Does Fixation Reflect Fascination? Eye Movements for Images of Different Levels of Restorativeness

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ABSTRACT

Fascination, a special bottom-up attention process, was proposed by the *Attention Restoration Theory* (ART) as a key factor for the restorative effects of nature. Previous eye-tracking studies have discovered the connection between fixation measures and image fascination level. However, the lack of specific tasks in the existing study impaired the validity. The goal of the current study was to replicate Berto et al. [2] using a revised approach that includes a fascination-compatible task to control the top-down process. Six students from Clemson University viewed 24 images of high and low fascination levels (natural vs. urban), and their eye movements were recorded. The mean fixation duration and the mean number of fixations were compared across fascination levels. However, we did not find differences in fixation measures between high fascination and low fascination scenes. Although shorter fixations were found for female participants, there was no significant interaction between the type of scene and gender. We discussed possible explanations for the insignificant results and provided recommendations for future research.

CCS CONCEPTS

• **Applied Computing-Psychology**;

KEYWORDS

Eye movements, Fascination, Attention Restoration Theory, Natural vs. urban environments

ACM Reference Format:
Shuai Yuan and Xuewei Chen. 2022. Does Fixation Reflect Fascination? Eye Movements for Images of Different Levels of Restorativeness . In *Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY*. ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/1122445.1122456

1 INTRODUCTION

Nature affords easy and cost-free ways to recover from stress and mental fatigue [3]. Research has shown that people can gain such restorative experiences by viewing nature from a window [15], sitting and walking in urban parks [11, 17], and viewing pictures and videos of natural environments [1, 19]. Studies often adopt the *Attention Restoration Theory* [12] to explain the mechanism for restorativeness. Based on this theory, a key factor in restorative experiences is a special type of bottom-up attention process called fascination. Recently, several eye-tracking-based studies have lent Preliminary support to the fascination of nature [5]. We aimed to investigate fascination of nature and its relation with eye-movement measures with a focus on revising previous experimental procedures.

1.1 Attention Restoration Theory

The *Attention Restoration Theory* (ART), proposed by Kaplan [12], has established the link between cognitive function, stress, and the attention process. Two types of attention borrowed from William James [9] have been differentiated; they are involuntary attention, which is effortless and stimuli driven, and voluntary attention, which requires efforts and depends on expectations. Though not perfectly overlapped, such two types of attention generally belong to bottom-up attention and top-down attention in cognitive psychology. Voluntary attention, based on ART, is susceptible to fatigue in an environment with attention-demanding tasks and distractions (e.g., urban life), resulting in reduced cognitive functions and increased stress. On the other hand, involuntary attention, renamed as fascination, is more resistant to fatigue. And more importantly, soft fascination, as a special type of bottom-up process, may also contribute to the restoration of voluntary attention from fatigue.

Argued by ART, nature plays an important role in attention restoration by providing soft fascination - the sensory-driven attention experiences which are gentle, positive, and allow reflection. For example, clouds, snow patterns, the motion of leaves in the wind may draw attention while allowing reflection, but blood on the ground may catch attention while suppressing other thoughts. However, although the effects of stress reduction and cognitive restoration have been confirmed in many studies [16], fewer studies directly tested if nature plays a better role in soft fascination than cities, or what elements in nature might be fascinating.

1.2 Fascination and Eye-tracking

Eye-tracking might provide insights into the bottom-up attention patterns for viewing natural and urban environments. Previous studies have found the connection between high fascination environments and eye movement measures, such as longer fixation durations, a smaller number of fixations, or an enlarged pupil size [2, 4, 5, 14, 18, 20]. Fixation duration and number of fixations are

Woodstock '18, June 03–05, 2018, Woodstock, NY

ACM ISBN 978-1-4503-XXXX-X/18/06…$15.00
https://doi.org/10.1145/1122445.1122456

found to be the most robust measures that may reflect scene fascination level.

In the first eye-tracking based restorativeness study, Berto and collages [2] showed participants pictures of high fascination environments (lake, river, sea, hills, wood, forest, .etc.) and low fascination environments (industrial zone, housing, historical center, and urban areas) to the participants and recorded the eye movement view the scenes. The authors hypothesized that the amount of exploration (travel distance) and the number of focused attention (fixations) would differ for a different level of fascination. As a result, they found that high fascination pictures were viewed with a smaller mean number of fixation and shorter mean travel distance; they interpreted the results as that high fascination environment is better at retaining attention so that attention foci changed less frequently and moved for a shorter distance. Notably, in order to exclude the influence of a top-down process, the author deliberated precluded a task and instead asked participants to freely explore the images without trying to memorize the scenes.

Berto et al. [2] has been replicated by several other studies which found consistent connections between fixation measures and fascination/restorativeness. A study using head amount display by Valtchanov Ellard [20] investigated the eye movements in urban and natural images that are unaltered or altered in low-level visual properties. Reduced numbers of fixations were found for nature scenes compared to urban scenes. Similarly, Franek and collages [4, 5] conducted two studies to replicate B's research. In their first study, they investigate three groups of pictures, including European cities, historic European cities, and natural sceneries. In their second study, urban scenes, nature scenes with leaves on trees, and the same scene without leaves were tested. For the two studies, a smaller fixation number and a longer duration were found for viewing natural scenes.

Those studies have shown the robustness of fixation behavior as the indicator of fascination. However, there are competing explanations for an increased fixation duration, such as the larger amount of time needed to understand the contents [6, 18]. In addition, the lack of a task in the instruction undermined the validity of the results because participants may create their internal tasks.

1.3 Research Goals and Questions

There is a need to further understand the bottom-up attention patterns related to viewing natural vs. urban environments. Although existing studies found that fixation behavior may reflect fascination, the lack of specific tasks in eye-tracking experiments impaired the validity of the connections. Therefore, the goal of the current study was to test the feasibility of a revised eye-tracking approach that included a compatible task. We aimed to replicate Berto et al. [2] while giving a task to facilitate the bottom-up attention.

Our hypothesis was: With an instruction that controlled the top-down attention, we would replicate the findings of [2], such that the number of fixations would be greater for viewing high fascination scenes compared to low fascination scenes; the mean fixation duration would be in an inversed relationship with fascination level.

2 METHODS

2.1 Participants

The study recruited six Clemson students who were young adult between the ages of 20 to 28 (M age = 24.5, SD = 2.59, 3 female) with ability to read and speak in English. Participants were balanced across gender and have different backgrounds, e.g., automotive engineering, computer science, and parks, recreation, and tourism management (PRTM). To represent the way how common people perceive environments, we excluded students from environmental design-related departments. Participants were recruited on a voluntary basis through posts and messages in communication application groups (e.g., WeChat, GroupMe).

Figure 1: Examples of a high fascination scene (above) and a low fascination scene (below).

2.2 Stimuli

Twenty-four images of high and low restorativeness levels will be used (see Figure. 1 for examples). The images were gained from a previous peer-reviewed study [1], which has shown that only natural images could improve cognitive function after viewing. For our study, all images were transformed into a 1680x1050 pixel resolution using the Adobe Photoshop CS6. According to [1], the urban images were from Ann Arbor, Detroit, and Chicago, and the nature images were from the scenery of Nova Scotia.

2.3 Apparatus

Eye movement will be recorded by an unobtrusive GP3 eye tracker with a visual accuracy of 1 degree and a sampling rate of 60 Hz (one sample every 16 ms). The eye-tracker will be controlled by a desktop PC with a 1680x1050 pixel screen and be attached under the monitor. The presentation of stimuli will be controlled by a PsychoPy 3.0 program run on the same PC.

2.4 Research Design

We conducted a single-factor within-subjects experiment to compare urban (low fascination) vs. natural (high fascination) scenes. Twenty-four static images will be randomized and arranged into four different sequences. To replicate previous studies [2, 5], we choose the mean number of fixations and the mean duration of fixation as the dependent variables.

2.5 Procedure

The participants will be tested individually. The instruction used by [2] will be revised to incorporate a fascination-compatible task to control the potential influence of self-defined tasks. Participants will be given the following instruction: *"Now a series of photos will appear on the computer screen. You should look at the photos and feel how your attention is captured by interesting things in the pictures. Don't try to memorize any detail because you don't need to answer any questions related to your memory. We just want to record your eye movement when you look at the photos. Before the presentation of every photo, a fixation point will appear. Look at the fixation point before you begin exploring each photo."* The participants will sit about 70cm from the computer screen. Before viewing a stimulus, every participant will take a 5-point eye tracking calibration and validation. Then, the images were presented in a specific order. A fixation point with a white background will appear for 2s before every stimulus image to ensure that the participants begin exploring each image from the same point. Each image will be presented for 15s, and total image viewing during will be approximately 6 min 50s.

3 RESULTS

3.1 Data analysis and description

As expected, two dependent variables, the mean counts of fixations and the mean durations of fixations, were analyzed. First, we only included the fixations of which durations were within three SDs from the mean (0.158s-0.773s) to exclude the impact of outliers. Second, we averaged the fixation counts and the fixation durations across scenes (Table 1). As suggested by [2], using an image as the unit of analysis instead of participants would allow us to focus on the variance due to images within a scene category (natural or urban), which was aligned with the interests of environmental design. Third, we conduct t-tests to compare the fixation measures between viewing high vs. low fascination scenes (the hypothesis). However, because we have not found significant differences across fascination levels, we also looked at the mean fixation measures of each participant across scene categories (Figure 2) and the scan paths of two participants for several images (Figure 3). By observation, we found apparently larger individual differences than differences

Table 1: Descriptive statistics of mean fixation durations and mean fixation counts by scene categories (urban, natural).

	mean	sd	min	max
Fixation duration Natural	0.134	0.011	0.118	0.150
Urban	0.136	0.008	0.117	0.148
Mean Fixation count Natural	249.6	17.2	213	278
Urban	247.4	21.7	219	300

across scene categories. Last, we analyzed the moderating effect of gender using two-way ANOVA.

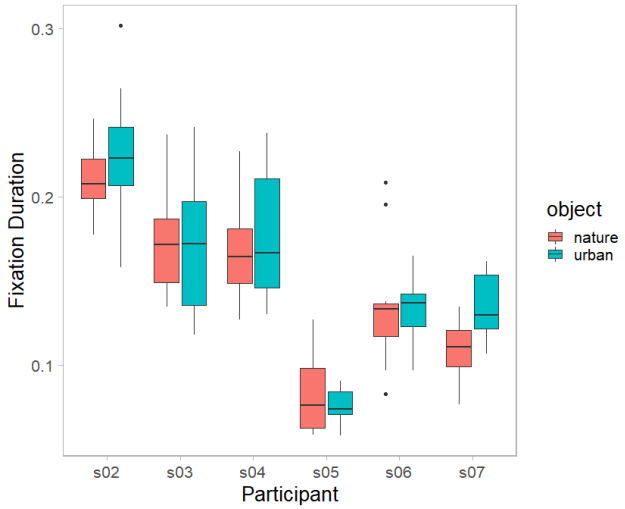

Figure 2: Boxplot of fixation durations by participants and scene categories.

3.2 Fixation and Fascination

Independent samples t tests were conducted to assess the effect of scene category (natural vs. urban) on the mean fixation measures. However, the results did not show a statistically significant difference in the mean fixation duration, $t(22) = -0.43, p = 0.67$, or in the mean fixation count, $t(22) = 0.27, p = 0.79$. Overall, these results did not support our hypothesis that viewing high fascination scenes were related to less mean fixation counts and longer mean fixation duration.

3.3 The effect of gender

In order to further explain the insignificant results, we additionally examined the moderating role of gender using within-subject fascination level x gender ANOVAs (Figure 4). For the mean fixation durations, we found significant longer fixation durations for male, $F(3, 140) = 28.50, p < 0.001, \eta_p^2 = 0.17$, but no significant effect of scene category, $F(3, 140) = 0.51, p = 0.48, \eta_p^2 = 0.004$, and no interaction between gender and scene category. For the mean fixation counts, the results also showed significant fewer couts for male, $F(3, 140) = 29.67, p < 0.001, \eta_p^2 = 0.17$,, but no significant effect

Figure 3: Scan paths of two participants for two natural and two urban scenes.

of scene category, $F(3, 140) = 0.02, p = 0.87, \eta_p^2 = 0.0002$,, and no significant effect of the interaction term.

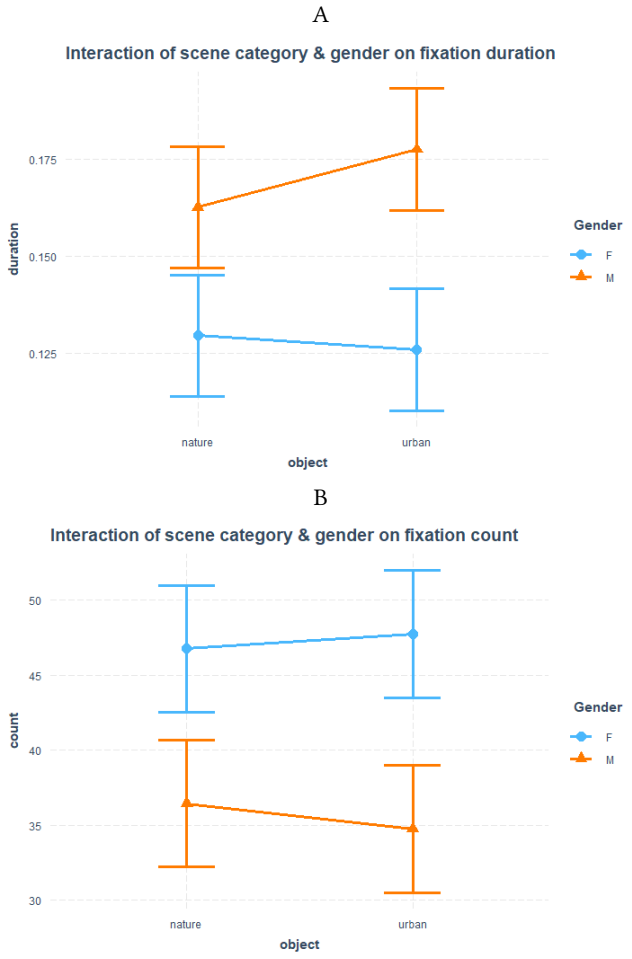

Figure 4: Differences in (A) mean fixation durations and (B) mean fixation counts by scene categories and gender.

4 DISCUSSION

There is a need to further understand the bottom-up attention patterns – fascination - related to viewing natural vs. urban environments. Although existing studies have shown that fixation behavior may reflect fascination, the validity of the connections may be impaired by the lack of specific control for top-down attention. This study aimed to replicate the results of [2] using clear instruction to control the effects of top-down attention. To our surprise, we have not found any significant effects of fascination level (natural scenes vs. urban scenes) on bottom-up attention represented by fixation measures.

To explain the insignificant results, we may consider that the low sample size in this current study was not able to represent the visual attention pattern of university students. We only recruited six participants, while other eye-tracking-based restorative environment research employed more than fifty participants [4, 5, 20]. A large sample may be essential for our research aim because of the great individual variation in our dependent variables.

Another explanation is that there were personal interests-related confounders such as gender and factors of personal background of nature experiences. Our findings suggested that females fixated for a shorter time than males. This is aligned with past findings that greater fear and less fascination were reported for women compared to men in cities [10] and forests [21]. However, gender was not found to interact with the effects of fascination levels. Factors related to personal background of nature experiences such as nature orientedness, nature hobbies, childhood nature experiences have been found to influence restoration from nature [13]. Unfortunately, we were not able to test such possibilities because this study did not measure such factors.

However, the revised instruction in the current study may also lead to different results compared to previous studies in which participants were required to freely explore the scenes. Such instructions, for example, could be "View an image with composure. Do not try to remember its content or its details" [5:13], or "you should look freely at the photographs, don't try to memorize any detail because this is not a memory task and no task related to the photograph contents will occur at the end of the eye movements recording" [3:188]. By contrast, we asked participants to "feel how your attention is captured by interesting things in the pictures." Eye movements are dependent on tasks that can influence top-dop attention. Therefore, more research is needed to explore the potential influence of instruction in eye-tracking-based restorative environments research to help decide the appropriate tasks.

This study has several limitations. The sample size was too small to represent the college student population with different personal factors related to the interest in cities and nature. In addition, our exclusive reliance on eye movement measures did not allow us to know the context and meanings for the fixations. Future studies may measure a set of potential moderators and mediators (e.g., nature hobbies, childhood nature experiences) to help interpret the eye movement results. It would also be helpful to gain the verbal description of the pictures to disambiguate the vagueness of fixation behaviors and provide meanings of attentional foci [7, 8].

5 CONCLUSION

The effect of bottom-up attention (fascination) of nature on eye movements is still not clear. This study applied a revised instruction to control the top-down attention but failed to replicate previous studies on fascination of nature and fixation behaviors. We highlight the importance of exploring the appropriate tasks in eye-tracking-based restorative environments research. We also recommend future studies to address the personal factors related to interest in or emotional responses to nature and to disambiguate the vagueness of fixation behavior by collecting verbal descriptions of scenes.

REFERENCES

[1] Marc G Berman, John Jonides, and Stephen Kaplan. 2008. The cognitive benefits of interacting with nature. *Psychological science* 19, 12 (2008), 1207–1212.
[2] Rita Berto, Stefano Massaccesi, and Margherita Pasini. 2008. Do eye movements measured across high and low fascination photographs differ? Addressing Kaplan's fascination hypothesis. *Journal of Environmental Psychology* 28, 2 (2008), 185–191.

[3] Angel M Dzhambov, Matthew HEM Browning, Iana Markevych, Terry Hartig, and Peter Lercher. 2020. Analytical approaches to testing pathways linking greenspace to health: A scoping review of the empirical literature. *Environmental Research* 186 (2020), 109613.

[4] Marek Franěk, Jan Petružálek, and Denis Šefara. 2019. Eye movements in viewing urban images and natural images in diverse vegetation periods. *Urban Forestry & Urban Greening* 46 (2019), 126477.

[5] Marek Franěk, Denis Šefara, Jan Petružálek, Jiří Cabal, and Karel Myška. 2018. Differences in eye movements while viewing images with various levels of restorativeness. *Journal of Environmental Psychology* 57 (2018), 10–16.

[6] Joseph H Goldberg and Xerxes P Kotval. 1999. Computer interface evaluation using eye movements: methods and constructs. *International journal of industrial ergonomics* 24, 6 (1999), 631–645.

[7] Jana Holsanova. 2006. Dynamics of picture viewing and picture description. *Advances in Consciousness Research* 67 (2006), 235.

[8] Jana Holšánová. 2008. *Discourse, vision, and cognition*. John Benjamins.

[9] William James. 1892. *Psychology, briefer course*. Vol. 14. Harvard University Press.

[10] Bin Jiang, Cecilia Nga Sze Mak, Linda Larsen, and Hua Zhong. 2017. Minimizing the gender difference in perceived safety: Comparing the effects of urban back alley interventions. *Journal of Environmental Psychology* 51 (2017), 117–131.

[11] Marcus Johansson, Terry Hartig, and Henk Staats. 2011. Psychological benefits of walking: Moderation by company and outdoor environment. *Applied Psychology: Health and Well-Being* 3, 3 (2011), 261–280.

[12] Stephen Kaplan. 1995. The restorative benefits of nature: Toward an integrative framework. *Journal of environmental psychology* 15, 3 (1995), 169–182.

[13] Kalevi M Korpela, Matti Ylén, Liisa Tyrväinen, and Harri Silvennoinen. 2008. Determinants of restorative experiences in everyday favorite places. *Health & place* 14, 4 (2008), 636–652.

[14] Yiping Liu, Mengjun Hu, and Bing Zhao. 2019. Audio-visual interactive evaluation of the forest landscape based on eye-tracking experiments. *Urban Forestry & Urban Greening* 46 (2019), 126476.

[15] Sepideh Masoudinejad and Terry Hartig. 2013. Window view to the sky as a restorative resource for residents of a densely populated city. In *10th Biennial Meeting, Division of Environmental Psychology, German Psychological Association, Otto-von-Guericke University, Magdeburg, Germany*.

[16] Brittany N Neilson, Curtis M Craig, Raelyn Y Curiel, and Martina I Klein. 2021. Restoring attentional resources with nature: A replication study of Berto's (2005) paradigm including commentary from Dr. Rita Berto. *Human factors* 63, 6 (2021), 1046–1060.

[17] Ann Ojala, Kalevi Korpela, Liisa Tyrväinen, Pekka Tiittanen, and Timo Lanki. 2019. Restorative effects of urban green environments and the role of urban-nature orientedness and noise sensitivity: A field experiment. *Health & place* 55 (2019), 59–70.

[18] Xinxin Ren. 2019. Consensus in factors affecting landscape preference: A case study based on a cross-cultural comparison. *Journal of environmental management* 252 (2019), 109622.

[19] Roger S Ulrich, Robert F Simons, Barbara D Losito, Evelyn Fiorito, Mark A Miles, and Michael Zelson. 1991. Stress recovery during exposure to natural and urban environments. *Journal of environmental psychology* 11, 3 (1991), 201–230.

[20] Deltcho Valtchanov and Colin G Ellard. 2015. Cognitive and affective responses to natural scenes: effects of low level visual properties on preference, cognitive load and eye-movements. *Journal of Environmental Psychology* 43 (2015), 184–195.

[21] Agnes E Van den Berg and Marlien Ter Heijne. 2005. Fear versus fascination: An exploration of emotional responses to natural threats. *Journal of Environmental Psychology* 25, 3 (2005), 261–272.