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Research has shown that helicopter noise from tourist flights is very common in some national parks and wilderness areas. At Grand Canyon National Park, aircraft noise has been found to be as high as 76 dB(A) with as many as 43 noise events in a 20-minute period. The present study examined the influence of 40 dB(A) or 80 dB(A) helicopter noise on assessment of a popular Grand Canyon vista in a laboratory simulation. Participants (44 female and 36 male undergraduates) viewed 68 slides of scenic vistas and assessed them on naturalness, preference, and scenic beauty and evaluated dimensions of freedom, annoyance, solitude, and tranquility. Compared to a control condition of background natural sounds (e.g., birds, brooks), noise conditions negatively impacted all dependent measures. Although the effects were most pronounced at the 80-dB level, even the 40-dB helicopter noise negatively impacted all dependent variables. Results suggest that helicopter noise interferes with the quality of the visitor experience and even affects the perceived aesthetic quality of landscapes.

Keywords landscape assessment, natural environments, noise, outdoor recreation

Legislation establishing U.S. national parks and wilderness areas has sought both to preserve these assets for future generations and to provide unique recreational opportunities. For example, wilderness areas are designed to provide "outstanding opportunities for solitude or a primitive and unconfined type of recreation" (National Wilderness Preservation Act 1964, Section 2c). Some exhilarating, unique, and unconfined recreational experiences, however, involve the use of tourist aircraft, snowmobiles, or motorized off-road vehicles to explore the preservation areas. Although off-road vehicles impact the physical landscape, aircraft generally do not, and aircraft permit views of the landscape that are otherwise inaccessible to those with certain disabilities.

However, even aircraft generate noise, and one of the primary reasons for visiting a national park, wilderness area, forest or other outdoor recreational environment is to escape the noise found in urban areas (Driver, Nash, and Haas 1987). Escaping noise ranks fourth in importance of sixteen preference domains, after enjoying nature, physical fitness, and reducing tension, by users of wilderness and nonwilderness recreational areas (Driver, Nash, and Haas 1987). Therefore, when sounds that are deemed inappropriate for a given area are encountered, the noise will then be considered annoying and will most likely detract from other important preferred experiences such as the enjoyment of nature and reduction of tension. Noise produced by aircraft in wilderness areas may represent undesirable sounds of

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urbanization or technological intrusion and likely will be evaluated negatively even at low levels of noise (Tarrant, Haas, and Manfredo 1995). This is in contrast to natural sounds, such as nonturbulent water and wildlife, which may be evaluated positively even at extremely loud levels (Anderson et al. 1983). For these reasons, then, it can be argued that the aural component of the nature experience is a very important one. The wind rustling through the leaves, the babbling brook, the thundering waterfall, bird songs, and wildlife calls are all part of experiencing and appreciating nature. It is difficult to see how these experiences would not be compromised by the auditory intrusions of aircraft.

Tarrant, Haas, and Manfredo (1995) examined visitor characteristics and dose exposure (number, proximity, and type) on evaluations of aircraft overflights in wilderness areas. Respondents had strong negative attitudes toward hearing and witnessing aircraft in wilderness areas. Participants found sightseeing and single-engine aircraft the most annoying. Path coefficients further underscored this assumption, with high item loadings appearing for annoyance ($r = .93$), solitude ($r = .88$), and tranquility ($r = .87$), thereby suggesting that visitor evaluations of aircraft overflights are multidimensional.

The multidimensional issue has also been supported by research examining visitor response within the national parks system (NPS). McDonald, Baumgartner, and Iachan (1995) concluded that the aircraft noise problem in national parks cannot be diagnosed simply in terms of a single characteristic (length of time sound was heard, number heard, or loudness of the sound). Although the data indicate that these characteristics affect visitors' reactions, it also appears that just noticing aircraft (auditory or visual) in NPS or wilderness areas triggers an important reaction. This initial baseline reaction may occur because the presence of any aircraft noise disrupts the feeling that the wilderness is a pristine area in its original natural state.

Noise is defined as *unwanted* sound, so by definition it has a subjective component. Sounds that are loud, unpredictable, and uncontrollable are likely to be perceived as noise. Moreover, in predicting annoyance, the degree to which the sound is perceived as avoidable and abnormal to the situation may be extremely important (Cohen et al. 1986; Glass and Singer 1972; Kryter 1985). Thus, noise produced by engine-driven transportation devices is reported as more annoying if the noise is irregular and unpredictable. Rhythmic sounds, such as those from engines, are judged to be more annoying than continuous ones, even when other properties of the noise remain the same (Dailey and Redman 1975; Galloway and Jones 1974; Kryter 1985).

Research examining noise in the context of recreational activity has been completed by researchers in Australia. Dellora, Martin, and Saunders (1984) studied conflicts between fourwheel drive users, bushwalkers, picnickers, and other recreationists in Victoria. These researchers found that motorcycle noise at sound levels greater than 68 dB(A) was the main cause of recreational conflict. However, noise produced at sound levels lower than 68 dB(A) was not taken into consideration in this study.

Kariel (1990) obtained data from three Canadian national parks via a survey in highway-oriented campgrounds. Participants were asked to rate a variety of technological and natural sounds commonly present in the area using a five-point bipolar scale measuring pleasantness and annoyance. Rank-order results indicated the top eight annoying noises to be technological in origin, with chainsaws, motorized trail bikes, and car noises the most annoying. Aircraft noise was rated as the sixth most annoying noise in this study. Kariel's results indicated that the level of human- and technology-related sounds should be kept generally low in outdoor recreation-type environments. Kariel (1990, 148) concluded that "it would also be desirable to restrict or regulate the use of sound-producing items, such as aircraft overflights, snowmobiles, generators, motorboats, and radios, in order to safeguard a recreational milieu." Given the multiple-use mandate of many federal land administrators in the United States and the variety of recreational motives brought to these areas by visitors, the results of this study are particularly compelling.

With the passage of the National Parks Overflights Act in 1987, the issue of aircraft overflights has captured attention from congressional leaders, federal land managers, the National Park Service, the Forest Service, the Bureau of Land Management, the Federal Aviation Administration, municipalities and counties, developers, home owners, and business interests in the United States. Given the multiplicity of interests involved in the issue, it is easy to recognize why research has accelerated during the past ten years. Under this recently passed federal mandate, a number of federal land managing agencies were instructed to submit reports to Congress detailing the impacts overflights have on national parks and wilderness areas. This requirement has subsequently led to a number of research projects examining the many facets involved with aircraft overflights.

One group of researchers summarized two studies examining the overflight issue in a number of wilderness areas throughout the United States using both on-site interview and telephone survey methodology (Fidell et al. 1996). This study focused on all types of aircraft overflights and found helicopters and military aircraft to be significantly more annoying to recreationists than high altitude jets and small private aircraft. However, the wilderness areas examined in these studies varied greatly with regard to the occurrence and decibel level of aircraft overflights, with a far lower exposure rate than areas such as the Grand Canyon. Still, the results of these studies led the authors to conclude a reliable effect of aircraft noise exposure on annoyance, at least in some of the wilderness areas investigated. Based on these findings, annoyance should remain the principle dependent measure when studying the impacts of aircraft noise on visitors to natural areas.

In order to assess the frequency of aircraft overflights, Tabachnick, Howe, and Fidell (1992) examined all types of aircraft overflight exposure in national parks and wilderness areas. This research produced a rank order of commercial helicopter sightseeing tour services flying in and around the national parks and wilderness areas of the country. The Grand Canyon ranked highest, with 36 independent tour operators providing sightseeing helicopter rides through the canyon. The next highest rankings included Haleakala (12 operators) and Hawaii Volcanoes National Park (8 operators). Although these three parks were ranked significantly higher than any of the other parks or wilderness areas included, this does not mean that other areas are not prone to helicopter tour operations. In fact, aircraft noise exposure has been estimated recently to impact 140 units of the National Park System (Chandler 1997).

The 1987 National Parks Overflight Act (Public Law 100-91) also requires the National Park Service and the Forest Service to identify "acceptable levels" of aircraft overflights in federal wilderness areas. Consequently, some research has measured ambient conditions in a variety of locations throughout the national parks and wilderness system that have been identified as overly affected areas. Horonjeff, et al. (1993) sought to provide baseline information about the intensity and duration of aircraft noise in Grand Canyon, Haleakala, and Hawaii Volcanoes National Parks. Measurements were obtained at 23 separate locations within Grand Canyon

National Park, many of which were designated as no-flight zones as a result of regulations put into effect by way of Special Federal Aviation Regulation 50-2. Results from this study found aircraft sound levels as high as 76 dB(A) in Grand Canyon. In some areas of Grand Canyon, aircraft noise is audible 79% of the time, with as many as 43 separate aircraft noise events occurring within every 20-minute interval. Furthermore, a number of the measured locations in the Grand Canyon produced interesting echo phenomena, where it was possible for a single aircraft to sound as if three or four separate aircraft were present, even without the aircraft being visible. The results show not a single location recorded in Grand Canyon National Park to be totally free of aircraft noise. With these findings in mind, it is easy to recognize why aircraft overflights, along with air quality and visitor management, have been the dominant topics at the Grand Canyon recently.

Affect and the environment. Affect, or emotion, is a central component of experience and behavior in any environment, whether natural or built (Ulrich 1993). It has been established that few meaningful thoughts, actions, or environmental encounters occur without affect (Ittelson 1973; Izard 1977; Zajonc 1980). Consequently, an individual's affective state is a significant factor in any environmental experience (Lazarus, Kanner, and Folkman 1980; Russell and Snodgrass 1987).

Based on past research it can certainly be argued that natural areas are sought out in order for people to restore themselves from the stress encountered in everyday life. In support of this notion, over 100 studies have found convincing evidence that natural environments are important in facilitating recovery from stress, and stress reduction consistently emerges as one of the key perceived benefits of a wilderness experience (for reviews see Knopf 1987; Ulrich, Dimberg, and Driver 1991). Laboratory research examining restoration after exposure to a stressful event using both physiological and psychological measures have indicated that individuals recover the quickest when exposed to natural settings (Ulrich et al. 1991). Thus, the natural environment seems to be facilitating a restorative function. As Kaplan (1995) has pointed out, natural environments are often a destination for those in need of restoration and must include the attributes of tranquility, peace, and silence (Kaplan 1995; Kaplan and Talbot 1983). These restorative properties have been hypothesized to be a product of the adaptive process through which humans evolved (Ulrich 1993). Consequently, if environmental stressors such as noise pollution are found to disrupt these attributes, restoration may not occur, and negative outcomes may result. Furthermore, if an individual is seeking to escape the restrictions of the urban world, and his or her affective encounter with the natural area is a negative one caused by ambient stressors, it follows that the individual's well-being and health may adversely be affected as well (Russell and Snodgrass 1987).

One component of the experience with natural environments is simply viewing the landscape (Ulrich 1993). For those who find special meaning in viewing wilderness or national park landscapes, affective components may be examined by focusing on the feelings and perceptions of the individuals who visit, view, or inhabit the specified landscape. The response of these individuals is typically of an aesthetic dimension, with preference, or like–dislike affect (Zajonc 1980) being the variable operationalized. Preference is associated with pleasurable feelings and neurophysiological activity elicited by an encounter with a given landscape (Berlyne 1971).

Landscape assessment techniques. The term "landscape" clearly exhibits a visual emphasis, although the other sensory systems are certainly an integral contributor to the overall experience in natural surroundings. Still, landscape assessment research has primarily focused on the visual properties of the land area under study. Consequently, the dimension most often measured is the scenic quality of a given area (Daniel et al. 1973; Zube 1974). This variable also has been described as visual quality (Shafer and Richards 1974), scenic beauty (Daniel and Boster 1976), landscape preference (Buhyoff and Wellman 1978), visual attractiveness (Brush 1979), and aesthetic quality (Feimer, Smardon, and Craik 1981).

Psychophysical landscape assessments typically represent the experiences of visitors to the area under study by means of color slides. Criticism has focused on whether human reactions to areas represented by photographs are valid indicators of reactions that would occur if people were to visit the areas and view them directly (Henry and Matamala 1990). However, when comparing between perceptual data gathered using color slide depictions of landscapes and data obtained at the actual sites where those slide photographs were taken, a very close relationship between the two has been established (Daniel and Boster 1976; Jackson, Hudman, and England 1978; Malm et al. 1981; Shafer and Richards 1974; Zube, Pitt, and Anderson 1975). Correlations between photo-based and direct on-site assessments have been found to be .80 or greater (Daniel 1990). Furthermore, research specifically assessing the ambient environmental stressor of visual air quality based on judgments of actual park visitors versus judgments by college student volunteers revealed that color slides are an adequate means of representing visibility-relevant aspects of scenic areas (Daniel 1984).

Landscape assessments utilizing psychophysical methodology have been obtained using Likert-type rating scales (Brush 1979; Daniel and Boster 1976), rank orders (Shafer and Brush 1977), forced choice paired comparisons (Buhyoff and Wellman 1978; Mace and Loomis 1995), magnitude estimation (Buhyoff, Wellman, and Daniel 1982), and Q-sorts (Pitt and Zube 1979). Daniel and Vining (1983) argue that perception should not change as a function of the method of expressing judgments. Data obtained from several direct tests of this argument have provided support (Daniel and Boster 1976; Pitt and Zube 1979; Ward and Russell 1981). Therefore, the underlying relationship that is revealed appears to be valid no matter what type of data-gathering device is employed.

Problem under study. The aesthetic dimension of landscape assessment has been found to be closely related to other psychological dimensions. In this context, a landscape that is determined to be scenically beautiful also elicits positive ratings of tranquility, freedom, and solitude (Daniel 1984; Ulrich 1977; Ulrich, Dimberg, and Driver 1991). Given that affective experiences are important in viewing natural areas and that noise has affective consequences, the question for the current study was whether noise itself, specifically helicopter noise typical of tourist aircraft in national parks, would influence perceived aesthetic quality of landscapes as well as feelings of tranquility and solitude. The procedure of the current study produced 42 helicopter noise events in a 31.5-minute interval, with helicopter noise audible 66% of the time. This frequency was employed to approximate real-world conditions in such national parks as Grand Canyon. The noise was presented at either a 40 dB(A) level or an 80 dB(A) level, with a control condition containing natural sounds (birds, brooks) at up to 60 dB(A). It was hypothesized that even the low-level helicopter noise would increase annoyance while viewing slides of scenic vistas, and that the noise would also influence scales measuring scenic beauty, naturalness, preference, solitude, tranquility, freedom, and affect.

Method

Participants

Eighty undergraduate introductory psychology students (44 females and 36 males) enrolled in a land-grant university in the Rocky Mountain region served as research participants. There were no restrictions for participation so long as each participant had no color-vision or hearing deficiencies. Responses to the experimental set were eliminated for one female participant as a result of incomplete and missing data.

Apparatus

A room measuring 19 ft 9 in. (6.02 m) × 21 ft 7 in. (6.58 m) with the walls painted black to minimize reflection was used to test the research participants. Four Realistic Minimus-77 8-ohm (55W) speakers wired through an Optimus STA-300 amplifier/receiver were used to project the sound. One speaker was placed in each of the four corners of the room. Sound presentation was controlled using Sound Edit Pro software in conjunction with a Macintosh Quadra 950 computer.

A Mast System Two slide projector equipped with a Buhl f5.7mm lens and a high intensity ELH300 watt bulb was used to project the slides. This slide projector was equipped with a random access motor unit and an RS-232 computer interface, enabling projector control via computer. The projector was mounted on a platform 71 in. (1.8 m) high, in a control room directly behind the laboratory. The image projected on the screen was 34.5 in. (.88 m) × 51.5 in. (1.31 m), with the screen mounted on a wall 22 ft (6.71 m) away. The base of the screen was 63 in. (1.6 m) off the floor. Each participant sat at one of two rectangular tables 15 ft (4.72 m) away from the screen. Tables were equipped with wooden dividers to separate the participants. This configuration allowed four participants to run through the experimental procedures at a time.

The set of slides depicting scenic views of the Grand Canyon used in this study were taken from the Desertview Point monitoring station with a distant view to the west. The visual range depicted in this set of slides was 150 km, with Mount Trumbull the farthest dominant point. The highest quality base photographs resembling the clearest possible conditions taken from the Desertview Point monitoring station were selected.[1]

In addition to the Desertview scenes, other distractor slide stimuli used in this experiment portrayed natural landscapes found in the southwestern region of the United States. A total of 15 slide stimuli comprised this group, and included the following environments: six slides depicting desert landscapes in Arches, Canyonlands, and Zion national parks; three scenes of mountain water features (stream, river, lake), three slides depicting mountain peaks, and three mountain forest scenes.

Human perception of loudness corresponds most directly to the physical intensity of a given sound. Sound pressure level is typically measured using the decibel scale. More specifically, the dB(A) scale typically is used to most adequately approximate the response of the human auditory system (Hall and Taylor 1977; Kariel 1990; Kryter 1985). The decibel scale is a logarithmic scale ranging from zero (hearing threshold) to 130 (pain threshold). Experimental conditions in the present study produced sound levels at 40 dB(A) and 80 dB(A), the extremes of sound levels typical at the Grand Canyon (Horonjeff et al. 1993). Sound at 40 dB(A) can be categorized as quiet to very quiet, with common examples being soft music from a radio or an automobile travelling 25 miles per hour 50 feet away. With the logarithmic nature of the decibel scale, sound at 80 dB(A) is 100 times as intense as sound at 40 dB(A). Examples of 80 dB(A) sound include a freight train at 50 feet, or a second floor apartment located along a busy street in a large city such as New York or Los Angeles.

Sounds typically encountered in a Class I Wilderness Area free of any human-produced sound were used as background auditory stimuli in order to create a more natural setting. These natural background sounds included such sounds as wind, bird songs, babbling brooks, and natural quiet, all corresponding to the visual environment being depicted. Nature sounds were taken from recordings made in numerous wilderness areas throughout the western portion of the United States. These natural sounds also allowed the noise generated from the projector fan to be significantly masked. Background nature sounds were presented in a range from 0 to 60 dB(A), a range typical of ambient conditions at Desertview, Arizona (Horonjeff et al. 1993), and throughout the southwestern region of the United States. Natural sounds were predominantly below the 40-dB(A) level, with the exception of one environment where thunder was presented at 59 dB(A).

Helicopter noise was either present or not present in all test trials. In the trials where helicopter noise was present, it was either at a 40-dB(A) or an 80-dB(A) level. Helicopter noise was further edited with this program to produce fade-in and fade-out effects using a sound-editing computer program. These manipulations produced sound stimuli that reflect a naturally occurring environmental setting in Grand Canyon National Park. Audio simulations in the laboratory have been shown to significantly reflect on-site ratings for both natural and urban environments (Anderson et al. 1983; Ulrich, Dimberg, and Driver 1991; Zube et al. 1985). Furthermore, varying decibel levels have been used successfully in audio studies simulating both urban and natural environments (Anderson et al. 1983; Kryter 1985; Ulrich, Dimberg, and Driver 1991; Zube et al. 1985).

Procedure

Participants completed the experiment in order to partially fulfill a research requirement for an introductory psychology course. Upon entering the laboratory room, participants were randomly assigned to one of four seats facing the projection screen and separated from other participants by a wooden partition.

A 20-item positive and negative affect scale (PANAS) with key descriptive words evaluated on a five-point Likert-type scale (very slightly to extremely) was distributed to participants. This survey is two-dimensional, producing both positive and negative affect scores. Examples of positive items include "enthusiastic," "proud," and "inspired," and examples of negative items would include "distressed," "irritable," and "jittery." Reliabilities range from .86 to .90 for positive affect, and .84 to .87 for negative affect. Both positive and negative convergent validities have been found to be very good at .89 and .95 respectively. Discriminitive validity has been shown to be somewhat low, with results ranging from −.02 to −.08 (Watson, Clark, and Tellegen 1988). Positive and negative affect were assessed using the PANAS survey both prior to noise exposure and following evaluation of all experimental stimuli. In other words, a pre–post design was utilized to evaluate affect.

Noise sensitivity has been found to moderate the effects of noise, especially with regard to the level of annoyance experienced (Job 1988). Those who are more sensitive to noise are more likely to become annoyed (Iwata 1984; Stansfield et al. 1985).

Therefore, the 21-item Weinstein Noise Sensitivity Scale with a six-point response format ranging from strongly agree to strongly disagree was given to participants. This scale utilizes a median-split to distinguish between low and high noise sensitivity.

Other factors such as gender (Hambrick-Dixon 1988; Holding and Baker 1987; Koelega, Brinkman, and Bergman 1986), previous noise experience (Hambrick-Dixon 1986), and residential living experience (Nagar, Pandey, and Paulus 1988) have been found to moderate the effects of noise. For these reasons, a demographic information questionnaire was also distributed to each participant. Following completion of these surveys, participants were given an explanatory instruction sheet to familiarize them with the procedural aspects of the landscape assessment. Once instructions were covered, any remaining questions were answered, and subjects were given a set of landscape evaluation forms.

Each group of four participants viewed the same set of 68 slides and were exposed to the same auditory stimuli in one of three randomized orders. The first five slides represented practice trials, immediately followed by the target set of 21 slides (6 slides of the Desertview vista and 15 scenic distractor slides), with the target set repeated for each noise condition. Each slide was shown for 30 seconds. Participants were instructed to imagine themselves as visitors to the depicted areas and to envision themselves as actually being present in the environment when completing their ratings. The experimental set consisted of 21 slides that were randomly distributed in one of three orders. Therefore, each participant made 68 landscape ratings, including 5 practice trials, with helicopter noise present on 42 of the remaining trials, an exposure rate approximating usual conditions at the Grand Canyon. Following the presentation of each slide stimulus, the landscape rating forms were completed. Participants rated each depicted landscape with seven one-to-ten scales measuring naturalness, freedom, preference, annoyance, solitude, scenic beauty, and tranquility. Although it would be desirable to assess each of these attributes with multiple items, in the interest of time they were measured with single items, a procedure that retains a high degree of reliability and validity (e.g., Herzog and Bosley 1992). After the last slide, participants were asked to complete the PANAS affect measure once again. Participants were then fully debriefed and free to leave.

Results

Analyses[2] were conducted on the averages of the ratings of the Desertview slides, with the three noise levels as the independent variable. Means and standard deviations on the seven scales are presented in Table 1. Perhaps the most striking pattern is revealed when examining the means for annoyance across all levels of noise. Further examination reveals similar patterns emerging for the attributes of naturalness, freedom, preference, solitude, and tranquility across noise levels. In this regard, these attributes became more negative as noise level increased. As shown in Table 2, relatively high correlations were found to exist between all seven dependent measures, with the highest positive correlation between solitude and tranquility. Annoyance produced high negative correlations with tranquility, solitude, preference, and freedom. It appears, then, that the attributes selected for evaluation with the Desertview slide set are highly correlated.

High correlations between the dependent measures in the Desertview slide set argued for a multivariate analysis of variance (MANOVA). In order to complete this analysis, annoyance was reverse-scored to allow the composite variable formed

TABLE 1 Means and Standard deviations for Predictor Scales in the Desertview Slide Set as a Function of Noise

Condition	Annoyance	Tranquility	Solitude	Preference	Naturalness	Scenic Beauty	Freedom
Control							
Mean	2.55	7.96	8.36	7.35	8.86	8.02	8.32
Standard deviation	1.99	1.92	1.64	2.16	1.33	2.00	1.62
40 dB(A)							
Mean	4.77	5.82	6.33	6.09	7.92	7.66	7.07
Standard deviation	2.37	2.31	2.19	2.25	1.80	1.96	1.94
80 dB(A)							
Mean	8.27	3.23	4.02	4.04	6.86	7.10	5.51
Standard deviation	2.08	2.44	2.46	2.50	2.70	2.24	2.50

TABLE 2 Correlations of Predictors for the Desertview Slide Set

	Nat.	Free.	Pref.	Annoy.	Sol.	SB	Tranq.
Naturalness	1.000						
Freedom	.6202	1.000					
	$p < .001$						
Preference	.6012	.6577	1.000				
	$p < .001$	$p < .001$					
Annoyance	−.4702	−.5824	−.6754	1.000			
	$p < .001$	$p < .001$	$p < .001$				
Solitude	.5512	.7073	.6622	.7178	1.000		
	$p < .001$	$p < .001$	$p < .001$	$p < .001$			
Scenic Beauty	.5558	.4300	.5674	−.3224	.3892	1.00	
	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < .001$		
Tranquility	.5661	.6684	.7291	−.7675	.8343	.4127	1.000
	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < .001$	

by MANOVA to be deemed meaningful. A three-way, completely within-subjects, repeated-measures MANOVA was performed on the seven dependent variables: naturalness, freedom, preference, annoyance, solitude, scenic beauty, and tranquility, with noise as the independent variable. Demographic variables such as sex, size of hometown, and recency of visitation to a wilderness area were included in this analysis. In no case did a demographic variable produce a significant effect on the dependent scales. Noise sensitivity was also measured with the Weinstein Noise Sensitivity Scale, with a median-split producing no significant effect with any of the dependent scales. A significant main effect was found for noise, $F(2, 1419) = 533.97$, $p < .0001$. Estimates of the eta square statistic indicate that the noise main effect explains about 43% of score variances.

Univariate analyses of variance were completed in order to determine which dependent measures were accounting for the significance. Significance was produced for each of the seven dependent measures, as depicted in Table 3. As expected, noise had a significant impact on annoyance, $F(2, 1419) = 846.54$, $p < .0001$, *eta square* = .54. Noise sensitivity was also treated as a covariate, with no significant decrease in the annoyance effect being obtained for those more sensitive to noise, as determined by a median-split. Noise level also had a large significant effect on tranquility, $F(2, 1419) = 531.54$, $p < .0001$, *eta square* = .43, and solitude $F(2,1419)$

TABLE 3 Univariate ANOVA: Main Effect for Noise

Variate	Hypoth. *SS*	Error *SS*	Hypoth. *MS*	Error *MS*	*F*	Signif. of *F*	eta-*square*
Annoyance	7869.08	6595.18	3934.54	4.65	846.54	.0001	.54
Tranquility	5308.93	7086.40	2654.46	4.99	531.54	.0001	.43
Solitude	4423.47	6395.83	2211.72	4.51	490.70	.0001	.41
Preference	2643.20	7610.94	1321.60	5.36	246.40	.0001	.26
Freedom	1879.24	5984.06	939.62	4.21	222.81	.0001	.24
Naturalness	949.44	5812.76	474.72	4.10	115.71	.0001	.14
Scenic Beauty	202.78	6079.72	101.39	4.28	23.66	.0001	.03

= 490.7, $p < .0001$, *eta square* = .41. Of particular interest were significant effects produced on such visual attributes as scenic beauty, $F(2, 1419) = 23.66$, $p < .0001$, although the effect size was small, *eta square* = .03. This environmental attribute previously has been examined exclusively from a visual perspective in numerous studies. It is interesting to witness an auditory stressor seeming to have an impact, albeit slight, on a primarily visual experience.

Multivariate contrasts corrected for dependent measure correlations were made between the three distinct noise conditions to ascertain if significant differences existed. The first comparison examined the no-control condition versus the 40-dB(A) helicopter noise condition. A significant difference was found to exist between these two levels, $F(7, 1413) = 49.92$, $p < .0001$. A second comparison tested the 40-dB(A) noise level with the 80-dB(A) helicopter noise condition. Again, a significant difference between these two noise conditions was found, $F(7, 1413) = 97.03$, $p < .0001$. Follow-up univariate analyses were performed on the two significant comparisons. The univariate results for the first comparison are depicted in Table 4. Interestingly, all seven dependent scales were found to be significantly different between these two conditions. Similarly, univariate analyses for the comparison between the 40-dB(A) helicopter noise and the 80-dB(A) helicopter noise conditions produced differences between the two conditions on all seven scales (see Table 5).

Positive and negative affect were assessed with the PANAS scale and analyzed for pre–post differences. This scale produces a score for both positive and negative

TABLE 4 Univariate ANOVA for the Control Versus 40 dB(A) Planned Comparison

Variate	Hypoth. *SS*	Error *SS*	Hypoth. *MS*	Error *MS*	*F*	Signif. of *F*	eta *square*
Annoyance	1169.63	6595.18	1169.63	4.65	251.65	.0001	.18
Tranquility	1082.46	7086.40	1082.46	4.99	216.75	.0001	.15
Solitude	950.00	6395.83	950.00	4.51	210.77	.0001	.15
Freedom	369.69	5984.07	369.69	4.22	87.66	.0001	.06
Preference	374.70	7610.94	374.70	5.36	69.86	.0001	.05
Naturalness	206.08	5821.76	206.08	4.10	50.23	.0001	.04
Scenic Beauty	30.49	6078.72	30.49	4.29	7.12	.008	.01

TABLE 5 Univariate ANOVA for the 40 dB(A) Versus 80 dB(A) Planned Comparison

Variate	Hypoth. *SS*	Error *SS*	Hypoth. *MS*	Error *MS*	*F*	Signif. of *F*	eta *square*
Annoyance	2892.76	6595.18	2892.76	4.65	622.40	.0001	.43
Tranquility	1588.11	7086.40	1588.11	4.99	318.08	.0001	.22
Solitude	1269.42	6395.83	1269.42	4.51	281.64	.0001	.20
Preference	996.61	7610.94	996.61	5.36	185.81	.0001	.13
Freedom	577.64	5984.07	577.64	4.22	136.97	.0001	.10
Naturalness	270.08	5821.76	270.08	4.10	65.83	.0001	.05
Scenic Beauty	74.08	6078.72	74.08	4.29	17.29	.0001	.01

affect, treating each as dominant, independent dimensions. Exposure to the environmental stressors had a strong significant effect on positive affect, $t(79) = 8.10$, $p < .0001$, $R^2 = .46$. Participants' positive affective state decreased significantly after exposure to noise and haze ($M = 30.16$ versus 23.95). Negative affect also was affected significantly by exposure to the experimental conditions, $t(79) = -3.92$, $p < .0001$, $R^2 = .16$; after being subjected to varying levels of noise and haze, negative affect increased significantly (M = 13.86 versus 16.35).

Discussion

It has been suggested that airflights in wilderness areas represent undesirable sounds of civilization and will be evaluated negatively even at low levels of noise (Anderson et al. 1983; Tarrant et al. 1995). The results of the present study support this contention. Each of the seven scale ratings was found to be influenced by noise, with the strongest effects being on annoyance, solitude, and tranquility. Tranquility and solitude have been examined in numerous recreation studies and are attributes addressed in the Wilderness Act of 1964. This line of research has found that the primary reasons for visiting natural environments include escape from the stress of urban areas and the attainment of tranquility and solitude (Driver, Nash, and Haas 1987). Sounds that interfere with these experiences are considered annoying and have significant negative effects on these attributes (Kariel 1990). These effects were present even at low levels of helicopter noise.

Beyond annoyance, tranquility, and solitude, this study found that an auditory stressor affected visual landscape quality. Naturalness has been identified as an important attribute of scenic environments, is mandated in the Wilderness Act, and has been found to be related to scenic beauty (Daniel and Hill 1986; Kaplan, Kaplan, and Wendt 1972; Zube 1974). Results from the present study showed that helicopter noise also affects the perceived naturalness of a landscape, and that as loudness increased, the landscape was perceived as less natural. Preference has been studied in numerous landscape assessments and has been found in the past to be highly correlated with scenic beauty when assessing natural environments. This relationship was supported in the present study, with preference also significantly decreasing when helicopter noise was present. Freedom, or the ability to move through the environment without being confined, is another important provision of the Wilderness Act that has been studied primarily as a visual attribute of depicted landscapes. Helicopter noise also restricted the perception of freedom.

Loudness has been found to be a key factor with regard to the level of annoyance produced by transportation noise (Galloway and Jones 1974; Kryter 1985). To test whether this relationship holds true in landscape assessments of natural settings, comparisons were made between the 40-dB(A) and the 80-dB(A) levels of helicopter noise. Annoyance significantly differed between the two conditions, and was especially evident when examining the magnitude of the effect. In the 40-dB(A) condition, annoyance was found to account for 18% of the variance, whereas in the 80-dB(A) condition, annoyance accounted for 44% of the variance. Once again, differences were found to exist between these two noise levels for each of the seven measured attributes. Therefore, as the loudness of helicopter noise increased from 40 dB(A) to 80 dB(A), an occurrence that simulates usual conditions at the Grand Canyon, attributes that have been deemed an integral part of a visit to such an environment decreased significantly and became much more negative.

Affective reactions to ambient environmental stressors were examined in this study using the PANAS scale. As hypothesized, both positive and negative affect as measured by the subsets of this scale were found to be significantly more negative after exposure to helicopter noise. These results would be expected when considering past research examining ambient environmental stressors (Campbell 1983). If these affective findings can be validated with field research, many negative consequences may result. Certain cognitive dimensions associated with a variety of outdoor recreational activities and experiences may be negatively affected both at the time of the visit and when recalled in the future. A negative experience may lead to certain psychological needs remaining unfulfilled, especially when considering the reasons people seek out natural areas (Driver, Nash, and Haas 1987; Driver, Tinsley, and Manfredo 1991; Ulrich 1993).

When the findings from this study are viewed in relation to past research examining noise in urban settings, it becomes evident that the results may be analogous to the effects produced by noise in the built environment. In fact, when considering that people are visiting natural areas to escape the stressors found in the city, experience solitude and tranquility (Driver, Nash, and Haas 1987), restore themselves (Ulrich 1993), and enjoy nature (Driver, Tinsley, and Manfredo 1991), the psychological effects of transportation noise may be even more pronounced in natural environments. This becomes especially important when considering the rapid increase and spread of human-produced noise throughout the parks and wilderness areas of the United States. Escape from this ambient environmental stressor then becomes more and more difficult. For example, helicopter tours in the Grand Canyon have increased from 40,000 in 1987 to 95,000 in 1996 (Kanamine 1997). On the busiest days, up to 100 helicopters may be in the airspace above the Grand Canyon at any give time. Helicopter noise is audible 79% of the time (Horonjeff et al. 1993), and can echo for up to 16 miles along the inner walls of the canyon (Kanamine 1997).

Although these results suggest that the predictors used in this study account for many of the important qualities found in the depicted landscape, research should continue to search for other, perhaps superior, landscape predictors and methods. The procedures and predictors used in this study were chosen for both practical and theoretical reasons, and it certainly is evident that other important attributes were not included. Although the temptation to evaluate more predictors simultaneously seems inherent with landscape assessment, it creates a variety of statistical difficulties when the number of regression variables is increased. Compromise is always inevitable, yet the multidimensional complexity of landscape assessment implies the need for a program of research rather than a mere assemblage of studies.

From a procedural perspective, given the design of this study it could be argued that participants quickly learned to anticipate the helicopter noise following exposure to a few trials, which could potentially impact their landscape evaluations. However, given the current exposure rate of helicopter noise at the Grand Canyon, visitors on-site would certainly learn to anticipate noise events if standing at an overlook for any significant amount of time.

Due to the lack of research examining noise issues in the remaining natural areas of the United States and the world, there are a multitude of research questions that need to be addressed. One prospective line of research should address the source attribution and perceived meaning associated with a given noise. Previous research has found that people will tolerate or even be pleased with a disturbing sound, at least for a short time period, if they believe that it will aid or benefit an experience or activity. Within a wilderness or park setting examples may include such things as the sound of a snowmobile or helicopter when it signifies that rescue is on the way. In addition, ameliorative efforts involving aircraft noise at national parks will need to consider impacts on the passengers in the aircraft. This becomes especially important with helicopter noise, as recent estimates show the vast majority of visitors to the Grand Canyon who are engaging in air tours are visitors from other countries, especially Japan (Kanamine 1997). According to a recent study, of the 480,000 tourists who took Grand Canyon air tours from Las Vegas in 1996, 440,000 were foreigners (Steinhauer and Karlsen 1997). Therefore, multiple issues immediately become apparent, including prior use history, recreational activity, and social context of the visitor. Future research needs to address these concerns.

The strong effects produced by noise in this study argue for a comprehensive field study examining the impacts of noise in natural locations where these events occur on a daily basis. Research completed on-site would also speak to the issue of external validity, and should be extended to other natural areas affected by noise. With regard to helicopter noise, park areas located in Hawaii should receive immediate attention, as overflights have become so common that local residents now commonly refer to the helicopter as "the state bird." Furthermore, other noise-producing aircraft in natural landscapes should also be investigated (airplane noise over the Indian Peaks Wilderness Area in Colorado, for example). More generally, any human-produced noise that is commonly encountered in scenic landscapes, whatever its source, should also be examined to assess the psychological impact it has on the visitor to these natural areas. This program of study could examine such noise-related events as snowmobiles in Yellowstone National Park, as well as the noise produced by cruise ships in the inlet regions of Alaska and Puget Sound. In addition, a cogent program of research completed both in the field and the laboratory would greatly contribute to model development and the many theoretical implications of noise exposure in natural environments. Furthermore, the results from such a program of research could greatly impact the management of parks and other natural environments throughout the world.

A final limitation concerns the specific environments depicted with slide and sound stimuli used in this study. Because the stimuli represented landscapes found only in the southwestern region of the United States, the experiment's generality was reduced. This limitation serves to illustrate the intricacy and situation-specific nature of the attributes examined in this study. For example, results from this study may represent the experience of a visitor standing at an overlook on the south rim of the Grand Canyon, but may not represent the experience of a visitor at the bottom of the canyon or at a point in-between given current flight pattern regulations. With this in mind, however, it should be mentioned that since sounds are detectable and identifiable from great distances and at very low sound levels even without registering on a sound meter, they can still be deemed intrusive and provoke negative reactions (Kariel 1990). As distance from a sound source doubles, a reduction of about 6 dB results. Furthermore, noise produced by mechanical devices is not absorbed well by vegetation (Anderson et al. 1983; Dailey and Redman 1975; Harrison, Clark, and Stankey 1980; Kariel 1990). Moreover, the mere presence of vegetation appears to elevate expectations of environmental quality (Anderson et al. 1983). Future research should address these concerns by specifically investigating ambient environmental stressors in the many varied and unique landscapes of the United States and the world. A program of study maximizing these suggestions would provide a more complete understanding of landscape assessment and the effects of ambient environmental stressors when they are found in natural environments.

Notes

1. These base slides were also manipulated via computer to produce hazes of varying magnitudes across the entire scene. Each Desertview slide contained exactly the same geographic features in exactly the same locations. Subsequent analyses revealed no effects on the dependent measures for the levels of haze examined; since noise was the main focus of this study, no further discussion of haze effects is included for the sake of brevity.

2. Analyses presented here are restricted to the Desertview slides since that is the vista most subject to real-life helicopter noise; examination of the dependent measures for the distractor set of slides shows very similar results.

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