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Abstract: Ample research shows that spending time in natural (vs. urban) environments, or merely watching nature scenes, can seemingly replenish depleted cognitive resources and thereby improve cognitive functioning. While such findings are traditionally explained by referring to Attention Restoration Theory (ART), in the present research, we outline and test a potential alternative explanation for nature-related performance benefits. Our account centers on the notion that the aesthetically pleasing character of nature scenes simply fosters individuals' willingness to work, including working on the cognitive tasks used in attention restoration research. After outlining our theoretical proposal, we report the results of a preregistered showcase study in which we asked participants (N = 219) to watch a slideshow of fifteen photos of natural scenes/elements. The beauty of the slideshow images was manipulated by presenting either aesthetically attractive nature images (beautiful nature condition) or nature images where the aesthetic qualities had been removed through pixilation (pixelated nature condition). We subsequently tested the effect of this manipulation on participants' performance on a simple and mindless "clicking task", consisting of freely clicking radio buttons. We also varied the number of clicking tasks participants had to perform (between-subjects); while all participants had to click buttons after the nature slideshow, a subset of them also had to do the clicking task *before* watching the slideshow images. Results show that participants who only had to do the clicking task once (i.e., after the slideshow) and who had watched beautiful nature clicked more buttons, and reported to feel more motivated to click buttons compared to participants who had watched relatively unappealing pixelated nature images. This general nature-related performance enhancement could account for the general pattern of positive nature effects on cognitive tasks without requiring ART's additional assumptions of resource replenishment and resource specificity.

Keywords: nature; attention restoration; willingness to work; mindless work; beauty; preregistration

1. Introduction

The last decade has seen a true explosion of psychology research into human-environment interactions (Steg, Van den Berg, & de Groot, 2013), with researchers showing particular interest in learning how interacting with *natural* environments can yield beneficial effects (Hartig, Mitchell, De Vries, & Frumkin, 2014). To this day, one of the most widely studied effects in this research area is that spending time in natural (vs. urban) environments, or merely watching nature scenes, can seemingly replenish cognitive resources and improve cognitive functioning (Kaplan & Berman, 2010; Schertz & Berman, 2019). The present work is part and parcel of this research stream, but, driven by issues in the field (Joye & Dewitte, 2018), it aims to propose a hitherto underexplored explanation for such nature-induced cognitive performance benefits.

Our paper has three objectives. First, we provide a concise, but critical literature review of the standard theorizing about nature–related cognitive performance benefits. Second, we outline an alternative account for such nature-induced cognitive benefits. We argue that, rather than replenishing cognitive resources that are specifically taxed by *cognitive* tasks (Kaplan & Berman, 2010; Schertz & Berman, 2019), nature's aesthetic features can yield unspecific motivational benefits that may enhance performance on any task, irrespective of its cognitive demands. Following up on this theoretical proposal, our third objective is to report and discuss the results of a preregistered showcase study that provides a first test of our alternative account.

1.1. The main tenets of Attention Restoration Theory

Research into nature–induced cognitive performance benefits is traditionally guided and inspired by Stephen and Rachel Kaplan's Attention Restoration Theory (ART; Kaplan & Kaplan, 1989; Kaplan, 1995; Kaplan & Berman, 2010; Schertz & Berman, 2019), where nature's beneficial effects are situated in its potential to improve the capacity for directing attention. People are assumed to draw upon directed attention in situations and during activities where they have to concentrate on a particular task (e.g., proofreading), while at the same time ignoring or blocking out competing (external or internal) stimulation. In ART, directed attention is regarded as a limited resource that can tire upon intensive and prolonged use, which can lead to directed attention fatigue (Kaplan & Kaplan, 1989, Kaplan, 1995; Kaplan & Berman, 2010; Schertz & Berman, 2019), and unfavorable states and/or behavioral outcomes, such as increased distraction, aggression (Kuo & Sullivan, 2001; Wang et al., 2018), or impulsivity (Berry et al., 2015).

Just like tired muscles need rest to recover, ART states that a depleted capacity for directed attention needs rest to (self-)replenish (Kaplan, 1995; Kaplan & Berman, 2010; Kaplan & Kaplan, 1989; Schertz & Berman, 2019). One of the major contributions of ART-inspired research is that it has highlighted how immersion in, or exposure to physical environments can bolster this (self-)replenishment process, with such environments typically being referred to as "restorative environments". Backed up by a burgeoning research literature, the current consensus among restoration researchers is that having contact with (unthreatening) natural environments – and especially green- and blue-space – provides a powerful means to combat and recover from directed attention fatigue, whereas "grey" urban environments tend to hamper replenishment of attentional resources (Schertz & Berman, 2019).

ART postulates that nature facilitates attention restoration because natural environments abound with "soft fascinating" stimuli, such as "... clouds, sunsets, snow patterns, the motion of the leaves in the breeze ..." (Kaplan, 1995, p. 139). Fascinating (natural) elements, settings, and phenomena effortlessly draw and hold one's attention in a gentle way, without putting any further demands on directed attention (Basu, Duvall, &

Kaplan, 2019; Herzog, Black, Fountaine, & Knotts, 1997). When exposed to, or surrounded by such natural fascinations, individuals function in another attentional channel than when using directed attention, leaving directed attention – if fatigued – an opportunity to rest and replenish itself. Urban environments, on the other hand, are often rife with "dramatic stimulation" that needs to be blocked out (e.g., cars, billboards; Berman, Jonides, & Kaplan, 2008), which makes that functioning in such settings requires further directed attention capacity rather than enabling replenishment.

To sum up, advocates of ART propose that (a) nature-driven cognitive performance benefits occur via a replenishment process, and that (b) this involves the replenishment of a particular cognitive resource, i. e., directed attention. While in the present work we also presume that nature can yield performance benefits on cognitive tasks, in the next sections we aim to demonstrate that there is currently only a weak empirical basis to conclude that attentional resource replenishment is underlying these benefits, thus paving the way for a more parsimonious explanation of such nature benefits.

1.2. Do nature-induced performance benefits reflect replenished resources?

To verify if nature can facilitate attentional resource replenishment, restoration studies usually adopt a three-step experimental paradigm (Stevenson, Schilhab, & Bentsen, 2018). In a first phase (at Time 1), participants have to execute a cognitively demanding task intended to fatigue directed attention. In a following phase (at Time 2), participants are shown, or immersed in natural (vs. control/urban) environments, directly after which they need to perform a second cognitively demanding task (at Time 3) – with performance on the latter being the central outcome measure. Using this experimental paradigm, studies generally show that participants perform better on the task executed at Time 3 after seeing (visuals of) natural as opposed to urban (or control) environments. Advocates of ART generally assume that, inasmuch as the (cognitive) fatigue induction at Time 1 depletes directed attention, the nature advantage in task performance observed at Time 3 signals attentional resource replenishment facilitated by exposure to nature stimuli.

While this three-step experimental paradigm is widely used in restoration research, it has recently been criticized on the grounds that it fails to adequately test ART's replenishment idea (Joye & Dewitte, 2018). Specifically, the widespread practice to fatigue *all* participants at Time 1 does not permit one to ascertain that superior task performance at Time 3 is driven by nature (vs. urban/control) scenes facilitating the replenishment of directed attention, or whether nature can also have beneficial effects via performance-enhancing processes operating independent of resource depletion. In the absence of a control group of relatively unfatigued individuals, better task performance at Time 3 after seeing nature is *both* consistent with a depletion/replenishment account as with accounts centering on performance-enhancing mechanisms that operate independently from depletion.

1.3. Are nature-induced performance benefits resource-specific?

In restoration research, various experimental tasks are employed to demonstrate that nature's restorative effects specifically operate on directed attention. These include – but are not limited to – such tasks as the digit span forward/backward (Berman et al., 2008), the Stroop task (Beute & De Kort, 2014), the sustained attention to response task (SART; Berto, 2005; Lee, Williams, Sargent, Williams, & Johnson, 2015), or the attention network task (Berman et al., 2008; Gamble, Howard, & Howard, 2014). Because a common denominator between these and other tasks is that their execution (presumably) relies on directed attention, a nature (vs. urban) advantage on these tasks is usually taken as evidence that nature is especially beneficial for this cognitive capacity. However, advocates of ART seem to overlook the possibility that there might be other common denominators between these tasks.

For example, at a basic level, a shared ground between many, if not all attentional tasks used in restoration research is that participants in the first place need to be *motivated to work* on a task. An alternative and more parsimonious explanation for cognitive performance benefits is thus that these simply reflect increased willingness to work, instead of a restored attentional capacity. To the best of our knowledge, this notion has neither been tested nor ruled out.

1.4. Towards an alternative explanation for nature-induced cognitive performance benefits

In the absence of an unambiguous test of the ART's attentional resource replenishment idea, and in light of further conceptual and methodological difficulties surrounding ART (Joye & Dewitte, 2018), we decided to take a step back, and to look at whether nature might lead to performance benefits on tasks irrespective of resource depletion and of the task's demand on directed attention. With the present work, we specifically aim to both theoretically elucidate and empirically test the notion that (the aesthetic qualities of) natural scenes/elements simply foster individuals' engagement with tasks largely independent of their cognitive demands. Such a general nature-related performance enhancement could account for the general pattern of positive nature effects on cognitive performance without requiring the additional assumptions of resource replenishment and resource specificity. Central to our account – and as already touched upon in section 1.3 – is that at a most basic level, participants in restoration studies typically have to *work* on a particular cognitive task. Probably, for a good deal of participants, the goal to persist and perform well on such tasks is not very important. The Stroop task (e.g., Beute & De Kort, 2014) or the SART (e.g., Berto, 2005), for instance, do not seem to be intrinsically rewarding (Filipas, Mottola, Tagliabue, & La Torre, 2018; Pattyn, Neyt, Henderickx, & Soetens, 2008) and participants may very well be motivated to work and perform well on these tasks for other reasons than personal fulfilment or task pleasure (e.g., to keep to a commitment made to the experimenter).

Whatever motivates participants in restoration research to work on cognitive tasks, this motivation does not take place in a vacuum, but belongs to a broader goal system that consists of multiple goals a person simultaneously holds (Kruglanski et al., 2002). Importantly, if it is someone's goal to work for a considerable amount of time on a non-rewarding task – as is the case in restoration studies – then during that work episode other goals remain unfulfilled. An exclusive and prolonged focus on one goal can however be costly if it hampers the pursuit of other, personally important goals (Kurzban, Duckworth, Kable, & Myers, 2013), and people will therefore try to reach and preserve a relative balance in goal pursuit/spent effort between the multiple goals within their goal system.

If performance on a task is in itself not very important or rewarding (as seems to apply to cognitive tasks used in restoration research), then the need to retain a balance between goals will manifest itself in the fact that other goals will soon become salient as the work episode progresses. While there might be a myriad of goals that can compete with a work goal, we suspect that in work situations, it will especially be hedonic goals that will become salient and attractive (Inzlicht & Schmeichel, 2012). Hedonic goals are typically satisfied by activities/stimuli that are relaxing, fun, pleasurable, and/or enjoyable, such as – say – eating comfort food, shopping, playing video games, or even experiencing aesthetically enjoyable stimuli, like beautiful music or attractive nature scenery.

Central to our account is that the increasing importance of hedonic goals during a work episode can interfere with the goal to work, and – in so doing – hurt work performance. Importantly, the point at which hedonic goals become salient and start to interfere with the goal to work on a task will in part depend on the degree to which hedonic goals have been fulfilled by events prior to the work episode. If people have experienced something pleasurable before work (e.g., watching one's favorite movie), it might take longer for hedonic goals to become salient during work compared to the situation when having experienced something comparatively less rewarding before work (e.g., being stuck in a traffic jam). Such hedonic goal fulfilment can delay or buffer the interference between work and hedonic goal pursuit, translating in better work performance compared to the situation when work was not preceded by something pleasurable.

Instead of being indicative of attentional resource replenishment, we propose that nature-induced performance advantages on cognitive tasks (i.e., “work”) observed in restoration research reflect the fact that the experience of nature before working on non-rewarding cognitive tasks is simply better able to satisfy hedonic goals than comparatively less rewarding experiences/stimuli (e.g., nature photos where aesthetically diagnostic information, such as color or visual detail, has been removed). This goal-fulfilment can temporarily hold off the interference that might arise between the goal to work (on cognitive tasks) and the need for hedonic stimulation. In accordance with this notion, studies have observed performance benefits on cognitively challenging but non-rewarding tasks (e.g., the Stroop task; Krebs, Boehler, Appelbaum, & Woldorff, 2013; solving arithmetic problems: Bijleveld, Custers, & Aarts, 2010) after receiving monetary rewards. Just like monetary gains, nature experiences may be rewarding (by having hedonic value) and thus promote performance on non-rewarding tasks (see Fig. 1 for a schema of our account).

The hedonic value of the nature used in restoration research (i.e., mainly green- and bluespace) is well-established. Ample environmental psychology research shows that – at least in WEIRD samples – people have an aesthetic preference for natural landscapes and elements over urban settings (Biederman & Vessel, 2006; Yue, Vessel, & Biederman, 2007; Vessel, Maurer, Denker, & Starr, 2018), with researchers tracing this preference back – amongst others – to our shared evolutionary past (Wilson, 1984) or to differences in processing demands imposed by natural versus urban scenes (Joye, Steg, Ünal, & Pals, 2016). Inasmuch as the experience of aesthetically appealing stimuli (like nature scenes) has hedonic value (Skov & Nadal, 2020), beautiful nature might be better able to fulfil hedonic goals than stimuli that are aesthetically less appealing.

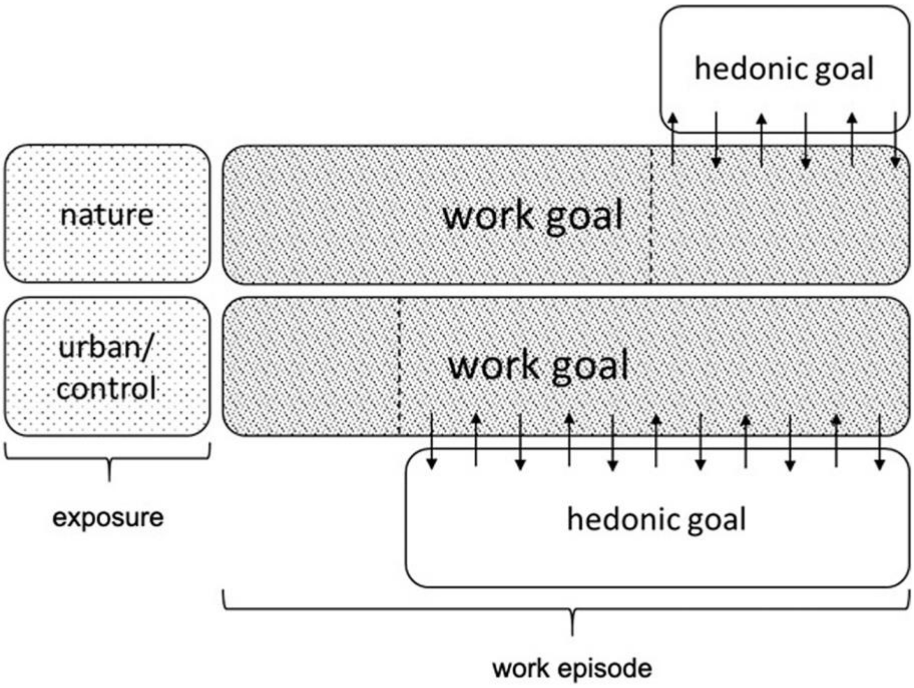

Fig. 1. Schematic representation of our alternative account for nature-induced cognitive benefits. In the “exposure phase” participants are exposed to either aesthetically appealing nature scenery or to comparatively unappealing stimuli (often urban scenery), while in the subsequent phase – the “work episode” – participants are expected to work on a particular (often cognitively demanding) task. Compared to relatively unappealing urban scenes (or to receiving no stimulation at all), the pleasurable stimulation provided by nature scenes in the exposure phase delays or buffers the interference of hedonic (i.e., pleasure) goals during the work episode.

1.5. A showcase study

Guided by the previous theoretical framework, we expected that experiencing aesthetically appealing nature (vs. relatively unappealing stimuli) would have motivational influence, in that after/during watching such nature, participants would be more willing to work on a non-rewarding task.

As a first "showcase" test of our account, we conducted a pre-registered lab study in which participants had to watch a slideshow of fifteen photos of natural scenes/elements. We manipulated the beauty of the slideshow images (between-subjects) by showing them either aesthetically attractive nature images ("beautiful nature condition") or the same nature images where the aesthetic qualities had been largely removed through pixilation ("pixelated nature condition"). We subsequently tested the effect of this manipulation on participants' performance on a very simple and mindless "clicking task", consisting of freely clicking radio buttons. Crucially, this task did not pose any demands on any cognitive function more complex than the sensorimotor processes required to navigate a mouse cursor to a non-moving target (i.e., buttons) in the absence of distractors and time constraints. The cognitive ease of this clicking task made it unlikely that a nature-related benefit on the task would reflect the replenishment of a presumed directed attention resource.

In addition to manipulating the beauty of the nature images, we also varied the number of clicking tasks participants had to perform (between-subjects). While all participants had to click buttons after the nature slideshow, we asked a subgroup to also do the clicking task *before* watching the slideshow images. The rationale for this was to follow the setup of typical restoration studies, where a (cognitive) task is not only administered after, but also before nature exposure (in an attempt to deplete to-be-restored attentional resources). Moreover, the pre-slideshow clicking task also served as a control condition, against which we would be able to compare post-slideshow clicking behavior in the beautiful and pixelated nature conditions (for participants who did the clicking task only once). By this means, we were able to explore whether potential differences between the two slideshow conditions would reflect a motivating effect of beautiful nature images or a demotivating effect of pixelated nature images.

We submitted two preregistered hypotheses. First, guided by the notion that aesthetically attractive nature constitutes pleasurable stimulation (Biederman & Vessel, 2006; Yue et al., 2007), and that providing something pleasurable before working on a non-rewarding task increases the willingness to work on that task, we hypothesized that participants in the beautiful nature condition would click more buttons than participants in the pixelated nature condition (Hypothesis 1). At the time of the preregistration, we believed that this effect would take place irrespective of the number of clicking tasks participants had to perform. Second, based on the notion that motivation to work dwindles upon repeating a mindless task like clicking buttons, we expected that participants who only had to perform one clicking task would click more buttons than participants who also did the task *before* the nature slideshow (Hypothesis 2).

2. Methodology

2.1. Preregistration

For the present study, we preregistered the theoretical rationale and main hypotheses, the calculation of sample size, exclusion criteria, as well as the target analyses. The preregistration document can be accessed via https://osf.io/439um.

2.2. Participants and design

The study was approved by the institutional ethical board. Two-hundred and nineteen participants (age: M = 44.43, SD = 12.94; 122 females) participated in this lab study, which was part of a multi-study experimental session at an eastern European university. The majority of participants in our sample had obtained a higher education degree (unfinished high school: 0.5%; secondary education: 11%; higher education: 82.6%; unfinished higher education: 5.9%).

Sample size for the present study was determined before data collection using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), recommending a required sample size of 210 participants, based on a medium effect size (f = 0.25; this effect size refers to the main effect of our main IV – "slideshow condition"), an alpha-level of 0.05, and a power of .95. We sampled somewhat above this sample size to account for sample attrition.

We used a 2 by 2 between-subjects design, with "slideshow condition" (beautiful nature vs. pixelated nature) and "task condition" (single vs. repeated task) as the between-subjects factors, and number of buttons clicked as the dependent variable. The number of participants per cell was: beautiful nature – repeated task condition: n = 54; beautiful nature – single task condition: n = 55; pixelated nature – repeated task condition: n = 55; pixelated nature – single task condition: n = 55. In the Appendix we list additional measures taken for the present study, including descriptives per condition.

2.3. Manipulations and measures

2.3.1. Slideshow of beautiful versus pixelated nature photos

We collected fifteen high-resolution photographs of aesthetically appealing natural settings/elements/phenomena using *Google Images*. The photo set included images of mountains views, sunsets, and forests, but also of small beautiful natural elements, such as tiny glistening water droplets on leaves. In the beautiful nature condition, we showed participants the original (but resized) photographs, whereas in the pixelated nature condition, we used the same pictures as in the beautiful nature condition, but pixelated each photo using an online pixilation application (accessible via www.onlinepngtools.com; pixilation size was set at a value of 30). As low-level structure/detail of images is known to contribute to the aesthetic qualities of pictures (Valtchanov & Ellard, 2015; Van den Berg, Joye, & Koole, 2016), and as pixilating removes that low-level structure/detail, we expected that pixelating would substantially reduce the aesthetic qualities of the photos, while at the same time preserving general color information. In other words, pixelating allowed us to isolate and specifically manipulate the beauty of the photos. The picture sets can be consulted via the following link: htt ps://osf.io/yz32v/.

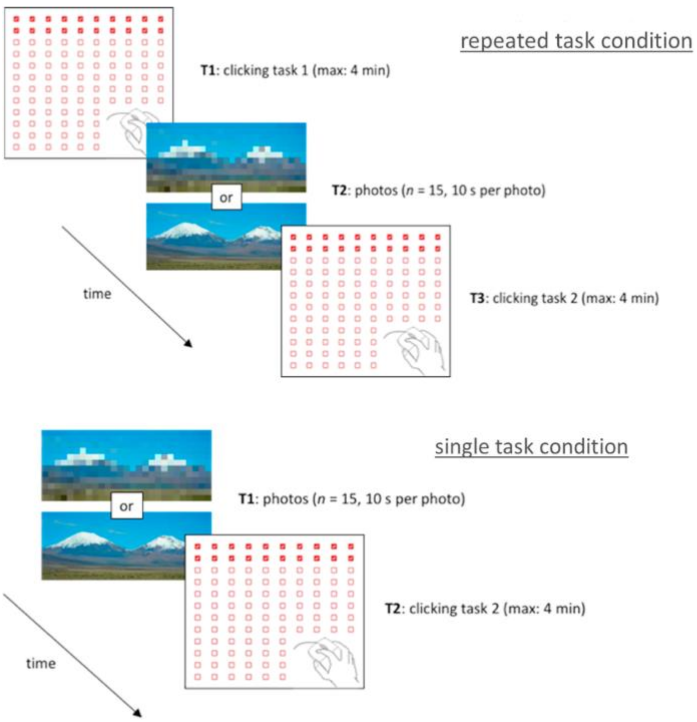

Fig. 2. Schemas of the experimental procedure used in the present study, for participants in the repeated task (upper schema) and single task condition (lower schema). Each participant either saw the beautiful nature photos or the pixelated counterparts.

It is important to note that while we are aware that pixelating can introduce further differences between the original and pixelated photos than mere aesthetic value, this is not something unique to our approach. In restoration research it is common practice to compare (images of) natural with urban scenes (Stevenson et al., 2018), and also these scene categories differ on multiple other dimensions than their aesthetic value (e.g., signs of human presence, presence of artefacts, differences in color).

2.3.2. Beauty ratings of the slideshow photos

To verify if participants indeed perceived the beautiful nature versus pixelated nature slideshow photos as more beautiful, we asked them to rate how “beautiful”, “fascinating”, “rewarding”, and “ugly” they considered the entire set of nature photos (we also asked participants how much “awe” the images triggered, but due to a translation error we were unable to use this item; 7-point scale ranging from “strongly disagree” to “strongly agree”). Work in the field of empirical aesthetics shows that these items refer to the experience of beauty and aesthetic appeal (Schindler et al., 2017). We created a “beauty index” by averaging the first three items ($\alpha = 0.90$; we left out the item “ugly”, because – after reverse-coding – it turned out to reduce the scale’s reliability, although not affecting results in any way).

2.3.3. Behavioral task: clicking radio buttons

To gauge participants’ performance on a non-rewarding and cognitively undemanding task, we gave them the opportunity to simply click radio buttons. We specifically presented them a matrix of 500 clickable buttons (organized in 50 rows of 10 buttons; see Fig. 2 for a schematic representation) and requested them to click as many buttons as they wanted. This clicking task was implemented and executed on the survey platform *Qualtrics*, and permitted us to straightforwardly quantify how much participants worked. This clicking task is highly similar to the repetitive tasks used in experimental economics research aimed at gauging "pure" work effort (such as centering slider scales, e.g., Gill & Prowse, 2019; clicking on circles, e.g., Takahashi, Shen, & Ogawa, 2016; clicking alternate buttons, e.g., Ariely, Gneezy, Loewenstein, & Mazar, 2009).

Even though clicking buttons might ask some concentration and eye-hand coordination, the task is unlike the "relatively demanding attentional tasks" (Stevenson et al., 2018) that are traditionally used in ART research to demonstrate nature's restorative effects. The use of radio buttons is standard practice in digital/online surveys, and our participants belonged to a professional panel, familiar with this response format. Moreover, the act of freely pressing buttons (with no time or accuracy requirements/instructions) in itself does not seem to pose any important demands on working memory, nor does it require blocking out simultaneous distraction or attentional cues – mental processes that are assumed to lead to attentional depletion, and that are tested in ART research using tasks such as the SART (Berto, 2005; Lee et al., 2015) or digit span task (Berman et al., 2008). If aesthetically attractive photos of nature would positively affect performance on such a simple task, then this would lend support to the idea that beautiful nature can motivate to work.

2.3.4. Self-reported motivation to work

In addition to assessing participants' work performance via the clicking task, we also gauged their work motivation using two self-report measures. We asked them how much effort they had put into the clicking task ("effort index"; 5-point scale ranging from "very little effort" to "very much effort") and how motivated they were to perform the clicking task ("motivation index"; 7-point scale ranging from "very unmotivated" to "very motivated").

2.4. Procedure

The study started off with a general introduction, explaining participants that behavioral scientists often try to get insight into the “laws” governing the human mind/brain by asking subjects to execute simple and repetitive behavioral tasks. By providing participants this cover story, we tried to give them a minimal reason to subsequently work on what might come across as a seemingly meaningless task: clicking radio buttons.

After this general introduction, participants were randomly assigned to either the repeated task condition or the single task condition and either to the beautiful or the pixelated nature condition and provided informed consent before starting the actual study. For participants in the repeated task condition, the study began with the clicking task.

After a general introduction to the study, we informed participants that they would see a matrix of 500 clickable radio buttons on the next page, and instructed them that they had to click buttons (using the mouse) until they no longer felt like it, at which point they could click away to the next page of the survey. We explicitly communicated to them that they were free to click as many (or as few) buttons as they wanted, to make sure that clicking was a “pure” reflection of their willingness to work (and not, say, a reflection of their agreeableness towards the experimenter).

After briefing these participants about the clicking task, they could click away to the next page where they were presented with the matrix of 500 radio buttons, all of which could be clicked. Not all 500 buttons were simultaneously visible on the computer screen, so participants had to scroll down during the clicking task (computers and computer settings were identical across participants). For each participant, we counted the number of buttons clicked as the central behavioral measure of work performed. Participants were free to stop and click away to the next page at any point. Because of limitations in allocated study time, the length of the clicking task was limited to 4 minutes, after which the page showing the radio buttons automatically advanced.

After this first clicking task, participants in the repeated task condition were invited to watch the slideshow of nature photos. Participants in the single task condition did not have to perform a pre-slideshow clicking task; for them the experiment started off with the slideshow (after receiving a general introduction to the study). Participants in the beautiful nature condition were presented a slideshow with the original nature photos, participants in the pixelated nature condition were presented a slideshow with the pixelated photos.

For the slideshow, we instructed participants to closely watch each photograph, and to be aware of their feelings and thoughts while watching. Each slideshow image was displayed on the screen for 10 seconds, after which the page auto-advanced to the next picture. Photo presentation order was identical for all participants.

After the slideshow, all participants had to perform the clicking task – this was the second clicking task for participants in the repeated task condition, and the first one for participants in the single task condition. The instructions were identical to the instructions given to participants who had to perform a pre-slideshow clicking task. We again counted the total numbers of buttons clicked as an indicator of work motivation. After clicking, we measured participants' self-reported motivation (i.e., effort index, motivation index), asked them to aesthetically evaluate the slideshow images (i.e., beauty index), and ended the study by debriefing and thanking participants.

3. Results

3.1. Outlier selection

We excluded four participants from all analyses based on outlying values for the average number of buttons clicked (*M* = 129.07, *SD* = 121.55). We preregistered two different exclusion criteria – 2.5 and 3 *SD* from the mean – but for the sake of simplicity we report the results with the more conservative criterion here (i.e., +3 *SD*s from the mean; 4

participants removed) and present the results with the less stringent criterion (and with all outliers included) in the Appendix.

3.2. Preliminary analyses

We first checked whether the original (beautiful) nature photos were indeed seen as more beautiful than their pixelated counterparts. For this, we conducted an independent samples *t*-test (with degrees of freedom corrected for violation of homogeneity of variances) with slideshow condition (beautiful nature vs. pixelated nature) as the independent variable, and the beauty index as the dependent variable. This analysis revealed a statistically significant effect of slideshow condition, t (183.29) = − 11.19, $p < .001$, Cohen's $d = 1.51$, confirming that participants indeed considered the beautiful nature slideshow images as more beautiful ($M = 5.59$, $SD = 1.09$) than their pixelated counterparts ($M = 3.40$, $SD = 1.74$). Thus, our manipulation of beauty was successful.

3.3. Preregistered analyses: effects of slideshow condition and task condition on buttons clicked

To test whether beautiful (vs. pixelated) nature would make participants want to work more, we ran a two-way ANOVA with the slideshow condition (beautiful nature vs. pixelated nature) and task condition (single vs. repeated task) as the independent variables, and the number of post-slideshow buttons clicked as the dependent variable.

While this analysis did not reveal a significant main effect of slideshow condition on the number of buttons clicked (cf., Hypothesis 1), $F(1, 211) = 1.44$, $p = .232$, $\eta^2_p = 0.01$, it yielded a significant main effect of task condition (cf., Hypothesis 2), $F(1, 211) = 4.00$, $p = .047$, $\eta^2_p = 0.02$, showing that participants clicked more buttons in the single than in the repeated task condition. There was also a significant slideshow condition by task condition interaction, $F(1, 211) = 4.56$, $p = .034$, $\eta^2_p = 0.02$, suggesting that the effect of beautiful (vs. pixelated) nature on button clicking was a function of the number of times participants had executed the clicking task (see Fig. 3).

Planned comparisons revealed that within the single task condition, participants clicked significantly more buttons, $F(1, 211) = 5.53$, $p = .020$, 95% CI 8.09 to 91.76, $\eta^2_p = 0.03$, after watching beautiful nature ($M = 162.07$, $SD = 125.74$) than pixelated nature images ($M = 112.15$, $SD = 83.22$). In contrast, in the repeated task condition, there was no significant difference between the beautiful nature ($M = 100.15$, $SD = 107.44$) and pixelated nature condition ($M = 114.17$, $SD = 117.52$) for number of buttons clicked, $F(1, 211) = 0.44$, $p = .508$, 95% CI -55.66 to 27.62, $\eta^2_p < 0.01$. Thus, partly in line with our preregistered hypothesis, participants who did the clicking task only once worked more on a mindless routine task after seeing beautiful (vs. pixelated) nature images. (Note that there were no significant differences in average clicking time per button between conditions, F's < 1).

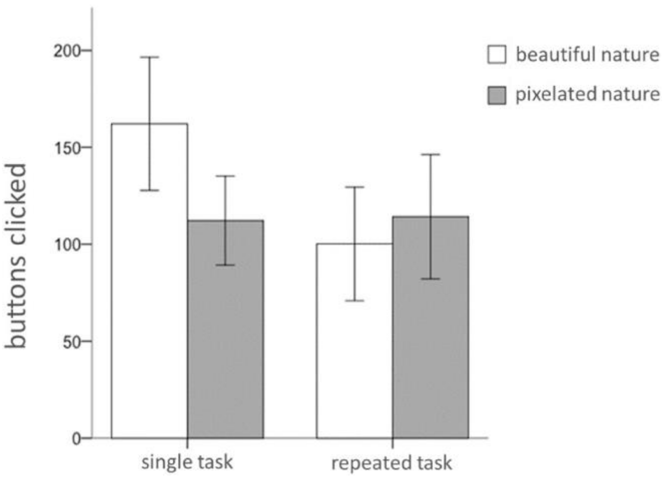

Fig. 3. Number of buttons clicked as a function of slideshow condition and task condition (error bars represent 95% confidence intervals).

3.4. Exploratory analyses: exploring the direction of the effect of slideshow condition on clicking

While the results from the preregistered analyses show that the number of buttons clicked is higher in the beautiful than in the pixelated nature condition for participants in the single task condition, at the same time our analysis remains silent about where the effect is situated. Was it exposure to beautiful nature images that made participants click more, did pixelated nature make them click fewer buttons, or did both processes operate simultaneously?

To shed light on this issue, we performed an exploratory analysis. Recall that all participants in the repeated task condition (n = 108) began the study with a clicking task, only after which they saw the nature slideshow – either the original (i.e., beautiful) or pixelated version. Clicking behavior on this first (pre-slideshow) clicking task can therefore function as a control condition, against which post-slideshow clicking behavior in the beautiful and pixelated nature condition for participants in the single-task condition can be compared.

To test this, we created a new dependent variable by merging participants' clicking performance (i.e., number of buttons clicked) on the pre-slideshow clicking task of participants in the repeated task condition with the post-slideshow clicking performance of participants in the single task condition. After also creating a new independent variable coding for the type of slideshow participants had to watch before clicking (i.e., no slideshow [= control condition], beautiful nature condition, or pixelated nature condition) a one-way ANOVA revealed a significant overall effect, $F(2, 212) = 3.53$, $p = .031$, $\eta^2_p = 0.03$, with participants clicking significantly more buttons in the beautiful nature condition (M = 162.07, SD = 125.74) than in the control condition (M = 122.94, SD = 103.27; p = .026, 95% CI 4.63 to 73.65), while there was no significant difference (p = .541, 95% CI -45.51 to 23.94) between the control and the pixelated nature condition (M = 112.15, SD = 83.22).

Thus, while participants clicked more buttons in the beautiful nature than in the pixelated nature condition (cf., section 3.3), they also clicked significantly more buttons in the beautiful nature condition than in the control condition, while there was no significant clicking difference between the pixelated nature condition and control condition. Combined, these findings suggest that the beautiful nature images indeed increased participants' willingness to work, rather than that it was – say – the unpleasantness of watching pixelated nature images that made participants give up sooner on the clicking task. Clicking differences between the (slideshow) conditions are thus driven by beautiful nature images *boosting* work performance.

3.5. Exploratory analyses: effects of slideshow condition and task condition on self-reported motivation and effort

In addition to testing the effect of our manipulations on actual work performed, we also tested whether the results obtained for clicking buttons would be reflected in the motivation and effort indices. Note that correlation analyses showed that the number of buttons clicked correlated positively and significantly with the motivation index, $r(217) = 0.48$, $p < .001$, and with the effort index, $r(217) = 0.26$, $p < .001$, and the effort index and motivation index correlated positively with one another, $r(217) = 0.47$, $p < .001$.

We ran a two-way ANOVA with the slideshow condition (beautiful nature vs. pixelated nature) and task condition (single vs. repeated task) as the independent variables and the self-report measures as the dependent variables. These analyses yielded no significant main effect of slideshow condition for both the effort and motivation index (both p's > 0.404), but revealed a (marginally) significant main effect of task condition (single vs.repeated task) for the motivation index, $F(1, 211) = 3.38$, $p = .068$, $\eta^2_p = 0.02$. There was no significant main effect of task condition for the effort index, $F(1, 211) = 2.32$, $p = .130$, $\eta^2_p = 0.01$, although the effect was directionally similar as for the motivation index.

In line with the results for clicking buttons, there was a significant slideshow condition by task condition interaction for both the motivation index, $F(1, 211) = 6.93$, $p = .009$, $\eta^2_p = 0.03$, and the effort index $F(1, 211) = 6.25$, $p = .013$, $\eta^2_p = 0.03$ (see Fig. 4). Planned comparisons revealed that in the single task condition, participants felt (marginally) significantly more motivated, $F(1, 211) = 2.78$, $p = .097$, 95% CI -0.10 to 1.22, $\eta^2_p = 0.01$, and reported to have invested significantly more effort on clicking, $F(1, 211) = 5.54$, $p = .020$, 95% CI 0.07 to 0.82, $\eta^2_p = 0.03$, in the beautiful nature condition (motivation index: $M = 4.43$, $SD = 1.41$; effort index: $M = 2.39$, $SD = 1.00$) than in the pixelated nature condition (motivation index: $M = 3.87$, $SD = 1.70$; effort index: $M = 1.94$, $SD = 0.91$).

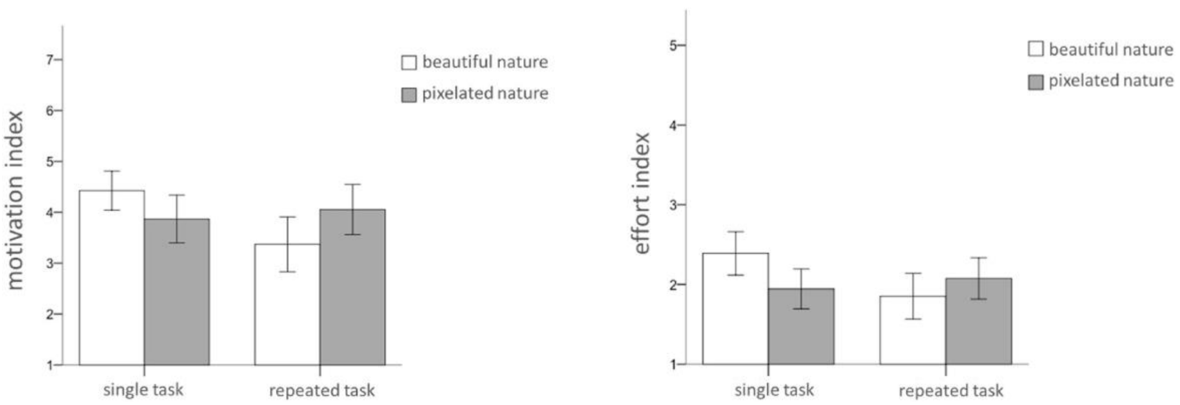

Fig. 4. Scores on the motivation index (left) and effort index (right) as a function of slideshow condition and task condition (error bars represent 95% confidence intervals).

In the repeated task condition, there was no significant difference on the effort index between the beautiful nature ($M = 1.85$, $SD = 1.05$) and pixelated nature condition ($M = 2.08$, $SD = 0.95$), $F(1, 211) = 1.39$, $p = .239$, 95% CI -0.59 to 0.15, $\eta^2_p = 0.01$, whereas participants scored significantly lower on the motivation index in the beautiful nature condition (*M* = 3.37, *SD* = 1.96) than pixelated nature condition (*M* = 4.06, *SD* = 1.81), $F(1, 211) = 4.23$, $p = .041$, 95% CI -1.34 to − 0.03, $\eta^2_p = 0.02$.

In sum, participants in the single task condition reported to have been more willing to work on the clicking task, and to have put more effort in work, after seeing the original, beautiful (vs. pixelated) nature images. These results are in line with the results found for actual clicking.

4. General discussion

For already more than three decades, nature-related cognitive performance benefits are typically explained by referring to ART, and still today the theory is used as a theoretical backbone for many nature-based health interventions (Van den Berg, 2017; Williams et al., 2019). ART's replenishment idea is however rarely tested in a direct way (Joye & Dewitte, 2018). Also, because ART-based research almost exclusively employs attentional/cognitive tasks in its studies, it is inevitable that any positive nature effects on task performance are consistent with ART's attention-specific account, whereas simpler, non-specific explanations for such findings are largely left unconsidered.

Guided by the observation that there is currently little empirical evidence to support ART's notion of nature-driven cognitive resource replenishment (Joye & Dewitte, 2018), we put forward a more parsimonious explanation for such nature benefits. Put simply, our account starts from the idea that cognitive tasks used in ART research are "work" and that people are more willing to work after having engaged in a pleasurable activity. "Restorative" nature benefits then reflect little more than an increased willingness to work after being exposed to aesthetically pleasing (nature) stimuli (cf., Inzlicht & Schmeichel, 2012). While this account and the underlying argumentation do not disprove ART in any way, they do show that – in light of the current available empirical evidence – the ART assumptions of resource/attention-specificity are not needed to explain the existing pattern of results.

Importantly, our account can accommodate the phenomenon of "instoration", which refers to the notion that exposure to nature can yield cognitive benefits, even without a prior cognitive depletion task (Joye & Van den Berg, 2013). Instoration has been observed in a host of studies (e.g., Beute & De Kort, 2014; Korpela & Ratcliffe, 2021), and ART researchers take the phenomenon to suggest that nature is not only capable of recharging, but also of *building* resources. Instoration seems to pose a challenge for ART, as the theory implies that nature specifically acts to recharge depleted cognitive resources. Our alternative proposal can account for instorative effects, as nature can exert its motivational potential on subsequent tasks both in the absence and presence of a task preceding the nature exposure – what mainly matters is that the task following the (rewarding) nature experience has a relatively low reward value, and is appraised as "work".

In addition to outlining our alternative account for cognitive nature benefits, we presented the results of a preregistered "showcase" study of our proposal. In that study, we asked participants to watch a slideshow of nature pictures and to perform a task posing little demands on attentional/cognitive resources, i.e., clicking radio buttons. Consistent with the hypothesis that aesthetically pleasing nature can encourage to work, we found that participants in the single task condition clicked more buttons during the clicking task after seeing aesthetically pleasing (vs. pixelated) nature images. Results from additional exploratory analyses comparing beautiful nature with a control condition provide further evidence that beautiful nature can indeed make participants work more (rather than that pixelated nature decreases willingness to work).

Our results contribute to a growing body of research into the psychosocial benefits of natural settings, such as reducing stress (Ulrich et al., 1991), improving mood (Beute & De

Kort, 2014) and mental health (Bratman, Hamilton, Hahn, Daily, & Gross, 2015; Cox et al., 2017), increasing prosociality (Piff, Dietze, Feinberg, Stancato, & Keltner, 2015; Joye & Bolderdijk, 2015), and improving cognitive function (Berman et al., 2008). Importantly, as successfully executing the cognitive tasks used in restoration research also depends on participants' willingness to work, our results raise the possibility that superior performance on such tasks after seeing natural (versus urban) scenes might just as well reflect motivational differences stemming from differences in aesthetic value between both scene types. While this account has already been hinted at (Joye & Dewitte, 2018), we think it deserves further consideration in restoration research.

While our study provides support for the notion that aesthetically pleasing nature can motivate to work, it also yielded some unexpected results. For instance, we only found our target effect in the single task condition. One explanation could be that completing the clicking tasks twice triggered a tendency to behave consistently, and that this overshadowed the aesthetically rewarding effects of viewing beautiful nature scenes. Alternatively, the hedonic value of the beautiful nature slideshow may simply not have been high enough in the repeated-task condition; the combined effect of performing an unrewarding clicking task and seeing aesthetically pleasing nature images might have carried too little total hedonic value to significantly affect the post-slideshow clicking task.

Future research may look at the how the effectiveness of natural beauty on the clicking task compares to other types of reward, such as receiving money (e.g., Bijleveld et al., 2010; Krebs et al., 2013). Another important question is what the minimal "dose" of natural beauty needs to be to observably affect participants' work performance, and how this dose can be effectively administered in settings where participants may pay less attention to the nature slideshow – think for instance of online settings[1].

There might be alternative explanations for our findings. One such explanation is that beautiful nature increased button clicking by promoting prosocial goals (rather than by decreasing interference from task-incompatible hedonic goals). People might have multiple reasons to put effort in working on a non-rewarding laboratory tasks such as the one used in our study, and one of them might be doing the experimenter a favor. In line with research that shows that exposure to nature can increase prosocial inclinations (Piff et al., 2015; Joye & Bolderdijk, 2015), viewing aesthetically appealing nature could indeed have increased the relevance of such prosocial goals, leading to increased clicking.

While we have tried to prevent that participants clicked buttons out of agreeableness or compliance (by explicitly communicating that they were free to click as many buttons as they wanted), some of them might still have been motivated by prosocial goals. Future research might try to disentangle whether nature-induced engagement in non-rewarding tasks stems from the fulfilment of hedonic goals, the promotion of prosocial goals, or even from a combination of both. Note however that this alternative explanation would not fundamentally change the main message of the current paper, i.e., that nature can boost performance on non-rewarding tasks irrespective of their cognitive demands. In addition to stemming from the fulfillment of hedonic goals, the motivation to work on such tasks might as well get a boost from nature activating prosocial values.

A second alternative explanation is that differences in clicking behavior between the beautiful nature and pixelated nature conditions might still reflect the replenishment of

[1] Following up on our results, we already conducted a first (but unsuccessful) online study (N = 212). In the Appendix, we describe the full methods and results of that study and discuss possible reasons for not observing nature-related benefits in this setting.

attentional resources. Most probably, participants did not begin this lab study in a fully rested state, and watching beautiful (vs. pixelated) nature might therefore still have partly resolved attentional fatigue. However, these group differences in the state of a potential attentional resource could only manifest themselves on the level of clicking task performance if this task required directed attention. As the clicking task involved nothing more than clicking radio buttons in the absence of time and performance pressure, we deem it unlikely that it significantly drew on a specific attentional resource.

One might also argue that clicking buttons requires directed attention to withstand the impulse to prematurely abandon the task, but this definition of directed attention would sit difficult with the specificity claim of ART by rendering virtually any task or activity a directed attention task. In addition, even if nature effects on the clicking task reflected the replenishment of attentional resources, this effect should especially hold for participants in the repeated task condition, because they have done the task twice. Our data however show that increased button clicking occurred for participants who have not done a pre-slideshow clicking task, which makes it unlikely that our findings reflect resource replenishment.

While we mainly aimed to make a theoretical contribution with the present work, our findings may also be of practical value, although the scope of those practical implications deviates from the implications following from ART. Existing explanations of restorative nature effects especially focus on cognitively demanding tasks, such that nature might particularly benefit everyday activities that involve important cognitive demands (e.g., job performance, studying). In contrast, in our account, nature might yield benefits for a wider range of (everyday) activities, including unrewarding tasks with prominent cognitive demands, but also unpleasant activities that do not require significant cognitive effort (e.g., running errands, doing the dishes). Moreover, if it is the unrewarding (rather than cognitively demanding) nature of tasks that is important, cognitively demanding tasks should not benefit from nature exposure if they are rewarding (consider, for example, performance on challenging computer games). Hence, in contrast to ART, our account applies to a non-overlapping (and likely larger) set of everyday activities that may benefit from contact with nature.

Our account also has practical value in that it allows us to make specific recommendations for researchers investigating nature's cognitive benefits. As the account specifies that cognitive nature benefits occur via nature's aesthetically rewarding features, one straightforward recommendation is to make sure that participants experience the stimulus material (e.g., videos of nature scenes) as sufficiently rewarding. This can either be done by selecting stimuli that have sufficient aesthetic reward value, but also by checking if participants are sensitive enough to the aesthetic properties of the stimuli (e.g., by measuring their reward sensitivity: Carver & White, 1994). Additionally, it might be worthwhile to assess if individual participants indeed experience the target (cognitive) task as "work" rather than "play"; playful tasks can be intrinsically motivating, leaving little place for nature to exert its motivational potential.

5. Conclusion

In the present work, we introduced an alternative account for why nature can provide cognitive benefits. While ART has traditionally centered on nature's capacity to engage effortless attention (or: "fascination"), a more parsimonious explanation is that seeing pleasurable nature simply motivates participants to work on non-rewarding tasks. While our results do not disprove ART in any way, our proposal might provide a viable and parsimonious account for why people perform better on the cognitive tasks administered in restoration research, without making additional claims regarding the existence of a depletable cognitive resource. Could it be that there are *multiple* distinct processes underlying nature-induced cognitive benefits, reflecting both specific resource replenishment and generally increased motivation? Perhaps yes, but we believe it is up to advocates of ART to present better evidence for the assumption that such benefits specifically reflect cognitive resource replenishment. We hope that future studies into nature-induced performance benefits will build on our exploration of nature's motivational potential, thus stimulating a research dialogue on the proximate source(s) of this invaluable psychological service.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.newideapsych.2022.100946.

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