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Exploring the Benefits of Komorebi Light Patterns: A Pilot Study

Zhujing Zhang, Marilyne Andersen

Laboratory of Integrated Performance in Design (LIPID), School of Architecture, Civil and Environmental Engineering (ENAC), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

E-mail: zhujing.zhang@epfl.ch

Abstract. Nature has long been recognized for its restorative benefits. Since most of our time is spent indoors, incorporating natural elements into our experience of indoor spaces can be a powerful way to enhance well-being. One such element, the dappled sunlight filtering through trees—called Komorebi in Japanese— has been shown to have restorative effects both in outdoor and indoor settings. To explore the potential benefits of Komorebi light patterns indoors, a pilot study was conducted with 23 participants. The study examined subjective and physiological responses to 12 different Komorebi video sequences projected in a controlled environment. Results indicated that Komorebi videos significantly influenced perceptions of openness, pleasantness, brightness, satisfaction with brightness, and naturalness, with certain videos showing distinct differences in how participants responded to variations in the distribution and movement of light patches. However, no significant physiological differences were observed across conditions.

1 Introduction

Nature's restorative effects—reducing stress, enhancing cognition, and fostering emotional well-being—are well documented [1]. As more time is spent indoors, integrating natural elements into built environments has gained attention. Among these elements, the dappled sunlight filtering through trees—known as Komorebi in Japanese—has been shown to have a strong restorative effect in nature [2]. For the indoor environment, integrating Komorebi light patterns into building interiors holds high potential as a biophilic design strategy—using facades or adaptive lighting systems to recreate natural light effects—that can potentially enhance occupant well-being through dynamic lighting experience [3, 4]. Research on human response to Komorebi is expanding: one study compared Komorebi image versus video found that dynamic Komorebi is perceived as more fascinating and strongly associated with nature than static [5]. Another study examined the naturalness of Komorebi's movement by replacing organic, irregular light patches with uniform white circles and manipulating their temporal composition [6]. Comparing dynamic movement derived from real Komorebi, random motion, and a static control, no significant effect on stress recovery or perceived naturalness was found—an outcome the authors attributed to the drastic alteration of the light patch characteristics. These findings underscore the need to study Komorebi holistically, accounting for its spatial-temporal effects—critical for evaluating how light patterns affect well-being [7, 8, 9]—which have not been thoroughly analyzed despite Komorebi's distinctive spatial composition and dynamic movement. To further the understanding of Komorebi and its potential for use indoors, research methods must preserve Komorebi's natural essence while allowing for variations. This pilot study initiates an exploration of Komorebi's temporal and spatial characteristics and their impact on human responses.

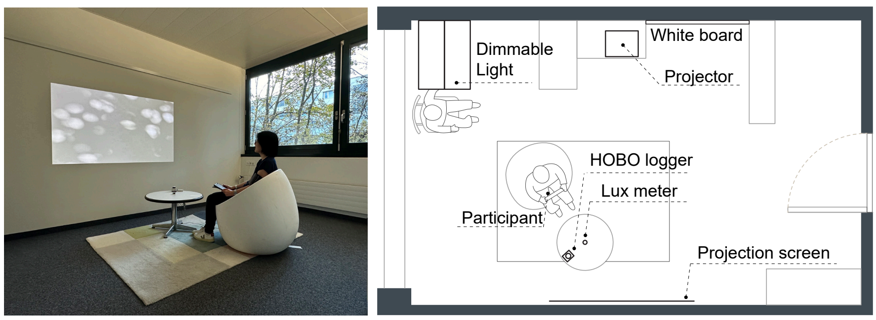
2 Methodology

We used controlled room projections of Komorebi videos—varying in spatial and temporal composition—to preserve the qualities of dappled light while maintaining experimental control. Subjective measures and physiological biomarkers were selected based on prior researches for their relevance to Komorebi's potential restorative effects [10].

2.1 Komorebi video collection

Komorebi videos were recorded outdoors under clear skies, capturing sunlight filtered through tree canopies. A high-resolution camera in manual mode ensured consistent exposure and sharpness. Twelve 60-second videos (24 fps) were collected, representing varying spatial distributions and temporal dynamics—ranging from manually controlled (_mT) to natural and strong wind-driven movements (_T). Based on a prior study [11], videos were categorized using two spatio-temporal metrics: average movement and spatial randomness of light patches. All videos were luminance-calibrated to ensure each video had the same average luminance. Thumbnails of the Komorebi videos are shown in Fig. 4 below, arranged to illustrate the transition from regular to increasingly irregular light patch distributions.

2.2 Experimental room setup



(a) Experiment room setup (b) Floor plan

Figure 1: Experimental setup

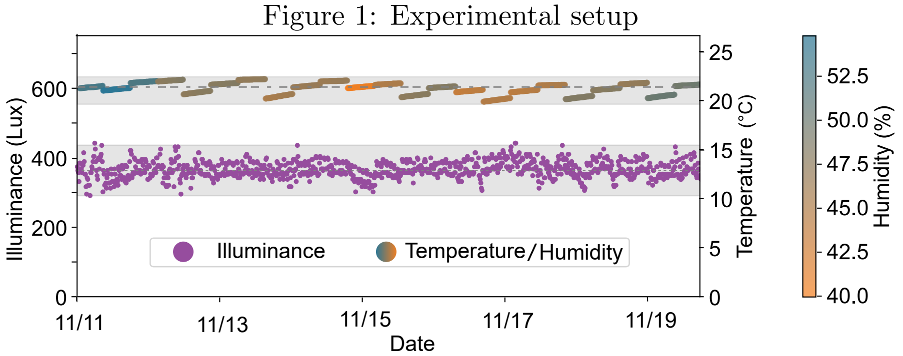


Figure 2: Temperature, humidity and illuminance during experiments

The experiment was conducted in a casual indoor space, illustrated in Figure 1a, featuring a window surrounded by trees. Komorebi videos were projected onto a wall perpendicular to the window to enhance visual continuity with the outdoor environment, as shown in the room layout in Figure 1b. Videos were projected using a high-resolution projector, with consistent lighting maintained by indirect, dimmable ceiling illumination adjusted in real-time based on lux meter readings to ensure stable illuminance at the participant's position. Environmental conditions—temperature (20–22,°C), relative humidity (40–54%), and illuminance (301–442 lx)—were continuously monitored using a HOBO device placed on the table in front of the participant. As shown in Figure 2, these values remained within established comfort ranges defined by ASHRAE55[12] (20–24,°C, 30–60% RH) and EN12464-1[13] (300–

500 lx for indoor visual tasks), with a gradual increase in temperature observed throughout the day due to solar gain.

2.3 Experimental protocol

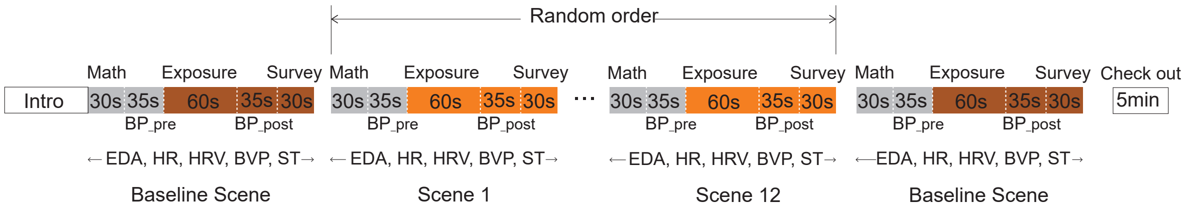


Figure 3: Experiment protocal

The experimental protocol (Fig. 3) began with a 15-minute introduction, covering procedure details, physiological device setup, and a brief trial. Baseline sessions featuring a static stripe pattern were conducted at the beginning and end of the experiment to assess potential ordering effects—systematic changes in participants' responses that could result from the sequence of stimulus presentations rather than the stimuli themselves [14]. Each session followed a consistent sequence: a 30-second standing math test, seated blood pressure measurement (35 seconds), viewing a 60-second Komorebi video, another blood pressure measurement (35 seconds), and a 30-second questionnaire. Twelve Komorebi scenes were presented in randomized order. The experiment concluded with a 5-minute final feedback interview, lasting approximately 60 minutes in total. Twenty-three participants (8 male, 15 female; ages 18–35) completed the study. This study was approved by the EPFL Human Research Ethics Committee (HREC000571).

2.4 Subjective and physiological measures

Subjective responses were collected through questionnaires on a tablet, assessing calmness, pleasure, naturalness, openness, brightness, satisfaction with brightness and thermal comfort. Blood pressure (BP) was measured at designated time points using an Omron EVOLV wearable BP device. In addition to discrete measurements, an Empatica wristband continuously recorded electrodermal activity (EDA), heart rate (HR), heart rate variability (HRV) and blood volume pulse (BVP) throughout the experiment.

2.5 Statistical methods

To evaluate participant responses to Komorebi videos, Linear Mixed Models (LMM) were applied, accounting for repeated measures by modeling participants as random intercepts and video stimuli as fixed effects. This analytical approach has been used in similar studies [7, 15, 16]. For this study, the LMM was implemented using the `lmer()` function from R's `lme4` package.

$$\text{Dependent Variable} \sim \text{Video} + (1|\text{Participant})$$

Potential confounders—including age, sex, and "environment lived in over the past five years"—were assessed using Bonferroni correction across all tests. For binary variables, Wilcoxon rank-sum tests were used; for multi-level categorical variables, Kruskal–Wallis tests were applied. Variables showing both statistical significance and moderate effect sizes ($r \geq 0.3$, $\varepsilon^2 \geq 0.06$) were included as covariates in the final model. To identify which subjective and physiological measures were significantly influenced by the Komorebi videos, Type II ANOVA was performed on the LMMs, with Bonferroni correction applied for multiple comparisons ($\alpha_{\text{adjusted}} = 0.0071$ for subjective and $\alpha_{\text{adjusted}} = 0.01$ for physiological measures). Measures exceeding these thresholds and meeting the effect size criterion ($\eta^2 > 0.064$) [17] were retained for further analysis. Perceptual differences between specific video conditions were explored using pairwise comparisons, adjusted using False Discovery Rate (FDR) correction, and visualized through heatmaps. Lastly, ordering was assessed by comparing the first and last baseline ratings using a paired test.

3 Results

ANOVA on LMM showed significant effects of Video condition on five subjective measures: **openness**, **pleasantness**, **brightness**, **satisfaction with brightness**, and **naturalness** (all $p \leq 0.024$, η^2 between 0.075 and 0.41). The strongest effects were observed for openness ($p < 0.0001$, $\eta^2 = 0.196$), pleasantness ($p < 0.0001$, $\eta^2 = 0.187$), and naturalness ($p < 0.0001$, $\eta^2 = 0.41$), and these were retained for further analysis. Brightness ($p < 0.0001$, $\eta^2 = 0.132$) and satisfaction with brightness ($p < 0.0001$, $\eta^2 = 0.123$), although significant, had comparatively smaller effects. Calmness ($p = 0.024$, $\eta^2 = 0.075$) and thermal comfort ($p = 0.063$, $\eta^2 = 0.065$) did not meet the threshold for further analysis. Physiological measures (EDA, BP, HR, HRV, BVP) showed no significant differences (all $p > 0.22$, $\eta^2 < 0.05$). "Environment lived in over the past five years" significantly influenced brightness ratings (p = 0.0003, $\varepsilon^2 >= 0.068$) and was included as a covariate in brightness analyses.

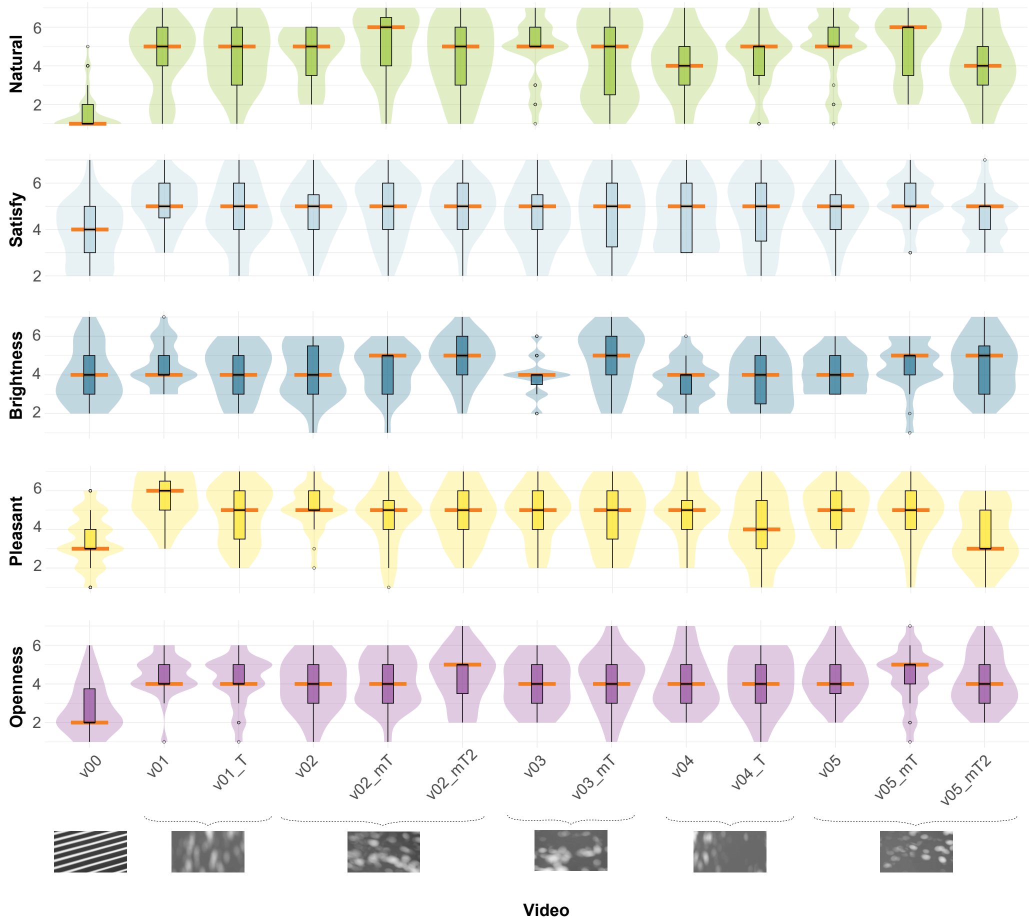


Figure 4: Distribution of subjective ratings

Participants' ratings for each subjective measure across different Komorebi video conditions are presented in Fig.4. Additionally, perceptual differences between various Komorebi video patterns are illustrated using heatmaps in Fig.5, where comparisons showing large effect sizes are highlighted with colored boxes: green for Naturalness, light blue for Satisfaction, dark blue for Brightness, yellow for Pleasantness, and purple for Openness.

Ratings of perceived **naturalness** varied notably across Komorebi video groups, emphasizing the significant influence of temporal dynamics on perceived naturalness. Notably, substantial differences emerged between two Videos with manually generated motions, v02_mT and v05_mT2. Despite being manually controlled, the unpredictable motion of v02_mT closely resembled natural patterns, resulting in higher naturalness ratings. Conversely, the abrupt, sudden motion of v05_mT2 was perceived as least natural, highlighting that the type of motion

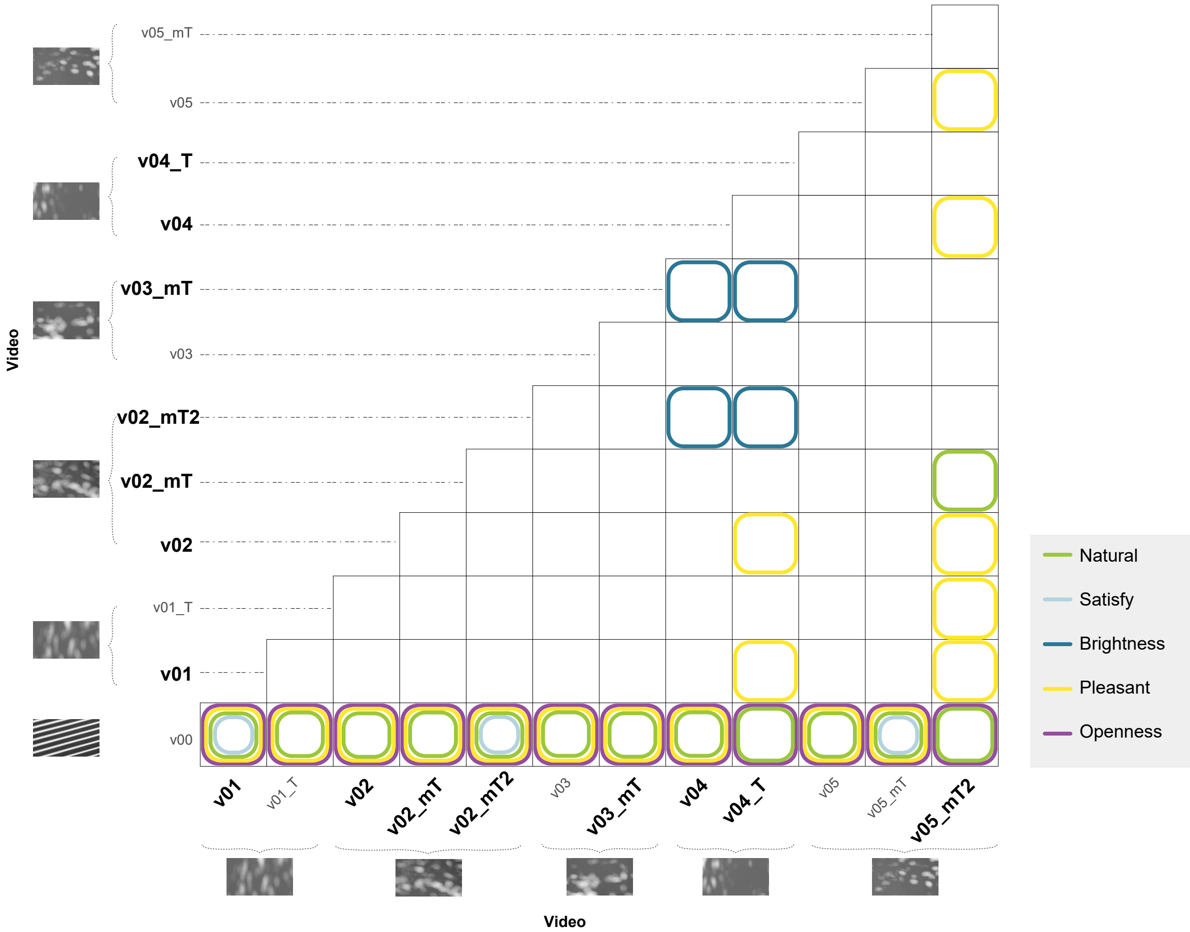


Figure 5: Pairwise comparison of perceptions

critically impacts naturalness perception.

Pleasantness ratings declined with increased temporal movement, particularly in videos featuring pronounced movements like the strong swinging motion in v04_T and sudden, short movements in v05_mT2. Videos with gentle or mild motion, such as v01, v01_T, v02, v04, and v05, generally received higher pleasantness ratings. Although v01_T's motion is higher than v01 but still less intense than other groups. Overall, excessive or unnatural motion negatively impacted pleasantness.

Both spatial distribution and temporal dynamics impacted perceived **brightness**. Videos with pronounced temporal movement, particularly within spatially matched pairs (e.g., groups v02, v03, and v05), were rated as brighter. Conversely, the lower brightness ratings of group v04 suggest that its spatial characteristics negatively influenced perceived brightness. Notably, the largest brightness differences occurred between group v04 and groups featuring strong temporal movements (v03_mT and v02_mT2). Interestingly, **satisfaction with brightness** remained relatively consistent across all Komorebi videos.

Openness ratings were generally stable across video conditions, except for higher ratings in v02_mT2 and v05_mT, both characterized by smooth manual motions, highlighting this type of temporal movement have potential to enhance openness perception.

Overall, the baseline condition received lower ratings on most subjective measures, except for brightness, which was experimentally controlled. The most substantial differences emerged between the static shading condition (v00) and the Komorebi videos, indicating that the dynamic

Komorebi patterns were perceived as significantly more open, natural, pleasant, and satisfying in terms of brightness. No ordering effects were observed across baseline sessions.

4 Main findings and Discussion

Under controlled conditions, Komorebi videos significantly influenced subjective responses—including openness, pleasantness, brightness, satisfaction with brightness, and naturalness—but did not produce significant changes in physiological measures, likely due to limited exposure time and sample size. However, trends observed in EDA and HRV (characterized by lower p-values and higher effect sizes), though not statistically significant, suggest potential areas for further investigation

The inclusion of a static baseline proved essential, clearly demonstrating significant perceptual contrasts with Komorebi conditions. Notably, temporal dynamics played a critical role: dappled light patterns featuring unpredictable yet smooth movements were perceived as far more natural and pleasant than those with abrupt or repetitive motions. The sense of openness in the space was similarly influenced by the temporal dynamics, with some smooth motion making the environment feel more open. While temporal movement generally enhanced perceived brightness, the spatial characteristics in certain video groups—whether related to random distribution or other spatial features—led to lower brightness ratings and deserve further investigation. Interestingly, although perceived brightness varied across conditions and was similar between the baseline and Komorebi videos, participants consistently reported greater satisfaction with brightness in Komorebi conditions compared to the baseline, highlighting the unique advantage of dynamic Komorebi in enhancing brightness satisfaction.

"Environment lived in over the past five years" emerged as a confounder for brightness perception, possibly reflecting differences in daily light exposure across residential settings. However, given our limited sample size (n=23), this finding should be interpreted cautiously and verified in larger studies.

The current approach of grouping videos by spatial distribution and temporal movement did not fully capture the complexity inherent in Komorebi dynamics; future research should consider analyzing complementary dimensions of variation. Additionally, video selection was limited to the widest range of features practically obtainable by the authors. Although the projection setup did not fully replicate natural light's intensity, contrast, or spectral characteristics, it allowed controlled investigation of visual perceptions of Komorebi patterns indoors.

5 Conclusion

The study, involving 23 participants and 12 Komorebi videos, explored how variations in light patterns influence human responses. It identified key subjective measures that showed significant effects and highlighted specific videos that elicited observable differences in perception.

This pilot study serves as an initial exploration toward a deeper understanding of Komorebi's effects, whose proper investigation will require larger sample sizes and a refined protocol informed by the pilot study's findings. Ultimately, this work aims to support restorative indoor lighting environments and to contribute to selecting promising features of Komorebi patterns in terms of potential well-being benefits for their occupants, which may inspire further translations into shading designs incorporating these features, or other forms of nature-inspired elements brought indoors.

6 Acknowledgments

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