

## Stopping the train of thought

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# Stopping the Train of Thought: A Pilot Study Using an Ecological Momentary Intervention with Twice-Daily Exposure to Natural versus Urban Scenes to Lower Stress and Rumination

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**Background:** Stress, and specifically perseverative cognition, is considered to have considerable detrimental effects on mental and physical health. Interventions that can offer temporary stress relief could, therefore, bring considerable health benefits. Previous research has pointed to stress-reducing effects of exposure to nature after acute stressors, but has not yet investigated effects in the realm of everyday life. The present pilot study explores whether an ecological momentary intervention using exposure to natural images could be effective in lowering stress and improve mood. **Methods:** Fifteen participants (12 females) scoring above threshold on stress, depression, or anxiety completed two study periods of 6 days. They watched an urban (control) or natural slideshow twice daily. Using Ecological Momentary Assessment, effects on mood, and stress-related complaints were measured in everyday life. **Results:** Compliance to the study protocol was high, especially in the first week, with slightly more videos watched in the morning than in the evening. We found indications of improvements in mood, self-reported worrying (but not stress levels), and heart rate. **Conclusions:** The results suggest that twice-daily exposure to restorative visual content could be a viable Ecological Momentary Intervention, with the potential to reduce self-reported worry, lower autonomic activity, and increase positive affect.

## INTRODUCTION

Worry is an inherent part of everyday life. People ruminate about past stressful events and worry about those to come. According to the perseverative cognition hypothesis (Brosschot, Gerin, & Thayer, 2006; Brosschot, 2010), worry and rumination form a considerable component of prolonged stress. Although acute

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stress reactivity does sometimes induce negative health effects, such as an asthma attack or migraine (Chrousos, 2009), more severe and chronic detrimental health effects are attributed to prolonged stress (see e.g. Chrousos, 2009; McEwen, 1998; Linden, Earle, Gerin, & Christenfeld, 1997; Selye, 1950).

Rumination and worry have been linked to a range of mental and physical health outcomes. A recent experience sampling study revealed that the amount of worry in everyday life predicted the number of psychosomatic complaints (Verkuil, Brosschot, Meerman, & Thayer, 2012). Experimentally induced as well as naturally occurring rumination were further found to increase autonomic activity (see e.g. Brosschot, van Dijk, & Thayer, 2002, 2007; Ottaviani, Shapiro, Davydov, Goldstein, & Mills, 2009; Ottaviani et al., 2016). Another experience sampling study revealed that ruminative self-focus after negative events prolonged negative affect (Moberly & Watkins, 2008a), which, in turn, also predicted later ruminative self-focus (Moberly & Watkins, 2008b). In addition, rumination was found to be predictive of heart rate variability in everyday life (Verkuil, Brosschot, Tollenaar, Lane, & Thayer, 2016). A connection between rumination and psychopathology has also been established, specifically pertaining to depressive symptoms (see e.g. Aldao, Nolen-Hoeksema, & Schweizer, 2010; Nolen-Hoeksema, 1991; Pasyugina, Koval, De Leersnyder, Mesquita, & Kuppens, 2015; Robinson & Alloy, 2003; Ruscio et al., 2015).

The inability to refrain from perseverative cognition may be at the core of the pathogenic effects of stress on health (Brosschot, Pieper, & Thayer, 2005). Finding interventions that support stopping this negative train of thought could thus help improve health. In a clinical context, successful restorative therapies have been identified, including, for instance, mindfulness therapy (Grossman, Niemann, Schmidt, & Walach, 2004), worry reduction interventions (see e.g. Jellesma, Verkuil, & Brosschot, 2009), or imagery distraction (see e.g. Digdon & Koble, 2011). This paper explores exposure to natural scenes as another possible candidate.

Many people actively seek out natural environments to unwind and to get away from their daily hassles. Research has pointed to several health benefits of exposure to nature (see e.g. Beute & de Kort, 2014a; Tzoulas et al., 2007). These beneficial effects are often attributed to nature's stress-reducing potential (see e.g. Mitchell & Popham, 2008), are traditionally tested by contrasting natural and human-made environments, and are proposed to run through both affective (Ulrich, 1983) and cognitive (Kaplan, 1995; Kaplan & Berman, 2010) pathways. Mood enhancement and recovery of physiological reactivity have been reported after visiting natural environments (see e.g. Hartig, Evans, Jamner, Davis, & Gärling, 2003), but also after viewing images or videos of natural environments (see e.g. Beute & de Kort, 2014b; Fredrickson & Levenson, 1998; Ulrich et al., 1991). Importantly, these studies have all focused on immediate stress reactivity rather than on prolonged stress. Thus, additional

evidence is necessary to support claims made of the long-term health benefits of nature through stress reduction.

There are, however, a number of studies that provide initial support for these long-term health benefits through stress reduction. An fMRI study revealed that a rural as opposed to an urban upbringing was related to lower reactivity to stressors (Lederbogen et al., 2011). In addition, more green in the proximity of the home was correlated with a healthier cortisol secretion pattern (Ward Thompson et al., 2012) as well as longer telomere lengths (Woo, Tang, Suen, Leung, & Wong, 2009). At the same time, living in greener areas was found to be associated with better general health (Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006), longevity (Takano, Nakamura, & Watanabe, 2002), and even lower mortality rates (Mitchell & Popham, 2008). Yet because of their correlational nature, these outcomes do not ascertain a causal relation between nature exposure, perseverative cognition, and health.

Since rumination and worry are inherent parts of daily life, it would make sense to also study these phenomena in the realm of everyday life. Ecological Momentary Assessment (EMA; Shiffman & Stone, 1998) allows investigating everyday phenomena in their natural context (Beute, IJsselsteijn, & de Kort, 2016). Using smartphone technology, participants are asked to respond to short questionnaires a number of times per day. These measurements are sometimes enriched with ambulatory sensor data, including for instance heart rate. Ecological Momentary Interventions (EMI; Heron & Smyth, 2010) go one step further and combine momentary assessments with interventions. Many of these interventions have been geared to expand therapy beyond counseling sessions in a number of domains such as smoking cessation, mental health, and physical exercise (Heron & Smyth, 2010).

In order to see whether EMI could be successfully implemented to improve stress-related outcomes, we conducted a pilot study combining daily ecological momentary assessment with twice-daily exposure to natural or urban photos. Participants were asked to imagine being in the displayed environments. Effects of this twice-daily exposure were tested on a number of outcomes related to stress: mood, stress level, worry, heart rate, psychosomatic complaints, and mental well-being. As previous research has indicated that restorative effects of natural versus urban environments are more pronounced for those in higher need of restoration (i.e. suffering from mental health issues; Roe & Aspinall, 2011; Beute & de Kort, 2018), we specifically targeted participants with mild or higher depression symptoms and/or high stress levels. In addition, rumination—a main focus within the current study—is highly related with depression levels. We hypothesised that exposure to natural environments would result in better mood, lower stress levels, and better stress-related outcomes as compared to exposure to urban environments. In addition, we expected that mental well-being (depression, anxiety) would improve after a 6-day exposure to natural content, but not after the same exposure to urban content.

METHOD<sup>1</sup>

## Design

A crossover design was employed with two study weeks (Slideshow Content: Nature versus Urban scenes), counterbalanced in order. The Urban scenes study week was added as the control week to ensure that effects would not be due to watching a slideshow twice daily on its own. Daily questionnaires and slideshows were presented on a tablet provided to the participants. Each week consisted of three sessions: a first session in the laboratory, an experience sampling period, and a second session in the laboratory. There was an interim period between the two study weeks to ensure that no beneficial effects of exposure to the previous slideshow content were still present. As no previous research exists to indicate how long potential effects remain, we decided to make this interim period 4 weeks.

## Participants

In total, 15 participants (12 female) were recruited and completed the experiment. They were contacted through a local database, consisting of participants that subscribed to participate in studies (both online and on campus) of the university department for which the authors work. This database is quite diverse and contains people of all ages (children to elderly) and backgrounds. Participants typically receive an email with an invitation to participate in a study, just as in the present study. Before entering the study, they were asked to fill in a selection questionnaire. The majority of participants in our study were students. All but one participant completed both conditions. This one person could not participate during the second study week (urban condition) due to personal circumstances. The age of participants ranged between 18 and 29 years, with a mean of 21.6 years ( $SD = 3.0$ ). For this study, we wanted to recruit participants with heightened levels of depression or anxiety, and/or with above-threshold stress levels. Selection criteria were as follows: a minimum score of 14 (“mild depression”) for the Beck Depression Inventory-II (BDI-II), *or* 21 for the Symptoms Checklist-90-R (SCL-90-R) anxiety scale, *or* of 14 on the Perceived Stress Scale (PSS). No exclusion criteria were applied. See the Measures section for a description of these scales. Participants that fulfilled the selection criteria were invited to participate in the study. Table 1 presents the range and means on the respective selection scales. All participants fulfilled the criterion on the PSS

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<sup>1</sup> The outcomes reported here are part of a larger study investigating the effects of twice-daily exposure to natural versus urban environments on mood, stress, sleep, mental well-being, self-regulation, and cognitive performance. This paper will not report the outcomes on self-regulation and cognitive performance.

scale; the average score on the BDI-II was above the criterion. On average, however, anxiety scored lower than the criterion. Ethical approval for the study was obtained from the department's ethical committee. In total, the experiment took about 5 hours and participants received €50.00 compensation for their effort.

## Procedure

Participants came to the laboratory where they first filled in a number of questionnaires related to mental well-being (SCL-90-R subscales), followed by baseline measurements of cognitive performance (not reported in this manuscript). After this, they received instructions about the use of the tablet (see "Slideshows" for further details). They subsequently took the tablet home with them and received notifications four times per day for 6 consecutive days to fill in the experience sampling questionnaire. They returned 1 week later to hand in the tablet, to fill in the questionnaire probing mental well-being, and to perform the cognitive performance tasks for a second time. A similar cycle was run for the second study week, which was scheduled 4 weeks after the first one ended. At the end of this week, they were thanked and paid for their participation.

## Slideshows

The slideshows were created from images from local urban and natural scenes. Participants were exposed to a different slideshow twice daily. Each slideshow lasted 3 minutes and consisted of 18 different scenes. Twelve different slideshows were compiled. In total, 108 unique photos were used for each environment type. Therefore, throughout the experiment, each photo was shown twice, but no slideshow had the exact same content. All photos were taken in clear weather conditions and were matched in lightness. The urban photos consisted of everyday urban scenes in the southern regions of the Netherlands, including both inner city and residential areas. The nature photos were also collected in nearby parks and natural areas in the southern regions of the Netherlands and included woodlands and heathland. Each photo was shown for 10 seconds, after which the next photo would automatically appear. To increase engagement in the slideshow, motion was added to the photos (e.g. zooming in and out). The

TABLE 1  
The Scores on the Selection Scales

	<i>Range</i>	<i>Mean (SD)</i>
Beck Depression Inventory-II	11–30	16.53 (6.25)
SCL-90-R Anxiety	9–35	24.73 (8.94)
Perceived Stress Scale	14–25	20.53 (3.14)

photos were shown on a Samsung Galaxy Tab 3<sup>®</sup> with a 7-inch TFT LCD screen with a resolution of 1024 × 600 pixels. Participants were instructed to view the slideshows once in the morning and once in the afternoon and to imagine being in the displayed environments. The application stored the time the video was started and whether the video was terminated prematurely. Participants were instructed to watch the morning slideshow before 12:00 hours and the evening slideshow after 17:00 hours. They could see whether they had viewed the video as a finch appeared beside the video button if they had already watched it that day.

## Measures

*Ecological Momentary Assessment.* The ecological momentary assessment was conducted using the same device on which the slideshows were viewed. Participants received four beeps throughout the day on the tablet. These beeps were scheduled at semi-random times between 8:30 and 20:45. The first beep was scheduled in the morning, between 9:30 and 11:45, the second between 12:30 and 14:45, the third between 15:30 and 17:45, and the last one between 18:30 and 20:45. As the majority of the participants were students, the beeps were scheduled in such a way that they would always go off in the breaks in between the lectures (i.e. between :30 and :45). The questionnaire consisted of the following components:

*Mood:* Mood was measured on three dimensions: hedonic tone, energy, and tension. Each dimension consisted of four items (two reverse coded) and scores per dimension were calculated by taking the mean of these four items. The response scale ranged from 1 (*Not at all*) to 7 (*Very much*). Items for energy and tension were derived from the Activation-Deactivation adjective checklist (Thayer, 1989), whereas the items for hedonic tone were derived from the Uwist Mood Adjective Checklist (Matthews, Jones, & Chamberlain, 1990). Energy was measured with the items: “tired”, “energetic”, “wide awake”, and “lack of energy”. Tension was measured with the items “tense”, “jittery”, “calm”, and “at rest”. Reliability of both scales was high (Cronbach’s alpha = .80; .73). For hedonic tone the items were “happy”, “cheerful”, “sad”, and “blue”, with good reliability (Cronbach’s alpha = .82).

*Stress level and worry:* Stress level was measured with a single item: “How stressed do you feel right now?” Worry was measured with two items: “At this moment, I am worrying” and “At this moment, I ruminate”. All three items were measured on a response scale ranging from 1 (*Not at all*) to 7 (*Very much*). Worry was calculated by taking the mean of these two items, which had good reliability (Cronbach’s alpha = .86).

*Psychosomatic complaints:* A selection of three frequent psychosomatic complaints (headache, neck- and back-pain, stomach and bowel problems) were included. The participants were asked to report whether they were experiencing

this problem *at the moment*. In addition, one item assessed momentary health: “At this moment, I feel good”. Again, all items were measured on a scale ranging from 1 (*Not at all*) to 7 (*Very much*). The psychosomatic complaints data did not adhere to a normal distribution. Therefore, we decided to recode the data such that 1 (*Not at all*) was recoded to 0 (*no*) and all other responses to 1 (*yes*). Subsequently, occurrences of “yes” and “no” were aggregated for the two conditions (Nature vs. Urban), while adjusting for the number of responses (due to missing values) by dividing the aggregated value of “yes” and “no” codes by the number of responses given (urban: 230; nature: 264).

*Heart Rate.* Directly after filling in the EMA questionnaire, participants were asked to measure their heart rate by starting up an external application called MyHeartRate (VitTrox Technologies, available from <http://facion.net/WhatsMyHeartRate>). Participants were asked to hold their finger in front of the camera and the application automatically registered their heart rate. Heart rate has been successfully measured in a similar way in earlier research to predict emotional states (Lakens, 2013). A total of 463 heart rate measurements were gathered. The measured heart rates ranged between 4 and 122 beats per minute ( $M = 72.50$ ,  $SD = 13.70$ ). Missing values (80; 14.7%) were due to participants missing the beep, forgetting to do the measurement, or the application being unable to measure heart rate. For heart rate, all measurements below 40 were considered invalid and deleted (6; 1.3%).

*Mental Well-Being. Symptoms CheckList-90-R (SCL-90-R):* The Dutch version of the SCL-90-R (Arrindell & Ettema, 2003) was administered. The subscale Anxiety was used in the screening test. Furthermore, at the beginning and at the end of each study week, four subscales of the SCL-90-R were administered in the laboratory. These four subscales were: depression (15 items), anxiety (10 items), insufficiency of thinking and deciding (10 items), and psychosomatic complaints (12 items). The items represent symptoms and were measured with regard to the past week. The response scales ranged from 0 (*Not at all*) to 4 (*Very much*) and scores were calculated by adding all the items for each subscale. Reliabilities of all four subscales were good (Cronbach’s alpha: depression,  $\alpha = .92$ ; anxiety,  $\alpha = .90$ ; insufficiency,  $\alpha = .88$ ; psychosomatic,  $\alpha = .85$ ).

*Beck Depression Inventory-II (BDI-II):* The BDI-II (Beck, Steer, & Brown, 1996) was administered as a screening test. We used the Dutch translation of the BDI-II (Van der Does, 2002). The BDI-II has 21 items, with scores between 0 and 3, and is measured in relation to the past two weeks. Scores were calculated by summing all items; a score exceeding 14 (mild depression) was chosen as the selection criterion.

*Perceived Stress Scale (PSS):* The PSS (Cohen, Kamarck, & Mermelstein, 1983) consists of 10 items measuring stress levels over the past month. Responses range from 0 (*Never*) to 4 (*Very often*) and a sum score was



calculated. Within the age range of 18–29, the mean score was 14.2 (Cohen et al., 1983). Therefore, a score exceeding 14 was chosen as selection criterion.

## RESULTS

The results section consists of two parts. The first part presents analyses related to compliance with the study protocol. The second part discusses the analysis potential of this study protocol, and then illustrates the study potential by presenting the results for one analysis strategy.

### Ecological Momentary Intervention: Compliance with the Study Protocol

Participants were instructed to watch two videos per day, one in the morning and one in the evening. Only participants who watched more than two-thirds of the videos completely per week (more than eight videos) were included in the analyses. For this reason, one participant was excluded from the analyses. In addition, only responses that were given within 30 minutes after the beep were taken into consideration; all other responses were treated as missing values. Of the remaining 14 participants (of which one participant only completed one study week due to personal circumstances) 543 responses were included in the analyses (83.8% response rate). The number of responses per study session ranged between 7 and 24 (out of 24;  $M = 20.3$ ,  $SD = 3.5$ ).

The morning videos were watched between 5:45 and 12:00 (14:00 on one occasion) and the evening videos were watched between 17:15 and 00:15, see Table 2 for the compliance data. In the nature condition, the majority of participants watched all twelve videos; the remaining others watched 11 videos (4/14; 29%). Three evening videos and one morning video were missed. In the urban condition, slightly more videos were missed. Again, more videos were missed in the evening (seven) than in the morning (two).

Compliance could also differ between the first and second study week. Indeed, this appeared to be the case. Only one video was missed during the first week,

TABLE 2  
Overview of Compliance Data

	<i>Nature</i>			<i>Urban</i>			<i>Week 1</i>			<i>Week 2</i>		
	<i>W</i>	<i>M</i>	<i>% M</i>	<i>W</i>	<i>M</i>	<i>% M</i>	<i>W</i>	<i>M</i>	<i>% M</i>	<i>W</i>	<i>M</i>	<i>% M</i>
Morning	83	1	1.2	76	2	2.6	84	0	0	75	3	3.8
Evening	81	3	3.6	71	7	9.0	83	1	1.2	69	9	11.5
Total	164	4	2.4	147	9	6.1	167	1	.6	144	12	7.7

Note: W = Watched, M = Missed, % M = percentage missed.

whereas all other videos were missed during the second week (nine evening, three morning videos).

## Ecological Momentary Assessment

*Effects of Slideshow Content on Mood, Worry, Stress, Heart Rate, and Psychosomatic Complaints.* In this section, we will first present preliminary analyses as an illustration of the data analysis and outcome potential of the present study protocol. Given the nested nature of the data, hierarchical linear modeling was used to analyze the data using STATA 14. A series of two-level random intercept models were run, with responses nested within participant. For the 14 participants, data were collected for two experimental weeks, each week consisting of 6 days with four observations per day. For each participant, thus, a maximum of 48 observations could theoretically be collected if no beeps were missed. A total of 543 observations were collected (please note: one participant only participated in one week), representing a response rate of 83.8 per cent. The models were run with Slideshow Content as (only) fixed factor. All analyses were run with the variables as they are (i.e. no centering was applied).

When running this model, outcomes showed that Slideshow Content significantly affected hedonic tone, with participants reporting more positive affect in the nature week than in the urban week. However, no significant effects were found for tension or energy. (See Table 3 for the statistics.) These results partly confirm our hypothesis.

As we hypothesised, worry scores were significantly lower in the nature condition. However, no effect was found on reported stress level (see Table 3). Participants indicated that they worried less when watching nature twice daily than when watching urban scenery.

Heart rate appeared to be affected by Slideshow Content, with lower heart rates recorded in the nature week than in the urban week (see Table 3).

For psychosomatic complaints, we planned to analyze the categorical data with a chi-square test, but results indicated that for both conditions the distribution of “yes” and “no” answers was exactly 50/50. The single item measuring momentary health also yielded no significant difference between the two conditions. Importantly, none of the outcome variables was affected by the order of our manipulation.

*Mental Well-Being.* Mental well-being was measured on four subscales of the SCL-90-R: depression, anxiety, insufficiency, and psychosomatic complaints. Difference scores were calculated for all dimensions by subtracting scores after the respective study week from the scores at the beginning of that study week. Negative scores hence indicate an improvement in well-being after the 6-day exposure. A series of four HLM models were run with depression, anxiety, insufficiency, and psychosomatic complaints as dependent variables. All

TABLE 3  
HLM Outcomes and Descriptives for the Effect of Slideshow Content on the Outcome Variables

	<i>B</i> ( <i>SE</i> )	<i>p</i>	95% <i>CI B</i>	<i>Nature</i> <i>Margins</i> ( <i>SE</i> )	95% <i>CI Margins</i>	<i>Urban</i> <i>Margins</i> ( <i>SE</i> )	95% <i>CI Margins</i>	<i>ICC</i>
Hedonic	-.17 (.07)	.002	-.314-.029	4.93 (.19)	4.55-5.31	4.76 (.20)	4.38-5.15	.45
Energy	-.11 (.09)	.226	-.280-.066	4.58 (.15)	4.29-4.87	4.47 (.15)	4.18-4.77	.22
Tension	.03 (.08)	.725	-.128-.184	3.06 (.15)	2.77-3.35	3.09 (.15)	2.80-3.39	.27
Rumination	.40 (.11)	<.001	.175-.618	3.12 (.23)	2.67-3.57	3.52 (.23)	3.06-3.97	.30
Stress	.13 (.12)	.253	-.096-.362	3.18 (.18)	2.82-3.54	3.31 (.19)	2.94-3.68	.19
Heart rate	4.21 (1.06)	<.001	2.13-6.29	70.34 (1.79)	66.82-73.86	74.55 (1.83)	70.95-78.14	.23
Mom. health	.11 (.09)	.220	-.068-.297	4.49 (.25)	3.99-4.98	4.60 (.25)	4.10-5.10	.45

Note: CI = Confidence Interval; ICC = IntraClass Correlations.

responses were nested within participant ( $n = 14$ ) and Slideshow Content was added as (the only) fixed factor. The HLM results are summarised in Table 4. Counter to our expectations, no effects of Slideshow Content on SCL-90-R subscale data were found.

## Further Analysis Strategies

The previous analyses already showed some potential of the data, but an Ecological Momentary Assessment protocol also allows for more complex analyses. This section will present some examples. Besides inter-individual effects one can also investigate intra-individual effects of Slideshow Content on the dependent variables. This, for instance, allows testing for temporal effects. By comparing outcome variables at different time points after watching the slideshow, one can investigate whether and how long any beneficial effects linger after the slideshow exposure. This would require adding Time of day to the model. First, one would have to single out endogenous dynamics in affect over the day by adding Time of day and Time of day squared (as mood often shows a non-linear pattern over the day). Then, the interaction between Time of day and Slideshow Content could signal increments or decrements in mood over the day due to the intervention.

Cumulative effects could also occur, for instance in better affective and stress outcomes towards the end of the study period. This can be tested by adding the interaction between Study day and Slideshow Content to the model.

The model presented here used fixed effects of Slideshow Content. Making these slopes random could also provide additional information. Random slopes indicate that effects are different between individuals. For instance, one person may be insensitive to the manipulation whereas another may show more pronounced effects. This could, for instance, be the case for individuals with a higher need for restoration (e.g. due to lower affective states or higher stress levels, see Cohen et al., 1983, for an example). In this latter case, one can examine the covariance between the random intercepts and random slopes. Take, for example, the influence of Slideshow Content on hedonic tone. If the covariance is significant, this indicates that the level of hedonic tone for each individual is related to the slope of the effect of nature on hedonic tone. This could signal that people with lower hedonic tone levels might benefit more from the intervention (see e.g. Cohen et al., 1983).

## DISCUSSION

The potential beneficial effects of exposure to natural environments on stress and perseverative cognition were investigated in a pilot study by exposing participants to slideshows of natural and urban environments twice daily for 6 days. We expected that—compared to urban environments—exposure to nature would

TABLE 4  
HLM Outcomes and Descriptives for the Pre and Post Measurements of Mental Well-Being

	<i>B</i> ( <i>SE</i> )	95 % <i>CI</i> <i>B</i>	<i>p</i>	$\Delta$ <i>Nature</i> <i>Margins</i> ( <i>SE</i> )	95 % <i>CI</i> <i>Margins</i> <i>Nature</i>	$\Delta$ <i>Urban</i> <i>Margins</i> ( <i>SE</i> )	95 % <i>CI</i> <i>Margins</i> <i>Urban</i>
Depression	1.64 (1.89)	-2.06-5.35	.385	-1.93 (1.87)	-5.60-1.74	-.29 (1.87)	-3.95-3.38
Anxiety	.29 (1.40)	-2.46-3.03	.838	-1.71 (1.13)	-3.94-.51	-1.43 (1.13)	-3.65-.79
Insufficiency	-1.64 (1.61)	-4.17-1.74	.307	-2.29 (1.20)	-4.64-.066	-3.50 (1.20)	-5.85-1.15
Psychosom. complaints	-1.07 (1.43)	-3.87-1.73	.454	-1.71 (1.10)	-3.87-.44	-2.79 (1.10)	-4.94-.63

positively influence well-being and lower stress on a number of variables. More specifically, we aimed to investigate whether an Ecological Momentary Intervention offering natural images could help lower prolonged stress through worry and rumination.

We used Ecological Momentary Assessment to measure mood, worry, stress levels, and heart rate in everyday life in parallel with a twice-daily intervention using natural versus urban slideshows. Compliance with the study protocol was high, especially during the first week, with the majority of participants watching all required slideshows. If slideshows were missed, they were most likely to be missed during the evening and also slightly more likely in the urban than in the nature condition. It is unclear from our data whether urban slideshows were missed more often due to lower fascination qualities or perceived restorative value. However, there was a clear pattern indicating that the morning is more suitable for this type of intervention in terms of adherence. More importantly, our data signal that compliance was lower during the second study week. The majority of videos were missed during this week. Any future study using this type of intervention may need to address this issue, for instance, by improving motivation to watch the videos during the second week or by using a between-subjects rather than a within-subjects design.

Although our results are preliminary, they suggest that there may be a stress-reducing potential of the intervention. Our expectations concerning beneficial effects of twice-daily nature exposure—as opposed to twice-daily exposure to urban scenery—were partly confirmed. We found that positive affect increased and worry and heart rate decreased when participants viewed natural environments. Tension, energy, and self-reported stress level did not improve when viewing the natural images.

Mental well-being improved over time in both the urban and the nature week. On the one hand, the EMA protocol itself could have had sensitising effects on registering inner mental states. As a result of this, participants might have struggled less with retrospective bias—often overestimating more extreme emotions (Thomas & Diener, 1990)—and therefore judged their mental state more positively. Indeed, other researchers have also found lower depression scores after implementing an ESM protocol (Broderick & Vikingstad, 2008). This may be an important point to take into account in future research, as comparing pre- and post-scores may be affected by the study design itself and may therefore not reliably reflect any changes in affective states. This could potentially be overcome by investigating temporal effects within the EMA data (e.g. comparing scores at the beginning versus end of the study week) rather than including retrospective questionnaires.

Alternatively, taking a moment of relaxation each day to watch the slideshows in itself could have helped recover mental well-being (see e.g. Grossman et al., 2004), but adding the urban scenery as control condition countered this alternative explanation as any beneficial effects of natural content will go beyond just taking a moment of rest. To this purpose, we specifically instructed participants

to imagine being in the displayed environments while viewing the slideshow. Twice-daily exposure to natural content potentially offered participants a “micro-restorative” experience (Kaplan, 2001) that increased positive affect, and lowered rumination throughout the day.

The preliminary analyses performed in this article show promising results, but more complex analyses would be possible with a larger sample allowing for even more detailed investigation of the effectiveness of the slideshow intervention. More specifically, one could investigate temporal patterns (e.g. wash-out or accumulative effects of the intervention) and individual differences (e.g. the role of need for restoration) in the beneficial effects on well-being. This may require some slight changes to the protocol, especially when one wants to see whether and how long beneficial effects linger after the morning slideshow. In that case, one may want to instruct participants to watch the slideshow at a predetermined time, in order to have the same time span between watching the slideshow and filling in the momentary assessments. This may, however, affect compliance with the study protocol as in the present study participants were allowed to watch the slideshow at their own convenience.

The sample used in this study consisted of people with a high need of restoration, reflected in mild or higher levels of anxiety/depression and/or high stress levels. It would be interesting to further study whether, as we expected, it is indeed especially this group of individuals that would benefit from this type of ecological intervention. The statistical model discussed (as based on Cohen et al., 1983) in the Results section would allow for making this type of inference.

Measuring human behavior and cognition in everyday life offers great advantages, not least since worry and stress are very much day-to-day phenomena. The downside in this research, however, was lower experimental control over the circumstances in which the slideshows were watched.

Another video-related issue concerns attrition. Extreme stress levels (e.g. being under high time pressure) or mood states may lead participants to skip the slideshow. In the present study, compliance was relatively high but, especially when using more complex analyses into for instance the relation between need for restoration and efficacy of the intervention, this may pose a potential threat to the validity of the study. This could be overcome by adding a question at the end of the day asking participants to report reasons for missing a slideshow.

In addition, as multiple outcome variables are measured at the same time there is always a risk of finding any results by chance because of multiple hypothesis testing. However, measuring multiple outcomes can also be informative especially if self-reported data are combined with ambulatory physiological measurements, as long as the outcomes corroborate each other.

The exposure period in this study was only 6 days and with a small sample, but we found promising suggestions for beneficial effects of nature exposure on hedonic tone, worry, and heart rate. We found these effects in everyday life,

while participants were facing real-life stressors. Importantly, at least for the duration of the study period, participants showed relatively good adherence to the study protocol, which required them to watch a short slideshow each morning and evening with the most optimal adherence during the morning sessions and first study week. As self-tracking is increasingly becoming an integral part of our everyday lives, this offers possibilities for research as well as health interventions, especially when applied for a longer duration. Every smartphone owner has unlimited access to online video streams; thus restorative media content can be easily incorporated into our daily routines. This provides opportunities for offering tailored micro-restorative experiences—such as exposure to natural scenes—that could contribute to escaping the negative spiral of prolonged stress on health.

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