How Does the Brain Engage with Daytime and Night-time Sceneries?

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Abstract: This study aims to compare restorative and recovery potentials between daytime and night-time. The experiment was conducted by showing a total of 12 images to 60 participants to measure the brain response to an electroencephalogram (EEG). As measures of the psychological impact of the images, perceived restorative and recovery scales were used. The self-reported data indicates that day-time sceneries are rated more positively than night-time sceneries in terms of restorative and recover effect. Latent class analysis was carried out to explore classes – or sub groups – in the data and to identify significant emotional discriminators between the two sets of images. A three-class model produced the best fit, with image scene, and four of the EEG emotional parameters (i. e. excitement, interest, relaxation and engagement) significantly discriminating between the three classes.

Keywords: Restorative, recovery, psychophysiological responses, landscape preference

1 Introduction

In this study, we attempted a new method of analysing daytime and night-time sceneries using mobile electroencephalography (EEG), which is directly related to people's perception of the environment. The development of mobile EEG devices has led to active research on people's perceptions of architectural spaces or outdoor environments. Previous studies using EEG in the field of architecture and environmental planning can be classified into three categories: (1) measurement of user influence on specific elements of indoor environments (TILLEY et al. 2017); (2) tools for determining specific architectural elements (HWANG et al. 2013, KIM & LEE 2009); and (3) analysis of visual attention with user interest areas (HWANG et al. 2013). Many EEG studies on aspects of environments have shown generally beneficial effects of green spaces or specific colours and environments in producing preference or restorative effects from natural landscapes. However, there have been no sufficient research studies involving comparative analysis of daytime and night-time scenery. In this study, mobile EEG was used to evaluate the daytime and night-time sceneries related to the perceived restoration characteristics according to the environmental environment.

Attention restoration theory (ART) illustrates that directed attention is voluntary, core to maintain focus, controls distractions through inhibitory mechanisms, and requires effort (KAPLAN 1995). Landscape preference and restorative quality evaluation methods can be divided into non-verbal and verbal evaluation methods (CHEON et al. 2019). The non-verbal evaluation method analyses external expressions of emotions, such as facial expressions, voices, and gestures, or measures physiological reactions using scientific experimental equipment. A verbal evaluation method is a way to describe participants' emotional state using a self-report questionnaire or adjective survey (PARK et al. 2011). Environmental psychology researchers have consistently focused on the restorative potential of natural environments compared to urban environments. However, they have often used verbal evaluation methods, such as video and

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photographic experiments where subjective measures were taken in the laboratory (MAVROS et al. 2012).

The purpose of this study is to investigate the effects of daytime and night-time scenery on the psychological and physiological changes to the human body, focusing on restorative and recovery effects. As a non-verbal evaluation method, we attempted to use mobile EEG device, which is directly related to peoples' perceptions of an environment. The specific research hypotheses in relation to the objective of this study goes as follows:

- H1: Daytime scenes will be rated more positively than night-time scenes in terms of self-reported perceived restorative and recovery scale.
- H2: Daytime scenes will be associated with EEG output indicating restorative health effects (i. e. increased relaxation and lower arousal parameters) as compared to night-time scenes.

2 Methods

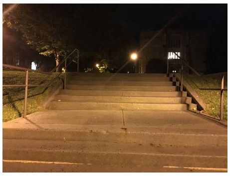
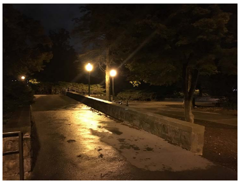
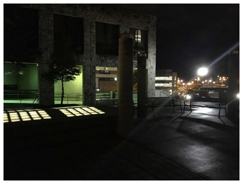
2.1 Participants

A total of 62 participants (31 males and 31 females) with an average age of 31 took part in this study. The inclusion criteria for this study required participants on the following criteria: (1) no brain or psychiatric disorders; (2) no ophthalmic disease; (3) normal blood pressure without history of heart diseases; (4) no medication taken for any treatment during the study period; (5) physically and mentally healthy with no anxiety in enclosed areas. The data was collected from 60 participants (30 males and 30 females) excluding two participants who had noises in the brain waves due to movements during the measurement process. Our research protocol and survey instrument were approved by the Institutional Review Board of Virginia Tech.

2.2 Experimental Images

All photos for this study were taken during the same season on Virginia Tech's campus. It consists of six sets. Each set has two photos of daytime and night-time scenery. Photo set one depicts an enclosed setting near stairs, photo set two an open setting, set three an enclosed setting surrounded by building, set four an enclosed setting surrounded by trees, set five a crooked path setting, and set six an enclosed setting surrounded by architectural features (Table 1). All photos were intended for a natural environment where there is no expectation of deliberate negative or positive emotions.

Table 1: Experimental images

	Set1: enclosed setting near stairs	**Set2: open setting**	**Set3: enclosed setting surrounded by buildings**
Daytime			
Night-time			
	Set4: enclosed setting surrounded by trees	**Set5: crooked path setting**	**Set6: enclosed setting surrounded by architectural features**
Daytime			
Night-time			

2.3 Procedure

When participants calibrate their EEG devices, he or she adjusts their postures for 5 minutes, seats on the chair, and selects the breathing option. First, background brain waves- the spontaneous electrical activity of cerebral cortical neurons- were measured with eyes opened and recorded for 1 minute and 30 seconds without external stimulation proceeded by a resting period. Second, after a 2-minute break, participants observed six daytime scenery photographic stimuli for two minutes (appearing for 10 seconds after a 10 second interval for each photo) while EEG captured their emotional response to the stimuli. The participants observed the night-time scenery stimuli for two minutes- in the same way that participants observed the daytime scenery stimuli- after a two-minute break. Third, participants were asked to review all 12 slides and rate them on four dimensions. Each slide was presented for 20 seconds. Subjective responses were provided on a paper questionnaire. The EEG output was directly recorded by the computer. Finally, participants filled out a debriefing questionnaire indicating their demographic data.

2.4 Outcome Measures

2.4.1 Questionnaire for Subjective Preferences

Depending on the various environments, recovery and recovery potential have been studied mainly by self-reporting methods (ULRICH 1984). Four questions were selected to capture subjective preferences for photographic stimuli. First two questions are related to Perceived Restorative Scale, which was developed based on ART (KAPLAN et al. 1998). As mentioned above, the restorative quality described by ART involves four dimensions: being away, fascination, extent, and compatibility (OHLY et al. 2016). Among them, we chose two concepts: (1) being away ("it is a place where you can think of exciting things while relaxing away from tired daily life") and (2) fascination ("this place is wide enough to find new things that stimulate one's curiosity."), with both items ranked on a Likert-scale ranging from "Not at all (1)" to "Extremely likely (10)". The scores of these two items were added together to calculate the perceived restorative scale score for each slide.

The two remaining items were designed to the dimensions of the recovery scale. We borrowed a questionnaire from (STAATS et al. 2003) used to ask participants about the possibility of recovery of the scenes in the slides: (1) attention ("it feels like I can recover my attention when I'm here.") and (2) relieve stress ("it is likely that all the tension will be released here."). Again, both items were ranked on a Likert-scale ranging from "Not at all (1)" to "Extremely likely (10)". The sum of these two items' score was used as the recovery scale score.

2.4.2 EEG Outcome Measures

We used an Emotiv EPOC EEG headset for our study (ASPINALL et al. 2015, BADCOCK et al. 2013, MAVROS et al. 2012) which also provides software to analyse raw EEG data (emotiv.com). Our study used "Emotiv Xavier Control Panel" emotion-detection software that interprets the EEG oscillations of the various bands into 5 emotional parameters: excitement (i. e. arousal of short duration – several seconds), interest (i. e. the degree of attraction or aversion to the current stimuli), stress (disappointment or cognitive load), engagement (i. e. alertness), and relaxation (i. e. an ability to switch off and recover from intense concentration).

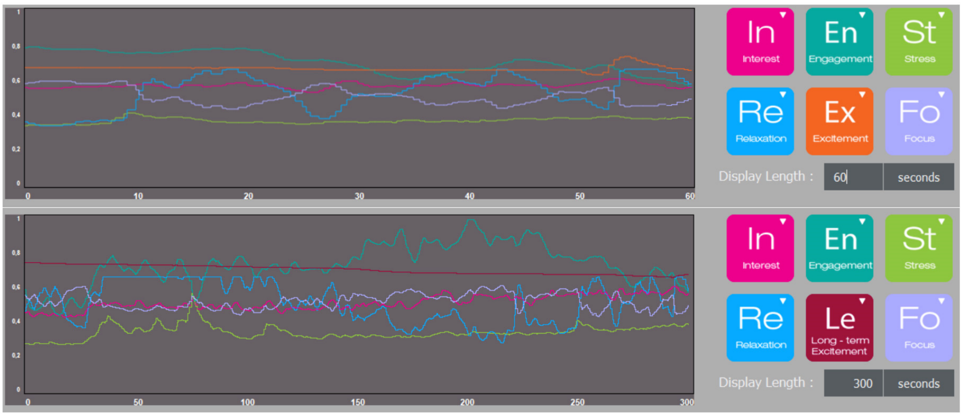


Fig. 1: Emotiv Xavier Control Panel: Detection's performance matrix

3 Results

3.1 Subjective Preferences

Significant differences were found between daytime vs night-time scenes on all of the subjectively ranked questions. Comparing the average between the two groups, the level of perceived restorative and recovery scales, in general, were higher in daytime scenery. The results of the paired sample t-test showed that both of the daytime scenery's perceived restorative and recovery scales were significantly higher than the perceived restorative and recovery scales of night-time scenery (Table 2). In addition to the daytime-night-time scenery comparison, the self-reported data illustrates that natural sceneries were evaluated more positively than urban sceneries.

Table 2: Paired T-test of self-reported level of restorative and recovery scale (n = 60)

		Daytime Scenery	**Nighttime Scenery**	**t**	***p***
Perceived restorative scale	**being away**	7.32±1.12	4.92±2.12	1.96	0.015*
	fascination	6.98±1.04	4.39±2.39	3.75	0.011*
Perceived recovery scales	**attention**	7.20±1.30	5.85±1.43	6.12	0.000**
	relieve stress	6.89±1.25	3.15±1.67	5.11	0.000**

** $p < 0.01$, * $p < 0.05$; A higher score indicates a more positive outcome

3.2 The EEG Data

Our findings indicate that daytime and nighttime scenery affect emotions and human brain response in terms of restorative and recovery effect. This study measured the perceptions broadly with daytime and nighttime landscape photographic stimulations, using both verbal and non-verbal methods. The methods utilized in this study presents a useful research design for evaluating environmental elements that cause restorative and recovery effects.

3.2.1 Latent Class Analysis (LCA)

The model fit was examined by increasing the number of latent classes from one to four. In Table 3, AIC and SsABIC values decreased from one class model to three class models, but increased in four class models. The LMR LR results of the two- and three- class models were significant at the .05 level, while the four-class model was not statistically significant. In addition, the Entropy coefficient was very high (.865) in the three-group model. However, the two- class and four- class models showed .6 points, indicating poor accuracy of group classification. Considering goodness-of-fit statistics, significance test, accuracy of group classification, and simplicity and interpretability of the model, three group models were selected.

As a result, all classes met the minimum membership probability of 0.70 as suggested by NAGIN (2010). This demonstrates that the probability of belonging to a class of individuals is obvious, and that the classes included in the model are heterogeneous.

Table 3: Goodness-of-fit analysis of latent class model

Number of Classes	1 Classes Model	2 Classes Model	3 Classes Model	4 Classes Model
AIC	1245.3	1234.9	1232.7	1239.3
SaBIC	1246.7	1237.9	1237.2	1245.5
BIC	1262.5	1272.8	1291.1	1318.4
LMR LRT p value	–	.009	.016	.467
Entropy	–	.654	.865	.631

SaBIC: sample size adjusted Bayesian information criterion, LMR LRT = Lo-Mendell-Rubin Likelihood-ratio test

3.2.2 Latent Class Profiles

Table 4 shows that the classes are of approximately the same size i. e. 68.3 % of participant cases are in Class 1; 13.9 % in Class 2; 17.8 % in Class 3. Depending on each class profile, we attempted to name each class to take into account the characteristics of the response probabilities.

As Class 1 shows a higher probability of responding positively towards daytime sceneries (87 %), Class 1 was named 'Daytime Predominate'. Class 2 profile shows that similar possibilities of positive preferences for each group of daytime and night-time images. Reflecting these characteristics, Class 2' was named 'Neutral'. Lastly, as the night-time images positively predominate in Class 3 (76 %), this class was titled 'Night-time Predominate'.

Exploring the means of EEG outputs, Cluster 1 (Daytime preference) is associated with lower excitement, higher engagement and increased relaxation; Cluster 3 (Neutral) with higher excitement, lower relaxation and lower engagement. This pattern is clearly shown in Fig 2 below, illustrating the cluster profile for the Daytime preference (class 1), and Neutral (class 2) and Night-time preference (cluster 3) images.

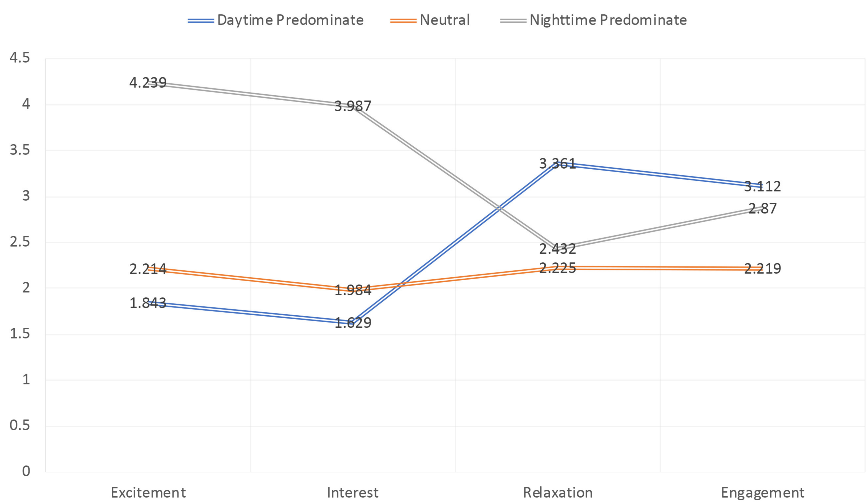


Fig. 2: EEG emotion profile

Table 4: Latent class profiles

		Latent Class		
		Daytime Predominate (Class 1)	Neutral (Class 2)	Night-time Predominate (Class 3)
Response probabilities within each class	Daytime	0.872	0.488	0.756
	Night-time	0.173	0.512	0.244
Mean of EEG Output	Excitement	1.843	2.214	4.239
	Interest	1.629	1.984	3.987
	Relaxation	3.361	2.225	2.432
	Engagement	3.112	2.219	2.870

4 Conclusion and Outlook

This study is an investigative study to examine characteristics of the restorative and recovery effects of daytime and night-time scenery. The subjective data indicates that daytime sceneries are rated more positively than night-time sceneries in terms of restorative and recovery effects. This also confirms restorative theory indicating a positive psychological effect of nature-environment scenes. Latent class analysis was carried out to explore classes – or sub groups – in the data and to identify significant emotional discriminators between the two sets of images. A three-class model produced the best fit, with image scene, and four of the EEG emotional parameters (i. e. excitement, interest, relaxation and engagement) significantly discriminating between the three classes ($p<0.05$). Daytime landscapes are related to higher levels of relaxation and lower arousal or excitement, and higher arousal level with night-time sceneries. Our EEG analysis indicates that relaxation and excitement (a factor group we have interpreted as arousal) can significantly predict image scene with lower arousal and higher levels of relaxation associated with the daytime scenery.

Our findings show that daytime and night-time scenery affect emotions and human brain response in terms of restorative and recovery effect. This study measured the perceptions broadly with daytime and night-time landscape photographic stimulations, using both verbal and non-verbal methods. The methods utilized in this study presents a useful research design for evaluating environmental elements that cause restorative and recovery effects.

This study describes the initial evidence that EEG responses are different depending on daytime or night-time sceneries. However, there are certain limitations. The first is that there were not enough environmental settings to conduct experiments, even though we used the representative environmental settings within the Virginia Tech campus effectively. Second, there is a possibility that the presentation of the scenery in a static way, such as a photograph, does not capture the dynamic characteristics of the scenery- falling short of capturing the meaning and feelings of the actual scenery. In a real environmental setting, a contrast from a laboratory setting, results may show a slightly different outcome. Even accounting for these two limitations, the findings from this study demonstrates evaluative potential incorporating EEG with subjective measures, which opens up new possibilities for future research on landscape evaluation.

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