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Art Immersion: Evidence for attention restoration in museums

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ABSTRACT

Navigating crowded urban environments can significantly deplete attentional resources over time, making individuals less attentive and more prone to distractions. While previous research suggests that natural settings can help replenish attentional resources depleted by urban life, little is known about whether similar benefits may arise from tranquil artistic settings, like museums and art exhibitions. Here, we drew on the Attention Restoration Theory to test the restorative effects of a museum visit compared to a walk in an urban environment, using a within-subject pre-post design and a combination of self-reported, behavioral, and physiological measures. Participants completed two computer tasks assessing working memory and attentional control and filled out questionnaires assessing perceived restoration, emotions and stress before and after either a museum visit or an urban walk. Physiological activity was monitored by measuring blink rate and pupil size via an eye-tracker. Results showed greater improvement in attentional control abilities following the museum visit. Additionally, self-reported measures indicated that the museum visit was perceived as being more restorative than the urban walk. Similar improvements were observed for working memory, stress and emotions after both a museum visit and an urban walk. These findings suggest that immersion in artistic environments, like museums, can enhance key attention abilities more effectively than an urban walk, enabling individuals to replenish attention resources and become less distractible afterwards. Our results are encouraging in promoting the beneficial effects of museum visits on attention restoration.

1. Introduction

Navigating modern urban environments often requires people to direct attention toward goal-relevant elements (e.g., traffic lights) while ignoring distractions (e.g., flashy billboards). However, this process cannot continue indefinitely: over time, it can deplete attentional resources, making individuals more susceptible to distractions and more sensitive to stress (cf., Lambert et al., 2015; McKenzie et al., 2013). Previous research suggests that spending time in a natural environment can help restore attention and relieve stress (e.g., Fleming et al., 2024; McDonnell et al., 2025; McDonnell & Strayer, 2024), as natural environments should not place high demands on directed attention, but instead capture attention in a gentle and effortless way (Kaplan, 1995; McDonnell & Strayer, 2024). Yet, natural environments are not always easily accessible from urban areas, and people may seek closer locations to restore their “attentional energies”. An interesting line of research has proposed that museums and artistic exhibitions can facilitate attention restoration in the same way that natural environments do (Kaplan et al., 1993a, 1993b; Packer, 2008; Packer & Bond, 2010). However,

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studies on the restorative effects of museums and art have largely relied on self-reported measures, providing mostly anecdotal evidence overall. As museum attendance has yet struggling to return to pre-pandemic levels (American Alliance of Museums, 2023), highlighting the potential cognitive benefits of museum visits could encourage greater attendance.

The *Attention Restoration Theory*, from Kaplan (ART; Basu et al., 2019; Kaplan, 1995), describes the characteristics of environments capable of restoring attentional resources. According to ART, prolonged exposure to environments that place high demands on directed attention, such as urban settings, depletes attentional resources. The term “directed attention” is referred to the effortful process of focusing on relevant elements while simultaneously ignoring distracting stimuli (Joye & Dewitte, 2018). This depletion is expected to increase distractibility, irritability and difficulty concentrating (Kaplan, 1995). In contrast, environments that allow for a bottom-up direction of attention can engage attention effortlessly and, in turn, help replenish the depleted attentional capacity. According to ART, restorative environments must possess four key characteristics: 1) There should be *compatibility* between the environment and a person’s goals and preferences. In other words, individuals must enjoy spending time in the environment. 2) The environment must create a sense of *being-away* from routine and from the demands of directed attention. Kaplan emphasizes that “being-away” refers to a conceptual rather than a physical transformation: even a familiar environment can provide a restorative effect if viewed from a different perspective. 3) The environment must have a rich and coherent *extent* or scope, making it feel like a distinct world of its own. In other words, it must provide enough elements for exploration and engagement. 4) The environment must engage people through what Kaplan calls *soft fascination*. Soft fascination is defined as a modest attentional hold that allows space for reflection and the resolution of internal thoughts (cf. Basu et al., 2019). According to the traditional view of ART, natural environments typically embody all four of these characteristics (cf., Kaplan, 1995). However, some researchers (including Kaplan) have pointed out that other settings, such as museums and art exhibitions, can also fit the definition of restorative environments (Kaplan et al., 2019; Packer, 2008; Packer & Bond, 2010; Scopelliti & Giuliani, 2004). Indeed, intuitively, museums can provide a sense of being away from crowded urban life, constitute an explorable new world, and can engage attention in an effortless way, as long as they are compatible with the person’s preferences.

In line with this reasoning, prior research has examined the cognitive restorative effects of museum visits. In one of his seminal works, Kaplan (1993) described both ordinary and non-ordinary visitors of an art museum reporting high levels of restoration in a survey, with ordinary visitors experiencing the greatest benefits. Paker (2008) and Paker and Bond (2010), used semi-structured interviews and self-reported questionnaires to investigate attention restoration across various outdoor and indoor environments, finding that restoration levels reported by museum visitors were comparable to those experienced in natural settings. Similarly, Scopelliti and Giuliani (2004) observed through a series of interviews that museums and nature walks were among the environments that best promoted a sense of relaxation and excitement. Nevertheless, although promising, these findings rely exclusively on self-reported measures, highlighting the need for a broader approach that can incorporate other measures, such as cognitive tasks from the psychological literature or tools for tracking physiological changes.

In contrast to museums and artistic environments, nature environments have been studied using measures beyond self-reports. Past research on the restorative benefits of nature has largely used behavioral performance on cognitive tasks to assess a core component of attention: attentional control (e.g., Bratman et al., 2015; McDonnell & Strayer, 2024; Stevenson et al., 2021). Attentional control is defined as the ability to regulate attention by resisting distractions while orienting (or re-orienting) attention on relevant elements of the environment (Diamond, 2013; Gratton et al., 2018; Miller & Cohen, 2014; Posner & Petersen, 1990). For example, individuals exert attentional control when they must ignore a phone ringing while driving through traffic. Although extensive research used behavioral performance on attentional control tasks to explore the effects of nature on attentional control (e.g., McDonnell & Strayer, 2024; Stevenson et al., 2021), to our knowledge, no study has investigated this in the context of museum visits and art exhibitions.

Similarly, although working memory abilities are expected to improve after spending time in nature (for two reviews, see Ohly et al., 2016; Stevenson et al., 2018), no study has tested this in the contexts of artistic environments. Working memory is defined as the cognitive system responsible for the active maintenance of information in memory while processing additional information in parallel (Baddeley, 2020; Engle, 2002). For instance, people rely on working memory when they must retain important information (e.g., the words of an interlocutor) while performing another task (e.g., driving a car). A *meta-analysis* conducted by Stevenson et al. (2018) found that natural environments, compared to urban environments, had a restorative effect on working memory, suggesting that the lower demand for directed attention during walks in natural environments freed up mental resources which, as a result, could be used to benefit working memory performance afterward. Similarly, visiting a museum may decrease attentional demands, free up mental resources, and consequently enhance working memory. Based on these premises, one should expect a museum visit to be more restorative than an urban walk, which, in contrast, is not expected to reduce attentional demands overall (cf., Lambert et al., 2015; McKenzie et al., 2013). This was the hypothesis we addressed in the present study.

1.1. Aims

In this project, we tested the level of cognitive restoration following a visit of an artistic environment (i.e., a museum) or an urban walk. Our study pursues three objectives, aligned with the three types of measures used:

- (1) *Exploring the effects that visiting a museum have on perceived restoration, stress and emotions.* We expected higher perceived restoration and positive emotions, along with lower self-reported stress and negative emotions following the museum visit compared to an urban walk.
- (2) *Investigating the benefits of a museum visit on attentional control and working memory.* We expected improved performance in two cognitive tasks measuring attentional control and working memory following the museum visit compared to an urban walk.

- (3) Assessing differences in mental load, as reflected in physiological indicators (blink rate and pupil size), during cognitive task performance after a museum visit compared to an urban walk. We expected lower mental load, indicated by a reduced blink rate and smaller pupil size, following the museum visit.

2. Method

2.1. Participants

Twenty-four (13 males and 11 females) participants were recruited via ads and word of mouth, receiving a \$50 Amazon gift card in exchange for their participation. Their age ranged between 19 and 51 years old (mean = 23.96, SD = 7.99). Twenty participants identified as university students, and four as graduate workers. They all had normal or corrected-to-normal hearing and sight and no mental or physical health issues. The research was approved by the University of Windsor Research Ethics Board (REB#24-155) and informed consent was obtained for each participant. The study protocol was preregistered on the Open Science Framework platform (see <https://osf.io/bfah7>). Data, materials and analysis code for this study are available by emailing the corresponding author.

2.2. Design

The experiment used a within-subject pre-post design, with Condition (museum vs. urban) and Time (pre-test vs. post-test) as within-subject factors. Each participant visited the Chimczuk Museum (Windsor, Ontario) and, on a different day, performed an urban walk near the University of Windsor campus. Each participant experienced both conditions, with the order of conditions counter-balanced across participants. Before each visit/walk, participants completed a mental counting task to induce mental depletion, followed by a pre-test phase that included the Positive and Negative Affect Schedule (PANAS) for emotional affect, a stress Visual Analogue Scale (VAS), a working memory task (Operation SPAN), and an attentional control task (Antisaccade). After each visit/walk, participants completed a post-test phase, which included the same PANAS questionnaire, stress VAS, and cognitive tasks. Additionally, they filled out the Perceived Restorativeness Scale. Using a wearable eye tracker, eye metrics were recorded before and after each visit/walk as participants performed the two cognitive tasks. See Fig. 1 for a visualization of the event flow.

2.3. Equipment and materials

2.3.1. Museum visit and urban walk

The museum visit took place inside the Chimczuk Museum (Windsor, Ontario). The Chimczuk Museum is a regional museum that hosts several exhibitions related to the culture and history of the city of Windsor, as well as artistic works created by Native American populations. The exhibition space consists of three rooms of different sizes and a large corridor connecting them (see Fig. 2). Visitor attendance varied across sessions; however, the exhibitions were never too crowded, with an average daily attendance of 58 visitors. The urban walk followed a 2.5 km round-trip route near the University campus, starting from the Faculty of Human Kinetics (see Fig. 2). The walk took place in a modestly populated Canadian city (Windsor, population: 236,789, Annual Average Daily Traffic volume (AADT): 231,300; Ministry of Transportation, 2021). Participants could walk on sidewalks for the entire route. The first half of the route passed through a residential area, lined with trees and houses. The second half continued through a commercial area with fewer trees and several shops, primarily restaurants and fast-food outlets (e.g., Harvey's). During the walk, participants encountered six intersections with traffic lights and crossed a railway line twice. Vehicular and pedestrian traffic was generally low, as the area is not a high-traffic zone in Windsor. Both the urban walk and the museum visit took place between 1:00 and 4:30p.m. for all participants.

2.3.2. Mental depletion task

To induce mental depletion, we asked participants to count backwards from 1000 (1005 during the second session), subtracting 7 each time, for a total of ten minutes. Participants did this aloud so the experimenter could correct them, and they were invited to restart if they reached 0 before ten minutes had passed. This is a well-established task to induce high mental load on participants (Jiang et al., 2019; McDonnell & Strayer, 2024). Once the mental depletion task was over, participants responded to four check questions measuring

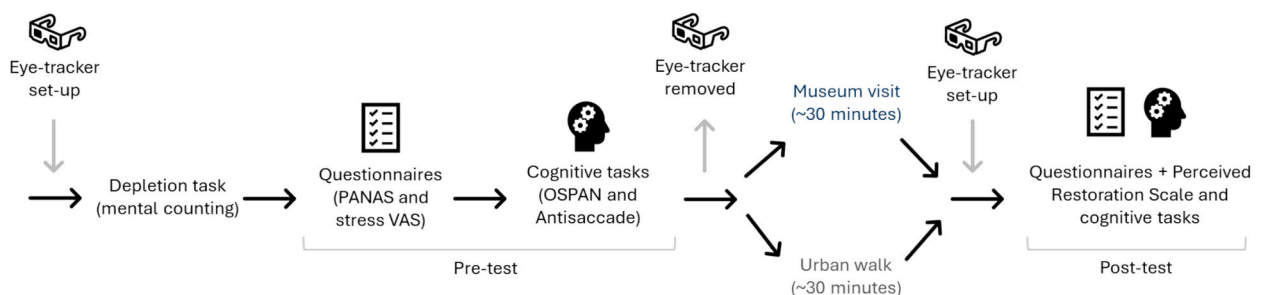


Fig. 1. Visualization of the event flow.



Fig. 2. Museum visit and urban walk. The left panel shows the floor plan of the museum at the top, with images depicting the museum environment at the bottom. The right panel shows the map of the urban walk at the top, with images of the urban environment at the bottom.

how tired they were, how much effort they exerted, how pleasant they found the task, and how frustrated they felt, on a scale from 1 (not at all) to 7 (extremely). Crucially, responses to the check questions did not differ between the museum and urban conditions, indicating that participants were equally depleted before each condition (all $t_s < 1$, all $p_s > 0.05$).

2.3.3. Perceived Restorativeness Scale

All questionnaires were created and administered using Microsoft Forms (Microsoft Corporation, Redmond, Washington, U.S.).

The Perceived Restorativeness Scale was used to measure subjective restoration after the museum visit and urban walk (McDonnell & Strayer, 2024; Pasini et al., 2014). We employed a shortened version devised by Pasini et al. (2014), which includes 11 statements grouped into four factors reflecting the Attention Restoration Theory: Fascination, Being Away, Coherence, and Scope (see Appendix A for an overview). For each statement, participants indicated how much the statement applied to the environment they walked in using an 11-point Likert scale.

2.3.4. Positive and negative affect Schedule (PANAS) scale

To track changes in perceived emotions, we used the Negative Affect Schedule (PANAS) questionnaire. This scale consists of 20 items, each composed of a single word representing a feeling or emotion (Thompson, 2007; Watson & Clark, 1999). Participants indicated how much they were currently experiencing each feeling or emotion using a 5-point Likert scale. Of the 20 items, 10 measured positive affects (e.g., excited, inspired), and 10 measured negative affects (e.g., upset, afraid). See Appendix B for an overview of the questionnaire.

2.3.5. Stress Visual Analogue Scale (VAS)

To track stress levels, we employed a stress Visual Analogue Scale (VAS). This is because stress has been found to decrease more after a walk in nature (Roger et al., 1991; Kaplan, 1995; McDonnell et al., 2025), leading us to expect similar patterns after a museum visit. This VAS consists of an 11-point horizontal line with anchors at “Not at all stressed” (0) on the left and “Maximally stressed” (10) on the right. Participants were asked: “How stressed do you feel right now?”.

2.3.6. Operation span task

The software OpenSesame (version 3.3; Mathôt, et al., 2012) was used to program the two cognitive tasks.

Changes in working memory were measured with performance on the Operation Span task (OSPAN). The OSPAN task is one of the most widely used measures of working memory (Draheim et al., 2021, 2022; Engle, 2002). In this task, participants must solve a series

of mathematical operations while simultaneously holding additional information (e.g., a series of letters) in short-term memory (Conway et al., 2005; Draheim et al., 2021). Among working memory tasks, the OSPAN has demonstrated good reliability metrics (Draheim et al., 2021; Unsworth et al., 2005). The task procedure was the following: first, participants were required to practice with 16 mathematical operations. Each math operation was presented with a question mark after the equal sign (e.g., $(3 * 5) - 9 = ?$). Participants had an unlimited amount of time to solve the equation, but they were required to do this as fast as possible. Once solved, participants had to press the spacebar and they were presented with a possible solution, for which they had to determine whether the solution was correct or false by keypress. The average completion time of these 16 mathematical operations plus 2.5 standard deviation was used to set up a deadline for subsequent operations. Then, new mathematical operations were presented, followed by a letter presented for 1 s. Participants had to solve the operations while holding into memory the sequence of letters presented in between operations. After each block of operations, participants had to enter the sequence of letters in the correct order. The number of operations and letters increased progressively: the first two blocks were composed of 2 equations and 2 letters and were considered practice trials. Then, the first two experimental blocks were composed of 2 equations and 2 letters, the following two blocks of 3 equations and 3 letters, up until 6 equations and 6 letters, for a total of ten blocks (see Fig. 3).

2.3.7. Antisaccade task

Changes in attentional control were measured with performance on the Antisaccade task. Extensive research on attention has identified the Antisaccade task as one of the best cognitive tasks for measuring attentional control (Draheim et al., 2021; Everling & Fischer, 1998). In this task, participants must suppress the reflex to look at a distractor appearing on one side of the screen and instead direct their gaze to a target presented on the opposite side (Draheim et al., 2021; Kane et al., 2001). This task is particularly effective in measuring attentional control due to its simplicity and higher reliability compared to other attentional control tasks (cf., Draheim et al., 2021). On each trial, a blank screen was presented for 500 ms, followed by a fixation point at the center of the screen for a variable interval of 1 or 2 s. Then, a distractor (*) appeared on one side of the screen for 300 ms, followed by a target letter (Q, O, or G) on the opposite side for 95 ms, which was immediately masked with “##”. Participants were required to identify the letter by pressing the correct key (see Fig. 3). Notably, everything occurred in less than 400 ms, so to correctly identify the letter, participants had to resist looking at the distractor and quickly shift their gaze in the opposite direction.

2.3.8. Eye-metrics

Blink rate and pupil diameter were used to detect physiological changes in mental load during the performance of these two tasks. Mental load refers to the mental resources required by a task, particularly from working memory and attention, with higher task demands imposing a greater mental load (Biondi, 2024; Cohen et al., 2017; Engström et al., 2017). Eye metrics have been shown to be reliable indicators of variations in mental load, as both eye blink rate and pupil size tend to increase with higher mental demands (Biondi, Graf, et al., 2023; Magliacano et al., 2020; Vasta et al., 2025). For instance, the studies by Biondi et al. (2023) and Kramer et al. (2013) reported an increased blink rate and greater pupil size, respectively, during tasks imposing a higher mental load due to an increase in their duration, in the processing of information, or their complexity. Examining changes in eye metrics can thus offer valuable, albeit preliminary, insights into fluctuations in mental load. Given that visiting a museum is expected to reduce the mental load associated with attentional demands, we hypothesized that participants would show better performance on attentional control and working memory tasks, as well as a lower blink rate and reduced pupil size after the museum visit compared to the urban walk.

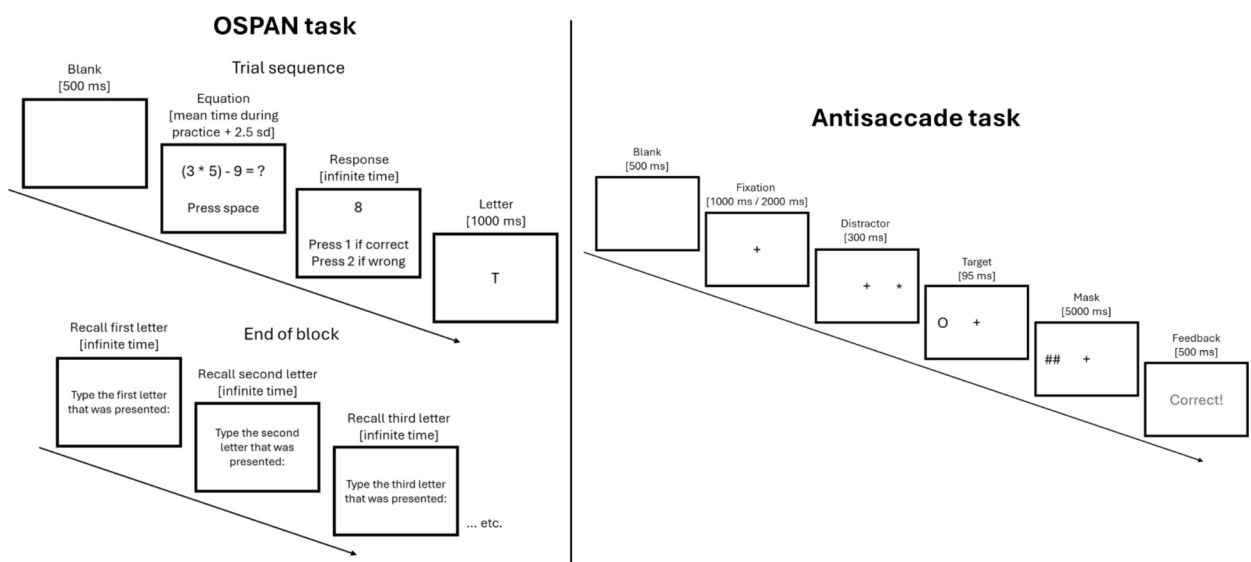


Fig. 3. Trial sequence of the Operation Span task (OSPAN) on the left panel, and Antisaccade task on the right panel. The duration of each step is indicated in square brackets.

The Pupil Labs NEON eye-tracking system was used for this study, which is a wearable eye tracker similar to a pair of goggles (Pupil Labs, Berlin, Germany). The NEON eye tracker has three cameras: two eye cameras and one world camera that records from the participant's perspective. The eye cameras sample at 200 Hz, while the scene camera records at 30 Hz with a resolution of 1920×1080 pixels and an 82 field of view. It converts eye movements into a data stream containing pupil position, pupil dilation, gaze vectors for each eye, and gaze point.

2.4. Procedure

Participants were invited to reach either the Chimczuk Museum or the Faculty of Human Kinetics, depending on the counterbalancing condition, where they were guided to a quiet room. In the museum condition, the room was an empty storage room, located close the museum entrance. In the urban condition, the room was the Human System Lab, located at the second floor of the Faculty of Human Kinetics. Both rooms were provided with a large table facing a wall, and participants were invited to sit at this table. Next, they were equipped with the eye tracker, and a 10-second baseline was recorded. During baseline participants were asked to look at a white cross on a black screen. Baseline duration followed guidelines for pupil diameter correction (cf. Mathôt et al., 2018; Fink et al., 2024). Then, they performed the mental depletion task aloud for ten minutes. When a participant made an error, the experimenter instructed them to restart from the last correct number. Next, participants completed the PANAS scale and the Stress VAS, followed by the two cognitive tasks (OSPAN and Antisaccade). The order of the cognitive tasks was counterbalanced across participants.

Then, the eye tracker was removed, and participants were instructed to either take an urban walk or visit the museum, depending on the counterbalancing condition. We chose to remove the eye tracker during the walk/visit because physiological measurement devices are known to affect people's emotions and memory (c.f., Vasta, Andrao, et al., 2025). During the urban walk, participants were asked to refrain from answering calls, messaging, or listening to music or podcasts. Additionally, they were asked to take pictures of two specific buildings along the route to confirm they followed the correct path. During the museum visit, participants could explore the floor freely, starting from the room shown in Fig. 2, but were instructed not to spend more than 40 min inside the exhibitions. Importantly, the museum visit and the urban walk did not differ in terms of duration (30.3 and 32.5 min, respectively; $t(23) = 0.22, p > 0.05$).

After completing the visit or walk, participants were re-equipped with the eye tracker, another 10-second baseline was collected, and they completed the PANAS scale again, along with the Perceived Restorativeness Scale. Finally, participants completed a shorter version of the two cognitive tasks, with practice trials removed. The task order remained the same as in the pre-phase.

2.5. Data processing and analysis

2.5.1. Questionnaires

For the Perceived Restorativeness Scale, responses were averaged to obtain four scores, corresponding to the following factors for each condition and participant: Fascination, Being Away, Coherence, and Scope. For the PANAS, responses were grouped based on whether they indicated positive or negative affect, then averaged to obtain two scores for each condition and participant. For the Stress VAS, raw scores were used for each condition and participant.

2.5.2. Cognitive tasks

For the OSPAN, letter recall accuracy was used as the main metric for each participant and condition. This was calculated as the proportion of correctly recalled letters out of the total presented. For the Antisaccade task, trial accuracy was used as the main metric for each participant and condition, with each response classified as either "correct" or "incorrect".

2.5.3. Eye-metrics

Blink count was extracted using the blink detection algorithm in Pupil Labs NEON software (v 31.10.23, Pupil Labs, Berlin, Germany; https://assets.pupil-labs.com/pdf/Pupil_Labs_Blink_Detector.pdf). First, the algorithm classifies each frame (every 5 ms) of the eye camera video as either a blink onset (eyelid closing event), a blink offset (eyelid opening event), or a no-blink event. Events are classified based on a confidence threshold of 0.25 for blink onset and offset (i.e., a frame is labeled as a blink onset or offset only if its probability is larger than 0.25). Next, the algorithm filters out blink onsets or offsets that are not followed or preceded by the complementary event within 30 ms, as well as blinks lasting less than 100 ms (Fink et al., 2024). Blink rate during cognitive task performance was calculated for each participant and condition by dividing the total number of blinks by the total duration (in minutes).

Pupil diameter was detected using Pupil Labs NEON software, which constructs a three-dimensional model of each eye independently and measures pupil diameter in millimeters (for details on the measurement method, see Pfeffer & Dierkes, 2024). Next, pupil diameter was preprocessed prior to analysis using the statistical software RStudio (R: v 4.4.1), following the guidelines reported by Fink et al. (2024). First, we excluded video frames classified as blinks and frames where pupil diameter was larger than 8 mm or smaller than 2 mm, as these values are considered physiologically implausible (Kret & Sjak-Shie, 2019). Next, pupil data were baseline-corrected by subtracting the average baseline pupil diameter from each data point. Pupil data were then smoothed using a moving average criterion, where each data point was replaced with the average of the two previous points and the current one. Finally, data were filtered using the Median Absolute Deviation (MAD), which represents the absolute deviation from the median pupil speed change and is considered a more robust variability metric than traditional measures (Geller et al., 2020; Kret et al., 2019). Specifically, data points with a dilation speed exceeding the MAD were classified as artifacts and excluded. The average pupil diameter change relative to baseline during each cognitive task was used as the main metric for each participant and condition.

2.5.4. Analyses

To conduct the analyses, we used Linear Mixed Models (LMM) and Generalized Linear Mixed Models (GLMM) using the packages “lme4” and “emmeans” in RStudio (R: v 4.4.1). Compared to the traditional Analysis of Variance (ANOVA), these models do not rely on strict normality assumptions for the residuals distribution and allow for the interpretation of different types of data (e.g., averaged, continuous, or binary data). For completeness, ANOVA results are reported in the Supplementary Material. All models consisted of two levels (task-level and subject-level), with the task-level including Condition (museum vs. urban) and Time (pre-test vs. post-test) as fixed factors, and the subject-level allowing only intercepts to vary as random factors. Our primary focus was the interaction between Condition and Time. Specifically, we expected differences between the museum visit and urban walk conditions only in the post-test phase, as the pre-test phase did not involve any experimental manipulation. These analyses are consistent with the proposed analyses detailed in our pre-registration (see secondary analysis of our pre-registration: <https://osf.io/bfah7>). For analyses on the Perceived Restorativeness Scale, only Condition was included as a fixed factor, as this questionnaire was administered only during the post-test.

3. Results

Results are presented following the research objectives. For each analysis, the alpha level was set to 0.05. Cohen’s *d* or odds ratios (OR) are reported as a standardized effect size for significant results. Following Cohen (1988, 2013), a *d* between 0.20 and 0.50 indicates a small effect, a *d* between 0.50 and 0.80 a moderate effect, and a *d* above 0.80 a large effect.

3.1. Exploring the effects that visiting a museum have on perceived restoration, stress and emotions

Participants rated their level of cognitive restoration using the Perceived Restorativeness Scale during post-test only. Four LMMs were performed, with Fascination scores, Being Away scores, Coherence scores, and Scope scores as dependent variables, and Condition (museum vs. urban) as a fixed factor. Condition resulted significant for LMMs including Fascination, Being Away and Coherence ($\beta = 2.32, t(23) = 5.35, p < 0.001, d = 1.20$; $\beta = 1.03, t(23) = 2.08, p = 0.049, d = 0.46$; and $\beta = 2.60, t(23) = 5.82, p < 0.001, d = 1.18$, respectively), indicating higher self-reported ratings of Fascination, Being Away, and Coherence after the museum visit, compared to

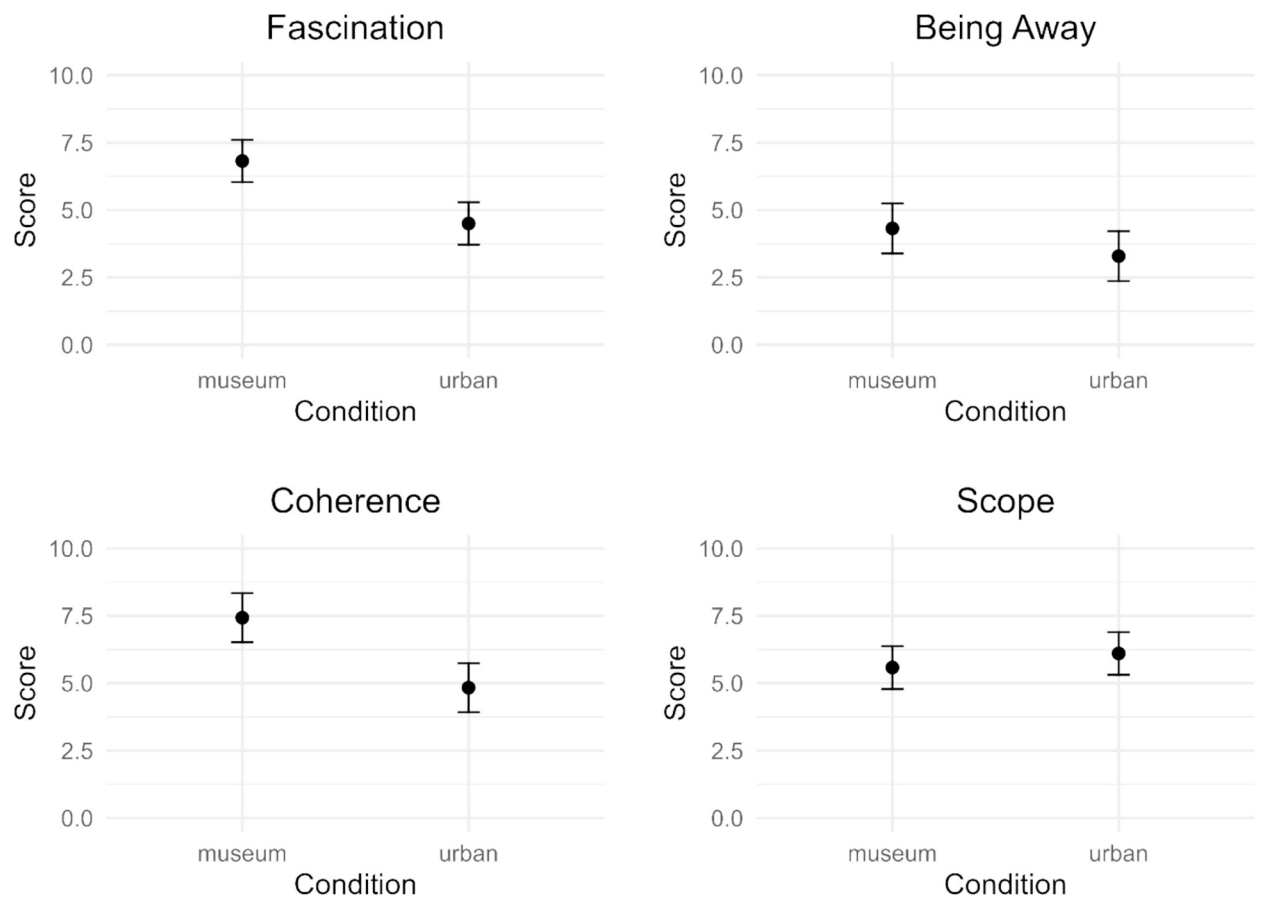


Fig. 4. Scores on the Perceived Restorativeness Scale, sorted by four factors: Fascination, Being Away, Coherence and Scope. Black dots represent aggregated means and error bars indicate standard errors.

the urban walk. Notably, Fascination and Coherence scores showed large effect sizes, whereas Being Away scores only a small effect (see Fig. 4). No significant differences were found for Scope scores ($t(23) = 0.95, p = 0.355$). These findings are consistent with previous literature on cognitive restoration in natural environments (e.g., McDonnell & Strayer, 2024; Scopelliti and Giuliani (2004)), and suggest that people perceive visiting a museum as a way to restore attentional resources and to feel free to focus effortlessly on its fascinating elements.

Participants rated their perceived positive and negative emotions using the PANAS questionnaire and their stress levels using a stress VAS during both the pre-test and post-test. LMMs were used to test the effects of Condition (museum vs. urban), Time (pre-test vs. post-test), and their interaction. No significant differences emerged when positive emotions were entered as the dependent variable (all $ps > 0.05$). When considering negative emotions as the dependent variable, only the main effect of Time resulted significant ($\beta = 0.18, t(69) = 2.45, p = 0.017, d = 0.61$), with lower self-reported negative emotions during the post-test of both conditions (see Fig. 5). When entering stress scores as the dependent variable, the main effect of Time resulted significant with a small effect size ($\beta = 0.79, t(69) = 2.38, p = 0.020, d = 0.42$) indicating that stress slightly decreased equally after both conditions. The main effect of Condition also resulted significant with a small effect size ($\beta = 0.75, t(69) = 2.26, p = 0.027, d = 0.39$), suggesting that overall stress levels were slightly lower before and after the museum visit compared to the urban walk (see Fig. 5). This latter result may be due to participants' awareness of the experimental condition they were about to perform (i.e., either walking in an urban environment or visiting a museum), which could have influenced their stress levels in advance. In contrast, the interaction between Time and Condition did not reach significance ($t(69) = 0.53, p = 0.596$).

3.2. Investigating the benefits of a museum visit on attentional control and working memory

The OSPAN task was used to measure working memory, while the Antisaccade task was used to measure attentional control. For the OSPAN, letter recall accuracy was entered as the dependent variable in an LMM, with Condition and Time as fixed factors. Only the main effect of Time was significant with a small effect size ($\beta = 0.06, t(69) = 2.07, p = 0.043, d = 0.44$), indicating that recall accuracy improved equally after both conditions (see Fig. 6). This small general improvement is likely attributable to a practice effect, such that participants performed better in recalling letters during the second testing (post-test) compared to the first (pre-test) as a result of completing a similar version of the same test twice. The interaction between Time and Condition, as well as the main effect of Condition, were not significant ($t(69) = 0.24, p = 0.812; t(69) = 0.41, p = 0.681$, respectively), suggesting that the improvement in recall accuracy did not differ after performing either a museum visit or an urban walk.

For the Antisaccade task, responses on each trial were dummy coded as 0 (incorrect) or 1 (correct) and entered as the dependent variable in a GLMM, with Condition and Time as fixed factors. The GLMM used a binomial family to account for the binary nature of the data. One participant was excluded from the analysis due to accuracy below 33 % (i.e., chance level) in one condition. The main effect of Time resulted significant ($\beta = 0.64, z\text{-score} = 7.16, p < 0.001, OR = 0.53$), indicating a higher likelihood of performing a correct response during the post-test phase compared to the pre-test phase in both conditions. The main effect of Condition also resulted significant ($\beta = 0.39, z\text{-score} = 4.25, p < 0.001, OR = 0.68$), suggesting a higher likelihood of performing a correct response in the museum condition compared to the urban condition overall (see Fig. 6). Crucially, the interaction between Time and Condition was significant ($\beta = 0.35, z\text{-score} = 2.86, p = 0.004, OR = 1.42$). Bonferroni-corrected post-hoc analyses showed a significant difference only in the post-test with a moderate effect size ($z\text{-score} = 4.25, p < 0.001, d = 0.50$), but not in the pre-test ($z\text{-score} = 0.48, p > 0.05$), indicating greater improvement in task performance after the museum visit compared to the urban walk (see Fig. 6). This is an important finding, suggesting that attentional control abilities improved more following the museum visit than the urban walk. This

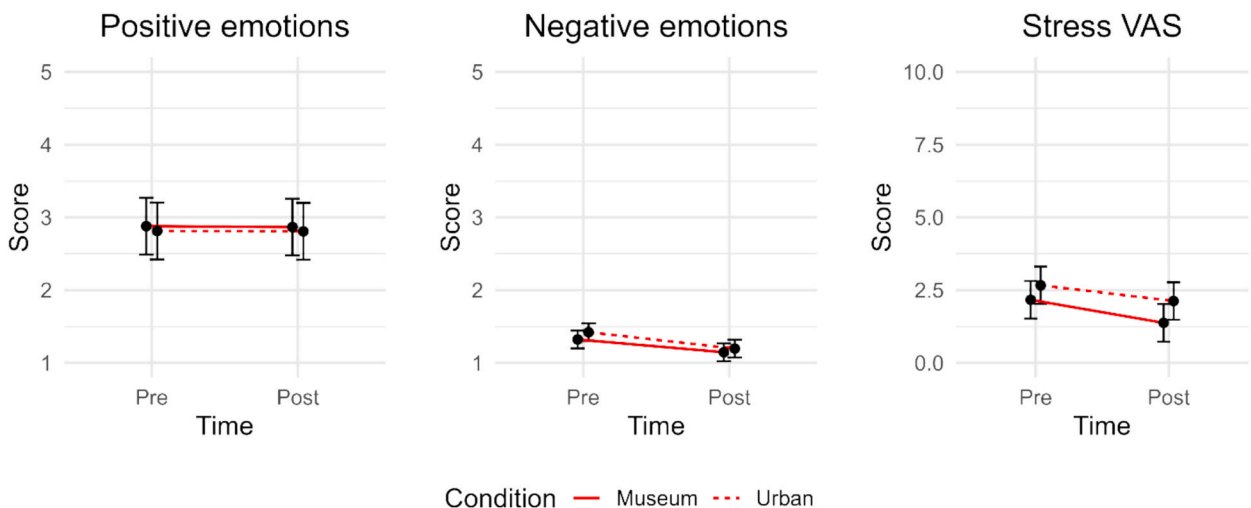


Fig. 5. Positive and negative emotions scores from the PANAS questionnaire and stress scores from the Stress Visual Analogue Scale. Black dots represent aggregated means, while error bars indicate standard errors.

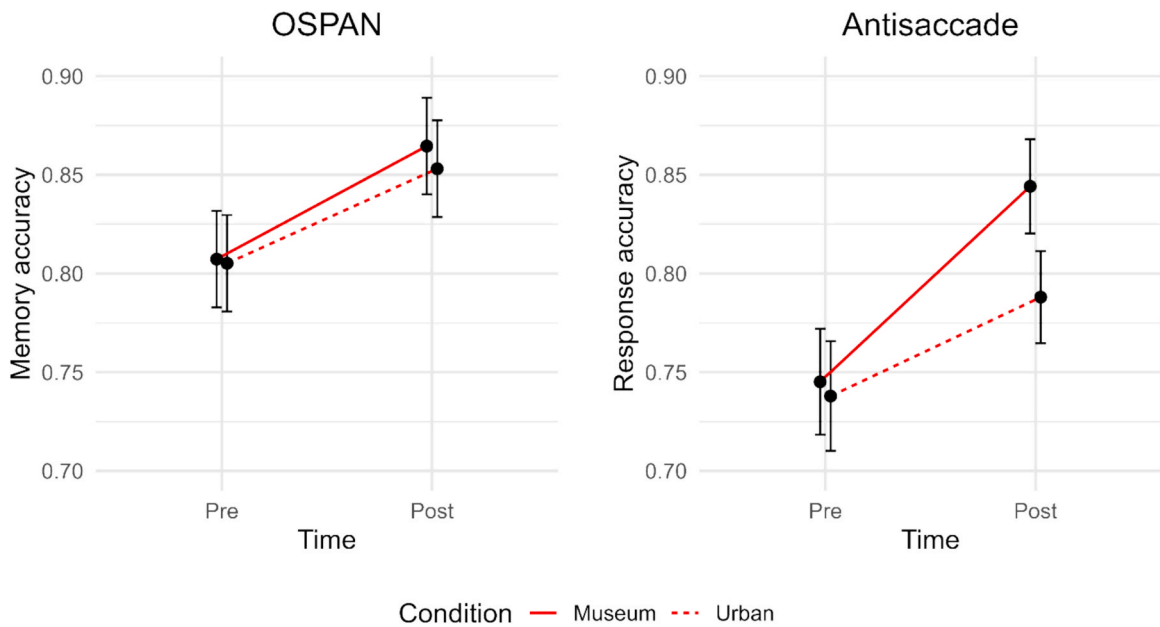


Fig. 6. Memory accuracy and response accuracy for the OSPAN and the Antisaccade tasks. Black dots represent the aggregated means while error bars indicate standard errors. Note that, although the outcome of the GLMM model for Antisaccade are expressed in logit (i.e., logarithm of odds ratios), in this figure we presented averaged accuracies as they are more easily interpretable.

result aligns with previous research on cognitive restoration in natural environments and indicates that visiting a museum can enhance attention.

3.3. Assessing differences in mental load during cognitive task performance, as reflected in eye metrics

We used blink rate and pupil diameter to estimate participants perceived mental load during the two cognitive tasks. One participant was excluded from the analyses due to the eye tracker failing to save data properly in one session. Blink rates recorded during the Antisaccade and OSPAN tasks were entered as dependent variables in two LMMs, with Condition and Time as fixed factors.

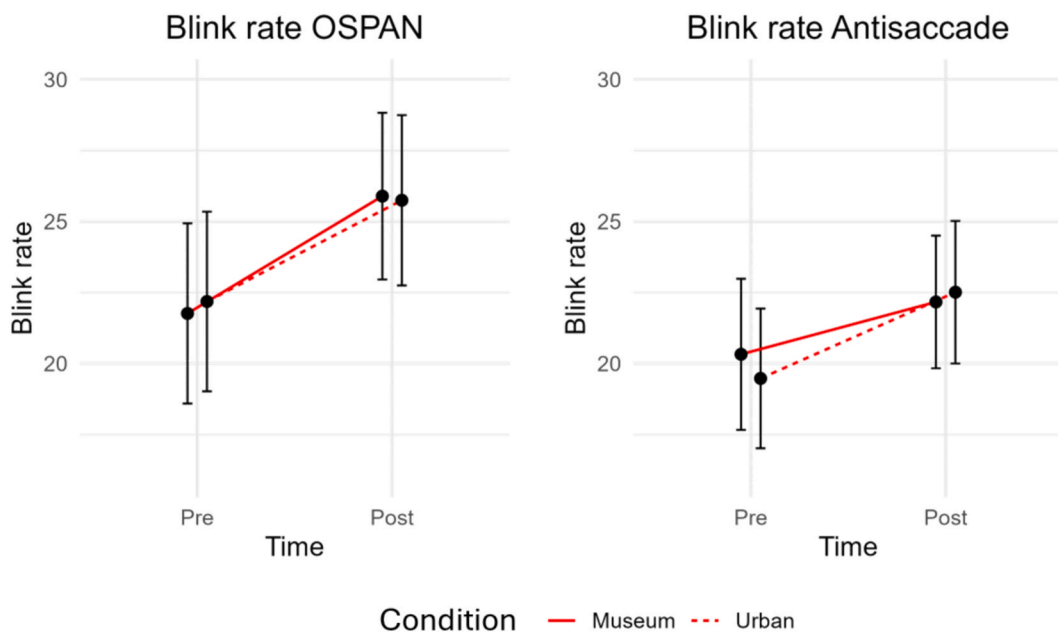


Fig. 7. Blink rate for the OSPAN and the Antisaccade tasks. Black dots represent the aggregated means while error bars indicate standard errors.

Only the main effect of Time during the OSPAN task was significant with a small effect size ($\beta = 4.13$, $t(66) = 2.45$, $p = 0.017$, $d = 0.26$), indicating a small increment in blink rates in the OSPAN post-test compared to the pre-test in both conditions (post-test = 25.8, SE = 2.88; pre-test = 22.0, SE = 3.11). Higher blink rates are commonly associated with mental fatigue (Fink et al., 2024). Indeed, the small increase in blink rate found during the OSPAN may reflect participants being more fatigued during the second OSPAN testing, regardless of the condition performed. No other significant effects emerged (see Fig. 7).

Average pupil diameter during the two cognitive tasks was entered as the dependent variable in two LMMs, with Condition and Time as fixed factors. No significant differences emerged (all $ps > 0.05$). However, interestingly, pupil diameter changes varied depending on the task. As shown in Fig. 8, pupil diameter increased overall compared to baseline during the OSPAN task ($t(22) = 3.02$, $p = 0.006$), whereas it decreased overall compared to baseline during the Antisaccade task ($t(22) = 3.03$, $p = 0.006$). This divergence may be due to differences in mental demands. During the OSPAN task, participants had to retain information in memory, and the increased pupil diameter may reflect the higher mental load. In contrast, the Antisaccade task required sustained focus but did not involve a hold on working memory. Thus, the decrease in pupil diameter may be attributed to the physical fatigue associated with repeated eye movements rather than changes in mental load. This interpretation aligns with previous research showing a reduction in pupil size due to physical fatigue (cf., Fink et al., 2024).

4. Discussion

In this project, we used a combination of self-reported, behavioral, and physiological measures to investigate whether visiting an artistic environment (i.e., a museum), compared to walking in an urban environment, can help restore attentional resources. Participants first underwent a mental depletion counting task to prime them for restoration. Then, to assess perceived restoration, stress, emotions, attentional control, and working memory, they were tested before and after either visiting a museum or taking a short urban walk (both lasting ~ 30 min).

Overall, our findings provided evidence that a museum environment can restore attentional resources more effectively than walking in an urban setting, as indicated by both self-reported and behavioral data. However, no additional restoration benefits of museum visits over urban walks were observed on working memory, and no significant reduction in mental load or stress of museum visits over urban walks was observed across any of our measures. These results align with Attention Restoration Theory (ART; Kaplan, 1995), which suggests that spending time in a museum can replenish cognitive resources and enhance attention. Notably, these findings are encouraging with respect to museum attendance, as they indicate that visiting a museum offers a way to restore attentional resources depleted by the heavy demands of urban life, helping people stay more focused on important information afterward. At the same time, our results do not suggest that taking a leisure walk in an urban environment increases stress. In fact, stress and negative emotions decreased equally after both the museum visit and the urban walk, and performance on the working memory task improved to a similar extent in both conditions. To our knowledge, this is the first study to use a combination of self-reported, behavioral, and physiological measures to show the attention restoration effects of visiting a museum. Below, we discuss the main results and their limitations in more detail, providing insights for both researchers and museum visitors.

First, self-reported measures showed increased restoration after the museum visit compared to the urban walk. While the higher

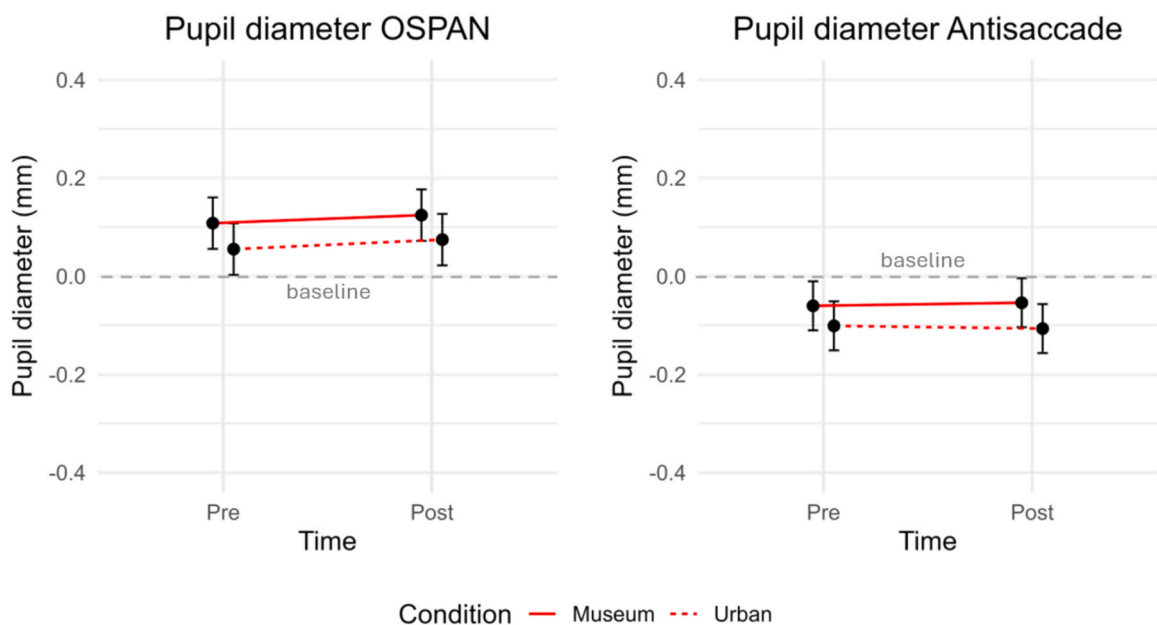


Fig. 8. Average pupil diameter for the OSPAN and the Antisaccade tasks. Black dots represent the aggregated means while error bars indicate standard errors.

scores on Coherence indicated that participants recognized the well-organized structure of the museum exhibition, higher scores on Being Away and Fascination suggested that participants experienced lower demands on directed attention and were free to focus their attention effortlessly on the fascinating elements of the environment (Pasini et al., 2014). This result is particularly interesting because it is corroborated by enhanced behavioral performance on our attentional control task (i.e., the Antisaccade task) after the museum visit. This is a crucial finding, as it indicates that attention restoration following museum visits is not limited to self-reported measures, but rather, participants were actually more focused and less distractible after being immersed in an artistic environment. According to ART, a sense of soft fascination caused by the visitors' attention being drawn via a "soft" bottom-up mechanism that gently attracts attention in a non-directed way, played a role in triggering this restoration. However, since this was an in-situ experiment, it was not possible to control for the level of soft fascination experienced across the two contexts (museum vs. urban). Replicating these findings in a controlled environment would help clarify the mechanisms that drive such restoration. In any case, improving attentional control can also go beyond reducing distractibility. Psychological literature has shown that attentional control is correlated with other long-term psychological traits, such as behavioral and emotional regulation (Urry & Gross, 2010), as well as mental (Milham et al., 2002) and economic well-being (Farah et al., 2006). In other words, museum visits may be important not only for replenishing attention abilities but also for improving everyday life in the long term. While we focused on the short-term effects of visiting a museum, it is reasonable to hypothesize that regular museum visits could lead to more stable improvements in attention abilities. Although this remains hypothetical, the present work can serve as a foundational step for future studies investigating these potential long-term effects.

While attentional control improved more after a museum visit, working memory capacity, as measured by OSPAN performance, showed similar improvements after the museum visit and the urban walk. Furthermore, we found no differences in mental load between the two conditions, as indicated by no differences in blink rate and pupil diameter. Notably, although our sample was relatively small ($n = 24$), differences between conditions were not even evident at a trend level, suggesting that either a museum visit may have limited impact on working memory or mental load recovery, or that a leisure walk in an urban environment may exert a similar positive effect to that of a museum visit on these outcomes. Interestingly, pupil diameter increased relative to baseline during the OSPAN, but decreased during the Antisaccade. This difference, although not directly related to the restorative effects of artistic environments, likely reflects the distinct cognitive demands of each task. The OSPAN, imposing a higher mental load on working memory, led to pupil dilation. In contrast, the Antisaccade, requiring rapid eye movements, likely induced physical eye strain, resulting in pupil constriction (cf., Fink et al., 2024).

Finally, stress levels decreased equally after the museum visit and the urban walk. This somewhat suggests that the observed improvement in attention after the museum visit may not be attributed solely to stress reduction, but rather to the reduced demands on directed attention resulting from immersion in an artistic environment. Moreover, these findings also suggest that both a leisure walk in an urban environment and a museum visit can have a similarly positive impact on stress relief. However, it is important to note that stress levels were consistently low in all our conditions (see Fig. 5), potentially limiting our ability to detect a further decrease. Similarly, we observed no significant differences in perceived positive or negative emotions between post-tests of the museum visit and the urban walk, except for a general decrease in negative emotions across both conditions. This reduction may be attributed to participant fatigue or frustration following the mental depletion task, with negative emotions and stress diminishing over time.

While this study presents promising findings, it is important to acknowledge certain limitations. First, the testing environment differed between conditions. Although we attempted to maintain consistent conditions during testing (e.g., illumination, silence, and tranquility), we could not fully control for participants' perceptions of the environment. Indeed, participants reported lower overall stress levels before and after the museum visit compared to the urban walk, potentially due to the museum environment being perceived as less stressful overall. Another limitation involves our two experimental conditions: while visiting museum is an indoor activity, walking in an urban environment is not. We chose this comparison to align with existing literature on cognitive restoration in natural environments. Notably, in our experiment the completion time did not differ across conditions. A final limitation of this study is the absence of a condition involving exposure to a natural environment. As a result, it is not possible to determine whether visiting an art museum is more restorative than walking in a natural setting, or vice versa. Indeed, our aim was not to compare natural and artistic environments, but rather to examine environments that are easily accessible within urban areas. Future studies are encouraged to explore this comparison.

5. Conclusions

This study used a pre-post, within-subjects design to investigate the restorative effects of visiting a museum. Compared to walking in an urban environment, visiting the museum more effectively restored attentional resources, as evidenced by both higher scores on the Perceived Restorativeness Scale and better performance on the attentional control task at post-test. Similar improvements in working memory and comparable levels of mental load were found after the museum visit and the urban walk, suggesting that only attentional abilities were specifically impacted by the museum experience. Likewise, self-reported stress and emotional states (positive and negative) did not vary as a function of the experimental condition. Notably, stress and negative emotions decreased after both the museum visit and the urban walk, suggesting that, although to a lesser extent than the museum visit, even a leisure walk in an urban environment may positively influence cognitive and emotional outcomes. Future studies could further explore this possibility, for example by including a control condition that differentiates between types of urban experiences (e.g., commuting to work vs. taking a leisure walk). Overall, our results suggest that visiting a museum can be a valuable way to restore attentional resources depleted by the demands of urban life. Given the well-established relation between attentional control and mental well-being (Milham et al., 2002), these findings can be important to overcome the current "mental health crisis", which estimates a 25 % increase in anxiety and mental

disorders following the first year of the pandemic (World Health Organization, 2022). Museum curators can leverage these results to promote museum visits, not only for their intrinsic cultural value, but also for their additional benefits to attention.

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CRedit authorship contribution statement

Nicola Vasta: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francesco N. Biondi:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Appendix A

Perceived Restorativeness Scale.

We are interested in how you experienced your walk / visit today. To help us understand your experience, we have provided the following statements for you to respond to. Please read carefully, then ask yourself: "how much does this statement apply to the environment I took my walk in today?".

To indicate your answer, select one of the numbers on the rating scale below each statement. For example, if you think that the statement does not at all apply to your experience of the environment you walked in, then you would select "0" (not at all), if you think it applies rather much, then you would select "6" (rather much), but if you think that it applies very much, you would select "10" (completely).

- _____ 1. Places like that are fascinating.
- _____ 2. In places like this my attention is drawn to many interesting things.
- _____ 3. In places like this it is hard to be bored.
- _____ 4. Places like that are a refuge from nuisances.
- _____ 5. To get away from things that usually demand my attention I like to go to places like this.
- _____ 6. To stop thinking about the things that I must get done I like to go to places like this.
- _____ 7. There is a clear order in the physical arrangement of places like this.
- _____ 8. In places like this it is easy to see how things are organized.
- _____ 9. In places like this everything seems to have its proper place.
- _____ 10. That place is large enough to allow exploration in many directions.
- _____ 11. In places like that there are few boundaries to limit my possibility for moving about.

Appendix Table A

Factor grouping for the perceived restorativeness scale.

Factor	Statement
Fascination	Places like that are fascinating.
	In places like this my attention is drawn to many interesting things.
	In places like this it is hard to be bored.
Being Away	Places like that are a refuge from nuisances.
	To get away from things that usually demand my attention I like to go to places like this.
	To stop thinking about the things that I must get done I like to go to places like this.
Coherence	There is a clear order in the physical arrangement of places like this.
	In places like this it is easy to see how things are organized.
	In places like this everything seems to have its proper place.

(continued on next page)

Appendix Table A (continued)

Factor	Statement
Scope	That place is large enough to allow exploration in many directions. In places like that there are few boundaries to limit my possibility for moving about.

Appendix B

Positive and Negative Affect Schedule (PANAS) scale.

		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
PANAS 1	Interested	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 2	Distressed	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 3	Excited	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 4	Upset	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 5	Strong	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 6	Guilty	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 7	Scared	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 8	Hostile	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 9	Enthusiastic	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 10	Proud	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 11	Irritable	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 12	Alert	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 13	Ashamed	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 14	Inspired	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 15	Nervous	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 16	Determined	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 17	Attentive	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 18	Jittery	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 19	Active	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
PANAS 20	Afraid	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

Appendix C. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.concog.2025.103939>.

Data availability

Data will be made available on request. The study protocol was preregistered on the Open Science Framework platform (see <https://osf.io/bfah7>). Data, materials and analysis code for this study are available by emailing the corresponding author.

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