RELAXING OR EXCITING? MOBILE EMOTION RECORDING IN NATURAL SETTINGS

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The health benefits of experiencing nature are well-known. Several established theories, such as attention restoration, biophilia, and awe theories, suggest that lowered emotional arousal is a mechanism of the health effects of experiencing nature. This has not been tested in nature walking experiences in the field, and has not accounted for the recent trend of constructing built features such towers, bridges, and museums to bring visitors in closer touch with nature. Wearable skin conductance recording technology has recently opened this avenue for research. The present study shows that these built features were associated with lower emotional arousal than natural areas, or than purely functional built features. However, individuals reporting improvment in health over the visit experienced relatively lower arousal in natural areas, yet higher arousal at built features such as bridges, towers, and museums aimed to bring them closer to nature. These effects point to biophilia and attention restoration occurring in natural environments, while built features focused on nature may be triggering awe.

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1 Introduction

Contact with nature is widely understood to enhance health. Natural environments restore attention and promote physical activity, resulting in positive emotions, reduced stress, and lower blood pressure in the short term, faster healing, and higher subjective well-being in the long term (Kaplan & Kaplan, 1989; Kaplan, 1995; Ulrich, Dimberg, et al., 1991; Ulrich, Simons, et al., 1991). These well-known outcomes are important reasons for governments to protect natural areas, and for park managers to invest in facilities for visitors such as interpretive programs, parking, trails, signage, benches, and lookout towers.

In recent years, there has been a noticeable increase in architectural attention to the design of these built features. They are now frequently designed not only for low cost and basic function, but also for their own aesthetic beauty and fit with the natural landscape (Wielenga et al., 2022, Wielenga, 2021). Examples include intricate and sculptural lookout towers, such as on the Devinska Kobyla hill near Bratislava, and museums which appear to grow out of the landscape, such as The Whale Museum in Norway. One major hope behind increased investment in these facilities is to improve the visitor experience. More concretely, it is assumed that a well-designed bench or lookout point provides closer and more intimate access to nature, and enhances the already-known positive effects of the natural environment. This assumption is untested, however, as emotional reactions to specific environmental stimuli are fleeting and difficult to capture in the moment (Bastiaansen et al., 2019). Developments in wearable tracking of emotional arousal have made such recording possible. When combined with GPS location tracking, wearable emotion recordings have opened up possibilities of linking emotional reactions to specific environmental stimuli (Mitas, Mitasova, et al., 2020; Strijbosch et al., 2021b)

Situating the present study in two natural areas in the Netherlands, we mobilize wearable emotion and location tracking technologies to examine visitors' emotional arousal at two protected natural areas, contrasting nature-enhancing built features with purely functional built features. We further link the differences herein to visitors' self-reported health.

2 Literature review

2.1 Health benefits of experiencing nature

The salubrious effects of experiencing nature on physical health are well-documented and have been explained by a number of potential mediators. Theories such as biophilia (Grinde & Patil, 2009; Wilson, 1986) and attention restoration theory (Basu et al., 2019; Ohly et al., 2016) suggest that built environments are too stimulating and information-rich, creating excess cognitive load and emotional arousal. The 'soft fascination' of natural environments, especially through the visual sense, decreases this excessive emotional arousal and thus allows restoration of cognitive and physiological capacities (Basu et al., 2019).

In contrast, Keltner and colleagues suggest that awe, an arousing yet uniquely beneficial emotion, is triggered by nature stimuli. Awe leads to prosocial and other health-reinforcing behaviors (Anderson et al., 2018; Harker & Keltner, 2001; Keltner & Haidt, 2003; Piff et al., 2015). Thus, theoretical explanations of how nature experiences contribute to health disagree on the mediating role of emotional arousal. While biophilia and attention restoration theories assert that nature improves health by decreasing emotional arousal, research on awe suggests that nature improves health through (a specific) increase in emotional arousal. Resolving this ambiguity is crucial for the management of natural areas. Improving public health is often a stated goal of managing natural areas for recreational visitors. However, management interventions vary, and can be designed to either increase (e.g., sweeping views, perceived risk) or decrease (e.g., gradual curves and ascents, low-key, minimalist built features) emotional arousal. These interventions can also deliberately vary between built and natural location contexts within a single natural area.

Furthermore, progress on the ambiguity around emotional mechanisms in natural areas has been difficult due to technical limitations of emotional arousal measurement. Field studies of nature experiences are typically based on self-report, which compresses emotional arousal experienced over varying natural environmental stimuli into a single number. This number fails to capture the inherent ebb and flow of emotional arousal triggered by specific stimuli and at a precise time (Bastiaansen et al., 2019) and is subject to well-known recall errors

(Zajchowski et al., 2016). Therefore, detailed physiological measurement of emotional arousal in real-world natural settings is necessary.

2.2 Wearable measurement of emotional arousal

Several important technological innovations have recently made it possible to continuously and accurately monitor emotional arousal in real-world settings. First, phasic skin conductance has been established as a valid indicator of emotional arousal, even during physical movement (Li et al., 2022) as slow temperature-related changes are filtered out by focusing on the phasic component of skin conductance (Benedek & Kaernbach, 2010). Second, devices to record skin conductance have become small, simple, affordable, and wearable. Third, software developments have enabled rigorous filtering of motion artifacts (Strijbosch et al., 2021a).

These technological developments have unlocked new insights into the ebb and flow of emotional arousal over the course of even small variations in stimuli, such as museum exhibits (Kirchberg & Tröndle, 2015; Mitas, Cuenen, et al., 2020), twists and turns of a roller coaster (Bastiaansen et al., 2022), and stops on a guided tour (Mitas, Mitasova, et al., 2020). Thus, it is now possible to address the issue of emotional arousal across natural and built features during a single visit to a nature area. Combining mobile skin conductance recording with self-report survey data also allows us to determine how variations in this emotional arousal correspond to health outcomes.

3 Methods

We used a mixed-method approach which combined physiological recording of emotional arousal, GPS-based location tracking, and self-report questionnaires before and after visits to natural areas. For the purpose of this study, two natural areas in the Netherlands were selected – Fort de Roovere and Nationaal Park Sallandse Heuvelrug. Although they are different in size and characteristics, they are both valued for their biodiversity, recreational opportunities, and cultural significance. We intercepted visitors entering these sites in the spring and summer of 2023. Participants were invited to respond to an intake questionnaire, wear a wristband which recorded their skin conductance as a proxy of emotional arousal, and carry a smartphone which recorded their location via GPS. Upon completing their visit, participants filled out a brief post-experience questionnaire.

3.1 Study sites

3.1.1 Fort de Roovere

Fort de Roovere is in the Netherlands between the cities of Steenbergen and Bergen op Zoom. Constructed in the 17th century, this fort witnessed numerous wars. Today, the fortification consists of four earthen bastions surrounded by a moat, with further outlying defensive works to the east and south. A small temporary building houses a lunchroom. We term this site a *green fort* as there are no stone or brick walls; all walls are fully planted. The entire area of the fort, and the western side of the moat, are completely covered in grass. Most of the moat is flooded with water. The outlying defensive works are completely overgrown by forest with occasional canals.

Figure 1: Fort de Roovere with Moses Bridge (center bottom) and Pompejus lookout tower (upper left)
Source: Marc Bolsius, 2024

Besides the lunchroom, Fort de Roovere contains a small, bare parking lot. The fort also includes two unique architectural features intended to enhance visitors' nature experience. One is the Moses bridge, which crosses the moat from the fort into the forest on its eastern side. The bridge is sunken into the water, essentially placing visitors at about chest level with the surface of the water. This creates a compelling visual and spatial effect that enables visitors to view aquatic birds, amphibians, and insects from an unusually close and unique perspective. The second such feature is the Pompejus lookout tower, which rises 25 meters above the northeast bastion, allowing a sweeping view of the surrounding agricultural landscape and forest (Figure 1).

3.1.2 Nationaal Park Sallandse Heuvelrug

Nationaal Park Sallandse Heuvelrug is in the east-central Dutch province of Overijssel and contains two distinct landscape types, forest and heather fields, on 2217 hectares of rolling hills (Figure 2). Most visitors enter the park from its northern edge near the village of Nijverdal. Here a large parking lot is situated across from a visitor center which contains a museum, restaurant, and souvenir shop (Figure 3). Numerous hiking paths originate at this point. About a kilometer south of the visitor center is the peak of the Noestelerberg, the first of the park's two hilltops. Here several benches form a popular lookout point.

Figure 2: Sallandse Heuvelrug purple heather field (foreground) with forested hilltop (background)

Source: Staatsbosbeheer

Figure 3: Nationaal Park Sallandse Heuvelrug visitor center
Source: Staatsbosbeheer

3.2 Sample

We used an intercept sampling approach, asking each visitor entering the site on foot from the main parking lot if they would be willing to participate in exchange for a free coffee or tea. To have a sufficient population of visitors to sample from, we limited data collection to busy days (Wednesdays and weekends) with weather suitable for outdoor recreation (no or little precipitation). We collected data at Fort de Roovere in April of 2023, including Easter weekend, and at Sallandse Heuvelrug in May and June of 2023, including the Ascension and Pentecost weekends.

Of 125 participants who provided data, either questionnaire, wearable, or GPS data were missing for 32 participants. From the remaining 93 participants, 21 exhibited wearable data that had too many motion artifacts in the physiological data to be useable, resulting in a final sample of 72 participants.

3.3 Measures

To record location, we lent participants a smartphone with the popular workout application Strava that recorded GPS location once per second. These data were then grouped into three environmental stimulus types: *nature-enhancing architecture,* which were built features aimed at bringing visitors in contact with nature, such as lookout towers, benches at scenic viewpoints, and nature museums; *non-nature architecture*, including parking lots, roads, and restaurants, which served a functional purpose and were not designed to bring visitors in contact with nature; and all other locations, which generally offered visitors unmediated contact with *nature*.

To measure emotional arousal, we outfitted participants with an Empatica E4 wristband to measure skin conductance, a proxy for emotional arousal, at 4 times per second. The wristband records skin conductance from 2 wires which attach to pre-gelled electrodes worn on the fingers (Figure 4). The skin conductance signal was cleaned from motion artifacts using the ArtifactZ function of the Breda Experience Lab Toolbox (Bastiaansen et al., 2022). Tonic changes in the signal due to temperature and wearing of the device were filtered out using deconvolution (Benedek & Kaernbach, 2010). Skin conductance signals were also Z-standardized to cancel out differences in skin responsiveness between participants, and log-transformed to reduce kurtosis.

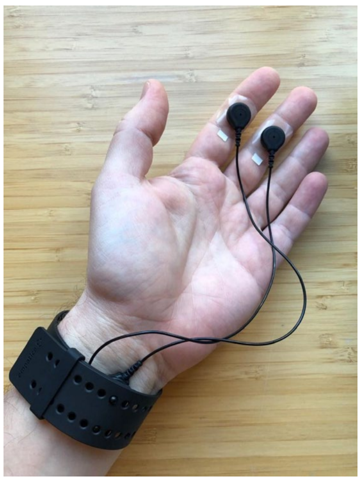

Figure 4: Empatica E4 Wristband
Source: Own

To assess self-reported health, we asked participants to fill out questionnaires at the beginning and end of their visit. The questionnaires contained the World Health Organization single item "How satisfied are you with your health?" on a 5-point scale ranging from "very dissatisfied" to "very satisfied" (Skevington et al., 2004). While such subjective measures are imperfect, they correlate at least moderately with some physical health measures and are able to discriminate between healthy and ill subsamples (Bech, 2001). We subtracted participants' pre-visit health from their post-visit health for an index of health change. Because most participants' self-reported health was unchanged from before to after the visit, we collapsed this variable into two categories, coded 1 if participants' health improved during the visit, and 0 if it did not.

3.4 Data analysis

We modeled the data using mixed-effects linear models with random intercepts per participant. We built our models in two stages. First, we modeled phasic skin conductance as a function of environmental stimulus type, using a dummy-coded predictor for *nature-enhancing* and *non-nature architecture*, taking *nature* areas as the reference category. Subsequently, we included health change as a predictor, and allowed it to interact with each of the previously entered predictors representing environmental stimulus types.

4 Findings

4.1 Descriptive findings

The 34 participant visitors to Fort de Roovere spent an average of 68 minutes visiting the fort (sd = 32 minutes). They reported fairly good health before (m = 3.79, sd = 0.73) and after (m = 3.88, sd = 0.77) their visit. Before- and after-visit health scores were identical for 31 of these visitors, and improved for 3. The 38 visitors to the Sallandse Heuvelrug stayed longer than visitors to the fort, spending an average of 108 minutres (sd = 93 minutes). Their self-reported health was likewise good before (m = 4.01, sd = 0.69) and after (m = 4.09, sd = 0.63) their visit. The change in health over the course of the visit was negative for 3 participants, positive for 6 participants, and remaining the same for 30 participants.

4.2 Spatial analysis of emotional arousal

Maps reveal striking variations of emotional arousal at each site, with blue indicating lower emotional arousal, and red indicating higher emotional arousal. At Fort de Roovere, emotional arousal was low in the forested area around the fort, especially to the east. On the other hand, the forested paths along canals just south of the fort featured strong emotions. Basically, when in the forest, participants got more emotional the closer to the water they got. This could be because the elevation changes are interesting, but also a bit frightening, as they are steep. Strong emotions were also experienced at the entrance, the lunchroom, and the location on the fort wall where the Moses bridge comes into view. Remarkably, the bridge and the tower themselves seemed to have a rather calming influence on average (Figure 5).

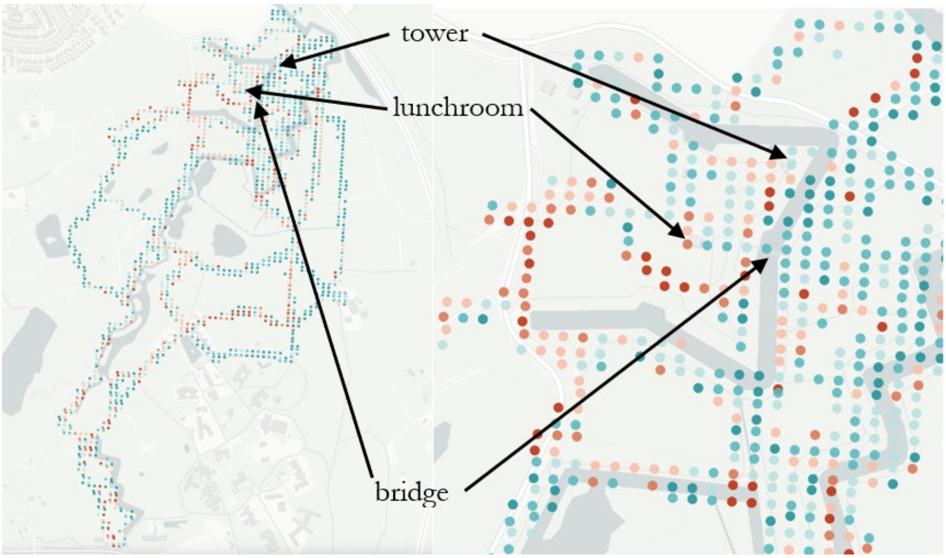

Figure 5: Map of emotional arousal across the entire Fort de Roovere site (left) and zoomed in to the most visited area (right)

Note: Lower arousal ▬ Higher arousal

Due to the much larger area covered, the map of the Sallandse Heuvelrug is more difficult to interpret qualitatively. It is clear, however, that most forested areas (upper half of the visited area) were lower in arousal rather than the heather fields (lower half). Furthermore, hiking paths with sweeping views of the landscape triggered relatively higher levels of arousal. Emotional response to the visitor center was mixed (Figure 6).

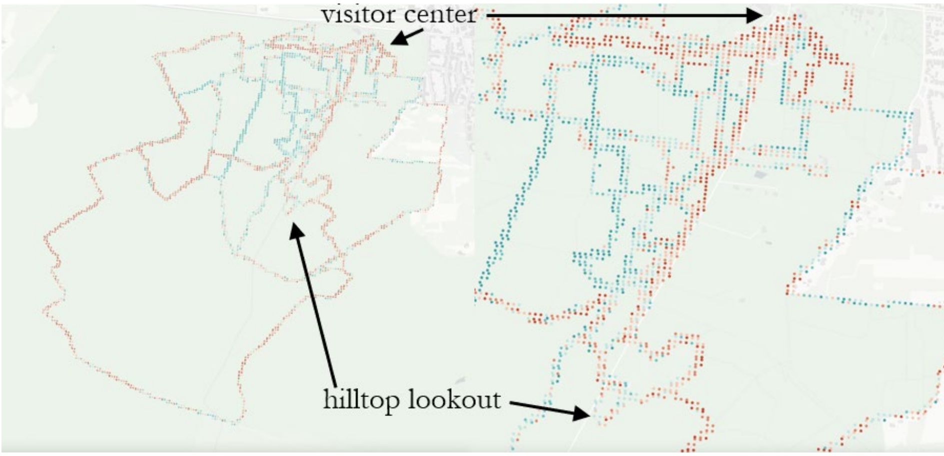

Figure 6: Map of emotional arousal across the entire Sallandse Heuvelrug site (left) and zoomed in to the most visited area (right)

Note: Lower arousal ▬▬▬▬▬▬ Higher arousal

Statistical modeling of emotional arousal as a function of environmental stimulus type demonstrated that nature-enhancing architecture was associated with lower emotional arousal than natural areas ($t = -5.022$; $p = <0.001$), while non-nature architecture was associated with higher emotional arousal than natural areas ($t = 32.183$; $p <0.001$) (Table 1).

Table 1: Multilevel model of phasic skin conductance as a function of environmental stimulus

Variable	Coefficient estimate (Standard error)	t-value
Constant	0.008432 (0.006466)	13.040***
Nature-enhancing architecture	-0.001758 (0.000325)	-5.022***
Non-nature architecture	0.01046 (0.000350)	32.183***

Note: Reference category: Nature areas. Significance codes for p values: *** < 0.001 < ** < 0.01 * < 0.05

4.3 Self-reported health change as moderator

We entered the variable of self-reported health change as a moderator term in the model of emotional arousal as a function of environmental stimulus (Table 2). This allowed us to determine at which locations a different momentary health outcome (improved vs. not improved) was associated with greater, or lower, emotional arousal. Participants who reported improved health over the course of their visit experienced slightly higher emotional arousal in built areas and much lower emotional arousal in nature, compared to participants whose self-reported health did not change or decline over the visit (all p's < 0.001).

Table 2: Multilevel model of phasic skin conductance as a function of environmental stimulus x health change

Variable	Coefficient estimate (Standard error)	t-value
Constant	0.08452 (0.006484)	13.036***
Nature-enhancing architecture	-0.002309 (0.000357)	-6.463***
Non-nature architecture	0.007973 (0.000346)	23.014***
Health change	-0.001515 (0.000718)	-2.109*
Nature-enhancing architecture x Health change	0.009553 (0.001786)	20.578***
Non-nature architecture x Health change	0.02054 (0.000998)	5.350***

Note: Reference category: Nature areas. Health change = 0 if not improved over visit; =1 if improved over visit. Significance codes for p values: *** < 0.001 < ** < 0.01 * < 0.05

4 Discussion

The present findings demonstrate that experiences of natural areas vary richly over space and time. Human-built features aimed at connecting visitors to nature, for example by creating opportunities to rest or gain a unique visual perspective on the landscape, had a calming effect on emotional arousal. However, participants who experienced higher emotional arousal at human-built features, but lower arousal in natural areas, were more likely to report increased self-reported health.

Participants who experienced better health outcomes had attentuated emotional arousal in natural areas, a finding consistent with low-arousal theories of nature experiences, such as attention restoration theory (Ohly et al., 2016) and biophilia (Grinde & Patil, 2009). However, higher emotional arousal among healthier participants at built features aimed to increase contact with nature seems more in line with awe experiences, which are highly arousing (Anderson et al., 2018). One potential explanation is the *way* individuals interact with nature is fundamentally different on walking trails (comprising most of the nature settings studied) and built features, such as towers and bridges, that aim to enhance contact with nature. Walks offer slowly unfolding, calming visual stimuli characteristic of 'soft fascination,' a response to stimuli extensively studied in attention restoration experiments (Basu et al., 2019). Built features such as lookout towers, bridges, and museums instead offer overviews and interpretive material aimed to deepen appreciation and attention to nature as a whole, increasing chances of awe experiences. This potential explanation may be used to generate hypotheses for future research.

To further disambiguate the meaning of these patterns would require more detailed self-report data, as well as more instances of built features. Furthermore, it is well-known that social interactions are a key source of both emotions (Mitas et al., 2023) and health (Cacioppo et al., 2002) and not only occur in natural areas, but may also be facilitated by built environments therein. For example, a twisty, isolated trail will feature less social interaction than a restaurant in the visitor center. We did not measure social interaction in the current study. The possibility that it is interacting with the spatial effects we found warrants further research.

Given that healthier participants experienced relatively higher emotional area at built features, and lower in natural areas (especially trails), suggests simply increased or attenuated emotional arousal does not make a nature experience healthier. Rather, both quiet trails which invite calm and contemplation (Kaplan, 1995) *and* an occasional lookout tower with an awe-inspiring overview of the entire natural area (Cajas, 2020) are probably best. In fact, previous research on skin conductance in cultural tourism contexts has confirmed that simply more emotional arousal is not necessarily better; rather it is the temporal profile bby which emotional arousal ebbs and flows that makes for an excellent experience (Mitas, Mitasova, et al., 2020; Mitas et al.). We hereby extend importance of well-designed emotional ebb and flow over an experience to the context of visiting natural areas.

4.1 Limitations

It is important to note that these results capture the difference between 9 participants for whom health improved, and 63 participants for whom it did not. As the group of participants for whom health improved is very small, owing to the generic single-item measure used, these findings should be seen as exploratory and interpreted with caution. Additional measures of outcomes (e.g., life satisfaction), potential psychological mechanisms (e.g., appreciation of beauty, cognitive restoration, social interaction), and qualitative data in participants' own words could enable further insights into the benefits of nature experiences.

The findings may have been influenced by the intercept sampling approach, as frequent visitors to natural areas may have been over-represented. Natural sites are often managed and developed with the hope of attracting a broader scope of visitors, including those who do not wander into nature often. Future research could undertake a targeted approach to bring less-frequent visitors to natural areas to determine if they experience the differences between natural and built features differently.

Finally, we recommend replication of the present study in other landscape morphologies. Changes in elevation are more dramatic in many natural areas, and produce emotionally intense awe and overview effects. In general, the research is limited by the choice of two sites. We therefore aim to continue collecting data at a greater variety of sites, both to increase the number of participants, as well as increasing the diversity of landscape features in each location context category. These would be worth capturing using the unique affordances of mobile emotion and location tracking.

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