

The nature gaze: eye tracking experiment reveals wellbeing benefits derived visual attention toward elements of nature

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1 The nature gaze: Eye tracking experiment reveals wellbeing benefits derived from

2 directing visual attention toward elements of nature

3

4 Abstract

5 1. The urban lifestyle has a profound effect on mental health, contributing significantly to the
challenges faced by people who reside in urban areas. Growing empirical evidence underscores
7 the potential of nature to alleviate these mental health burdens. However, we still lack
8 understanding on which specific natural elements provide these benefits.

2. Using eye-tracking technology, we experimentally explored the relationships between 9 10 intentional visual attention to natural (green) and human-made (grey) elements in urban areas and 11 their association with wellbeing measures. Participants took a 45-minute outdoor walk that 12 simulates a walk to and from work, in which we examined pre and post measures of cognition, affect, anxiety, and perceived restorativeness. Participants were prompted to direct their attention 13 to green, grey, or a mixture of both elements. By analyzing participants' eye movements and 14 patterns, we determined adherence to experimental conditions and related visual attention to 15 16 natural elements.

3. The experimental groups instructed to direct their visual attention to green, grey, or a mix of
both infrastructures exhibited differences in negative and positive affect, anxiety, and perceived
restorativeness, but not in cognition after a walk in an urban environment.

4. The percentage of time spent viewing natural elements showed that people who focused more
on green features reported a decrease in anxiety and higher perceived restorativeness. In contrast,
those who spent more time viewing gray elements reported increased anxiety and lowered
perceived restorativeness. The percentage of time viewing natural elements was not linked to affect

or cognition. Viewing trees showed the strongest association with wellbeing measures comparedto other natural elements.

5. Together, our results indicate that a simple behavior change (directing visual attention to elements of nature instead of gray elements) can produce mental health benefits in the form of reducing anxiety and perceived restoration for people in urban areas. Thus, efforts to integrate nature, especially trees, in urban areas and promoting city dwellers to visually interact with it during their daily routine can improve mental issues associated with urban lifestyle.

31

32 Introduction

33 Cities have become thriving centers of economic growth, innovation and knowledge 34 production, but these novel ecosystems (Kowarik 2011) can also have significant implications for the health and wellbeing of humans (Bertram & Rehdanz, 2015; Takahashi et al., 2021). Myriad 35 studies have linked urban lifestyles with chronic stress and mental fatigue that can lead to 36 noncommunicable diseases such as depression and anxiety (Lederbogen et al., 2011; Wang, 2004). 37 Urbanization is therefore emerging as a major contemporary global challenge with troubling 38 implications for human health, but nature has shown remarkable promise for addressing this 39 challenge (Colléony & Shwartz, 2019). Mounting empirical evidence underscores the mental 40 41 health benefits of nature interaction, including psychological restoration, stress reduction and 42 improved mood (Hartig et al., 2003; Roberts et al., 2019; Yao et al., 2021). Even a brief interaction 43 with nature can enhance happiness and reduce rumination (Bratman et al., 2015). Exposure to natural settings can also boost cognitive performance and attention restoration, suggesting a 44 45 positive impact on cognitive function and mental clarity (Berman et al., 2008; Tennessen and Cimprich, 1995; Kaplan and Kaplan, 1989). Therefore, interaction with nature in urban 46 environments has received considerable attention in research, as it can buffer against the mental 47

burdens of city living (Bai et al., 2012; de Vries et al., 2016; Lenzi & Perucca, 2020; White et al.,
2013). However, the relationship between nature and wellbeing is complex, with research often
addressing nature as a 'black box' where the underlying mechanisms remain largely unexplored
(Colléony & Shwartz 2019).

52 A typical approach to studying nature and wellbeing involves comparing wellbeing measures before and after nature visits or walks, contrasting these with experiences in urban 53 settings (e.g., Berman et al., 2012; Bratman, et al., 2015; Elsadek et al., 2019; Hartig et al., 2003). 54 Although these studies indicate a measurable difference between walking in natural and urban 55 settings, they do not address what aspects of the experience contribute to these benefits. For 56 57 example, multiple sensory aspects are involved in experiencing or interacting with nature, such as 58 seeing, hearing, smelling, and touching (Gaston et al., 2018). A recent experiment has demonstrated the effect these varied interactions in natural settings can have on positive affect 59 (Colléony et al., 2021). Studies of the psychological benefits of viewing nature using indoor 60 experiments have indicated that visual attention to nature is a primary avenue for benefits (Jo et 61 al., 2019). Direct visual contact with natural elements is likely a key factor in deriving wellbeing 62 benefits derived from nature, such as attention restoration from cognitive fatigue (Grinde & Patil, 63 2009; Varkovetski, 2015). But real-life knowledge on how visual attention to different nature 64 elements (e.g., trees, flowers) impacts psychological benefits is still scarce. This gap extends to 65 understanding the needed 'dose' of nature and the type of nature interactions that can optimize 66 benefits (Meredith et al., 2020; Richardson et al., 2021). This information can guide practitioners 67 in using natural elements as building blocks to design healthier environments (Colléony & Shwartz 68 69 2019; Hartig et al., 1996) and eye tracking technology can help establish this knowledgebase.

Eye-tracking research offers insights into human cognition and attention in various fields,
 including psychology, marketing, and user interface design (Meißner & Oll, 2019) and can be used

72 to understand how individuals perceive and value natural environments (e.g., Cottet et al., 2018). 73 Eye-tracking techniques come in various forms, such as desktop, virtual reality (VR), and mobile systems, each offering unique advantages and limitations. For example, desktop eye tracking offers 74 75 precise measurements in controlled settings, while VR eye tracking enables immersive studies, 76 and mobile tracking captures real-world interactions, but has calibration and comfort challenges (Holmqvist et al., 2011; Hutton, 2019). Each method is tailored for specific research needs that 77 balance control, realism, and mobility. Furthermore, eye tracking experiments can utilize various 78 indicators, chosen based on study objectives, to thoroughly analyze visual attention and cognitive 79 processes. Fixations and saccades are key indicators, identifying points of focus and shifts between 80 81 them, that uncover engaging aspects of landscapes and cognitive engagement. Fixations are 82 particularly effective in visual attention studies, offering direct insights into how visual intake of 83 environmental elements impact psychological responses (e.g., (Duchowski, 2007; Holmqvist et al., 2011). Fixations and saccades can also be used to generate gaze heatmaps that visually 84 represent areas with high gaze concentration, highlighting regions of interest. Other indicators can 85 reveal additional unique aspects of eye movement behavior. For instance, Time to First Fixation 86 (TTFF) can be used for assessing initial visual attention, Scanpaths for exploring fixation and 87 saccade sequences, blink rates and pupillary light reflexes for insights into eye health and attention 88 dynamics (Dewhurst et al., 2018; Simonetti & Bigne, 2022; Zou et al., 2023). 89

While mobile eye tracking studies in outdoor environments are increasing, they are still somewhat uncommon, even though essential gaze features are apparent when moving (Uttley et al., 2018; Jovancevic-Misic & Hayhoe, 2009). Studies that have allowed participants more active movement while viewing images have found differences between static and active viewing (e.g., Foulsham et al., 2011), where nearly all features of gazing differ between active and static viewing conditions (Haskins et al., 2020). Studies that have used this technology in mobile outdoor settings generally are completed with small sample sizes (less than 50 participants) and a relatively short
walk duration (less than 20 minutes; e.g., Gholami et al., 2021; Simpson et al., 2019; Trivic, 2023).
In these studies, researchers have found that, when undirected, participants look at human-made
structures more than natural structures (Gholami et al., 2021), and participants, especially when
elderly, look at the ground, ground level more than they look up (Simpson et al., 2019; Trivic, 2023).

To date, most research aiming to explore how individuals perceive and value landscapes 102 or natural environments has used eye tracking indoors on photographs or in still settings. These 103 104 studies have found that the assessed visual quality of landscapes relates to landscape heterogeneity 105 (de la Fuente de Val et al., 2006), degree of openness (Dupont et al., 2014), and fixation duration 106 on greenery (Kerimova et al., 2022). Stationary studies using images or photos have also examined 107 the associations between visual assessments of landscapes and restorative assessments of those landscapes. In these studies, landscape elements such as grass, trees, shrubs, and water have been 108 associated with positive restorative benefits, while built elements have been negatively associated 109 with restoration (Liu et al., 2022; Nordh et al., 2013). There are also significant positive 110 relationships between landscape preference, perceived restorativeness, and fixation percentage 111 (Wu et al., 2021). Valtchanov & Ellard (2015) found that the restorative aspects of natural 112 environments associated with visual properties of a scene may work through multiple mechanisms 113 where environments may only offer cognitive or affective benefits. Finally, Cottet et al. (2018) 114 found that specific natural landscape elements in urban settings may be important for wellbeing 115 benefits. However, there is a gap in understanding whether these patterns remain in real-life 116 117 outdoor environments in sedentary or active situations.

Here, we aimed to explore how visual attention to green elements may be associated withpositive and negative affect, anxiety, and attention. Using mobile outdoor eye tracking technology,

120 we conducted a controlled experiment, comparing three groups of participants who took the same 121 45-minute walk that simulates a daily urban walk to/from work, for instance. Unlike previous studies that focused on undirected visual attention during walks (e.g., Gholami et al., 2021; Rupi 122 123 & Krizek, 2019; Simpson et al., 2019; Trivic, 2023) our approach involved all participants experiencing the same route but with a unique element: directed visual attention. Participants were 124 instructed to concentrate their gaze on specific elements, green (vegetation), grey (man-made), or 125 a combination of both, and made stops at ten strategically chosen points that exemplified these 126 elements (Fig. 1). This variation allows to: (1) compare how directed visual attention influences 127 the nature experience of the same walk, including visual intake of nature or non-natural elements, 128 129 and wellbeing measures such as cognition, affect, anxiety, and restorativeness; (2) how the 130 percentage of time spent directing visual attention toward nature or grey infrastructure is related 131 to differences in cognition, affect, anxiety, and restorativeness using areas of interest while participants are stopped; and, (3) how the percentage of time spent directing visual attention toward 132 nature or grey infrastructure is related to differences in cognition, affect, anxiety, and 133 restorativeness using areas of interest while walking including to what extent different elements 134 of nature (e.g., trees and lawns) are associated with differences in cognition, affect, anxiety, and 135 restorativeness. We expected that a greater percentage of time viewing green elements would be 136 associated with increased cognitive function, improvement in affective measures, reduced anxiety, 137 138 and greater perceived restorativeness.

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------[Figure 1 about here]------

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141 Materials and Methods

142 Participants and Experimental Procedure

Over nine months, 117 adults (65 women, mean age = 26.1) without neurological or 143 psychiatric disorders were recruited to participate in the study. They participated in a guided walk 144 wearing eye tracking glasses to monitor their visual engagement on and around the campus of the 145 146 Technion – Israel Institute of Technology's in Haifa, Israel (Fig. 2). Before the walk, participants responded to a battery of psychocognitive measures of affect, anxiety, and attention (Fig. 1). Upon 147 completion, participants were fitted with Tobii Pro 2 eve tracking glasses and brief instructions 148 were given to limit their head movements and look directly through the glasses as much as possible 149 throughout the walk. A research assistant guided participants on a 45-minute walk (Bratman, 150 Hamilton, et al., 2015; Yao et al., 2021) from the campus laboratory to the adjacent neighborhood 151 152 and back, in which we integrated ten stopping points per participant (Fig. 2). After the walk, the 153 participants had their eye tracking equipment removed and then repeated the same set of psychocognitive measures, also including an additional scale that evaluated the perceived 154 restorativeness of the walk (Fig. 1). Together, this procedure took about 70 minutes and upon 155 completion the participants were compensated 50NIS (~\$15) for their time. 156

Individuals were randomly sorted into one of three experimental groups (39 participants 157 per group), which differ in the level of green elements at the stopping points, and the instructions 158 provided. Thus, they walked the same route but were stopped at different points along the way, 159 but the same number of points overall (Fig. 1). Participants in the 'green' group stopped at points 160 dominated by vegetation and were instructed to direct their attention to natural elements (Fig. 3a; 161 162 Fig. S1 in Supporting Information). Participants in the 'grey' group stopped at points dominated by human-made infrastructure such as buildings, pavement, and roads, and were asked to direct 163 164 their attention to man-made elements (Fig. 3b; Fig. S1). Participants in the 'mixed' group stopped at points with mixed green and grey elements and were instructed to focus on how nature and built 165 elements are mixed (Fig. 3c; Fig. S1). These directions were administered in Hebrew (see Text S1 166

in Supporting Information for an English translation). Five participants were disqualified (one
participant voluntarily quit halfway through, one admitted that they did not qualify based on the
consent form, and three were discounted because of a fundamental error with either the software
or hardware, resulting in limited or no data).

171

------[Figures 2 & 3 about here]------

172 Data Measures

173 The Tobii Pro 2 eye-tracking glasses (Tobii AB, 2015) were used to track eye movements with six inward-facing IR cameras and, using a single forward-facing camera to record the scene 174 in front of the participant. The eye movement recordings were then overlaid on the scene recording 175 and analyzed using the iMotions 9.x software package (iMotions, 2020). Using the eye-tracking 176 glasses, we recorded several visual attention variables (Fig. 1). Wellbeing outcomes and 177 demographic variables were collected in the before/after surveys (see Text S2 in Supporting 178 Information for full versions of these measures) and control variables were collected from 179 secondary resources (Fig. 1). 180

181

182 Eye-tracking Measures

In situ eye tracking is a relatively novel method for examining individuals' sight mechanisms, their interactions with environments, and how visual perceptions relate to thoughts, feelings, and reactions to environmental stimuli. This technique uses eye-facing infrared (IR) cameras to track eye movements, reflecting individuals' visual patterns when processing information (Koop & Johnson, 2011). The two most common metrics in eye tracking are saccades (lateral eye movements) and fixations (pauses in eye movement). Fixations occur when the eye stops moving and focuses on a stimulus, with a cluster of fixations around an object termed a gaze 190 or dwell (iMotions, 2020b). Observers fixate on items of interest, and analyzing gaze/dwell 191 patterns helps understand social information processing abilities (Birmingham et al., 2009) and discern preferences (Glaholt et al., 2009). In our study, we focused solely on fixations as they 192 193 indicate personal interests. Saccade analysis, more suited for studies of distress (like PTSD), 194 requires a strictly controlled environment. As our goal was to evaluate the impact of gaze on green elements, we did not measure other indicators such as Time to First Fixation (TTFF) and 195 Scanpaths, which assess different aspects of eye movement behavior, like initial visual attention 196 and sequences of fixations and saccades. 197

Eye tracking data were collected at both stops and continuously as participants moved 198 199 between stops. To gauge visual interest during the walk, we used two sets of indicators: one for 200 stops and another while the participants walked. Initially, fixation clusters (gazes) around stimuli 201 at stopping points were analyzed. We captured photographs at each stop and delineated polygons around Areas of Interest (AOIs), categorizing them as green (vegetation and bare soil), grey (man-202 203 made structures such as roads, pavements, buildings, and vehicles), and mixed (areas with indistinct separation between green and grey elements). The participants' eye movements were 204 205 then superimposed onto these photographs, allowing us to quantify the number of fixations and the duration of dwell time on these AOIs. Detailing AOIs into more specific green or grey elements 206 was challenging in our outdoor study, as participants varied in their physical positions, we 207 therefore needed to individually adjust AOIs, preventing extremely precise classification of each 208 209 element in our AOI digitization. Utilizing iMotions' gaze mapping algorithm, heatmaps were generated to visually represent fixations and gazes on the photographs, illustrating the intensity of 210 211 interest in specific AOIs based on the total time spent dwelling in them (iMotions, 2020b). For analyzing the stopping points, we calculated the sum of the fixation durations in milliseconds (ms) 212 while participants gazed at green or grey AOIs. We then summed the total time of fixations and 213

calculated the percentage of time for fixations on green and grey elements. This percentage variable was used in further analyses related to wellbeing measures. The mixed category was omitted from this analysis due to the difficulty in distinctly categorizing visual attention towards either of the two categories.

218 Conducting AOI analysis for the mobile phase of the walk posed a significant challenge, as it involved digitizing AOIs for every segment of the walk for each participant. Consequently, 219 220 fixations recorded between stops were manually coded by a researcher using iMotions. This process involved reviewing every 15th fixation and assigning it to specific elements such as trees, 221 bushes, lawns, flowers, people, buildings, vehicles, animals, etc., based on their appearance in the 222 video (see Fig. S2 for an example of this coding). The choice of the 15th fixation was a practical 223 224 compromise, balancing sampling effort with feasibility, given that the ideal scenario of using every 225 fixation was constrained by time limitations. When a fixation occurred on an area encompassing both natural and man-made elements, it was classified as 'mixed' (see Figure S2) and excluded 226 227 from the analysis. Thus, in the mobile phase, we summed the total fixation time, and calculated the percentage of time spent looking towards both green and grey categories, akin to the AOI 228 229 analysis at stopping points, and also towards each of the four natural elements (trees, bushes, lawns, and flowers). 230

The Tobii Pro Glasses 2 and similar eye-tracking devices struggle in bright sunlight due to interference from ambient IR radiation and reduced contrast for effective pupil detection. These glasses are optimized for reflected light capture, and Tobii recommends their use indoors with controlled lighting and minimal head movement. To mitigate the effects of sunlight, our experiment was conducted in the morning and evening with shadier conditions. Participants were also fitted with a baseball cap (Simpson et al., 2019) to reduce light interference, and were instructed to keep their heads as steady as possible. Despite these challenges, the glasses 238 successfully recorded the majority of eye movements, suitable for analysis with iMotions. 239 Participants with more than 66% of captured eye movements were included in the analyses. At the stopping points, where the participants were stationary, the recording quality was mostly adequate. 240 241 The majority of recording issues occurred during movement. The random assignment of participants to the experimental conditions should ensure that these limitations do not impact the 242 comparison between the experimental conditions. However, to account for the challenges of using 243 eye-tracking technology outdoors and other variability in total fixation time between participants, 244 we standardized the total fixation time towards each category or natural element. In all eye tracking 245 analyses, we used the percentage of total fixation time spent on specific categories or elements. 246 247 This metric was calculated by dividing the total time fixating on a specific category by the total 248 fixation time for each participant. We separately calculated this percentage for the green and grey 249 categories in the stopping point AOI analysis and both categories and individual elements (e.g., trees and flowers) in the mobile 15th fixation analysis. 250

251 Finally, we assessed whether the percentage of time spent looking at green or grey elements, as determined by eye tracking, aligned with the experimental groups (i.e., condition). 252 253 For this purpose, we conducted Kruskal-Wallis tests. The Kruskal-Wallis test, a nonparametric equivalent to a one-way ANOVA, is ideal when normality assumptions are not met, as in the case 254 of percentages. We ran four separate tests, with the condition as the independent variable and the 255 percentage of time spent looking at green and grey elements, both while stopped and while 256 walking, as dependent variables. This analysis revealed significant differences in the time spent 257 looking at green or grey elements between the three experimental groups during both the stops and 258 259 the entire walk (Fig. 4). Therefore, the time that participants spent looking at the green or grey elements corresponded to their assigned treatment conditions. Participants in the green group 260

focused more on green elements, whereas those in the grey group paid more attention to greyelements. The results of the mixed group conditions were intermediate, as expected.

263

------[Figure 4 about here]------

264 Wellbeing outcome, demographics, and control variables

Affective measures were measured using a questionnaire that included assessments of 265 anxiety, positive affect, and negative affect (PANAS - Positive and Negative Affect Scale). 266 267 Anxiety was assessed using the State-Trait Anxiety Inventory (STAI; (Elsadek et al., 2019; Spielberger et al., 1983). This survey consists of 40 items that assess both state anxiety (momentary 268 judgment) and trait anxiety (general levels of anxiety), where each is composed of twenty 269 questions. Questions are asked on a 4-point scale, where for state anxiety, participants are asked 270 to assess the intensity of their current feelings from (1) not at all, to (4) very much so, and for trait 271 anxiety, to assess the intensity of their feelings in general from (1) almost never to (4) almost 272 273 always. Positive and negative affect were evaluated using the Positive and Negative Affect Scale (PANAS; (Berman et al., 2012; Watson et al., 1988). This survey consists of 20 items that assess 274 both positive and negative affect, with 10 items for each. Questions are asked on a 5-point scale, 275 276 where participants are asked to assess the degree to which they felt the items describe their current 277 state from (1) very slightly, or not at all, to (5) extremely. Affective measures were taken before 278 and after the walk. For each measure collected, STAI, positive PANAS and negative PANAS, a difference in before and after scores was calculated. We used the official Hebrew translation of 279 each measure. 280

Participants were also given the Necker Cube Change Pattern Change Detection Task (NCPCT) cognitive task to measure cognitive ability related to attention. For the NCPCT task, which measures directed attention, participants used a computer to click every time they perceived 284 a change in the cube's orientation. Participants are instructed to focus on holding one pattern, and 285 therefore, a change is attributed to attentional fatigue (Hartig et al., 2003; Kaplan, 1995). Cognitive measures are not a measure of overall cognitive ability, but rather a measure of attention restoration 286 287 related to cognitive function. Participants were introduced to the task, given written instructions, 288 and allowed to practice for 10 seconds. The participants then completed the task in two rounds of 30-seconds each with the number of clicks indicating attention. A second cognitive task consisting 289 of the change blindness exercise was administered to all participants. The data for this task were 290 not viable due to an error in administering this task and not used in analyses. The NCPCT cognitive 291 292 measure was assessed before and after the walk, and similarly to affective measures, a difference 293 was calculated before and after scores.

In addition to affective and cognitive measures, participants were asked about their perceived restorativeness of the walk using the Perceived Restorativeness Scale (PRS-11). The PRS-11 was developed by Pasini et al., (2014) as a shorter alternative to the PRS developed by Hartig et al., (1997). The PRS-11 comprises 11 items that deal with fascination, being away, coherence, and scope. Participants are asked to rank their agreement with items on a 5-point scale from (1) not at all to (5) very much.

Participants were also asked to indicate their connection to nature using the nature 300 relatedness scale (NR-6). The NR-6 was developed by Nisbet and Zelenski (2013) as a shorter 301 302 alternative to the NR developed by Nisbet et al., (2009). The NR-6 consists of six items in which 303 individuals indicate on a 5-point bipolar scale how much they agree with each statement from (1) strongly disagree to (5) strongly agree. Demographic questions were also asked, including age, 304 305 gender, childhood residence size (medium/large city, small town, kibbutz), and current residence size (medium/large city, small town, kibbutz). Additional environmental control variables, 306 307 including air quality (measured using the Breezometer Air Quality Index or BAQI), temperature,

relative humidity, visibility, and cloud cover (%), were collected for each participant at the time
of their walk. These measurements were obtained while participants completed the before
questionnaire from the Israel Meteorological Service Station at the Technion, which records these
variables hourly (more details can be found at (IMS, 2023)).

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212	Data Analy	CIC
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Statistical analyses were performed in RStudio (version 1.1.456; R Core Team, 2018). 314 Preliminary data analysis confirmed that there were no significant differences between groups 315 based on control variables (i.e., environmental conditions) and latent variables were combined into 316 317 an index after determining alpha coefficients were acceptable (>0.75 for all scales; Text S3 in 318 Supporting Information). We performed three types of analysis: (1) analysis of changes in 319 wellbeing outcomes before and after interventions (without eye-tracking); (2) analysis of how differences in the percentage of fixations time on green and grey elements at stops were associated 320 with affective, cognitive, and restorative measures (AOI analysis at stops); and (3) analysis of how 321 the percentage of fixations time on green and grey elements, as well as specific natural elements 322 (trees, flowers, bushes, and lawn) throughout the walk were associated with affective, cognitive, 323 and restorativeness measures. 324

For the first set of analyses, mixed models for repeated measures were run with individual as a random effect to assess differences in PANAS, NCPCT, and STAI (state) before and after the walk given group assignment (green, grey, or mixed condition). The interaction of time (before/after) and condition (green, grey, and mixed) was used as an independent variable, along with individual (random effect) with all control variables listed in Fig. 1, including demographic and environmental variables. This results in four separate models, one for each dependent variable: PANAS (positive and negative), NCPCT, and STAI state. A linear model for perceived

restorativeness was also run, which is a measure only taken after the experiment, based on group assignment with the same variables mentioned in the previous analysis and no random effect. Estimated marginal means were calculated to examine differences in dependent variables between groups and differences before and after the experiment.

In the second set of analyses, we built 10 linear models to explore the variables that 336 influence the changes in PANAS (positive and negative), NCPCT, STAI state, and perceived 337 restorativeness during stops in areas of interest (AOIs). We calculated differences in the first four 338 response variables (measured before and after) by subtracting the pre-walk scores from post-walk 339 scores for each participant. The percentage of time gazing at green or grey elements while stopped 340 341 was used as independent variables, along with all control demographic and environmental 342 variables (Fig. 1). Due to the high correlations found between the percentage of time looking at green and grey elements (Fig. S3a & Fig. S3b), separate model sets were built for each variable. 343 This resulted in two model sets per dependent variable (changes in PANAS (positive and negative), 344 changes in NCPCT, changes in STAI state, and perceived restorativeness). For each model set, we 345 used forward stepwise model selection to create a set of candidate models starting with the null 346 and separate models for each variable. Variables from the AIC top-performing model were 347 propagated to the next step in an iterative process until a final AIC top-performing model was 348 identified (Venables & Ripley, 2002; Burnham & Anderson, 2004). 349

In our final set of analyses, focusing on the walking phase, we built 15 linear models to explore how the percentage of time spent fixating on green or grey elements, and specific natural elements, affected changes in PANAS (positive and negative), changes in NCPCT, changes in STAI state, and perceived restorativeness. The same methods used in the second analysis were used here for the walking phase data. Due to significant correlations among independent eye tracking variables (Fig. S3a & Fig. S3b), we created three sets of separate models for overall green, overall grey, and specific natural elements (combined). This approach led to 15 linear models, assessing the relationships between the five dependent variables and the fixation percentages on green, grey and four specific natural elements (trees, bushes, lawns, and flowers), with all control variables included (Fig. 1). As in the above analysis, forward stepwise model selection was used to identify top-performing AIC models.

Correlations between all variables were tested. Correlations between control variables 361 (demographic and environmental) and all independent variables of interest were <0.5. Correlations 362 between percentage of time viewing specific elements (trees, lawn, bushes, and flowers) were 363 <0.55. Correlations between percentage of time viewing green and grey elements were generally 364 365 high (between 0.64 and 0.91, p < .001), and so these variables were not put in models together. Full 366 correlation analyses with p-values can be found in supporting information (Figs. S3a & S3b). 367 Normality assumptions and multicollinearity were checked by plotting residuals and with variance inflation factors (values between 1.03 and 1.06), respectively. 368

369

370 **Results**

The first analysis revealed that the interaction between conditions and time (i.e., before and 371 after) was significant for positive affect and STAI state (Table 1). Participants in the green group 372 showed marginally higher average scores in positive affect after the walk compared to their pre-373 walk scores (p=0.064; Fig. 5a), and these scores were higher than those of the grey and mixed 374 groups after the walk. Both the green and mixed groups reported a decrease in negative affect after 375 the walk, unlike the grey group, where no change was observed (Fig. 5b), but there was no 376 377 difference between the groups (Table 1). No significant changes were found in NCPCT scores before and after the walk, nor between the conditions for all groups (Fig. 5c; Table 1). Pre-walk 378 379 STAI state scores were significantly higher than post-walk scores for both green and mixed groups

(Fig. 5d), and there was a significant difference between the green and grey groups (Table 1). The perceived restorativeness of the green group was significantly higher than that of the mixed and grey groups, receptively (Fig. 5e). Nature relatedness correlated positively with positive affect and perceived restorativeness (Table 1). Participants who spent their childhood in large or medium cities demonstrated lower NCPCT scores.

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-----[Figure 5 and Table 1 about here]------

386 The percentage of time that individuals spent fixating on green or grey elements was primarily correlated with changes in STAI and perceived restorativeness (PRS; Table 2). The percentage of 387 time spent gazing at green elements significantly reduced state anxiety, while gazing at grey 388 elements increased it (Table 2). In all STAI models, both age and cloud cover were consistently 389 negatively associated with STAI score differences (Table 2). Perceived restorativeness 390 demonstrated a positive association with the percentage of time gazing at green elements and a 391 392 negative correlation with percentage of time gazing at grey elements (Table 2). Naturerelatedness was positively related to perceived restorativeness (Table 2). Other control variables 393 were either excluded in the final model after AIC model selection or found insignificant (Table 394 2). No significant correlations were observed between changes in PANAS (positive and 395 396 negative) and NCPCT scores and the percentage of time gazing at green or grey elements. 397 Gender was negatively correlated with changes in positive and negative affect (Tables. S1-S6). Base models for the STAI and PRS models can be found in supplementary material (Tables. S7-398 S10). 399

400

-----[Table 2 about here]------

401 The results of the third analysis, examining fixations during the mobile phase, aligned with 402 the results of the previous analysis around the stopping points analysis (Tables 2 & 3). The 403 percentage of time spent fixating on green elements while walking was negatively associated with 404 changes in STAI and positively with perceived restorativeness, while the percentage of time spent fixating on grey elements demonstrated inverse trends (Table 3). Thus, more fixation on green 405 406 elements reduced state anxiety and increased perceived restorativeness, while fixation on grey 407 elements showed opposite trends. Nature-relatedness was positively associated with perceived restorativeness, and childhood residency negatively correlated with perceived restorativeness in 408 409 the grey group (Table 3). No significant relationships were found between the percentage of time spent fixating on green or grey elements and changes in PANAS (positive and negative) or NCPCT 410 scores (Tables S11-S16). Base models for the STAI and PRS models can be found in 411 412 supplementary material (Tables. S17-S20).

413 Wellbeing outcomes were also related to the percentage of time fixating on specific natural elements (Table 4). Changes in STAI (state) scores before and after the walk were negatively 414 correlated with the percentage of time fixating at trees, indicating that participants who spent more 415 time gazing at trees reported a greater reduction in state anxiety. The perceived restorativeness 416 models indicated that, along with trees, both bushes and lawns were marginally (p<0.1) and 417 positively related to increased perceived restorativeness (Table 4). Participants who spent more 418 time gazing at trees, bushes, or lawns during their walk reported significantly higher perceived 419 restorativeness than those who spent less time looking at these elements. Age and cloud cover 420 421 were significantly related to decreases in state anxiety from the beginning to the end of the walk. 422 Other control variables were either removed from the model based on AIC selection or found to be insignificant (Table 4). Nature-relatedness was positively correlated with perceived 423 424 restorativeness. No significant relationships were observed between PANAS (positive and 425 negative) or NCPCT scores and the fixation on any natural elements while walking (Tables S21426 S23). Base models for the STAI and PRS models can be found in the supplementary material427 (Tables. S24-S25).

428

-----[Tables 3,4 about here]------

- 429
- 430 Discussion

Empirical studies show that nature interactions can mitigate urban living's negative effects 431 on health and wellbeing (Hartig & Kahn, 2016; Jackson, 2003; Kabisch et al., 2017). Enhancing 432 urban design for the wellbeing of residents and nature requires a deeper understanding of how 433 specific natural or green elements can provide benefits to humans (Colléony and Shwartz, 2019). 434 435 Our study used mobile eye tracking in outdoor settings to examine the relationships between 436 human wellbeing and visual attention to green and grey elements. This is, to our knowledge, one of the first attempts to explore these relationships while participants actively moved through a 437 complex urban landscape, thereby aiming to bridge existing knowledge gaps in this area. We 438 demonstrated that, despite some technological challenges and limitations, eye tracking can be a 439 valuable tool to explore the relationship between visual attention to natural elements and wellbeing 440 in real-life, outdoor environments. Overall, our findings supported the relationship between 441 anxiety and restorativeness measures and the viewing of green or grey elements. Among 442 participants who undertook the same walk, those who focused more on green elements experienced 443 enhanced wellbeing benefits compared to those who primarily viewed man-made built elements. 444 Our results aligned with the findings of previous stationary indoor studies that directing visual 445 attention toward nature instead of the built environment can reduce anxiety and increase perceived 446 447 restorativeness (i.e., Liu et al., 2022; Nordh et al., 2013).

448 To date, most studies that have explored the relationship between green or nature and 449 wellbeing remain correlative and address nature as a 'black box' (Pett et al., 2016; Shanahan et al.,

450 2015). Our results showed that the time spent looking at trees specifically was associated with a 451 reduction in state anxiety and increased perceived restorativeness. Increased perceived restorativeness was also related to the percentage of time spent viewing bushes and lawn, but 452 453 viewing trees was the strongest predictor. This could be due to individuals associating trees with additional benefits compared to other green elements. For example, previous studies have found 454 that the thermal comfort benefits of trees are significantly related to psychological parameters 455 (Elsadek et al., 2019; Ren et al., 2022). These results strengthen the value of planting trees in cities 456 to provide various ecosystem services to residents (Endreny, 2018; Gómez et al., 2001). 457

Regarding positive and negative affect, our results align with studies suggesting that 458 459 walking in natural settings offers specific affective benefits such as reduced rumination or 460 decreased negative affect rather than increased positive affect (Bratman, Hamilton, et al., 2015). Positive and negative affect are distinct (Diener & Emmons, 1984), with differing impacts 461 observed in green versus urban settings (Legrand et al., 2022). However, our findings were 462 somewhat inconsistent. In the first analysis, participants who were primed to focus on green 463 elements and stopped in areas dominated by nature showed an increase in positive affect and a 464 decrease in negative affect. Similarly, those in the mixed element group experienced a decrease in 465 negative affect after the walk, but no differences were observed for participants primed towards, 466 and stopping at points dominated by man-made elements. In contrast, the second and third analysis 467 468 showed that visual attention towards green or grey elements did not demonstrate any effect on affect. Inconsistencies in our findings could be attributed to variations in analytical approaches. 469 First, the differences observed in the green and mixed groups could have been obscured when the 470 471 analysis encompassed the entire study population. Furthermore, the second and third analysis, focusing on differences in affect, did not account for among individual variation, potentially 472 473 concealing the effects by not considering the mean responses. Alternatively, what the participants

474 looked at rather than for how long could also explain our findings. Wellbeing from nature depends 475 not solely on the total time people spend in nature, but rather about the level of engagement 476 (Richardson et al. 2021). Our study did not measure momentary/in situ positive or negative affect, 477 limiting our ability to relate specific interactions with wellbeing outcomes. Future research can 478 benefit from investigating how affect or emotions are related to the length of time looking at 479 specific elements of nature.

Regarding cognitive measures, while prior studies linked gaze behavior with reduced 480 cognitive effort for attention recovery (Cottet et al., 2018; Franěk et al., 2018), our study recorded 481 no significant differences between experimental groups or in response to visual attention to 482 483 specific green, grey, and specific natural elements. In our experiment, all participants walked on 484 the same route in an urban environment (unlike other studies that mostly compare urban to natural walks (e.g., Bielinis et al., 2018; Bratman, Daily, et al., 2015; Takayama et al., 2014). The urban 485 environment is complex and dynamic, and other factors beyond visual attention can contribute to 486 (increase or decrease) the ability to restore attention and provide cognitive benefits. Natural 487 488 sounds, for instance, are known to enhance attention restoration (Van Hedger et al., 2019), yet our route exposed participants to urban noises like traffic and construction. Studies have shown that 489 cognitive performance improvements are related to natural environments, while 490 urban environments had the opposite effect (Stenfors et al., 2019). Therefore, our urban route might not 491 have led to observable changes in cognitive performance. The only marginally significant 492 493 difference in the before / after scores for attention performance was observed in the mixed group, where participants were not specifically instructed to direct their attention towards any particular 494 495 construct. It is plausible that the participants in the green and grey groups expended significant effort to adhere to their tasks, aware that their eye movements were under observation. This 496 497 heightened effort might have impeded their ability to derive cognitive benefits from the walk.

498 Considering these factors, we believe that further research using eye tracking technology in 499 outdoor environments would help strengthen our understanding of the relationship between 500 cognitive benefits and elements of nature.

501 The results of this study may be explained by common heuristics. Daniel Kahneman popularized the term 'what you see is all there is' in his description of the process by which the 502 brain is susceptible to cognitive biases that the information an individual has is all of the relevant 503 information (Kahneman, 2011). This phenomenon is usually viewed negatively, especially when 504 it comes to decision making (Kahneman et al., 2011), but if this mechanism underlies the 505 association between visual attention and mental benefits from nature, individuals could use this 506 507 bias to their advantage. Heuristics are theorized to have developed to ease decision making 508 (Haselton et al., 2015), and other studies have identified situations where heuristics can be 509 advantageous to individuals (Gigerenzer, 2008). Uncovering simple behavior changes that individuals can implement in their daily lives to improve their mental health, especially in areas of 510 higher mental burden (Gruebner et al., 2017), can lead to greater human wellbeing outcomes. For 511 example, urban dwellers are already at a greater risk of mental illness, including 20% more anxiety 512 compared to rural dwellers (Bhugra et al., 2019). Policies can be implemented to encourage urban 513 dwellers to be more mindful of elements of nature in their daily routine, reducing anxiety and 514 increasing restorativeness. 515

Understanding the effects of natural elements on mental state can also inform practitioners, such as landscape architecture and urban designers. We suggest specifically 1) the creation of spaces that have natural elements for individuals to look at; 2) designing natural spaces that encourage people to look at and interact with nature; and 3) including a greater amount of specific green elements such as trees, bushes, and lawns. If planners and landscape architects can attract people's attention to nature in their daily lives, such as on the way to work or school, this could

potentially significantly reduce an individual's daily mental burden. We suggest that future studies use eye tracking while considering landscapes with higher prevalence of these elements. Another benefit, beyond mental health, of increasing the ability of individuals to experience psychological restoration from natural elements is that those who benefit psychologically from nature may also be more likely to protect it (Hartig et al., 2007).

527

528 *Limitations and future directions*

Our study, while offering valuable insights into the relationship between visual attention 529 to natural elements and wellbeing, also confronts several limitations. Due to the need to avoid 530 531 bright sunlight (i.e., restricted working hours), the experiment spanned nine months. This extended 532 duration, coupled with its outdoor field nature, posed challenges in accounting for environmental 533 factors such as sound, noise, and smell, which may vary throughout the year. These factors are important as evidence suggests that other sensory elements can contribute significantly to 534 wellbeing (Franco et al., 2017). We did not monitor sensory elements beyond visual attention that 535 could have affected individual wellbeing, such as sounds or smells. As our environmental control 536 537 variables were not significantly different between the participant groups, we do not suspect that sounds and smells would have been significantly different between the groups. The random 538 distribution of participants in the conditions further minimizes potential biases that could influence 539 our results. However, future studies could benefit from shorter data collection periods, monitoring 540 these confounding factors, and exploring ways to mitigate them, such as using headphones to 541 shield noise. Care must be taken to ensure that such measures do not compromise the authenticity 542 543 of the nature experience or introduce additional bias. Future research should also seek to understand to what extent visual versus other sensory interactions with nature contribute to human 544 545 wellbeing (Colléony et al. 2021).

Furthermore, the walk's duration varied slightly among participants, and we encountered 546 technical issues with the Tobii Pro 2 Glasses, which performed suboptimally in bright light, humid 547 or warm conditions (above 28 degrees C) and following sudden or fast head movements. To 548 549 mitigate these challenges, we adjusted participants' start times around the weather, provided them 550 with baseball caps, and instructed them to look straight through the lens while minimizing fast movements. Despite these measures, the number of recorded fixations still varied between 551 participants. We addressed this by analyzing only the percentages of fixation time. These efforts, 552 combined with the random assignment of participants to conditions, likely minimized biases from 553 these issues and other disturbances during the walk (e.g., human activity). Notably, these 554 555 challenges predominantly affected the moving part of the analysis. The fact that both eye-tracking 556 analyses yielded similar results strengthened our confidence in their robustness. Nonetheless, we 557 cannot completely dismiss these potential flaws, and future research should consider them in experimental design, striving to standardize tracking time and conditions as much as possible. 558 Finally, our exclusive focus on fixations as the eye-tracking metric is a limitation. Future studies 559 would benefit from including a wider range of eye tracking metrics, such as saccades and pupil 560 dilation, to gain a more comprehensive view of visual engagement and cognitive processing in 561 natural settings, thus enhancing the robustness and validity of outdoor environmental research 562 findings. 563

564

565 Conclusions

Urbanization's impact on health and wellbeing, characterized by stress and mental fatigue, is increasingly recognized, with nature seen as a potential remedy (Bertram & Rehdanz, 2015; Lederbogen et al., 2011). However, the specific natural elements that most effectively enhance wellbeing in urban environments are yet to be fully understood. This understanding is crucial for

570 aligning public health and nature conservation goals, fostering connections to nature, and 571 designing sustainable cities (Colléony and Shwartz 2019). Our study contributes to bridging this knowledge gap, demonstrating that simply directing visual to green elements like trees, rather than 572 573 grey, significantly reduces anxiety and boosts restorativeness during routine urban walks. Participants who focused more on greenery experienced these benefits, while those observing grey 574 elements did not. This finding implies that a subtle shift in attention towards nature can 575 substantially improve daily wellbeing in urban areas. Such insights are vital for urban planning, 576 suggesting the creation of spaces that offer not just access to natural elements, but also promote 577 engagement with nature, potentially influencing wellbeing and pro-conservation behaviors 578 579 (Mackay & Schmitt, 2019; Shwartz et al., 2023). Understanding which natural elements confer 580 these benefits is key to transforming cities into healthier habitats for humans and wildlife alike. Our research highlights the importance of further exploring both visual and other sensory 581 interactions with nature in urban contexts, underscoring their significance in enhancing mental 582 health and wellbeing. We also demonstrate for the first time the potential benefits of using mobile 583 eye tracking technology in outdoor urban environments to explore how visual intake of nature 584 elements influences wellbeing, though challenges persist to effectively utilize this technology 585 outdoors. 586

587

588 *Ethics Statement*

589 Permission for this study was granted by the Technion Social and Behavioral Sciences

Institutional Review Board. Participants were paid approximately \$15 (50 □) to participate in the
study and signed informed consent.

592 *Contributions of Authors*

593	Whitney Fleming conducted statistical analyses, and drafted and edited the manuscript and its
594	supplemental material. Brian Rizowy conducted the field experiments and provided technical
595	analysis of eye tracking data. Assaf Shwartz contributed to all aspects of this manuscript.
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Figures and Tables:



- **Figure 1** Research framework flow chart providing an overview of the experimental design, the variables measured, and the
- analyses conducted in this study.



Figure 2 – Map illustrating the study area in and around the Technion campus in Haifa, the walking route and the designated stopping points. Participants, based on their group allocation, stopped at 10 specific points. These points are marked as green, grey, and mixed color, representing points predominantly featuring vegetation, man-made structures, or a blend of both, respectively. Figure S1 in Supporting Information provides the images and heat maps of the 30 points.



Examples of

910 stopping points for the green (a), grey (b) and mixed (c) groups in the experiment. Heatmaps of 911 participant's eye movements are overlayed on photos from the eye-tracking glasses with polygons 912 classifying the main features used in this analysis. For a complete view of all stopping points, their 913 categorization into the three conditions, and representative heatmaps see Fig. S1.





Figure 4. Boxplots presenting the differences in the percentage of total fixation time recorded for participants in each experimental condition (Green, Grey, or Mixed) for (A) green elements while stopped; (B) grey elements while stopped; (C) green elements while walking; and (D) grey elements while walking. Significant differences are indicated from Kruskal-Wallis tests (***=p<.001).



Figure 5. Estimated marginal means of differences between groups (green, grey, and mixed)
before and after a walk with p-values for: A) changes in Positive affect (PA); B) changes in
Negative affect (NA); C) changes in NCPCT; D) changes in STAI State scores; E) perceived
restorativeness (only measured after walk).

927	Table 1. Results of mixed models for repeated measures (MMRM) for positive affect (PA),
928	negative affect (NA), NCPCT, and STAI state. As well as results of a linear model for perceived
929	restorativeness (PRS). The table includes estimated coefficients for modeled independent
930	variables with \pm standard error of the estimated coefficients. Significance levels are shown: *p <
931	0.05, **p < 0.01, ***p < 0.001.

Between Groups					
Independent	PA	NA	NCPCT	STAI State	PRS
Variables					
Condition (Grey)	$\begin{array}{c} {\rm Coefficient} \pm {\rm St. \ Error} \\ {\rm -}0.18 \pm 0.15 \end{array}$	$\begin{array}{c} \text{Coefficient} \pm \text{St. Error} \\ \text{-}0.21 \pm 0.09 \end{array}$	$\begin{array}{c} \text{Coefficient} \pm \text{St. Error} \\ 2.56 \pm 1.50 \end{array}$	$\begin{array}{c} {\rm Coefficient} \pm {\rm St. \ Error} \\ {\rm -0.11} \pm 0.09 \end{array}$	Coefficient \pm St. Error -0.86 \pm 0.17***
Condition (Mixed)	$\textbf{-0.10} \pm 0.15$	0.03 ± 0.09	1.35 ± 1.52	$\textbf{-0.03} \pm 0.09$	-0.34 ± 0.17 *
Time (After)	0.15 ± 0.08	-0.25 ± 0.07 ***	0.74 ± 0.96	$\textbf{-0.19} \pm 0.05 \textbf{***}$	-
Gender	$\textbf{-0.04} \pm 0.12$	$\textbf{-0.08} \pm 0.07$	0.45 ± 1.10	$\textbf{-0.10} \pm 0.07$	0.13 ± 0.14
Childhood Residence (Large city/Medium city)	$\textbf{-0.18} \pm 0.16$	-0.04 ± 0.09	$-3.55 \pm 1.50*$	0.03 ± 0.09	0.021 ± 0.19
Childhood Residence (Small city)	-0.20 ± 0.15	0.14 ± 0.08	-1.41 ± 1.40	0.07 ± 0.08	0.26 ± 0.18
Current Residence (Large city/Medium city)	0.00 ± 0.23	-0.10 ± 0.13	2.59 ± 2.15	-0.01 ± 0.13	0.27 ± 0.28
Current Residence (Small city)	0.05 ± 0.24	-0.07 ± 0.13	0.87 ± 2.23	0.05 ± 0.13	0.07 ± 0.29
Nature Relatedness (NR6)	$0.20\pm0.07\texttt{**}$	-0.03 ± 0.04	0.67 ± 0.67	$\textbf{-0.07} \pm 0.04$	0.30 ± 0.08 ***
Age	0.01 ± 0.01	0.01 ± 0.01	0.07 ± 0.10	0.01 ± 0.01	$\textbf{-0.01} \pm 0.01$
BAQI Value	$\textbf{-0.01} \pm 0.01$	0.00 ± 0.00	$\textbf{-0.01} \pm 0.08$	0.00 ± 0.00	0.01 ± 0.01
Temperature	$\textbf{-0.01} \pm 0.01$	$\textbf{-0.01} \pm 0.01$	$\textbf{-0.19} \pm 0.11$	0.00 ± 0.01	0.00 ± 0.01
Relative Humidity	0.00 ± 0.00	0.00 ± 0.00	$\textbf{-0.01} \pm 0.04$	0.00 ± 0.00	$\textbf{-0.00} \pm 0.01$
Visibility Value	0.00 ± 0.01	0.00 ± 0.00	$\textbf{-0.06} \pm 0.07$	0.00 ± 0.00	0.012 ± 0.01
Cloud Cover	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.02	0.00 ± 0.00	0.02 ± 0.00
Condition Grey *Time	$\textbf{-0.11} \pm 0.11$	0.17 ± 0.09	-1.31 ± 1.36	$0.17\pm0.06^{\boldsymbol{\ast\ast}}$	-
Condition Mixed *Time	$-0.23 \pm 0.11*$	-0.03 ± 0.09	-2.59 ± 1.36	0.07 ± 0.07	-

Table 2. Results of linear models exploring the relationships between differences in STAI state
(before/after) and perceived restorativeness (PRS) and the percentage of time fixating at green or

grey elements while stopped at AOIs. The table includes estimated coefficients for modeled independent variables after AIC model selection and model fit statistics, with \pm standard error of the estimated coefficients. Significance levels are shown: *p < 0.05, **p < 0.01, ***p < 0.001.

_	Linear Models for AOIs				
	Independent Variables	STAI Green	STAI Grey	PRS Green	PRS Grey
-	Percentage time viewing	$-0.96 \pm 0.38*$	0.78 ± 0.27 **	2 93 + 1 10**	-3.21 + 0.74***
	Age	$-0.01 \pm 0.00*$	-0.01 ± 0.00 **		-
	Cloud Cover	-0.00 ± 0.00 *	-0.00 ± 0.00 *	-	-
	Nature Relatedness	-	-0.05 ± 0.03	0.30 ± 0.09 **	$0.33\pm0.08^{\boldsymbol{\ast\ast\ast\ast}}$
	Temperature	-	0.01 ± 0.01	-	-
	Final AIC	24.051	21.722	242.576	232.109
	Adjusted R ²	0.132	0.166	0.151	0.232
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952	Table 3. Results of line	ear models of p	ercentage time g	gazing at green o	or grey elements wh
) 53	walking on changes in	STAI state and	d perceived rest	torativeness (PR	S). The table includ

estimated coefficients for modeled independent variables after AIC model selection and model fit

statistics, with \pm standard error of the estimated coefficients. Significance levels are shown: *p <

956 0.05, **p < 0.01, ***p < 0.001.

	Linear Models While Walking: Green and Grey Overall				
	Independent Variables	STAI Green Coefficient ± St. Error	STAI Grey Coefficient ± St. Error	PRS Green Coefficient ± St. Error	PRS Grey Coefficient ± St. Error
	Percentage time viewing	-0.62 ± 0.26 *	0.44 ± 0.14 **	3.54 ± 0.70 ***	-2.13 ± 0.37 ***
	Age	$\textbf{-0.01} \pm 0.00\texttt{*}$	$\textbf{-0.01} \pm 0.00$	-	-
	Child residency (large or medium city)	-	-	-	0.07 ± 0.17
	Child residency (small city)	-	-	-	$0.35\pm0.17\texttt{*}$
	Cloud Cover	$\textbf{-0.00} \pm 0.00$	$\textbf{-0.00} \pm 0.00 \textbf{*}$	-	
	Nature Relatedness	-0.04 ± 0.03	-	$0.30\pm0.08^{\boldsymbol{\ast\ast\ast\ast}}$	$0.29\pm0.08^{\boldsymbol{\ast\ast\ast\ast}}$
	Temperature	-	0.01 ± 0.01	-	-
	Visibility Value	-	-	-	0.01 ± 0.01
	Final AIC	24.267	21.027	226.484	222.639
	Adjusted R ²	0.138	0.164	0.273	0.318
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6	Table 4. Results of linear	models of perce	ntage time gazin	g at specific natu	ral elements (trees
7	bushes, lawn, and flowers)) while walking	on perceived res	torativeness (PRS	S) and STAI scores
8	The table includes estimat	ed coefficients f	for modeled inde	pendent variables	after AIC model

selection, and model fit statistics, with \pm standard error of the estimated coefficients. Significance

970 levels are shown: $p < 0.1 \ p < 0.05$, p < 0.01, p < 0.001.

Linear Models while walking: Specific Green Elements				
	STAI	PRS		
Independent Variables	Coefficient \pm St. Error	Coefficient ± St. Error		
Percentage time viewing trees	$-1.54 \pm 0.57 **$	$5.88 \pm 1.58^{***}$		
Percentage time viewing bushes	-	$2.22\pm1.18^{\ddagger}$		
Percentage time viewing lawn	-	$10.29\pm5.36^{\ddagger}$		
Percentage time viewing flowers	-	-		
Age	-0.01 ± 0.00	-		
Cloud Cover	$-0.00 \pm 0.00*$	-		
Nature Relatedness	-	$0.25 \pm 0.09 **$		
Temperature	0.01 ± 0.01	-		
Final AIC	23.590	226.098		
Adjusted R ²	0.143	0.289		