Restoring Attentional Resources With Nature: A Replication Study of Berto's (2005) Paradigm Including Commentary From Dr. Rita Berto

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Objective: The aim of this study is to replicate Berto's (2005) heavily cited work on attention restoration.

Background: Nature interventions have gained increased interest for improving performance of attentionally demanding tasks. Berto (2005) indicated that viewing digital nature images could improve performance on a subsequent response inhibition task, the sustained attention to response task (SART). However, experimental design and statistical concerns about her experiments as well as failure to support her findings across multiple unpublished studies in our laboratory provided rationale for this replication study.

Method: Twenty participants were each assigned to one of three digital image conditions: nature, urban, and control. Participants performed the SART before and after digital image exposure.

Results: SART performance metrics (total correct target responses, mean response time, and transformed *d′*) were analyzed using 2 (SART) × 3 (image interventions) mixed design ANOVAs. The results failed to replicate Berto (2005).

Conclusion: Possible reasons for not replicating Berto (2005) are discussed, including (1) sample differences, (2) different testing environments and procedures, (3) insufficient attentional depletion, and (4) individual differences.

Applications: Research needs to determine the effectiveness of such interventions, the specific attention tasks that might benefit, and the individual difference variables relevant for attention restoration.

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INTRODUCTION

The limited cognitive capacity metaphor used to explain human performance is well received within the human factors and ergonomics (HF/E) community (Kahneman, 1973; Warm et al., 2008; Wickens, 1980, 1991, 2008). Assuming a capacity model, attention has been defined as "the process of allocating the resources or capacity to various inputs" (Hunt & Ellis, 2004, p. 87). HF/E professionals typically apply this capacity view of attention by designing systems that reduce the task load or eliminate distractions by changing interface characteristics (e.g., increasing signal salience) or task structure (e.g., automating certain subtasks), thereby allowing sufficient attentional resources to be devoted to the task in order to perform well.

However, there is another potential way to support sufficient allocation of attentional resources during task performance, specifically by shaping the nontask environment around the individual. The ability to be effective in tasks that are information rich and cognitively demanding is often dependent on the state of the individual and the context prior to task performance, which affects the availability of attentional resources (Kaplan & Kaplan, 2011). Particular types of nature environments have been proposed to promote effective task performance for demanding tasks. In environmental psychology, this effect has been referred to as psychological restoration or attention restoration, and the types of environments that promote this effect, such as nature, are called restorative environments (Staats, 2012).

Restorative Environments

Attention restoration is thought to be due to either (1) the features of nature environments being more likely to lightly capture involuntary attention, allowing for the finite resource of directed attention to recover (Kaplan, 1995), or (2) nature environments tending to promote stress reduction and the reduction of negative affect, which arguably contributes to more effective subsequent attention performance by freeing up attentional capacity (Ulrich et al., 1991). Indeed, improved task performance after exposure to nature, but not urban environments, has been observed for a variety of tasks thought to require directed attention (i.e., attention that is required to focus and inhibit distractions in support of difficult mental activity). A meta-analytic assessment of restoration via nature interventions for a variety of cognitive domains indicated that performance on working memory tasks, cognitive flexibility tasks, and, to a reduced degree, attentional control tasks benefits from nature interventions (Stevenson et al., 2018).

Berto (2005)

Heavily cited research by Berto (2005) provided significant support for attention capacity restoration in the form of improved task performance after a nature intervention. Importantly, Berto's research demonstrated that attention restoration is not limited to actual immersion in natural environments but can also occur by viewing digital nature images, suggesting a cost-effective approach for implementing nature environments in or near the workspace. She demonstrated attention restoration with the sustained attention to response task (SART), a task designed to be attentionally demanding and measure attentional lapses (Robertson et al., 1997). The SART displays numbers 1–9 randomly on a screen, and participants are asked to respond to each number quickly and accurately except for the number 3; when the number 3 is presented, participants must inhibit from responding.

The SART has been of interest to the HF/E community and involved in an ongoing debate regarding the underlying mechanism of vigilance within our community (i.e., mindlessness vs. resource theories to explain the vigilance decrement; Dillard et al., 2014; Funke et al., 2012; Head et al., 2013; Helton et al., 2009, 2008). While Robertson et al. (1997) suggested that the SART promotes mindlessness due to a routine response, several studies (Grier et al., 2003; Helton et al., 2005) have challenged this theory and suggested that the SART does induce high mental workload and stress, thus supporting the resource theory. Further, there is competing research on whether the SART even requires vigilance (Manly et al., 1999) or if it is more of a response inhibition task (Carter et al., 2013). Interestingly, Helton et al. (2005) suggested that the SART is unique in that it involves a motor control component not inherent in a traditional vigilance task, as responding to all numbers except the infrequent presentation of the number 3 creates a feedforward motor response that utilizes a different neural system than response inhibition. Since the SART may require motor control in addition to attentional control, we thought it was worthwhile to replicate a restorative effect with the SART, as the ability to restore attentional and motor control may make attention restoration more generalizable to HF/E practice than prior theory has suggested.

A brief review of Berto (2005) is needed in order to understand our rationale for performing a replication study of her work. Berto (2005) supported the notion of attention restoration using digital images and the SART across three experiments. In Berto's first experiment, participants performed the SART before and after viewing digital images. Participants were randomly assigned to view either 25 nature images or 25 urban images. The nature images contained lakes, rivers, sea, and hills, while the urban images contained city streets, industrial zones, and housing. The results of her first experiment indicated that participants in the nature image viewing condition performed significantly more accurately and faster on the second iteration of the SART compared to the first. Further, the same significant improvements in task performance were not experienced by those in the urban image viewing condition. Lastly, when comparing nature and urban viewing conditions during only the second iteration of the SART (i.e., 2nd SART for nature vs. 2nd SART for urban), comparisons revealed significantly faster response times (RTs) after viewing nature images but no changes in accuracy.

Berto's second experiment tested whether nonnature stimuli (i.e., geometric patterns), presumably requiring little cognitive effort to observe, would also have a restorative effect using the same attention task (i.e., SART) and paradigm. The stimuli set of 25 geometric pictures was selected by 4 cognitive psychologists on the bases of being considered "effortless to view." Examples of geometric pattern images are presented in the original paper (Figure 2, Berto, 2005) and included dark green, diamond-like quadrilaterals and light blue and green swirls. Results demonstrated that viewing geometric patterns resulted in no performance differences, suggesting that nature environments have a unique capacity to restore attention.

Berto's third experiment was identical to Experiment 1 with the exception of having participants self-pace their viewing time for each image. The purpose of this was to see if they would view nature images on average longer than urban images and thus improve performance further with a greater "dose" of nature exposure. Results indicated that nature images were viewed significantly longer than urban images by about 2 s per image. However, the average viewing time for both conditions (average 6.07 s/picture) was less than the viewing time for the first and second experiments (15 s/picture). Interestingly, the same patterns of significant performance improvements from Experiment 1 were not found in this experiment. An improvement in accuracy between the first and second iteration of the SART after viewing nature images was the only significant finding. As expected, there were no significant differences in accuracy between the nature and urban viewing conditions for the first iteration of the SART (i.e., before viewing the images), but unexpectedly, there also were no significant differences for the second iteration of the SART (i.e., after viewing the image) either. This brings into question the strength of the initial restorative finding from her first experiment.

The purpose of the present study was to replicate Berto's first experiment, which supported a restorative benefit from viewing nature images. There are several reasons for conducting this replication study.

1. Berto performed multiple *t*-tests without reporting any correction for family-wise Type I error inflation in both Experiment 1 (16 *t*-tests) and Experiment 2 (4 *t*-tests).
2. She also did not utilize an explicit control condition.
3. Berto (2005) reported d' as her measure of sensitivity, which is calculated as $d' = z(\text{FA}) - z(H)$, where FA is false alarms, H is hits, and z indicates z-scores. This measure can be problematic in this context because the likelihood of zero false alarms (i.e., absence of a response to a nontarget) during the SART is particularly high, as the nature of the task involves responding during the presentation of frequent nontarget distractors (i.e., all other numbers 1–9 except 3) and inhibiting a response during the infrequent target presentations (i.e., the number 3). Therefore, the likelihood of not responding during a distractor is low, as absence of a response is the correct "response" for the infrequent targets. The frequent presence of zero false alarms in the SART data makes the computation of d' unfeasible. Instead, one should either perform a loglinear transformation or compute A' as an alternative measure of sensitivity (see Stanislaw & Todorov, 1999), neither of which was reported in Berto (2005).
4. Multiple unpublished studies that were conducted in our laboratory, which involved digital nature interventions and the SART, failed to support attention restoration. Published studies from our laboratory and elsewhere with digital or simulated nature interventions and the SART also demonstrate an inconsistent pattern of results. Craig et al. (2015) showed restoration with accuracy measures (specifically commission errors) but not reaction time, while Craig (2016) showed restoration with reaction time but not accuracy measures. Berto (2005) showed restoration with both accuracy and reaction time in the first experiment but only with accuracy measures (commission errors) in the third experiment. Lee et al. (2015) showed restoration with omission errors and RT variability but not commission errors or average reaction time. Cassarino et al. (2019) found no effects on either accuracy or reaction time measures.

Due to the aforementioned reasons and the promising potential of using nature environments to improve attentional capacity, functioning, and performance in demanding contexts, it is important to replicate Berto (2005).

Goal and Predictions of the Present Study

The goal for the present study was to replicate the seminal work of Berto (2005) while accounting for the previously mentioned critiques. If the restorative effect of task performance with digital images is robust for the SART, then we would expect a significant interaction between pre- and post-image exposure and image content for accuracy, RT, and sensitivity. This interaction should reflect improved performance on the task after exposure to nature images but not for other image conditions.

METHOD

Participants

Sixty participants (30 men, 30 women) between the ages of 18 and 25 (M = 19.62, SD = 1.98) were included. Our sample size was based loosely on Berto (2005), which had 16 participants per condition. We included 20 participants per condition. Consistent with Berto (2005), our participants were undergraduate students. Our participants were recruited from Texas Tech University in Lubbock, TX, USA, whereas Berto's participants were recruited from the University of Padova in Padua, Italy. This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Board at Texas Tech University. Informed consent was obtained from each participant.

Experimental Design

Participants were randomly assigned to view images from one of three image content conditions: nature, urban, or control (geometric patterns). The images used were identical to those used by Berto (2005). Specifically, the images from her Experiment 1 were used as our nature and urban images, and the images from her Experiment 2 were used as our control images. Twenty participants (10 men, 10 women) were assigned to each image condition. All participants performed the SART prior to viewing the images and after viewing the images. The between-subjects independent variable was image content (nature vs. urban vs. control), and the within-subjects independent variable was time of administration of the SART (pre- vs. post-image exposure).

A 2 (pre- vs. post-SART) × 3 (nature vs. urban vs. control) mixed design ANOVA was computed for each task performance metric. Since the SART is a response inhibition task, performance metrics were accuracy (nonresponse to targets), RT to nontargets, and sensitivity to detecting a target. Accuracy was measured as the average number of total correct nonresponses to the targets. RT was measured as the average amount of time (in milliseconds) it took the participant to correctly respond once a nontarget was presented; importantly, this was computed for correct responses only. Sensitivity to detecting a target was measured by the loglinear transformed d' (as applying a loglinear transformation corrected for zero false alarms in our data; see Stanislaw & Todorov, 1999). Specifics about the apparatus, materials, and procedure that we used in this experiment and differences between our methodology and Berto (2005) are explained in Table 1.

Apparatus

Participants were seated at a desk. The images and the SART were presented on a monitor (10.5 in. × 13 in.) that was located on the desk and connected to a Dell Optiplex 960 computer. Participants were given the option to adjust the monitor to a height based upon their eye level and comfort, and participants could move their head freely throughout the task. Each participant completed the entire experiment on a single desktop computer, whereas Berto (2005) used two computers in her experiments, one to present the images and another to present the task.

Image Intervention

Our images were identical to those used in Berto (2005); example images can be viewed in her original article (Figure 1, Berto, 2005). There were 25 images per image content condition, and the image content conditions consisted of nature environments, urban environments,

TABLE 1: Differences Between Berto (2005) and the Current Study

	Berto (2005)	Current Study
Participants	Italy, average age of 23 years (*SD* = 3.22)	Southwestern United States, average age of 19.62 years (*SD* = 1.98)
Laboratory environment	Dim lighting for image viewing, brighter lighting for SART, separate computers used for displaying images and SART	Normal lighting and noise-canceling headphones for entire experiment, same computer used for displaying both images and SART
Image exposure time	15 s/image	10 s/image
SART procedure	Changes made to original SART: 240 digits presented, 24 targets, presented digit every 1,125 ms, no mention of mask in between digits or variations in font size	Consistent with original SART (Robertson et al., 1997): 225 digits presented, 25 targets, presented digit every 1,150 ms, included mask in between digits, font size of digits varied

Note. SART = sustained attention to response task.

and geometric patterns; the latter served as our control for the following reasons: (1) Berto (2005) demonstrated that viewing the geometric patterns had no significant effect on SART performance, and (2) we assumed that an active control condition, in which participants were viewing multiple neutral images, was better than viewing a static, blank screen, as it would be more similar to viewing multiple images in the experimental conditions.

During the image intervention, we presented images within an assigned condition at random on the computer screen for 10 s each. Berto presented each image for 15 s. However, more recent research presented the same images as Berto (2005) for 10 s each (Craig et al., 2015). Berto's (2005) third experiment allowed participants to decide the pace of viewing images in order to determine if viewing time impacted restoration. Participants in this experiment viewed restorative images for 7.04 s on average and urban images for 5.10 s on average. Further, Berto (2005) statistically compared the performance metrics for self-paced viewing times versus 15-s viewing times across her image conditions (nature vs. urban) and did not find any significant main or interaction effects. Thus, our rationale for presenting images for 10 s was two-fold: (1) Recent research was able to reproduce results similar to Berto's with this shorter viewing time (Craig et al., 2015), (2) Berto's (2005) study suggested that viewing times between 7 and 15 s did not seem to impact the potential for restoration, and the mean of these viewing times (11 s) is relatively close to Craig et al. (2015) presentation time (10 s).

Sustained Attention to Response Task

We used the original SART (Robertson et al., 1997) as our attentionally demanding task. However, Berto (2005) reported a SART 10 version that she developed, which deviated slightly from the original version. We used the original SART because the rationale for altering the original SART in Berto's study was unknown. Ultimately, we decided to utilize the original SART for greater generalizability. We report the specifics of the original SART below, noting deviations from Berto's SART 10 version.

The SART displayed digits 1–9 in a sequence of 225 numbers on a computer via SuperLab 4.5. Participants were exposed to each number 25 times during the duration of the task. A mask to prepare participants for the subsequent number presentation followed each number

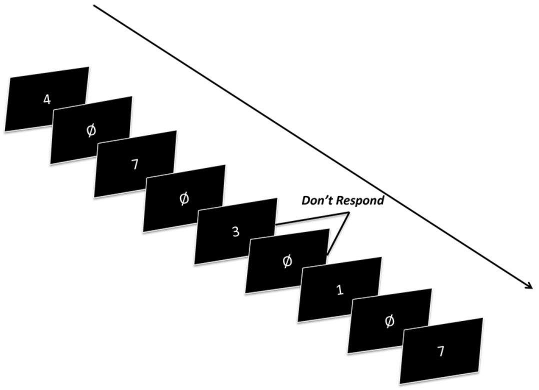

Figure 1. A visual representation of the SART. SART = sustained attention to response task.

presentation. The mask was a white circle with a 29 mm diameter and a backslash running through it. Both the numbers and mask were shown in the center of the screen on a solid, black background in symbol font. The font size of the presented numbers varied from one presentation to the next to increase difficulty. Font sizes included 48, 72, 94, 100, and 120 points. The mask did not change in font size.

The SART lasted 4.3 min; each number was presented for 250 ms, followed by a 900 ms mask. This essentially gave participants 1,150 ms between each numerical presentation to respond or inhibit a response. Participants were asked to press the spacebar on the keyboard in response to each of the 9 displayed digits except when presented with the target number of 3. This task required participants to actively repress the impulse to respond to the random presentation of the target number of 3 by inhibiting a response during its presentation. A visual depiction of the SART can be seen in Figure 1.

Procedure

Our procedure was mostly consistent with the procedure of Berto's (2005) first study, and deviations from her procedure are noted. Each participant individually completed the experiment in a psychology laboratory and wore noise-canceling headphones for the duration of the experiment. Berto did not report having her participants wear noise-canceling headphones. To begin the experiment, participants signed an informed consent document and then read instructions for performing the SART on a computer screen. Participants then practiced the SART to ensure that they comprehended the task. The practice SART was identical to that of Robertson et al.'s (1997), which exposed participants to digits 1–9 in a sequence of 18 numbers and included 2 presentations of the target number 3. After completing the practice session, participants completed the pre-image intervention SART. Next, participants experienced the image intervention and completed the post-image intervention SART afterwards. Lastly, participants completed a questionnaire to measure demographics and individual differences in environmental preferences.

RESULTS

We predicted a significant image content by SART administration interaction for all performance metrics, which included (1) total number of correct nonresponses to the targets, (2) RT for correct responses to the nontargets, and (3) transformed d'. Specifically, we predicted that the nature content condition would perform significantly better (compared to urban and control conditions) on all performance metrics in the post-image intervention SART (SART 2) compared to the pre-image intervention SART (SART 1). Better performance would be indicated by a higher number of correct nonresponses to the target, a lower mean RT for correct responses to nontargets (indicating faster RTs), and a higher d' value (indicating greater sensitivity to detecting the target). The results for each performance metric are presented in this section, and descriptive statistics for each performance metric are presented in Table 2.

Additionally, decrements in sustained attention performance can occur due to a decline in target sensitivity as well as from a shift in response bias. While Berto (2005) only assessed sensitivity to detecting a target, we performed a 2×3 mixed design ANOVA on a transformed measure of response bias, c (as applying a log-linear transformation corrected for zero false alarms in our data; see Stanislaw & Todorov, 1999), and found no significant effects,

TABLE 2: Descriptive Statistics for Performance Metrics

	SART 1		SART 2	
Performance Metric	Condition	*M* (*SD*)	Condition	*M* (*SD*)
Total correct nonresponses to targets	Nature	14.05 (6.82)	Nature	15.45 (7.84)
	Urban	17.35 (5.57)	Urban	17.25 (6.65)
	Control	17.85 (6.08)	Control	19.60 (5.58)
Mean RT (ms) for correct responses to nontargets	Nature	406.54 (116.93)	Nature	423.89 (131.89)
	Urban	419.12 (119.28)	Urban	413.82 (120.18)
	Control	471.78 (120.68)	Control	504.35 (125.10)
Transformed *d′*	Nature	2.56 (1.20)	Nature	2.83 (1.41)
	Urban	3.15 (1.01)	Urban	3.12 (1.20)
	Control	3.25 (1.00)	Control	3.64 (0.93)

Note. RT = response time; SART = sustained attention to response task.

indicating no shifts in response bias occurred. As such, we do not report the response bias analysis in this replication of Berto (2005).

Total Number of Correct Nonresponses to the Targets

The total number of correct nonresponses to the targets ranged from 0 to 25. Histograms and quantile–quantile (Q–Q) plots of this variable indicated a negative skew across conditions, such that most participants were highly accurate when performing the SART. Despite this, ANOVA should be robust to skewed data given our sufficient sample size and having equal sample sizes per condition (Keppel & Wickens, 2004). Levene's tests for SART 1 and SART 2 indicated that the homogeneity of variance assumption was met, $F(2, 57) = 0.81$, $p = .45$ and $F(2, 57) = 2.69$, $p = .08$, respectively. Since there were only two levels of the within-subjects independent variable (SART 1 and SART 2), the sphericity assumption did not need to be assessed for the current and all subsequent ANOVAs.

Contrary to our prediction, the image content by SART administration interaction was not significant, $F(2, 57) = 1.00$, $p = .38$, partial $\eta^2 = .034$. Main effects were also not significant. These results are visually displayed in Figure 2, in which there is a clear lack of accuracy improvement in the urban content condition but a slight, albeit insignificant, accuracy improvement in the nature and control conditions.

Response Time for Correct Responses to Nontargets

The mean RT for correct responses to the nontargets ranged from >0 to 1,150 ms. Histograms and Q–Q plots of this variable did not display any major nonnormality issues. Levene's tests for both SART 1 and SART 2 indicated that the homogeneity of variance assumption was met, $F(2, 57) = 0.04$, $p = .96$ and $F(2, 57) = 0.10$, $p = .91$, respectively. Since there were only two levels of the within-subjects independent variable (SART 1 and SART 2), the sphericity assumption did not need to be assessed.

Contrary to our prediction, the image content by SART administration interaction was not significant, $F(2, 57) = 1.83$, $p = .17$, partial $\eta^2 = .060$. Main effects were also not significant. These results are visually displayed in Figure 3.

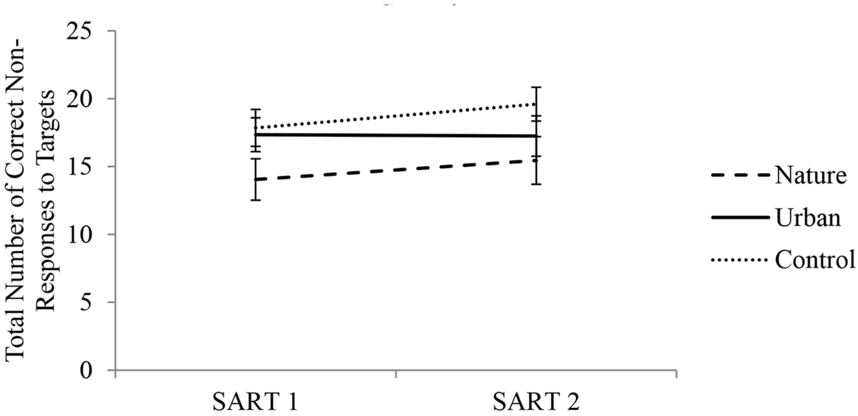

Figure 2. Mean total number of correct nonresponses to targets for each image content condition for SART 1 and SART 2. Error bars are standard error. SART = sustained attention to response task.

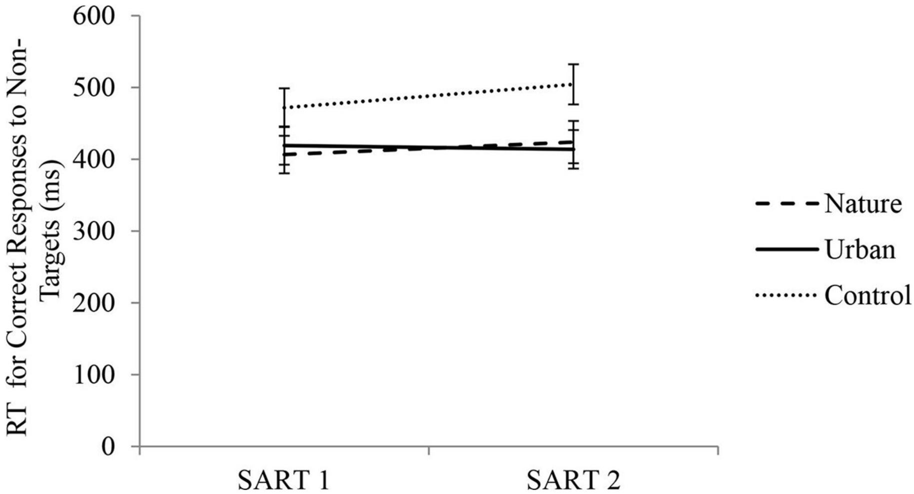

Figure 3. Mean response time in milliseconds for correct responses to nontargets for each image content condition for SART 1 and SART 2. Error bars are standard error. SART = sustained attention to response task.

Transformed *d′*

Sensitivity to detecting targets was measured by a loglinear transformation of *d′* and ranged from >0 to 4.88, so that higher values indicate greater sensitivity. Similar to the accuracy dependent variable, histograms and Q–Q plots of this variable displayed negative skew, indicating that only a few participants had low sensitivity to detecting the target; however, ANOVA should be robust to skew given our sample size (n = 20 per condition). Levene's tests for both SART 1 and SART 2 indicated that the homogeneity of variance assumption was met, $F(2, 57) = 0.36$, $p = .70$ and $F(2, 57) = 1.79$, $p = .18$, respectively. Since there were only two levels of the within-subjects independent variable (SART 1 and SART 2), the sphericity assumption did not need to be assessed.

Contrary to our prediction, the image content by SART administration interaction was not

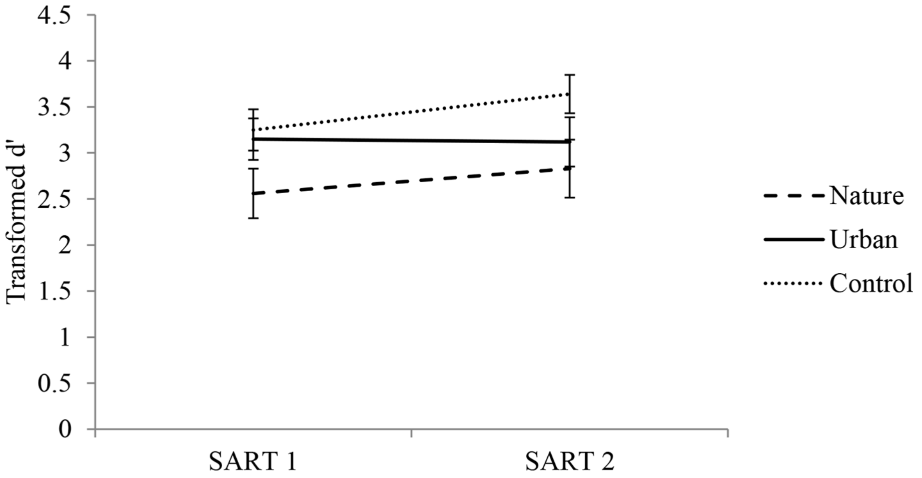

Figure 4. Mean transformed *d′* (sensitivity) for each image content condition for SART 1 and SART 2. Error bars are standard error. SART = sustained attention to response task.

significant, $F(2, 57) = 1.58$, $p = .22$, partial $\eta^2 = .052$. A main effect of SART administration was significant, $F(1, 57) = 4.48$, $p = .04$, partial $\eta^2 = .073$. Collapsing across image content conditions, participants were significantly more sensitive to detecting targets during SART 2 ($M = 3.20$, $SD = 1.22$) compared to SART 1 ($M = 2.99$, $SD = 1.10$), indicating a potential practice effect. A main effect of image content was not significant. These results are visually displayed in Figure 4. Although the pattern of means was in the expected direction, such that those in the nature condition improved in their sensitivity while those in the urban condition did not improve in their sensitivity, this pattern was not statistically significant. Further, the main effect of SART administration may have been driven by the unexpected increase in sensitivity of the control condition.

Are Participants Cognitively Depleted? A Comparison of Target Accuracy Among SART 1 Trials

One potential explanation for our aforementioned null findings may be that participants were not cognitively depleted after the first administration of the SART, thus resulting in a lack of subsequent cognitive restoration and superior task performance. To test this explanation, we assessed participants' accuracy on the first five targets of the SART 1 and compared that to participants' accuracy on the last five targets of the SART 1. If the SART 1 depleted participants, then participants should exhibit less accuracy on the last five target presentations compared to the first five. Since the SART 1 preceded any image intervention, the SART's ability to deplete attentional resources across participants was assessed regardless of their randomly assigned image condition.

Our rationale for conducting this analysis on accuracy was that target presentations were random, thus each participant was likely exposed to an unequal number of targets during any given time period of the task. Therefore, we only assessed participants' accuracy of detecting the first and last five targets of the SART. To ensure that participants were not still learning the task during the first five target presentations, we analyzed performance across the practice trials, and participants were highly accurate.

We performed a repeated-measures ANOVA comparing the accuracy of the first five targets to the accuracy of the last five targets during the SART 1. Histograms and Q–Q plots of this variable indicated a negative skew, indicating that most participants exhibited high accuracy on the first and last five targets. Despite this,

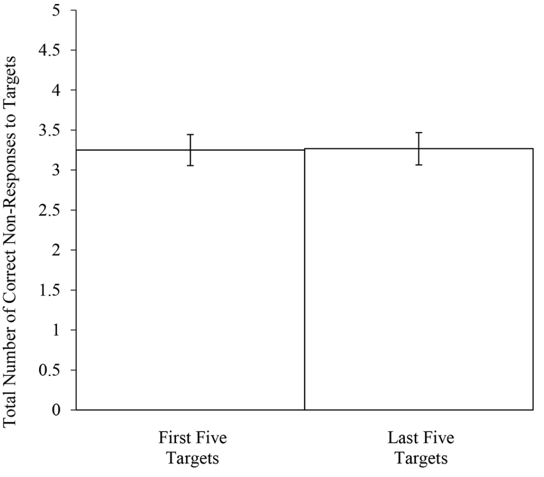

Figure 5. Mean total number of correct nonresponses averaged across image content conditions for all participants on the first five targets and last five targets of the SART 1. Error bars are standard error. SART = sustained attention to response task.

ANOVA should be robust to skewed data with our sample size (n = 20 per condition). Since there were only two levels of the within-subjects independent variable (first five targets and last five targets), the sphericity assumption did not need to be assessed. Accuracy on the first five targets (M = 3.25, SD = 1.50) was almost identical to the accuracy on the last five targets (M = 3.27, SD = 1.56), indicating participants may not have been depleted from performing the SART 1. These results are visually displayed in Figure 5. It is important to note that Hockey (1997) suggested that performance on a primary task could be maintained during high mental workload and stress states. Thus, it is possible that this performance does not reflect directed attention resource depletion.

DISCUSSION

The goal of this study was to replicate Berto (2005) first experiment, as that experiment demonstrated the potential for digital images to generate the restorative effect for performance on a response inhibition task, namely the SART. The SART was of particular interest to us, as it (1) may support a generalization of attention restoration since the SART involves a feed-forward motor response that utilizes neural systems distinct from attentional systems, and (2) has not consistently demonstrated an attention restoration effect across experiments conducted in and outside of our laboratory (Cassarino et al., 2019; Craig et al., 2015; Craig, 2016; Lee et al., 2015). Further, this replication addressed a few concerns from the original experiment. The present study corrected for family-wise Type I error inflation, provided an explicit control condition, and used a more appropriate measure of sensitivity. Consistent with Berto's (2005) study, our prediction was that there would be a significant interaction between pre- and post-image exposure and image content on the dependent variables used to measure performance. However, this prediction was not supported. Further, we computed Cohen's d for Berto's (2005) first experiment, as they were unreported: (1) comparing Session 1 and Session 2 in the restorative condition using the standard deviation of the difference scores (derived from the reported t-values) for d' (Cohen's d = .718), RT (Cohen's d = .527), correct responses (Cohen's d = .525), and incorrect responses (Cohen's d = .090); and (2) comparing restorative and nonrestorative conditions in Session 2 for d' (Cohen's d = .071), RT (Cohen's d = .387), correct responses (Cohen's d = .057), and incorrect responses (Cohen's d = .044). Although our experiment had an increased sample size compared to Berto (2005), we report small effect sizes, suggesting that our nonsignificant results are due to small effects and not sample size. The remaining discussion will focus on the (1) replication issue and (2) implications for using the SART in attention restoration research.

Replication Issues

While we cannot propose clear answers regarding the observed null effects, there are several potential explanations for the lack of observed differences in the present study. One limitation of this replication attempt is that it was unable to control for potential sample differences between the participants in Berto's (2005) study and the present study. Specifically, there may be temporal cohort effects, as Berto also published her research in the early 2000s, and the present research was conducted in 2017 and 2018. One potential difference between the two cohorts may be that there are observed differences in fixation duration and gaze patterns to digital media across generations (Djamasbi et al., 2011), suggesting there may be differences in how present and earlier samples attended to the image stimuli. Furthermore, individuals and groups may differ in how they react to attentional demands and task-induced stress (Matthews & Campbell, 1998) or how they perceive and relate to nature (Nisbet et al., 2009); as such, the impact of individual differences in explaining our null results should also be considered.

To our knowledge, limited research has been conducted on individual differences (i.e., trait and state characteristics) and how they impact attention restoration via nature interventions. One prior study conducted in our lab observed attention restoration via nature image interventions with the SART for individuals without depressive symptomatology but not for those with depressive symptomatology (Craig et al., 2015). However, we were not able to replicate this effect in a subsequent unpublished study when accounting for depressive symptomatology. While depressive symptomatology by itself does not appear to account for attention restoration for the SART, the results indicate that individual differences may play a role in explaining the ongoing difficulty in replicating the effect.

SART and Attention Restoration

Another potential explanation for our null findings is that the SART may not have been depleting enough to reduce attentional capacity in order to demonstrate restoration; this is of interest, as it is presently unknown if higher task demands are necessary for restoration to occur or if restoration can also occur after being presented with lower task demands. Interestingly, a meta-analytic study failed to provide support for the SART benefiting from nature interventions (Ohly et al., 2016), while a second meta-analysis indicated that the restorative effect is weaker with attention control tasks like the SART when compared to working memory or cognitive flexibility tasks (Stevenson et al., 2018). The restorative effect with the SART sometimes occurs (Berto, 2005; Craig et al., 2015) and sometimes does not occur (Cassarino et al., 2019). If the effect is somewhat weak for tasks like the SART, then other factors, such as prior levels of fatigue, individual differences, and population differences, must be carefully controlled for in order to reliably replicate the finding. Further, the SART specifically may involve motor control areas of the brain. Thus, an attentional task that is demanding but not conflated with motor control may be needed for attention restoration.

In summary, our failure to replicate Berto (2005) findings may stem from unmeasured confounds that are not traditionally assessed in this area of research, such as population/cultural differences or individual difference variables. In her commentary given later, Dr. Berto references the connectedness to nature construct as an interesting individual differences variable, which may be useful to consider in future replication attempts. However, as she further highlights, there may be differences in the two experiments that, separately or collectively, could account for our failure to replicate the restorative effect with digital images. We outlined these differences in Table 1. Importantly, if this were the case, our failure to replicate Berto (2005) findings would suggest that the restorative effect is extremely task specific to the point that relatively minor procedural deviations would impact the effectiveness of attention restoration.

Practical Implications

The present findings indicate that relying primarily on nature images to improve directed attention performance in any applied environment may not have a practically significant effect, particularly given our low observed effect sizes. However, more research is needed to clarify (1) whether there are unidentified differences in our samples that could prohibit restoration from occurring, (2) what specific nature stimuli could serve as an effective intervention, (3) whether certain types of cognitive tasks that may require directed attention are more sensitive to the restorative effect than others, (4) whether the cognitive tasks result in sufficient depletion to allow for restoration to occur, and

(5) which individual difference variables may be of relevance for this effect to occur.

KEY POINTS

- This study attempted to replicate Berto (2005), which showed improved performance on the SART after exposure to nature images.
- The replication was not successful; performance on the SART did not differ between nature, urban, and control conditions.
- Human factors professionals need to further research the impact of the following factors on attention restoration via nature interventions: (1) sample differences, (2) different testing environments and procedures, (3) insufficient attentional depletion, and (4) individual differences.

COMMENTARY FROM DR. RITA BERTO

Undoubtedly, my work (Berto, 2005) was an exploratory research study; though I didn't anticipate any kind of success coming from it, I was lucky enough to find encouraging and remarkable results, and I modestly admit that my study plotted a path in the restorative environment research. I can say it was of inspiration for a lot of colleagues who showed interest in my pioneer work (I thank each of them) and set up replication (direct or systematic) after replication (381 citations, source: Science Direct https://www.sciencedirect.com/science/article/abs/pii/S0272494405000381; 878 citations, source Google Scholar: https://scholar.google.it/scholar?hl=it&as_sdt=0%2C5&q=berto+rita+2005&btnG, December 2019).

Literature shows people need (and appreciate) daily restoration opportunities (Hartig & Staats, 2005). Nevertheless, people are not always (or yet) aware that exposure to natural stimuli is the best cost-free way to obtain restoration from mental fatigue. More specifically, there are people who think that nature can only restore when it is spectacular, and they don't understand that even nearby or simulated nature may perfectly match the daily need to recover from the mental load related to work, learning, driving, and daily hassles in general (Berto et al., 2018). This is a wide and important gap to fill, and this may be the reason that self-paced exposure to nature (in a lab experimental condition) may not work as expected.

It is a matter of fact that restoration occurs when a state of mental fatigue is present, but it also occurs when a "break," even very short, is perceived by the subject during ongoing activities. This aspect calls for the role of "being-away" in the restoration process and reminds us that more factors contribute to the process of attention restoration (Kaplan, 1995). If the participant sits in front of the same computer to recover attention that previously was used to induce the mental fatigue state, then s/he may perceive it as a unique task because no evident break is present, showing no shifts in the level of attention (Berto et al., 2015).

Though nature is hypothesized to restore all types of attentional depletion because the involved mechanism is innate and automatic (Kaplan & Berman, 2010), the individual must be "receptive" to the benefits of nature. This doesn't question the assumption of the existence of restorative benefits from nature; it simply means that individuals are not all fond of nature in the same way (Barbiero & Berto, 2018). The biological response to nature can be moderated by our individual sense of connection to nature (Mayer & Frantz, 2004), a characteristic of personality which can affect the onset and the outcome of the restoration process (Berto et al., 2018; Tang et al., 2015). The individual differences of connection to nature don't compromise the rationale of the Attention Restoration Theory (Kaplan, 1995) and/or the validity of Berto's paradigm (2005). Instead, these differences should push researchers to consider the existence of a sort of nature "threshold," which has to match the level of individual's receptiveness to be responsive (Berto et al., 2018). It is up to the researchers to find out the threshold of quantity/quality of nature that participants are more receptive/responsive to (Hägerhäll et al., 2018) in order to obtain the restorative benefits. At the same time, researchers must consider if the method they are using to deplete participants' attentional resources really represents a depletion for them; in fact, no effective "depletion" may result in a lack of subsequent cognitive restoration. Besides that, it is worth pointing out that our environmental experience is multisensorial, whereas lab experimental conditions may sometimes suffer from excessive isolation from the surroundings. Literature suggests that people perform best when the environmental stimulation level is moderate (Yerkes & Dodson, 1908), so to set a total (e.g., acoustic) isolation may paradoxically be counterproductive to the participant's restoration process and subsequent cognitive performance.

It is about time to exit the laboratory and to find ways to support efficiently the allocation of resources by shaping our living environments. Barbiero et al. (2017) have recently started testing the effect of a restorative school environment on the attentional resources of a group of primary school children attending that school. The restorative schoolroom is an indoor environment that has the restorative characteristics of the outdoor natural environment in order to foster the learning process. Preliminary results show that the restorative schoolroom helps primary school children maintain directed attention and focus more on the instruction because the room offers the opportunity of frequent micro-restorative experiences (Tennessen & Cimprich, 1995). When nature is not available, the presence of biomorphic forms, the layout, texture, color, smell, and material typical of nature in an indoor environment can work as well; this is the rationale behind the restorative environment design (Barbiero & Berto, 2016; Nousiainen et al., 2016). However, to really accomplish this aim, there is a need for a paradigm shift from "perceived restorativeness" to "objective restorativeness" to establish in advance to what extent a planned environment will be restorative (Berto & Barbiero, 2017).

The long evolutionary path of humanity in natural environments has left its mark on modern man in the form of predispositions (not learned but inherited) to pay attention and respond positively to certain characteristics typical of the natural environment (Parsons, 1991; Ulrich et al., 1991). For this reason, humans prefer environments characterized with attributes similar to "the" environment where they evolved (i.e., where they have learned to select important information, acquired appropriate response patterns, and learned to predict what might happen to them; Kaplan & Kaplan, 1982). Restorative design originates from this human–nature bond; those environments that respect and support this bond are restorative. To this end, it is necessary to think of new models for development of indoor environments capable of facilitating this intimate and innate connection that individuals have with nature, which is at the basis of the perception of restorativeness and contributes to individual's psychophysiological equilibrium and pleasure in living in one's environment.

AUTHOR NOTE

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