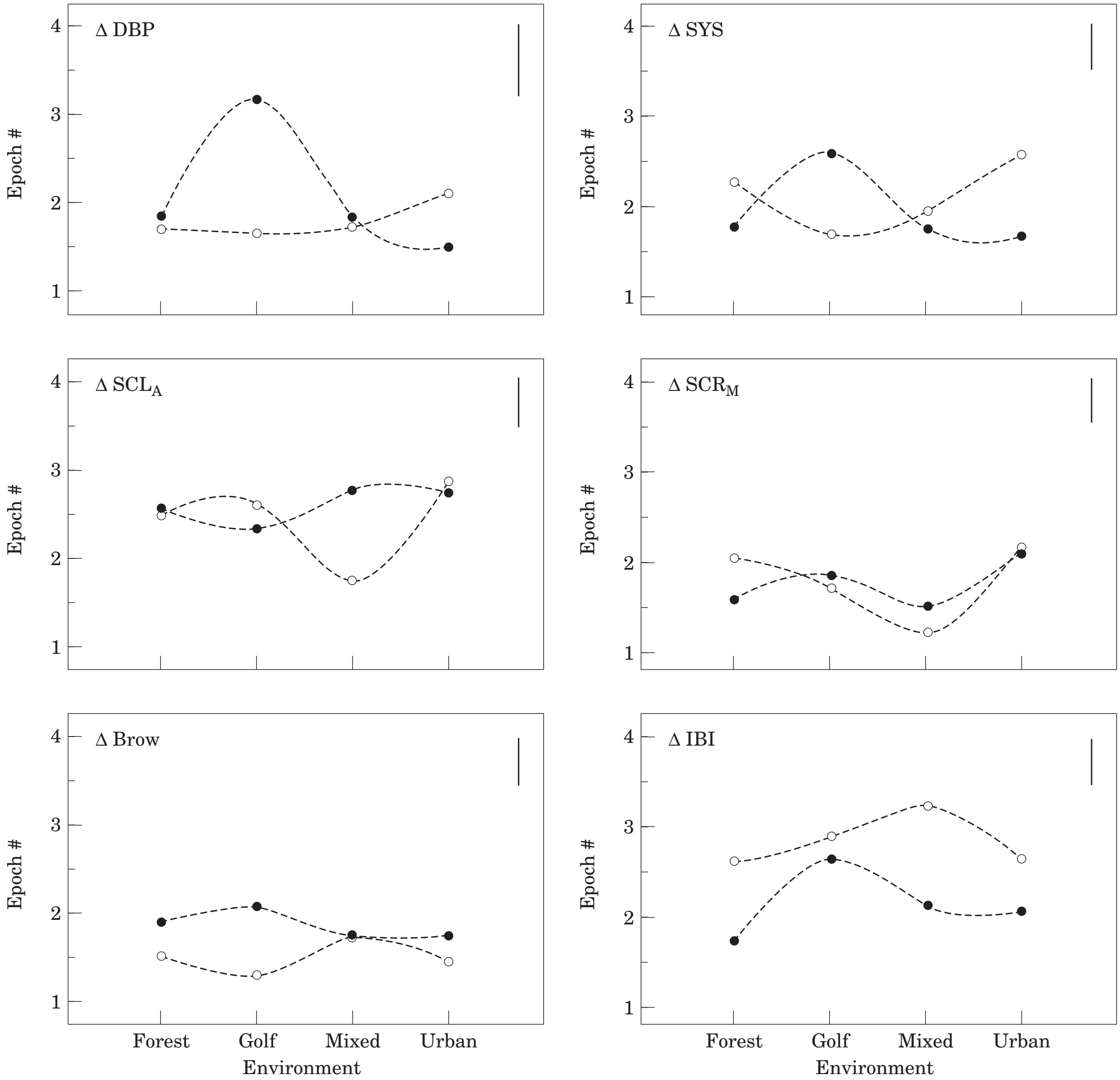

FIGURE 5. Speed of recovery as a function of Roadside Environment and Stressor Type. Speed of recovery is defined as the epoch in which the per cent change scores either first crossed or were equal to zero. The data represent mean values across subjects. The vertical black line in the upper right corner of each panel represents one-half the average 95% confidence interval for the data displayed in the respective panel. (○) passive; (●) active.

Skin conductance. No effects were significant for SCR_M. However, significant main effects for SCL_A did emerge for Sex, $F(1,141)=5{\cdot}91$, Roadside Environment, $F(3,141)=2{\cdot}69$, and Stressor Type, $F(1,141)=6{\cdot}46$. No higher order interactions approached significance. As can be seen in Figure 6, the average maximum SCL_A was higher in men than in women, higher for the active stressor relative to the passive stressor, and higher for participants who had previously viewed artifact-dominated vs nature-dominated roadside environments.

Facial EMG. For the Brow, Cheek and Mouth regions there was a significant main effect for Stressor Type, $F(1,144)=45{\cdot}72$, $F(1,142)=68{\cdot}88$, and $F(1,143)=139{\cdot}34$, respectively. The interaction of Sex and Stressor Type emerged as marginally significant for the Brow region, $F(1,144)=2{\cdot}79$, $p=0{\cdot}09$, and significant for the Cheek region, $F(1,142)=4{\cdot}05$. As can be seen in Figure 6, the average maximum activity over the Brow region was higher for the passive than for the active stressor, the average maximum activity over both the Cheek and Mouth regions was

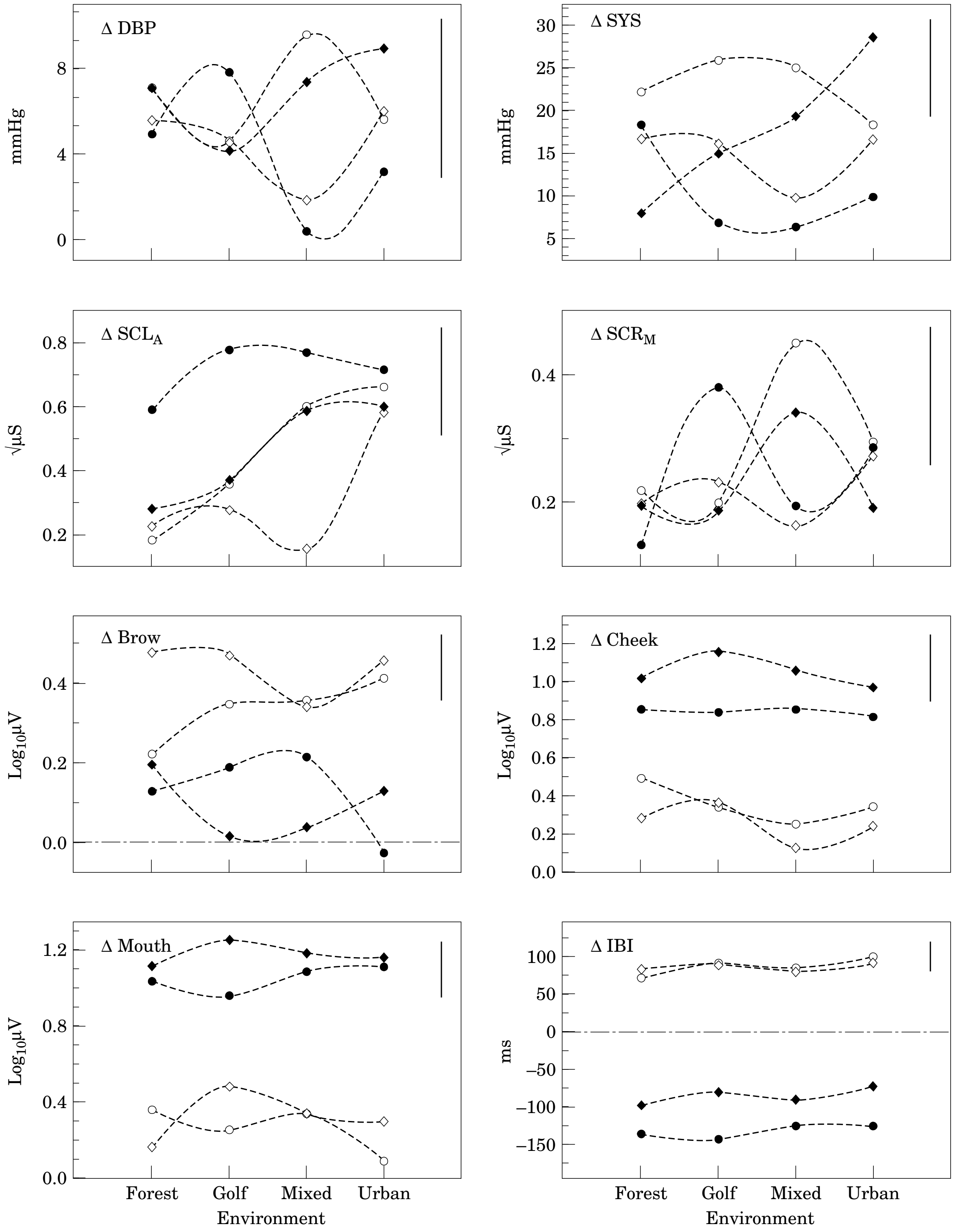

FIGURE 6. Relative changes in physiological activity to the second stressor as a function of Roadside Environment and Sex. The data represent mean values across subjects based on the largest responses to the second stressor. The vertical black line in the upper right corner of each panel represents one-half the average 95% confidence interval for the data displayed in the respective panel (○) passive (M); (●) active (M); (◇) passive (F); (◆) active (F).

higher for the active than for the passive stressor, and the Stressor Type effect was more pronounced over the Brow and Cheek regions for the women participants.

Performance. Aside from a significant main effect for Sex, $F(1,69)=3{\cdot}92$, which revealed that men, on average, attempted a higher percentage of problems than women (82·61% vs 77·43%), none of the other main effects or interactions were statistically significant. However, Games–Howell pair-wise tests disclosed that participants in the Golf condition performed more accurately than participants in the Forest condition (93·31% vs 89·14%, $p \leq 0{\cdot}05$) and, as can be seen in Figure 7, both of these values fall outside of the confidence interval for the average per cent correct achieved by participants who received the active stressor first.

A priori analyses. Limited but significant evidence emerged for our prediction that viewing nature-dominated roadside environments, relative to artifact-dominated roadside environments, would ameliorate the negative consequences of a future stressor. Specifically, the predicted pattern did emerge for SCL_A, $F(1,141)=8{\cdot}05$. The pattern of means and their respective confidence intervals are displayed in the middle upper left panel of Figure 6.

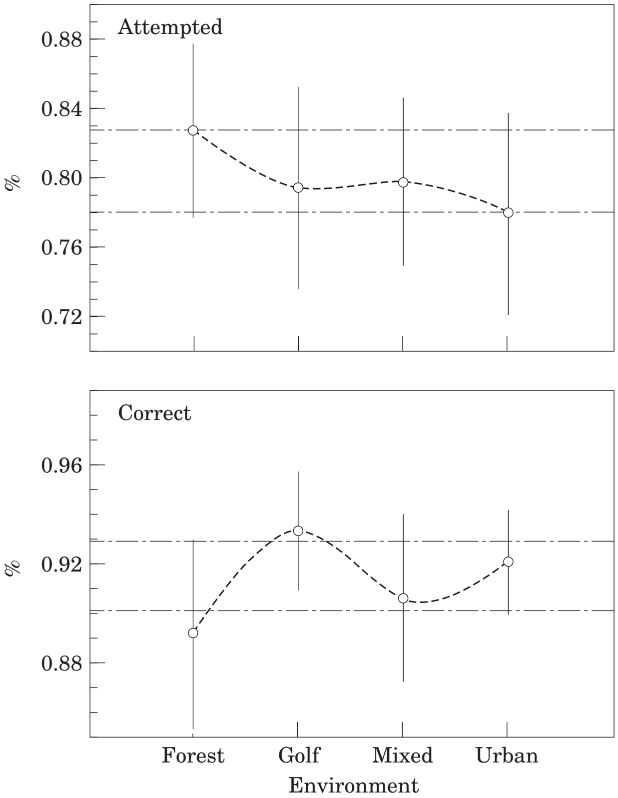

FIGURE 7. PASAT performance as a function of Roadside Environment. The parallel dotted lines represent the 95% confidence intervals for performance on the PASAT when it served as the first stressor. The thin black lines represent the 95% confidence intervals for mean performance on the PASAT when it served as the second stressor.

Discussion

Summary and implications of major findings

The active and passive stressors used in the experiment elicited responses indicative of different kinds of stress. The pattern of responses to the active stressor suggests a relatively specific activation of the sympathetic nervous system. That is, very little evidence of facial muscle activation was observed combined with marked increases in blood pressure and electrodermal activity, and marked decreases in heart period. The responses to the passive stressor suggest a more complex pattern of somatic and autonomic activation. That is, clear evidence of a negative emotional response was observed as indicated by marked decreases in the EMG activity in the Cheek region and marked increases in EMG activity in the Brow region, combined with moderate increases in blood pressure and electrodermal activity and moderate increases in heart period.

The pattern of significant responses to the different Roadside Environments was consistent with our first hypothesis. Compared to baseline levels, individuals were more autonomically responsive to the artifact-dominated environments than to the nature-dominated environments. Specifically, average skin conductance levels were higher in those participants exposed to the urban environments than in all other participants, and blood pressure was less labile in those participants exposed to the golf course environments than in all other participants.

The pattern of significant differences in recovery responses following the stressors was consistent with our second hypothesis. There was some evidence that exposure to artifact-dominated roadside environments both slowed down and impeded recovery from stress relative to exposure to nature-dominated roadside environments. Specifically, returns to baseline levels of heart period and skin conductance response magnitude were more likely in participants exposed to the golf course environments than in all other participants. The pattern of significant responses to the second stressor following exposure to the roadside environments is also consistent with our second hypothesis. That is, there was some evidence that exposure to nature-dominated roadside environments decreased the magnitude of the autonomic response to a stressor and concomitantly increased the ability to cope with the stressor. Specifically, the average size of the maximum increase in skin conductance levels to a stressor was significantly lower following exposure to nature-dominated environments than following exposure to artifact-dominated environments. And, interestingly, participants in the golf course condition performed more accurately on the subsequent mental arithmetic task than either those participants in the forest condition or those who performed the mental arithmetic task prior to viewing the simulated drive. The significant findings relevant to these hypotheses are summarized in Table 2.

In summary, it appears that the visual content of the roadside environment can modulate both the recovery from and immunization to stress in a manner consistent with both prior work and with our specific hypotheses. However, it also appears that the magnitude of this effect may be smaller and more complex than previously indicated, as many of the physiological effects that might have added support to the restoration and immunization hypotheses did not emerge (or they emerged for only one of the stressors). In particular, the strongest support for our hypotheses comes from those variables indexing cardiovascular and electrodermal activity, while support from electromyographic variables indicative of the predicted affective responding is conspicuous by its absence. The pattern of data reported here warrant hypothesizing a specific modulation of sympathetic activation, as opposed to a modulation of autonomic activation generally or an even more general modulation of basic emotional processes.[12]

A sympathetically mediated effect of this kind would be interesting for several reasons. First, with respect to the social action research agenda mentioned at the beginning of this report, these findings suggest to transportation and urban planners that the roadside elements they design and manage may well influence the psychological and physiological well-being of automobile commuters, irrespective of the objective and subjective travel impedance characteristics of commuter routes (*cf.* Stokols & Novaco, 1981; Novaco *et al.*, 1990). In particular, the increased levels of sympathetic arousal associated with artifact-dominated roadside environments could have implications for findings from previous research on commuting, such as negative worker morale on the job (Koslowski & Krausz, 1993) and post-commute evening chest pains reported for those with difficult commutes (Novaco *et al.*, 1990).

A sympathetically mediated effect could also have implications for broader theoretical and policy issues. The lack of parasympathetic nervous system and specific emotional effects in these data could, for instance, indicate a dissociation between general emotional responding and human responses to environmental elements (see Parsons *et al.*, 1995). If human environmental responding is partly a function of evolutionarily-mediated approach/avoid

TABLE 2
Summary of significant findings relevant to environmental hypotheses

Dependent variable	Environment	Recovery	Immunization
Zygomaticus major			
Corrugator supercilii	FOREST greater than OTHERS		
Orbicularis oris			
Inter-beat interval		GOLF more complete recovery than URBAN, (passive stressor)	
Diastolic blood pressure			
Systolic blood pressure		FOREST/MIXED more complete recovery than GOLF/URBAN (passive stressor) GOLF quicker recovery than URBAN (passive stressor) URBAN quicker recovery than GOLF (active stressor)	
Skin conductance level	URBAN greater than OTHERS		FOREST/GOLF less responsive than MIXED/URBAN
Skin conductance response		MIXED quicker recovery than URBAN. GOLF more complete recovery than OTHERS	
Per cent math attempted	—	—	
Per cent math correct	—	—	GOLF greater than FOREST

assessments based on the perceived safety and/or habitability of environments, as some have suggested (e.g. Appleton, 1975; Ulrich, 1983; Orians, 1986), then we might expect to sympathetic nervous system responding that differentiates nature-dominated from artifact-dominated environments, independent of concomitant facial muscle activity. That is, to gain an evolutionary advantage from positive, relaxing emotional responses to supportive environments, it is not necessary to communicate the feelings elicited by such environments through facial expressions. While a dissociation between general emotional responding and specific sympathetically-mediated emotional responding to environments is plausible, it is not a settled issue, as others have reported some differences in facial muscle responding with similar stress-recovery experimental protocols (Parsons, 1991*b*; Ulrich *et al*., 1991).

The findings indicating lower blood pressure, more complete recovery and better performance on the post-recovery math task for those viewing the golf course drive are also theoretically interesting. Given the previous research showing greater stress-reduction following exposures to more natural vs more urbanized environments, the findings here suggest that golf courses elicit responses similar to those of natural environments, despite the highly stylized and obviously designed character of golf courses. It is interesting as well that the golf course drive-through elicited calming, or stress-reducing responses more consistently than the forest drive-through. Two primary differences between these environmental types might help to explain this. First, the environments used to construct the golf course drive are presumably more attractive than the rural Texas roadsides that composed the forest drive. Several evolutionary models of environmental perception can account for this difference equally well. The undulating topography, extensive open spaces and occasional clusters of trees typical of most golf courses afford excellent prospect and refuge opportunities (Appleton, 1975), are reminiscent of supportive savanna environments (Orians & Heerwagen, 1992), may hold the promise of more information to be gained through further exploration of the environment (Kaplan & Kaplan, 1989), and are likely to be sources of involuntary attention or fascination (Kaplan, 1995). However, golf courses tend to be rather 'park-like' in appearance as well, and thus one might explain their greater attractiveness partly through dint of familiarity with an environmental type. Regardless of its origin, the presumably greater scenic attractiveness of the golf course drive-through likely contributed to its positive effects.

The second primary difference between the forest and the golf course drive-throughs concerns the unavoidable disparities in traffic speed and density. The average rate of travel across the scenes on the forest drive was 34 m.p.h. (54 k.p.h.) with 1·6 oncoming vehicles per minute (v.p.m.) on average, while the corresponding figures for the golf drive were 27·8 m.p.h. (50·0 k.p.h.) and 0·4 v.p.m. While there are differences here, they are not large, especially when compared to the figures for the urban [29·5 m.p.h. (47·7 k.p.h.) & 24·6 v.p.m.] and mixed [26·0 m.p.h. (41·6 k.p.h.) & 18·8 v.p.m.] drives, where rates of travel are comparable to the forest drive and traffic density is much higher. Add to this the fact that the video taped surrogates did not include traffic sounds and that instructions to the participants did not ask them to take on a driver's role, and it seems unlikely that the differences in traffic speed and density contributed much to the observed differences in responding to the forest and golf course drives.

External validity, limitations and future research

Because this is a laboratory study of human–environment transactions in large-scale outdoor environments, several comments regarding external validity (the extent to which findings generalize to different settings and populations) are appropriate. Field research is typically thought to be more externally valid than laboratory research, and in particular it is thought to be more ecologically valid (a specific form of external validity concerned with generalizations to nonlaboratory or 'real world' settings). However, the assumptions upon which this belief is founded are often misguided (see Anderson & Bushman, 1997).[13] For instance, field research in environmental psychology is often thought to be ecologically valid because it is conducted in an exemplar of the environmental class of interest (e.g. in the workplace, a school room, a shopping mall, etc). Yet, the loss of experimental control in such environments often carries with it a corresponding loss of internal validity (the extent to which alternative causal hypotheses can be ruled out) which necessarily reduces ecological validity. If the causal hypothesis of interest is in serious doubt, then there is nothing to generalize to other settings, and the research has no external validity (ecological or otherwise).

Similarly, laboratory research in environmental psychology is thought to have limited external validity because of the artificial nature of the laboratory setting. Participants in a laboratory experiment are variously thought to be guessing about experimental hypotheses, responding to experimeter demands, or experiencing evaluation apprehension, all because they know that they are subjects in an experiment (and perhaps especially so when multiple physiological measures are recorded, as in the present study). While these potential drawbacks represent valid concerns, current evidence suggests that these problems cannot be broadly presumed for laboratory research (Anderson & Bushman, 1997).

We believe that the commonly held presumption of superior external validity for field research stems in part from a confusion about what exactly is supposed to generalize from one research setting to another. The primary goal of laboratory research is the testing and development of theories about psychological processes and behavioral phenomena. What one wishes to generalize from laboratory research are general theoretical principles about psychological processes and behavior, not specific instantiations or operationalizations of theoretical constructs. Thus, in the present study we are concerned with the generalizability of the theoretically predicted differential influence of exposure to general classes of environments (i.e. nature-dominated and artifact-dominated) on the general psychological processes of stress and stress-reduction. This is the level at which theories about restorative environments are constructed (e.g. Ulrich, 1983; Kaplan & Kaplan, 1989) and it is the level at which self-reported benefits of natural environments have been expressed for the past 25 years in environment and behavior research (for reviews, see Driver *et al.*, 1987; Levitt, 1989).

From this perspective, then, it does not make sense to criticize the external validity of laboratory research *vis-à-vis* field research because, for instance, stress was indexed with psycho-physiological measures, or nature- and artifact-dominated environments were represented by video-taped surrogates. Rather, the external validity of this research would be suspect if the general psychological processes (i.e. stress and stress-reduction), the behavioral phenomena (transactions with different environmental types) and the demonstrated relationships among them could not be reasonably expected to generalize to other settings. Given the existence of similar findings from psycho-physiological research in both laboratory (e.g. Ulrich *et al.*, 1991) and field (Hartig *et al.*, 1991) settings, as well as the broader context of a long history of self-reported benefits of transactions with natural environments (Ulrich & Parsons, 1992) we contend that the research reported here can be reasonably expected to generalize to other settings.

We do not mean to imply with the foregoing arguments, however, that the generalizability of these findings is unbounded. As with any study that uses environmental surrogates, the ecological validity of this research is limited most importantly by the extent to which the surrogates accurately represent the environments of interest. While the Hi-8 mm video-taped drives projected onto a large [4x6 ft (1·2x1·9)] screen likely constitute reasonable approximations of the visual environment directly in front of a moving vehicle, automobile commuters typically see more of the surrounding environment than such a view affords (see above review of literature on where drivers look). Thus, it is possible that salient aspects of the visual environment were not well-represented in this study. It is possible, as well, that the aural environment exerts some influence on commuters, especially in high traffic areas, and the lack of sound on our video tape surrogates limits the applicability of these findings accordingly. It should be noted in this regard, however, that road noise and other noxious sounds are often masked by entertainment systems or conversations with passengers, and that an ecologically valid aural commuting environment is not necessarily dominated by external environmental sounds. Future research in this area might address these concerns by using more immersive environmental surrogates, perhaps through the use of increasingly more sophisticated virtual-reality systems (e.g. Aguirre & D'Esposito, 1997), or through the marriage of computer animation and digital video. Alternatively, concerns for the ecological validity of human–environment transactions might also be addressed through the use of field studies and ambulatory psycho-physiological recording equipment (see, for instance, Hartig, 1993). In either case, the ultimate goal is to produce findings that can inform social actions regarding commuter environments and behavior.

Though we have focused on external and ecological validity in these remarks, the internal validity of this research also could be addressed in future work by refining the manner in which artifact-dominated and nature-dominated drives were operationalized. Indeed, one of the strengths of laboratory research is the opportunity to isolate theoretically interesting conditions that do not ordinarily occur in field settings (Anderson & Bushman, 1997; see also, Mook, 1983). For instance, we constructed Forest, Golf and Urban drives by mixing scenes from each category with scenes from an arbitrarily defined 'control' condition, which we labeled 'Mixed'—residential areas with light commercial development allowed. Thus, the 10-min Forest, Golf and Urban drives actually contained only 5 min of footage explicitly representative of the given category. While such a strategy was consciously chosen with ecological validity concerns in mind, drives that more cleanly represent nature-dominated and artifact-dominated areas could be constructed for future work in order to establish the bounds of the potential effects of driving through these different areas. While the information gleaned from such a study might be less directly useful to urban and transportation planners, it could still influence the cost–benefit calculus used to make design decisions for commuter routes.

Acknowledgements

Primary support for this research was provided by grants from the United States Golf Association, the U.S.D.A. Forest Service, and the NSF. Portions of this research were presented at the annual meetings of the Society for Experimental Social Psychology (1993), the Society for Psychophysiological Research (1993), and the Environmental Design Research Association (1995). We are grateful to Jacklyn Vetkoetter for her assistance in serving as one of the experimenters; to Bruce Hull, Melanie Ihrig, Phyllis Sanchez, and Terri Erwin for their insightful comments; and to Bonnie Dickson-Diaz, Michele Hussey, Elnor Kinsella, Robert Price, and Young Kyoung Yi for their valuable help throughout the project. We are especially grateful to Daniel Bontempo for his expert programming assistance and to Kipp Aldrich and Jeff Griswold for their adroit editing of the environmental video tapes.

Notes

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(1) The focus of expansion refers to a localized area (usually no more than a few degrees of visual angle in either direction) ahead of the driver that is directly opposite the direction of travel. If the road is straight, the focus of expansion will be on the road ahead, whereas on curved sections and when approaching curves the focus of expansion will be off the road.

(2) In this context, natural refers to those environments in which vegetation, in one form or another (grasses, trees, forbs, shrubs), predominates (see Ulrich, 1986).

(3) Other issues that fall outside these categories have also been researched, such as stress attributable to the interior environment of the car or the physical comfort of the driver, but relatively little work has been done in these areas. See Sadalla and Hauser (1991) for a good review of stress-related physiological changes associated with driving.

(4) The EOG signals drifted unpredictably over time and thus were unusable as measures of gaze direction. Consequently they were not analysed further.

(5) Analysis of covariance (ANCOVA) models were tried, but in a number of the models the covariate interacted significantly with a number of the factors, thus violating one of the essential assumptions of ANCOVA.

(6) Urban was operationalized as a city or town larger than 50,000 people according to 1990 Census data.

(7) The increases in activity in the Cheek and Mouth regions in the Active Stressor condition are not interpretable in terms of either stress or emotional processes because participants in this condition were required to respond verbally.

(8) We adopted an equal interval strategy in designing this contrast, while fully recognizing that our theory makes only ordinal predictions. In the absence of any information to the contrary, this strategy appeared to us to be the most defensible.

(9) A criterion of 5% was chosen based on the amount of trial-to-trial variablity typically observed within subjects.

(10) If neither of these conditions were met then the point of recovery was defined as the epoch with the smallest response during the Drive phase.

(11) Because of the elimination of subjects who failed to meet the 5% increase criterion, the statistical models used to address the recovery issue were limited to main effects and two-way interactions.

(12) Given the necessarily greater complexity and higher information rate of the artifact-dominated environments, it may seem more parsimonious to propose a simple arousal overload model to explain differences produced by exposures to these two global environment types. Such a model, however, would have difficulty accounting for the differences that ocurred during the second stress period, after environmental exposures had ended (i.e. immunization effects), while these same differences can be accounted for in the evolutionary model as being due to the calming influence for half of the participants of being exposed to safe, habitable nature-dominated environments.

(13) The arguments presented here follow closely those in Anderson and Bushman (1997), though they are developed much more fully there.

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