Original Article

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A Study of Luminance and Visual Attention Patterns in Tourist Photography at Fairy Cave Sarawak

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Abstract:

Objective: Visual attention involves complex interaction between the cognitive and surrounding environment. Eye movement and light uniformity be the important factor that influence visual attention. Digital photos emit light compared the conventional photos. It would be advantageous to investigate and comprehend the significance of the amount of light that enters the eye, known as luminance. The primary objective of this study was to conduct luminance light and visual attention analysis using scenery images captured from tourist spots located in Fairy Cave, Sarawak.

Material and Methods: There were 3 parts in this study. Part One: convenient sampling was employed to recruit three adults as tourist photographers to capture images at four pre-selected tourist locations in Fairy Cave, Sarawak. Part Two: a total of 17 photographs were chosen from a pool of forty photographs for the purpose of conducting research on the luminance and visual activity. The luminance analysis evaluated the luminosity emitted by the digital display. The luminous properties were assessed using the CA-2500 2D Colour Analyzer manufactured by Konica Minolta in Japan. The brightness profile of the images is obtained by calculating the Michelson luminance. Part Three: the Dikablis eye tracker was utilised to test the visual attention via eye tracking pattern of a sample of thirty-six adults aged 18 to 40 years. The researchers recorded and examined the total amount and duration of the fixation eye movement.

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Results: The 3 photographers that were recognised exhibited both similarities and differences in their photographic skills and preferences. Nevertheless, this was not incorporated into our investigation of visible spectrum light. The observed difference in brightness profiles among the images was found to be statistically insignificant (p-value>0.05). Our study on eye-tracking behaviour in adults revealed significant variations in the total number of fixations (p-value<0.05).

Conclusion: Our findings provide valuable insights into the interplay between environmental lighting conditions and visual attention in this unique natural setting. Despite having various angle preferences, layperson photographers appear to engage in the same visible light spectrum. Our study indicates that when investigating preferences using the visual attention component, it is important to consider the total count of fixations. Additional investigation could entail the examination of professional photographers' photography.

Keywords: duration, eye movements, fixation, light analysis, luminance profile, virtual tourism

Introduction

Extensive studies have been conducted and confirmed the correlation between scene qualities and human eye movement patterns in landscape space fields[1,2]. Eye trackers can provide information regarding the visual perception of visitors, including aspects such as the forest area, the variety of landscape elements present within the space, and the degree of naturalness in the spatial arrangement[3,4]. According to Berto et al. (2008), there is a notable disparity in fixation counts and saccade distance between low-glamour stimuli and high-glamour scenes[5]. The visual observation behaviour is influenced by the openness of landscape space and the heterogeneity of a landscape[6,7]. The factors present in the landscape environment impact the characteristics of human visual behaviours. The initial reaction of the observer should involve directing their gaze toward the central region of the scene, as this central location is advantageous in efficiently obtaining significant information from the scene[8,9]. According to Tatler et al. (2005), when an observer perceives a significant element within a scene, they engage in a more extensive visual exploration within the spatial context[10].

Researchers have undertaken previous studies investigating fixations and visual attention[11,12]. The cognitive process of visual attention facilitates selecting significant information from the surrounding environment[13]. Humans can make choices and selectively digest information, as their visual capabilities are limited in their capacity to focus on every item within their area and gather relevant data. Visual selection encompasses various properties, including temporal and procedural aspects[14]. In contemporary research, various eye movements have become extensively employed to examine and comprehend the behaviour and cognitive processes of the eyes during various tasks, including but not limited to reading, observing landscapes and driving[15]. Researchers have successfully identified the specific regions that attract greater attention by monitoring and evaluating eye movement while seeing various stimuli, such as graphical images. Additionally, they have investigated the role of fixation eye movements in influencing this attentional process. According to Fitts et al. (1949), Gibbs and Bernas (2009), and Jacob and Karn (2003), visual attention encompasses two primary types of eye movement: fixation and saccadic[16–18]. The fixation component of eye movement often ranges from 50 to 600 milliseconds, with a frequency below 3 Hz[19]. Fixed duration is a metric used to quantify the level of information complexity. Fixational eye movement refers to the process in which the eyes focus on a specific location by occupying the foveal region of our visual field. This facilitated the acquisition of intricate visual information by our visual system[20]. In the real world, the eyes constantly move and look to acquire information. Only a few research studies have examined real-world scene photos to investigate the fact that attention is predominantly influenced by low-level image features[21]. These studies generally investigate the visual search process, which involves attracting attention through basic visual features and differences in features[22]. The primitive visual features and feature differences in question are derived from the concept of picture salience. This theory suggests that saliency maps are created by combining contrasts in image aspects that lack semantic interpretation, such as brightness, colour, and edge orientation[23].

Modern technology is improving the process of converting real-world images into digital formats. The consumer experience environment is experiencing a significant shift due to the rise of portable devices and the incorporation of interactive physical-virtual connections. This has resulted in the development of innovative hybrid experiences in the field[24]. The perception of images by the human visual system is facilitated by the reception and interpretation of light that has undergone reflection from various objects. The cornea functions as a frontal ocular structure, facilitating light transmission into the eye. The pupil, a central aperture surrounded by the iris, the pigmented part of the eye, facilitates regulating light intake into the eye. Migraine can be triggered by exposure to intense light[25,26]. Circadian photosensitivity variations are frequently observed due to fluctuations in the luminance profile exposure[27]. The perception of full colour positively impacts attention span more than black and white[28]. There exists a strong association between visual spatial attention and light-colour perception[29]. Two distinct aspects might be interpreted as the outcome of lighting effects: non-visual and visual effects. The concept of the non-visual effect encompasses a wide range of light-related phenomena, including but not limited to cell division, hormone synthesis, fundamental physiological processes, and behavioural alterations. It is important to note that these effects are independent of the image processing[30]. The visual effect refers to how the cortex within the brain interprets the image and transforms it into a meaningful experience. Visual attention is a process that involves intricate interactions between cognitive processes and the surrounding environment. Eye movement and the homogeneity of light are crucial factors that influence visual attention. Digital images produce light in contrast to conventional photos. Therefore, it would be advantageous to investigate and comprehend the significance of the amount of light that enters the eye, known as luminance. The primary objective of this initial investigation was to analyse the luminance light and examine the visual attention behaviour via eye tracking for each of scenic images captured by a novice tourist photographer in Fairy Cave, Sarawak.

Material and Methods

The present study utilised a cross-sectional research design methodology. The ethical committee approved this study [Approval code: 600-TNCPI(5/1/6)]. The investigations consisted of three distinct components. The project received financial support from Sarawak Digital Economy Corporation Bhd [100-TNCPI/PRI 16/6/2 (032/2022)]. All participants were provided with information regarding the purpose and methodologies employed in this research. Prior to their involvement, all participants provided informed consent.

Convenient sampling was employed to recruit three adults as photographers to capture images at four pre-selected tourist locations in Fairy Cave, Sarawak. Seventeen out of forty images were chosen for the study on the visible light spectrum and visual activity. Figure 1 displays the flowchart.

In Part One, a descriptive analysis was conducted on images captured by three photographers at four pre-selected tourist locations in Fair Cave, Sarawak. The first photographer was a 32-year-old Malay male. The second photographer was a 47-year-old Chinese female. The third photographer was a 48-year-old female of Iban descent. Photographers are instructed to capture images at four tourist places for inclusion in a virtual tourism video. Seventeen photographs were chosen from a pool of forty photographs to research the visible light spectrum and visual activity.

Part Two, a total of 17 photographs were chosen from a pool of forty photographs for the purpose of conducting research on the lighting and visual activity. For lighting analysis, the luminance metre 2D-Color Analyzer CA-2500, manufactured by Konica Minolta in Japan, was employed to quantify the level of brightness emitted to the human eye. The spectral response of the human eye exhibited a substantial association with the XYZ filters employed by the 2D-Color Analyzer. In order to achieve luminance and chromaticity measurements that closely align with the spectral response of the human eye, the CA-2500 employed XYZ filters that closely resembled the colour-matching functions of the CIE 1931. This approach distinguishes it from other luminance metres that utilise RGB colour-separation filters commonly employed by electronic video cameras. The Haier 32-inch Full HD LED TV, which functions as a digital display, exhibited the images with a consistent brightness level. The measurement was conducted at a distance of one metre using a handheld illuminance spectrophotometer (CL-500A, Konica Minolta, Japan) under well-illuminated normal office room light levels of 457.5 lux. The data management programme CA-S25w, developed by Konika Minolta in Japan, was utilised to capture and process each shot. The photographs were analysed using monochrome pseudocolour to eliminate

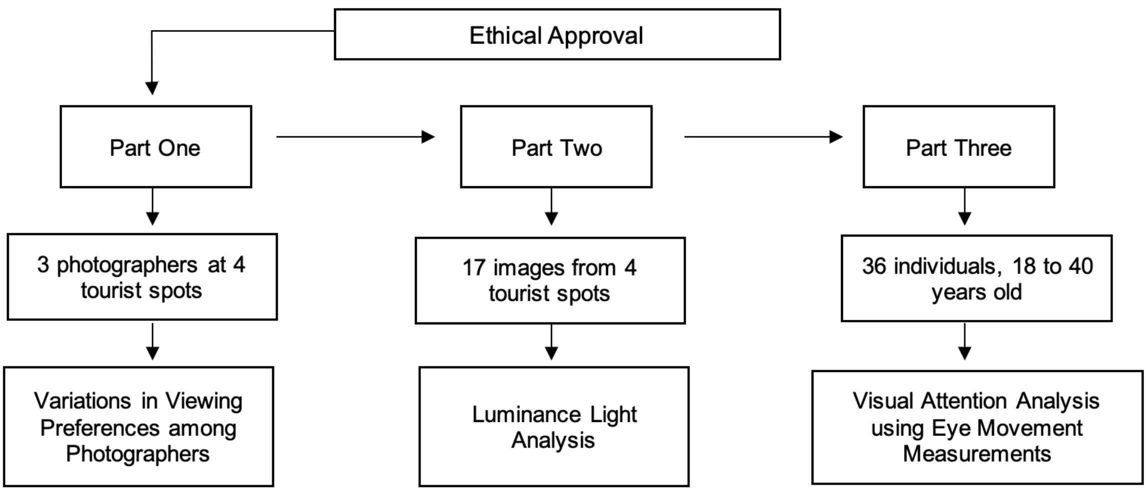


Figure 1 Part A, Part B, and Part C of the flowchart entail the investigation of the luminance light and exploring visual attention in scenic photographs captured by a tourist photographer at Fairy Cave, Sarawak.

potential colour distractions (Figure 2). Contour analysis allows for the quantification of luminance contrast similarity in pictures. Subsequently, the pseudocolour sensitivity was modified from monochrome to chroma vision. The brightness uniformity of each photograph was determined using a 50-pixel circle diameter. The quantity of circles depicted in the images is directly proportional to the dimensions of the photographs. The brightness and colour coordinate x-y values were provided for each circle. The calculation of Michelson contrast involved the assessment of the maximum and minimum brightness values observed in images. The contrast between the highest and lowest brightness points in a photo was demonstrated by Equation 1. Additional data on uniformity was collected by calculating the ratio between the minimum and maximum values in the overall reading. This ratio indicates the degree of even distribution or emission of light across the photos. High uniformity suggests that the disparity between the least and highest values is reduced or negligible.

$$L = \frac{(Lmax - Lmin)}{(Lmax + Lmin)} \qquad \text{Equation 1}$$

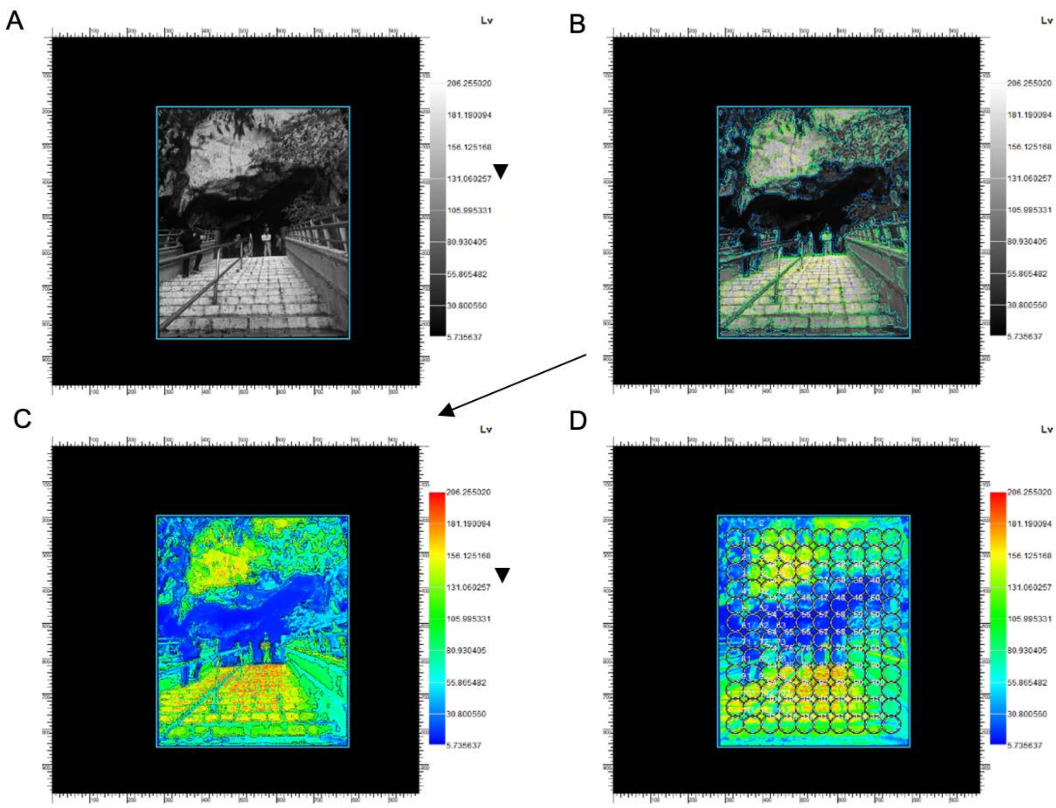


Figure 2 Photograph quantitative analysis from monochrome pseudocolour (A), contour pseudocolour (B), chroma pseudocolour (C), and localise luminance analysis by 50-pixel circle diameter (D)

In Part Three, an analysis was conducted on the visual behaviour features of four selected scenic images using fixation eye movement analysis. Thirty-six (36) individuals aged 18 to 40 years were selected using convenient selection to examine images. The inclusion criteria comprised individuals without any colour vision deficiency, visual anomalies, or ocular disorders. Additionally, participants were required to have a best corrected visual acuity of 6/6 at a distance and N5 at a close range. The screening processes encompassed the assessment of visual acuity at a distance and proximity and a colour vision test. The logMAR Letter Chart was utilised to test distant visual acuity at a distance of 6 metres, and the results were recorded in logMAR units. The measurement of near visual acuity was conducted using a near chart and documented using N notation. The Ishihara plate was employed to identify any impairment in colour vision. The visual behaviour characteristics when viewing the scenic pictures were analysed by measuring the eye movements using the Dikablis Eye Tracker. The measurements were conducted in standard room lighting conditions to enhance the visibility of the scenery. The eye-tracking system can be conveniently worn alongside spectacles, enabling real-time transmission of eye-tracking data. The frontal camera captured the subject's visual attention, while the eye camera exhibited the subject's eyes on the screen. The individual occupied a chair positioned at one metre from the television screen. The participants were provided instructions on wearing the eye-tracking gadget comfortably. The Dikablis eye tracker employed a method of detecting the pupil centre within each video image to track the eye movements. The variables that remained constant were the distance, pupil dilation, and illumination. Prior to conducting formal measurements, calibration was conducted on each participant. Every participant was instructed to refrain from moving their head to facilitate the calibration of their pupil and eye movements. The initial calibration involved determining the centre point, followed by calibration at four distinct points on the screen. Precisely the right and left upper corners and the right and left lower corners. There was a total of forty-nine scenery images displayed at eye level. Each individual's eye movement data acquisition was around 120 seconds. The eye tracking system's sensor was positioned on a wearable goggle connected to a computer through a lengthy cable in front of the subject's eye. This arrangement facilitated the observation of the participants' habitual posture. Both eyes' eye movements were documented, assigned numbers, and annotated.

Results

Variations in viewing preferences among tourist photographers

Photographs captured at site 1 (Table 1) displayed variability in terms of the distance of view and the extent of the field of vision. The photographer 1 exhibited a preference for a wider viewing distance, whereas photographer 3 expressed a preference for a closer viewing distance. For the second photographer, an intermediate viewing distance was used. Nevertheless, the extent of variation appeared to decrease when iconic elements such as images from site 2 were included. Photographs captured at site 3 revealed an additional intriguing aspect. Photographer 1 expressed a preference for including two distinct characteristics within a single shot, whilst the remaining two photographers shown a preference for single features. The photographs captured at site 4 also revealed significant concepts. The three photographers replicated the identifiable photos commonly featured in the promotional pamphlets of Fairy Cave with a high degree of resemblance. Moreover, they exhibited personal qualities in supplementary images. The inclusion of steps in the shot was a preference of photographer 1. Photographer 2 had a greater emphasis on the perspective of texture. Photographer 3 captured the image at an oblique angle to strategically position the light in a distinctive manner.

Luminance light analysis

The determination of Michelson contrast involved the comparison of the maximum and minimum brightness values inside an image. The minimum-to-maximum ratio is a metric that quantifies the uniformity of light distribution or emission in the images. Table 2 presents a summary of the contrast and uniformity seen in seventeen photos. The photos were subsequently reorganised based on the criteria of contrast and consistency, as in Table 3. Photograph number 17 exhibited the greatest contrast and the least uniformity. Photograph number 8 exhibited the least amount of contrast and the greatest degree of consistency. Based on the ANOVA results, there was no statistically significant difference seen among the three photographers (Analysis of Variance-Contrast: F(2,14)=2.166, p-value>0.05 and Uniformity: F(2,14)=2.204, p-value>0.05).

Visual attention analysis using eye movement measurements

The research comprised a sample size of 36 participants, with an equal distribution of 50% male and 50% female. The normal distribution of the mean and number of fixation data was determined using the Shapiro-Wilk test (p-value>0.05). A parametric test, one-way repeated measures ANOVA, was employed for data analysis. The fixation findings were determined based on the analysis of eye movement observed in the visual representation of the four tourist destinations in Fairy Cave, Sarawak (Figure 3). Upon viewing the photos, the subjects shifted their gaze towards the point of view, as depicted in Figure 4. As the eye moved, the visibility of coloured dots increased. The fixations were quantified based on the total counts and duration of these eye movements. This information provides valuable insights into how viewers allocate their visual attention when viewing tourist photos. The element of interest in the photo attracts the most attention and how attention is distributed across different regions of the image[37]. One-way repeated measure ANOVA revealed insignificant differences in the fixation duration [F (1.80, 62.93)=2.37, p-value>0.05)], but significant difference for the total number of fixations [F (3, 105)=11.32, p-value<0.05)]. The eye movement measurement findings are depicted in Table 4. Post hoc analysis with a Bonferroni adjustment revealed that the total number of fixations at Site 3 was statistically significantly lower [2.94 (95% CI, 0.22 to 5.7), p-value<0.05] from other sites (1, 2 and 4). It could be seen that the scenery photograph at site 3 had the lowest total number of fixations (mean of 12 counts).

Table 1 Photographs taken by three photograhers at four pre-determined tourist sites

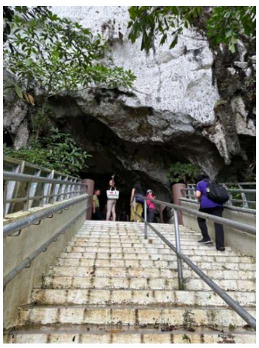
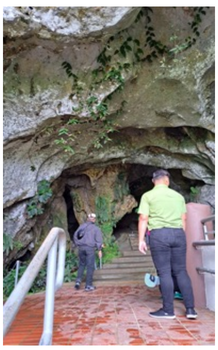
Scenic photographs of fairy cave	Photographer 1	Photographer 2	Photographer 3
Site 1			

Table 1 (countinued)

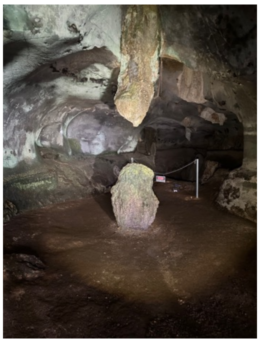
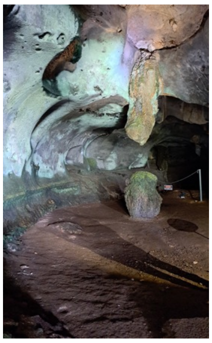
Scenic photographs of fairy cave	**Photographer 1**	**Photographer 2**	**Photographer 3**
Site 2			
Site 3			
			

Table 1 (countinued)

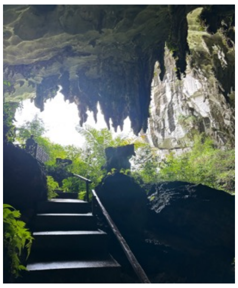
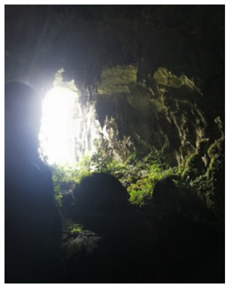
Scenic photographs of fairy cave	Photographer 1	Photographer 2	Photographer 3
Site 4			
			

Table 2 Summary of contrast and uniformity of seventeen photographs taken from four tourist sites in Fairy Cave, Sarawak

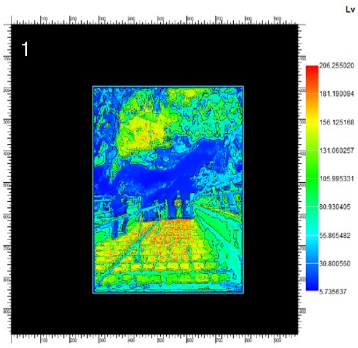
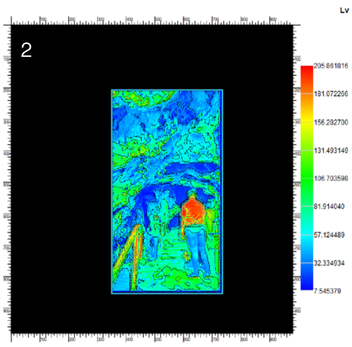
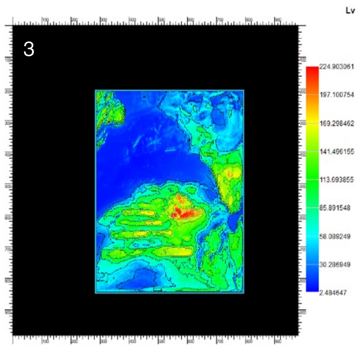
	Contrast (uniformity)		
	Photographer 1	Photographer 2	Photographer 3
Site 1	 0.87 (6.90)	 0.79 (11.67)	 0.92 (3.92)

Table 2 (countinued)

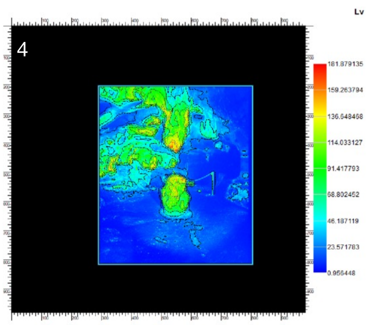
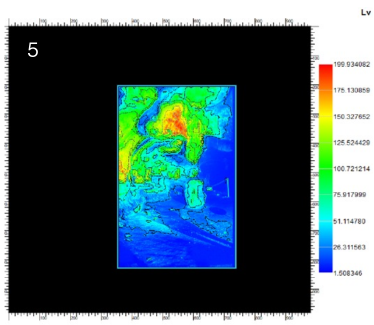
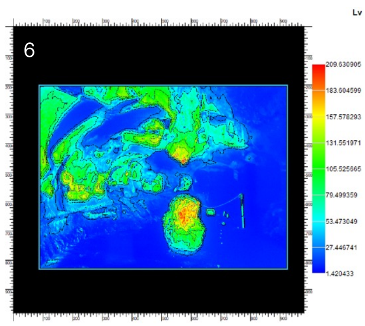
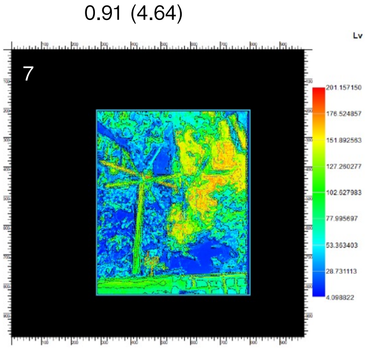
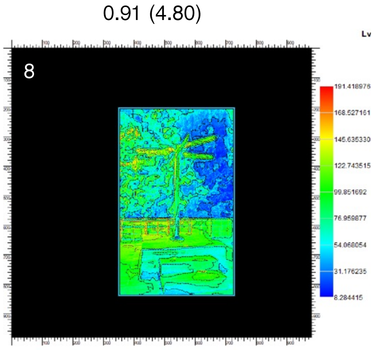
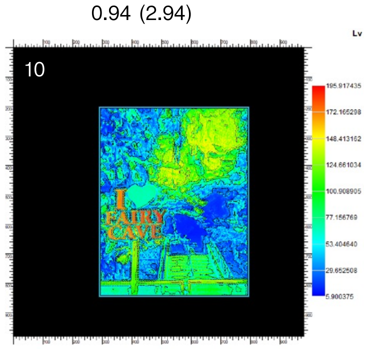
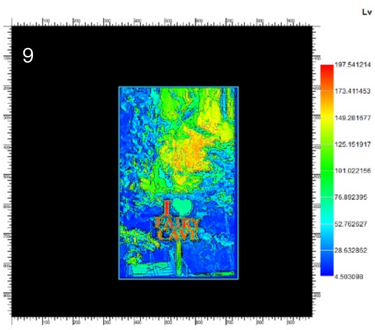
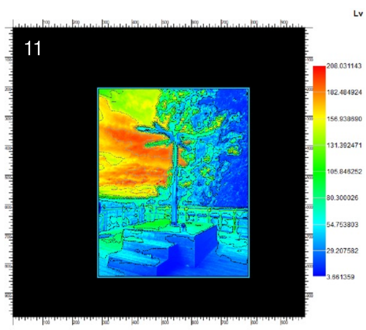
	Contrast (uniformity)		
	Photographer 1	**Photographer 2**	**Photographer 3**
Site 2	 0.91 (4.64)	 0.91 (4.80)	 0.94 (2.94)
Site 3	 0.82 (9.93)	 0.66 (20.20)	 0.81 (10.49)
		 0.79 (12.00)	 0.91 (4.85)

Table 2 (countinued)

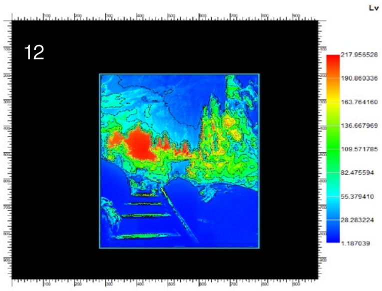
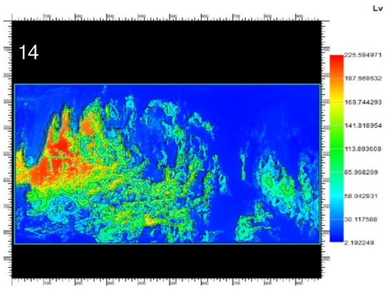
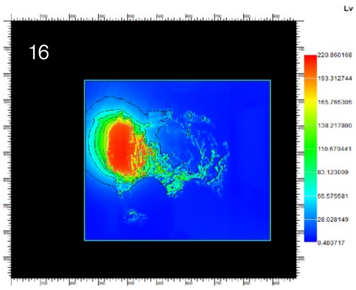
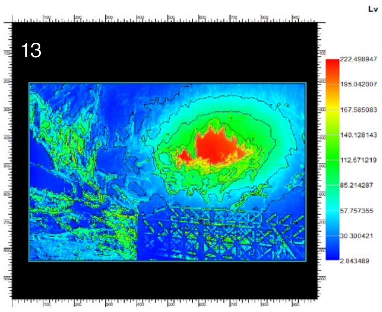
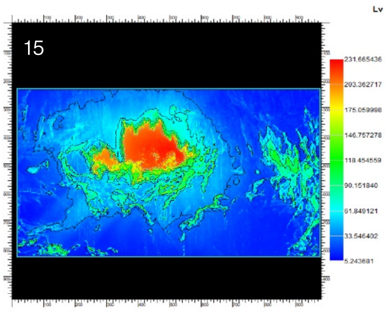
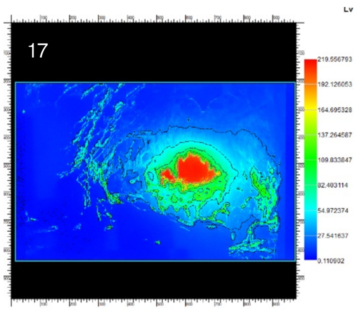
	Contrast (uniformity)		
	Photographer 1	Photographer 2	Photographer 3
Site 4	 0.93 (3.54)	 0.94 (2.96)	 0.96 (1.86)
	 0.88 (6.23)	 0.89 (5.98)	 0.98 (1.11)

Table 3 Ranking of photographs according to the contrast and uniformity data

Photographs number	Contrast	Uniformity
17	0.98	1.11
16	0.96	1.86
6	0.94	2.94
14	0.94	2.96
12	0.93	3.54
3	0.92	3.92
4	0.91	4.64
5	0.91	4.80

Table 3 (countinued)

Photographs number	Contrast	Uniformity
11	0.91	4.85
15	0.89	5.98
13	0.88	6.23
1	0.87	6.90
7	0.82	9.93
10	0.81	10.49
2	0.79	11.67
9	0.79	12.00
8	0.66	20.20

Table 4 Summary of eye movement measurements based on photographs taken from four tourist sites in Fairy Cave, Sarawak

Sceneric photographs	Total count of fixation	Duration of fixation in miliseconds
Site 1	15±5	694±260
Site 2	15±5	923±1,548
Site 3	12±6	1,216±1,739
Site 4	18±6	577±306

Figure 3 Subject wear an eye tracker for the eye movement measurement of the four tourist destinations in Fairy Cave, Sarawak

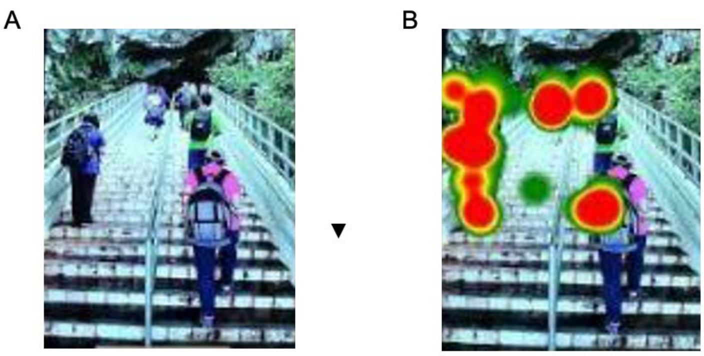


Figure 4 Sample of quantitative analysis on eye movement measurements (A), original photograph of Site 1 (B), heatmap of eye fixation on the photograph of site 1

Discussion

In this initial investigation, it was determined that there was variability in the tastes of photographers. Hence, it is imperative to conduct an inquiry into the diversity pertaining to gender, age cohort, ethnicity and demographic disparities, with the aim of acquiring additional empirical evidence to facilitate the creation of a comprehensive virtual tourism film in subsequent endeavours. Males exhibit a preference for capturing photographs from lower angles, whilst females tend to go for front-facing shots. In their paper on the impact of gender on selfie angle, Soranzo and Bruno (2020) provide support for the notion that females tend to opt for a neutral, frontal presentation, while males are more inclined to select angles below[32]. It can be inferred that there exist variations in photography preferences across different age cohorts. Individuals in their thirties have a simplistic perspective when observing their environment, whereas those in their fifties prefer to develop an emotional connection to the scenery. There are variations in employment choices based on age[33]. As individuals progress from their thirties to their fifties, the photographs taken tend to possess sentimental significance.

In the development process of signage, luminance is one of the important factors that needs to be measured. Luminance is a characteristic of the sign that influences how the signs will be perceived[34]. There is also a study that show the specific levels of luminance to be considered and how it must be set for any conditions of weather especially for signage that can be seen on roadside as it will give effect to the driving of the road users[35]. Photographers that employ high contrast techniques often exhibit a pronounced visual effect, as they employ deep blacks and dazzling whites to evoke a heightened feeling of drama and intensity[36]. The emphasis of details can be achieved by enhancing the definition and prominence of subjects. The utilisation of aggressive composition in high contrast images results in a pronounced tonal range, hence enabling the creation of striking compositions that accentuate shapes and forms[37]. The pronounced disparities have the ability to elicit intense emotions in observers, rendering them exceptionally efficient in communicating mood and ambiance. The quality and usefulness of tourist images in capturing the beauty and charm of prominent sites can be assessed by considering these characteristics.

Site 3 involved the wording photographs, which make it lowest of fixation count. This intricate visual concentration in the cognitive process due to involvement of visual information while ignoring others[38]. Photographs that have a single written message tend to capture more visual attention compared to those that contain many textual messages[39]. The significance of determining the appropriate location for tourism advertisements is crucial when contemplating the choice between fixed or mobile advertising. Site 1, 2, and 4 exhibit a consistent pattern of shifting their gaze to various regions within a scene. This phenomenon is influenced by a combination of bottom-up elements, such as saliency and stimulus-driven attention, as well as top-down factors, including task goals and cognitive strategies[40].

The photographer participation in part one may have a limited sample size, consisting of photographs from a specific period and potentially from a homogeneous group of tourists. This could impact the generalizability of the findings. Other than that, the natural cave environments are subject to variability in lighting conditions due to weather, time of day, and season. The study may focus primarily on static images, potentially overlooking the dynamic aspects of visual attention and luminance changes over time. This could limit understanding of how tourists interact with the environment in real-time. Future studies can expand the sample size and diversity of the photographers. We can control for environmental factors by conducting the study across different times of day and weather conditions to account for environmental variability. The study can include video recordings and real-time visual attention tracking to capture the dynamic interaction between tourists and the cave environment. This can provide a more comprehensive understanding of visual attention patterns.

Conclusion

This study aimed to analyze luminance light and visual perception using scenery images captured from tourist spots located in Fairy Cave, Sarawak. Our findings provide valuable insights into the interplay between environmental lighting conditions and visual perception in this unique natural setting. When investigating preferences using the visual attention component, it is essential to consider the total count of fixations. Ordinary photographers engage in the same visible light spectrum despite various angle preferences. Additional investigation could entail the examination of professional photographers' photography. This study investigates the impact of many elements, such as gender, age, ethnicity, cultural background, and other relevant variables, on individuals' preferences for photography in promoting visual tourism.

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Conflict of interest

There are no potential conflicts of interest to declare.

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