Simulating Nature?! The Impact of Indoor Exercising on Cognitive and Affective Functioning: A Randomized Crossover Trial

Maria Stefania Ionel[1], *M. Rosario Rueda*[2 3], *and Laura Visu-Petra*[1]

[1] Research in Individual Differences and Legal Psychology – RIDDLE Lab, Department of Psychology, Faculty of Psychology and Educational Sciences, Babes-Bolyai University, Cluj-Napoca, Romania

[2] Department of Experimental Psychology, Faculty of Psychology, University of Granada, Granada, Spain

[3] Mind, Brain, and Behavior Research Center, University of Granada, Granada, Spain

ABSTRACT

The present investigation focused on assessing cognitive and affective effects of indoor exercising while exposing the participants to a video simulation of nature (simulated nature), compared to the typical indoor exercising (control condition). Participants (N = 21, physically active amateur cyclists) completed an incremental effort test to establish their aerobic power. Next, they cycled for 55 minutes under one of two randomized conditions using a within-subjects design: simulated nature, involving the presentation of an outdoor soundscape video, versus the control condition, representing the indoor cycling condition. At the end of each cycling session, conducted 3-7 days apart, participants completed a set of psychological assessments focused on their cognitive functions, including executive attention, vigilance, working memory, as well as and affective functioning, encompassing anxiety, depression, negative and positive affect. The results suggest that exercising in simulated natural environment conditions has little significant cognitive and or affective benefits after controlling for physical effort.

KEYWORDS

executive attention
anxiety
depression
indoor exercising
cycling

An inner fascination with the natural environment is allegedly grounded in our species' evolutionary history (Bratman et al., 2012). Extant research suggests that exposure to nature buffers against the development of mental illness while also having restorative effects (Beute & De Kort, 2014; Bratman et al., 2015; Yao et al., 2021). Moreover, lack of contact with nature is linked with reduced optimal psychological functioning (Berman et al., 2008; Bratman et al., 2012; Bratman et al., 2015). The lockdowns caused by the COVID-19 pandemic were an example of phenomena contributing to a decline in the opportunities to have a direct experience with nature. Consequently, there has been a recent surge in applying digitalization, video games, and virtual reality in various forms of human activities, ranging from education to sports and exercise. Reputed cycling competitions such as Giro d'Italia, have employed various simulations of outdoor environment. Such simulations of outdoor environments have been extensively employed for indoor physical activities. This trend grew exponentially during the COVID-19 pandemic, which resulted in the temporary suspension of competitions across a wide range of sports and athletic disciplines. However, to date, little is known about whether practicing psychical activities in simulated natural environment results in significant changes in cognitive and/or affective functioning. We add to the literature by disentangling the potentially confounded effects of exercising and exercise-environment over affective and cognitive functioning.

Psychological Benefits of Exposure to Simulated Nature Environment

Extant research suggests that both exposures to nature and to simulations of nature result in significant beneficial cognitive and emotional effects (Bowler et al., 2010), with exposures to nature having on average, larger effect sizes. For example, a national survey of 2070 participants from Finland indicated that exercising outdoors had a higher impact on emotional well-being compared to exercising indoor, in simulated nature (Pasanen et al., 2014). Another meta-analysis reported both exposures to nature and laboratory simulations of nature (e.g., viewing photographs of natural environments) had positive effects on well-being, with higher effect sizes for conditions where contact with nature was direct (McMahan, & Estes, 2015). The literature has yet to establish a unitary concept to illustrate exposure to simulated nature, different terms being used such as: in-built environments (Pasanen et al., 2014), simulation of natural environments (Berman et al., 2008), virtual restorative environments, "synthetic" (Bowler et al., 2010), or laboratory simulations of nature (Ulrich et al. 1991), and so forth. In this paper, we use the term "simulated nature environment" in order to reflect visual simulations of nature.

Corresponding author: Laura Visu-Petra, Department of Psychology, Republicii Str. No 37, 400015, Cluj-Napoca, Romania. Tel/Fax: 0040 264 590967.
Email: laurapetra@psychology.ro

DOI • 10.5709/acp-0416-3

Various theoretical frameworks account for the positive effects described earlier. One of the theories explaining potential cognitive benefits of natural environments is the *attention restoration theory* (ART, Kaplan, 1995). According to ART, natural environments elicit an alternative form of concentration, which is typically involuntary and characterized by a sense of "fascination," "being away," "extent," and "compatibility," thus allowing the neural mechanisms underlying directed attention to have a chance to rest and replenish (Kaplan, 1995). Concerning affective benefits, *stress reduction theory* (SRT, Ulrich, 1981) provides an explanatory theoretical framework. According to SRT, natural environments have a restorative advantage over simulated ones due to their evolutionary role for humans. According to Ulrich et al. (1991), mere exposure to nature scenes activates our parasympathetic nervous system, reducing stress and autonomic arousal.

Other empirical studies investigated whether exercising in nature has greater psychological benefits compared to exercising indoor. For example, Rogerson et al. (2016) compared psychological and social outcomes of cycling outdoors (direct exposure to nature) to indoor cycling without any other supplementary stimuli (control condition). Following a baseline session, all participants completed two sessions of 15 minutes of cycling on an ergometer placed outside in a natural environment and inside in a laboratory setting. When compared with indoor laboratory setting (without natural exposure), findings showed that exercise in a real natural environment can promote working memory, as measured with the backwards span task, and facilitate social interactions, which can also positively influence future exercise intentions (Rogerson et al., 2016). In contrast, a distinct study comparing the effects of a three hour long green exercise (i.e., "physical activity in natural environments", in this case, mountain hiking in nature) intervention to an equally intense exercise on the indoor treadmill did not detect any significant differences in physiological stress-related indicators (salivary cortisol, Niedermeier et al., 2017, p. 905). In the aforementioned investigation, the positive effects were attributed exclusively to exercising, as no significant interactions between environments and exercise were detected (Niedermeier et al., 2017). A relatively recent review concludes that compared with indoor exercise, outdoor green exercise exerts a positive although relatively small-sized influence on affective outcomes and enjoyment but failed to identify significant effects in respect to emotions or biological stress markers (Lahart et al., 2019). Extant literature is even less clear in respect to potential interaction effects between exercising and environment (nature vs. simulations of nature) on cognitive and affective functioning. A relatively recent study investigated whether interactions between environment and exercising impact mood, energy levels and attention by employing four different experimental conditions: indoor exercise in simulated nature, outdoor exercise, indoor rest in simulated nature, and outdoor rest (Fuegen & Breitenbecher, 2018). Exposure to nature, irrespective of whether it involved exercise or rest, consistently had a positive impact on mood, while exposure to simulated nature in indoor settings positively impacted mood, but not cognitive functioning (Fuegen & Breitenbecher, 2018). Similar mixed findings were reported by Gatersleben and Andrews (2013), where walking in nature compared to being exposed to a video of walking in the same type of environment had beneficial effects on attention, but not on mood. However, the aforementioned investigation did not employ an experimental condition involving both exercising and exposure to simulated nature. Yet another experimental investigation comparing the effects on walking outdoors to walking on the treadmill with a virtual reality simulation of nature and to walking on the treadmill without any simulation, respectively, detected that exposure to exercise in a virtual simulation of nature positively impacted mood (Plante et al., 2003). Nevertheless, the impact was not significantly higher compared to the other conditions where exercising was involved.

Overall, the evidence regarding potential cognitive and affective benefits of exercising in nature compared to exercising in laboratory simulations of nature is inconclusive. Several factors might account for the current state of knowledge. First, due to the different methodological designs and limitations (such as lack of proper control conditions), comparability across the various empirical investigations is limited. Second, even fewer investigations explored the impact of exposure to simulations of nature while individuals were actually performing physical activities or exercising. More specifically, the control conditions involved passive exposure to videos of nature or to videos depicting physical activities performed in nature or walking, failing to provide information about the potential interaction between exercising and simulations of nature. Third, most of the investigations did not actively control for the effects caused by potential confounds (e.g., room temperature, atmospheric pressure, or humidity etc.). Exercise intensity is one such confound that was unaccounted for in all the previous empirical investigations that were described above. To conclude, the most recent meta-analytical investigation on the effects of green exercise on mental well-being concludes that the evidence falls short in supporting a significantly higher degree of psychological benefits stemming from exercising in nature or in simulated nature compared to exercising indoor, without employing any simulations of nature (Lahart et al., 2019).

The Present Study

In echoing the call for additional research in the green exercise domain, particularly regarding simulations of nature (Lahart et al., 2019), our main objective was to identify psychological benefits of exercising indoor at submaximal levels in two different conditions: a simulation of nature versus a simple indoor environment. We contribute to the literature by controlling for exercise intensity (75% of the participants' submaximal physical exertion), one potential confounded variable that could blur the conclusions regarding the benefits of exercising in different indoor environments.

In line with the previously outlined empirical investigations and with theoretical models describing the psychological benefits of exercising in simulated nature, we extend prior research by employing an experimental within-subject design with two different conditions: indoor exercising with simulation of nature (simulated nature condition) and indoor exercising without simulated nature (control condition). Therefore, we tested two main hypotheses:

(1) Indoor exercising with a video simulation of nature (simulated nature) will increase performance in core executive functions (executive attention, working memory, vigilance and sustained attention) compared to the control condition (indoor exercising without simulated nature), while controlling for exercise intensity.

(2) Indoor exercising with a video simulation of nature (simulated nature) will (a) reduce negative affect (negative affect, anxiety, and depression symptoms) and (b) increase positive affect compared to the control condition (indoor exercising without simulated nature), while controlling for exercise intensity.

METHOD

Participants

POWER ESTIMATION

In order to establish the power to detect mid-sized differences between the different conditions, we conducted an a priori power analysis by using the G-Power software, version 3.1, following the approach outlined by Faul et al. (2007). Our analysis indicated that the minimal sample size needed to detect mid- to large-sized effects with a power of .80 was 19 participants.

After obtaining the institutional ethics board approval for procedure involving studies with human participants, we collected data from 21 physically active Spanish amateur cyclists (2 females, M_{age} = 27.05, *SD* = 5.71), via opportunity sampling. To be eligible, participants had to have no current or past diagnosis of psychiatric disorders. One exclusion criterion was participation at professional level. Initially, 24 participants were recruited, but 3 dropped out after the first physical evaluation session due to lack of time. To control for individual differences in their performance, participants had to be physically capable of cycling for 55 minutes at 75% of their aerobic power (details included in the Procedure section). Before taking part in this study, participants were fully informed about the objectives of the study and provided a written informed consent as required by institutional regulations. At the end of the third session, participants were offered a compensation of 15 Euro.

Participants verbally reported that they regularly trained outdoors where they encountered natural settings using only their road bicycles. The participants had not trained indoors, nor had previous experience using a cycling simulator. Data were collected regarding how participants trained: hours per day, hours per week, and days per week (see Appendix A). In order to control for potential confounding variables, participants were given instructions to rest and abstain from caffeine, alcohol, any other stimulants, or from heavy exertion for a minimum of 24 hours before participating in the actual exercising task.

Procedure

We employed a within-subjects experimental design to compare the cognitive and affective outcomes of indoor exercise in two different conditions: a video of simulated nature versus control condition (indoor exercise without simulated nature). The simulated nature video (presentation of an outdoor soundscape video) was created by one of the collaborators by videotaping an outdoor cycling route nearby Granada (see Figure 1, Panel A), while the control condition presented a light blue screen without any video (see Figure 1, Panel B).

Participants were tested during three sessions (see Appendix B), as follows. During Session 1, participants completed an incremental effort to determine their submaximal aerobic power calculated by the submaximal oxygen consumption test (VO2 Submax; Sartor et al., 2013). The test was used to control for the variability in participants' aerobic capacity and lasted for approximately 20 minutes. The incremental effort test was assessed with the help of a bicycle ergometer, which determined the fitness level of each participant by measuring the amount of oxygen the body needed during intense exercise (see Appendix B for a detailed description of the test protocol).

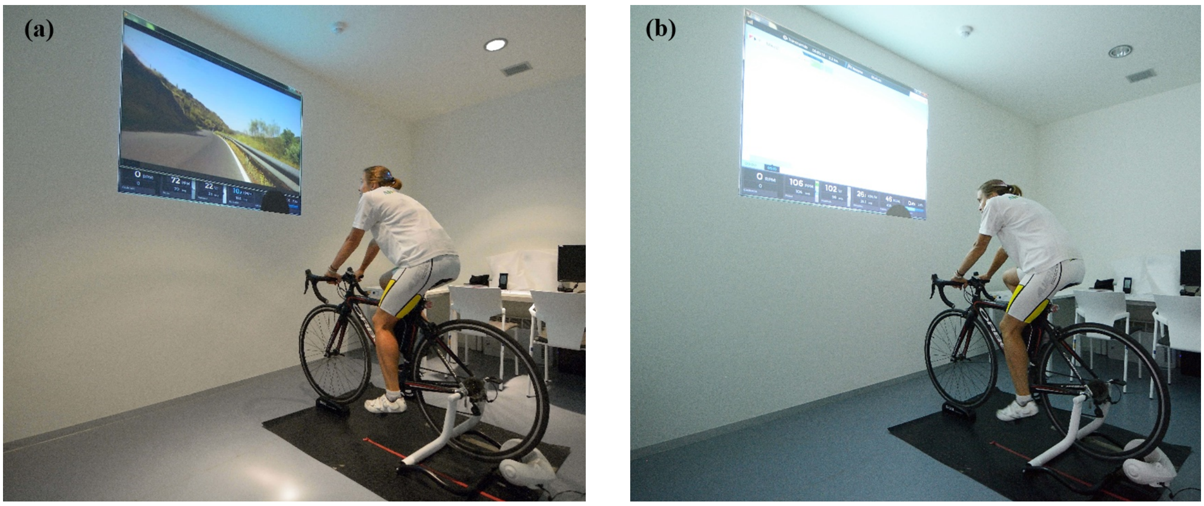


FIGURE 1.
Panel A: Simulated nature condition of the experiment. Panel B: Control condition.

During the next two sessions, the participants were instructed to bring their personal bikes. Each bike was connected to a cycling simulator – the Bkool® device (see Figure 1) that presents a variable resistance against a physical force applied by the user. The resulting power figures were displayed on the screen enabling the participants to monitor their exertion, measured as the applied force (Watts). Participants were instructed to maintain 75% of their aerobic power (measured in Session 1) throughout all the cycling period. All participants cycled for 55 minutes under both of the two conditions randomly assigned: indoor exercising with a video simulation of nature (simulated nature, see Figure 1, Panel A) versus indoor exercising (control condition, see Figure 1, Panel B). The order of the two conditions (Sessions 2 and 3) was counterbalanced across participants. The minimum number of days between the two conditions was two, and the maximum number was 7, with a mean of 3.10 days. Sessions 2 and 3 lasted for approximately three hours in total. External environmental influences that could have interfered with the task, such as temperature, humidity, and atmospheric pressure were kept constant throughout the sessions. Data regarding such conditions was assessed with a Weather Station – Ea2 Labs (see Appendix C). Each participant's heart rate variability (HRV) was monitored using a Polar Flow chest strap – V800. The Rating of Perceived Exertion scale (RPE, Borg, 1998) was administrated after 55 minutes of cycling in both conditions (see Appendix B).

Manipulation check. During the exposure to the simulated nature video, we ensured that our manipulation was effective by asking our participants to look at the screen throughout all the experiment and sustain the same physical effort (75% of their aerobic power measured in Session 1). If they did not, participants were asked to immediately look again at the screen (see Hauser et al., 2018, for manipulation checks in a similar context). After both cycling conditions, the measurements for affective and cognitive functioning were administered. While performing the cognitive tasks (executive attention, vigilance and sustained attention, and working memory capacity) each participant's HRV was monitored (see Appendix D). During Session 3, we calculated the baseline HRV by asking every participant to stay in resting state for 5 minutes.

The study was conducted in accordance with the Declaration of Helsinki and approved by the institutional ethics board.

Materials

COGNITIVE MEASURES

In order to detect whether exercising indoor in the two aforementioned conditions has a positive effect over cognitive functioning, we measured the core components of executive functioning (see Appendix E for details on the cognitive tasks). Similar measures were extensively used in other investigations (Berman et al., 2008; Bratman et al., 2012; Bratman et al., 2015).

Arrows and Words Task (AW, Aarts et al., 2010) is designed to measure executive attention by assessing task-switching behavior using incongruent arrow-word combinations as targets. The entire task lasted approximately 15 minutes, starting with a familiarization trial.

Psychomotor Vigilance Test (PVT, Basner & Dinges, 2011). Vigilance and sustained attention were measured using a precise computer-based version lasting 9 minutes, following a familiarization session.

Operation Span Working Memory Task (OSpan, Tokowicz et al., 2004) measured individual differences in working memory capacity. It involved solving mathematical expressions while maintaining sets of words in memory and lasted approximately 10 minutes, including a familiarization trial in the beginning.

AFFECTIVE MEASURES

Positive and Negative Affect Scale (PANAS, Watson et al., 1988). A Spanish version of PANAS was used to measure affective state (Sandín et al., 1999), with a 20-item self-report survey that is composed by a positive (10-item) scale (e.g., "interested," "excited"), and a negative (10-item) scale (e.g., "distressed," "upset"), each consisting of 5-point Likert rankings. Participants were asked to assess the degree to which they currently felt each of the items, ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). Higher means of the sum of scores indicate higher positive, respectively negative affect. Responses are summed to yield a total score that ranges 10-50 for both positive and negative affect.

Beck Anxiety Inventory (BAI, Beck et al., 1988). Recent anxiety symptoms were assessed using the Spanish version of the BAI (Magán et al., 2008), a 21-item multiple-choice self-report inventory that measures the severity of anxiety in adults. Each of the items on the BAI is a simple description of a symptom of anxiety in one of its four expressed aspects: subjective (e.g., "unable to relax"), neurophysiologic (e.g., "numbness or tingling"), autonomic (e.g., "feeling hot"), or panic-related (e.g., "fear of losing control"). It was completed in approximately 5 minutes using paper form and pencil. Each symptom item has four possible answer choices (*not at all* = 0, *mildly* = 1, *moderately* = 2, *severely* = 3). Responses are summed to yield a total score that ranges from 0 to 63, interpreted as "minimal" level of anxiety (total score 0-7), "mild" (8-15 score), "moderate" (16-25 score), and "severe" (26-63 score).

Beck Depression Inventory II (BDI-II; Beck et al., 1996). Depression symptoms were assessed using the Spanish version of BDI-II (Sanz et al., 2003), a 21-item of self-evaluative statements that measure the severity of depression in adults. It was completed in approximately 5 minutes using paper and pencil format. Each symptom item has four possible answer choices (*not at all* = 0, *mildly* = 1, *moderately* = 2, *severely* = 3). Responses are summed to yield a total score that ranges from 0 to 63, interpreted as "minimal" level of depression (total score 0-13), "mild" (14-19 score), "moderate" (20-28 score), and "severe" (29-63 score). Various investigations concluded that the BDI-II is informative and sensitive in respect to depressive mood and tendencies in both clinical and nonclinical populations or community samples (e.g., Alexandrowicz et al., 2014).

Statistical Analysis

All the analyses were computed with SPSS version 20.0 for Windows. We calculated the descriptive statistics (means and standard deviations for all the measured variables), conducted correlations between all the variables across the two conditions, and finally, performed analyses

TABLE 1.
Descriptive Statistics for Behavioral and Cognitive Data in Simulated Nature and Control Conditions

Type of measures	Variable	Simulated Nature			Control condition	
		N	*M*	*SD*	*M*	*SD*
Behavioral questionnaires –scores	PANAS-PA (+)	21	34.48	7.61	34.90	6.24
	PANAS-NA (-)	21	12.95	3.38	12.81	2.80
	BAI	21	7.00	7.85	6.67	6.32
	BDI	21	3.29	2.87	4.38	4.98
AW Switching Task – congruency	Congruent	20	576.70	195.15	560.30	198.28
	Incongruent	20	629.42	208.66	628.42	225.83
AW Switching Task	Conflict effect	20	52.73	77.81	68.11	77.01
PVT - mean RT	PVT Total (9 min)	21	311.20	24.60	312.50	26.24
OSpan working memory	Total RT	21	2270.78	299.20	2246.43	268.68
	Accuracy (Recalls)	21	38.57	10.41	36.81	6.91

Note. PANAS-PA – Positive and Negative Affect Schedule-Positive Affect score; PANAS-NA – Positive and Negative Affect Schedule-Negative Affect score; BAI – Beck Anxiety Inventory score; BDI – Beck Depression Inventory score; AW – Arrow Word Reaction Time (ms); PVT mean RT – Psychomotor Vigilance Test mean Reaction Time (ms); OSpan – Operation Span; Total RT – Total Reaction Time (ms); Accuracy (Recalls) – Accuracy meaning number of correct recalls.

of variance (ANOVAs) to test the core hypotheses. To counteract the potential problem of running multiple comparisons, Bonferroni corrections were employed. The normality assumption was tested via the Kolmogorov-Smirnov (K-S) statistic for all the continuous variables. The 8th participant (BK10) was eliminated from the ANOVA analysis of the AW task due to a high error rate of more than 53% during the task. In order to avoid including anticipatory responses or trials in which the participants were distracted and had an exceptionally high response time (RT, > 2 *SDs* from the individual mean), we applied a filter of > 200 and < 1100 ms, from a total of 6341 RT data, and 372 RTs were eliminated, which represented 5.86% of the overall RT data

RESULTS

Descriptive Statistics

Descriptive statistics for the physical work, perception of exertion, and duration of training time and for all the psychological and behavioral measures are displayed in Appendix A and Table 1, respectively. Correlations for simulated nature and control conditions are shown in Appendix F.

Cognitive Functioning

With respect to differences in executive attention assessed with the AW task (RTs) a four-way repeated measures ANOVA with exercising condition (simulated nature vs. control) × switching (switch vs. no switch) x task (word vs. arrow) x task congruency (congruent vs. incongruent). The results are presented in Tables 2 and 3. We did not find any statistically significant interaction effects for our main hypotheses. A statistically significant interaction between exercising condition × task congruency, $F(1, 19) = 4.36$, $p < .05$, $\eta^2 = 0.19$, was detected, suggesting that in the simulated nature condition, participants were slower (higher RT) when compared to the control condition in identifying the congruent stimuli. Another statistically significant interaction was detected between task x task congruency, $F(1, 19) = 6.90$, $p < .05$, $\eta^2 = 0.27$, indicating that in the simulated nature condition, a larger conflict effect for the word task was found (see Appendix G and H). A Bonferroni post hoc test for exercising condition x task congruency was performed (see Table 3). This indicated that in the simulated nature condition, the conflict effect was smaller when compared with the control condition.

In respect to differences in vigilance and sustained attention assessed with the PVT (see Table 2), a one-way repeated measures ANOVA (within-subjects variable: exercising condition) showed no statistically significant effects. Similarly, the performance on the working memory task showed no statistically significant changes across the conditions.

Affective Functioning

As for differences in affective measures (see Table 2), within-group one-way repeated measures ANOVA showed no statistically significant differences between the two conditions.

DISCUSSION

The current study investigated the impact of indoor exercising (cycling) on cognitive and affective functioning in two different conditions: exposure to video simulation of nature (simulated nature) versus a control condition. We controlled for the potential confounding effects caused by environmental factors (temperature, humidity, or atmospheric pressure) or by exercise intensity levels (aerobic power threshold and HRV).

With respect to the first hypothesis, our findings revealed that contrary to what we anticipated, exercising in a simulated nature context did not result in any notable performance increases in executive functions (executive attention, working memory, vigilance and sustained attention) compared to the control condition. This finding is in line with the conclusions of a relatively recent meta-analysis reporting that the restoring effects on cognitive abilities occurs only when participants

TABLE 2.
Means, Standard Deviations, and Repeated-Measures ANOVA for Behavioral and Cognitive Data – Within-Subjects Effects

Type of measures	Variable	Simulated Nature		Control condition		ANOVA		
		M	*SD*	*M*	*SD*	*F*	*df*	η²
Behavioral questionnaires	PANAS-PA (+)	34.48	7.61	34.90	6.24	0.16	20	.01
	PANAS-NA (-)	12.95	3.38	12.81	2.80	0.07	20	.01
	BAI	7.00	7.85	6.67	6.32	0.08	20	.01
	BDI	3.29	2.87	4.38	4.98	2.36	20	.11
Exercising Condition × Switching	Switch	630.37	28.93	609.21	26.21	0.66	19	.03
	No-switch	614.03	26.77	602.64	29.08			
Exercising Condition × AW task	Word	653.84	24.99	646.72	24.41	0.58	19	.03
	Arrow	585.75	30.99	569.95	32.52			
Exercising Condition × Congruency	Congruent	592.44	26.79	574.70	27.03	4.36*	19	.19
	Incongruent	647.14	28.50	641.97	29.06			
Exercising Condition × Switching v AW task	Switch – Word	667.17	27.41	652.00	23.63	1.98	19	09
	Switch - Arrow	592.58	32.17	576.07	32.25			
	No-switch - Word	639.50	23.79	641.44	26.26			
	No-switch – Arrow	578.91	30.49	563.84	33.49			
Exercising Condition × Switching × Congruency	Switch – Congruent	604.48	29.10	577.75	24.17	0.87	19	.04
	Switch – Incongruent	656.28	29.53	650.32	29.80			
	No-switch – Congruent	580.40	25.08	572.65	30.62			
	No-switch – Incongruent	638.01	28.34	633.63	28.91			
Exercising Condition × AW task × Congruency	Word – Congruent	618.51	25.34	606.10	25.45	0.05	19	.01
	Word – Incongruent	689.16	25.48	687.35	25.01			
	Arrow – Congruent	566.37	29.49	543.30	29.63			
	Arrow – Incongruent	605.12	33.48	596.60	36.11			
Exercising Condition x Switching × AW task × Congruency	Switch - Word - Congruent	635.00	129.09	605.99	97.06	1.29	19	.06
	Switch - Word - Incongruent	701.35	120.36	698.02	119.73			
	Switch - Arrow - Congruent	573.97	135.70	549.52	126.12			
	Switch - Arrow - Incongruent	611.20	157.25	602.62	165.13			
	No switch - Word - Congruent	602.03	104.08	606.21	136.42			
	No switch - Word - Incongruent	676.98	115.02	676.68	111.54			
	No switch - Arrow - Congruent	558.77	132.24	537.09	142.75			
	No switch - Arrow - Incongruent	599.05	147.46	590.58	162.44			
PVT - mean RT (9 min)	Total RT	311.20	24.60	312.50	26.24	0.05	20	.00
OSpan working memory	Accuracy (Recalls)	2270.78	299.20	2246.43	268.68	0.15	20	.01
		38.57	10.41	36.81	6.91	1.27	20	.06

Note. PANAS-PA – Positive and Negative Affect Schedule-Positive Affect score; PANAS-NA – Positive and Negative Affect Schedule-Negative Affect score; BAI – Beck Anxiety Inventory score; BDI – Beck Depression Inventory score; AW – Arrow Word Reaction Time (ms); PVT mean RT – Psychomotor Vigilance Test mean Reaction Time (ms); OSpan – Operation Span; Total RT – Total Reaction Time (ms); Accuracy (Recalls) – correct Recalls. η² = eta square; **p* < .05; ***p* < .01; ****p* < .001

are performing physical activities in real nature. Such effects were not observed for exercising in virtual or simulated nature environments (Stevenson et al., 2018). Various empirical investigations compared simulated natural versus urban settings (e.g., Berman et al., 2008; Beute & De Kort, 2014; Bratman et al., 2012; Pasca et al., 2022) uncovered potential benefits in respect to postexposure cognitive functioning. However, most of them identified rather small effect sizes and did not control for potential confounding effects stemming from exercise type and intensity. We add to the literature illustrating that when exercising type and intensity is controlled for, exposure to simulated nature results in negligible gains in executive functioning. Our null findings suggest that when exercising at submaximal effort, exposing participants to a soundscape video of nature does not compensate the benefits observed in settings where participants exercise in real nature (e.g., Bratman et al., 2015). The only significant interaction effect emerged between exercising condition and task congruency. This result indicates that participants in the simulated nature condition were slower, exhibiting higher RT when identifying congruent stimuli compared to the control condition. This unexpected finding may be attributed to potential distraction within our video simulation of nature (simulated nature) condition. Participants could have been diverted by the occasional presence of passing cars in the video, which, although contributing to the realism of the cycling environment, deviates from an exclusively natural setting. In the Limitations section, we discuss the potential explanations of this phenomenon. From a theoretical standpoint, our findings identified a potential boundary condition of the ART model (Kaplan, 1995), suggesting that the beneficial restorative effects are more likely to occur via exposure to real nature, rendering them hard to compensate via

TABLE 3.
Post Hoc Tests for Arrow Word (AW) Switching Task - Exercising Condition x Congruency

Exercising condition	Congruency	Mean difference	SE	*p* (Bonferroni-corrected)
Simulated nature congruent	Simulated nature incongruent	-52.81	8.75	.001**
	Control congruent	18.69	12.41	.892
	Control incongruent	-44.60	14.71	.041*
Simulated nature incongruent	Control congruent	71.51	14.53	.001**
	Control incongruent	8.21	12.68	.999
Control condition congruent	Control incongruent	-63.30	8.45	.000***

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

soundscape videos. Furthermore, our findings suggest that employing exclusively soundscape videos of natural environments is unlikely to trigger the entire array of psychological benefits with respect to cognitive functioning. One mechanism that might explain why a synthetic environment cannot exert cognitive benefits in the same way as actual nature relates to the visual perception of low-level features including important color properties (hue, saturation, and brightness), and spatial properties (density of straight and nonstraight edges, entropy) specific to real nature. A second explanation would suggest that cognitive faculties may not be activated to the same degree as in real nature because, regardless of the use of analog visual stimuli, the individual still knows that indoors there is a distinct lack of threats, obstacles, interruptions, etc. Finally, a third mechanism to be investigated involves other proprioceptive and sensory factors beyond vision and sound which could be important to realizing such benefits (e.g., special populations lacking sight/hearing) which were not directly provided by our simulated environment. A potential direction for future research would be to test whether exercising in more immersive simulations, such as virtual reality (VR), could replicate the positive effects of exposure to real nature.

With respect to the second hypothesis, our findings suggest that exposure to simulated nature compared to the control condition, under the condition of submaximal physical effort, resulted in negligible affective benefits (reductions in negative affect, depressive or anxiety symptoms, or increases in positive affect, respectively). Previous findings from a meta-analysis showed that real nature exposure, compared to laboratory simulations of nature indicates additional benefits from exposure to the real nature, especially in the realm of psychological well-being (McMahan & Estes, 2015). Exposures to laboratory simulations of nature resulted in smaller, yet still significant effect sizes (McMahan & Estes, 2015). However, research is also limited by a less strict control over exercise type and intensity, factors that could account for the significant effects detected. We add to the literature by showing that when controlling for such effects, exposing participants to simulations of nature offers little beneficial affective effects. Overall, our findings are in line with research reporting more reduced affective benefits of physical activity performed in indoor environments as opposed to exercising in nature (Pasanen et al., 2014). Relatively recent investigations (Brancato et al., 2022; Yu et al., 2018) reported that exposure to more immersive techniques, such as virtual reality simulations of forests resulted in a significant decrease in negative affective states (depression, anger, fatigue, tension, or hostility) compared to urban VR. Taken together, our findings suggest that the exposure to soundscape videos of nature alone such as the one employed in our study cannot elicit the same amount of affective benefits as those elicited by natural environments or more immersive simulations of natural environments (Yu et al., 2018). From a theoretical perspective our research contributes to identifying a boundary condition of the SRT, suggesting that the beneficial effects associated with exposure to natural environments cannot occur via mere visual reproductions of natural environments.

Taken together, our study expands the current scientific understanding regarding the potential cognitive and affective benefits stemming from exposure to simulations of natural environments in several ways. First, we found little evidence that exposure to soundscape videos of natural environment triggers cognitive and affective benefits. Second, by instructing the participants to exert submaximal physical effort, we controlled for potential confounded effects of exposure to simulations of natural environments and physical activities performed under such conditions. Thus, we add to the literature by employing a research design that controlled for the potential confounded effects of exercising while being exposed to simulations of natural environments. Third, we employed a sample of physically active adults, with no history of psychiatric disorders, contributing to the literature by identifying the extent to which exposure to simulations of natural environments elicits positive cognitive or affective effects in such sample. Our study showed that the exposure to simulation of nature did not provide any benefits for the cognitive and affective functioning, and we can conclude that soundscape videos of nature, at least in the conditions of our study, did not show the beneficial effects generally attributed to nature. We contribute to the literature on the psychological benefits of exposure to simulations of natural environments. Further theoretical and empirical progress is needed in order to capture the way in which simulated environments of nature impacts the individuals' psychological functioning; the ergonomic interaction of human-simulated environments needs to be further addressed.

Limitations

An important limitation in our study is the potential for distraction in the indoor exercising with a video simulation of nature (simulated nature) condition. Participants might have been distracted by the occasional presence of passing cars in the outdoor video, which, although contributing to the realism of the cycling environment, deviates from an exclusively natural setting. We view this as a potential limitation due to (a) the presence of nonnatural elements (i.e., cars) and (b) the possibility that observing passing vehicles could divert attention from the primary stimuli, the simulation of the natural environment. Furthermore, it is important to note that our participant sample consisted of individuals regularly engaged in physical activity. The observed effects may differ for individuals with less cycling experience, or those who engage in less physical activity. Future research could benefit from including participants with varying levels of cycling experience, potentially extending single-session exposure to multiple sessions. Additionally, there was an under-representation of females in our study. Future research should aim to include a more balanced gender representation. Our study also warrants further exploration into alternative indoor and outdoor environments. Clarifying which aspects of attention are impacted by exposure to natural environments, particularly during exposure, is essential. Utilizing various measures across multiple studies will provide a more comprehensive understanding of these effects. Another limitation of our study is the use of retrospective affective assessments. The affective effects of physical exercise under simulated nature condition, compared to the control condition, might be momentary (as captured with the PANAS). Ekkekakis and Brand (2019) suggested that affective responses to exercise are multifaceted, resulting in both pleasant and unpleasant experiences, both during and after exercise. Most existing research has focused on cognitive and affective measures postexercise (e.g., Berman et al., 2008; Bratman et al., 2015; Depledge et al., 2011). However, Ekkekakis and Brand (2019) suggest that affective rebounds are influenced by how one feels during physical exertion.

Future Directions

Future investigations should aim towards contrasting three exposures to different environments: simulations of natural environments, natural environments, and indoor environments (with no simulations). Direct comparisons of exposures to natural environments as opposed to simulations have been done previously (e.g., Rogerson et al., 2016). Moreover, we encourage the pursuit of comparing different types of simulations of natural environments, thus detecting which kind of simulation offers yields greater benefits. Various technological innovations such as exposures based on VR are now available and have the potential to provide a more immersive experience. Moreover, our findings suggest that relying exclusively on soundscape videos has a relatively decreased potential of eliciting the positive cognitive and affective benefits stemming from exposure to real natural environments. We encourage the development of simulations reliant of other types of sensorial inputs than visual. Besides, in order to design better therapeutic applications of green exercise, future research should clarify if environmental influences occur when exercise groups are greater in number, when the exercise mode is different from those already investigated (e.g., resistance exercise), or when the required focus on the exercise component is higher (Rogerson et al., 2016).

As an answer to the rapid grow of urbanization, it became important to adapt our indoor environments by integrating nature into the spaces we live in. Some studies proposed exposure to simulated nature as a way to enhance our health and well-being in indoor spaces (McSweeney et al., 2015). Nevertheless, the actual state of simulations of nature does not always have the promised effect, especially when compared to real nature, and McMahan and Estes (2015) revealed it in their meta-analysis. As suggested by Ohly et al. (2016) in a review focusing on the attention restoration potential of natural settings, there are clear benefits in including negative findings, as in our case, in order to accurately understand the phenomenon. Virtual reality could be a better way to simulate the environment, yet more research is needed to clarify its effects (Depledge et al., 2011; MacIntyre et al., 2020).

CONCLUSION

To conclude, notable progress has been made in understanding the benefits of exposure to nature on psychological functioning. The current study aimed to investigate the impact of indoor exercising (cycling) with a video simulation of nature (simulated nature) compared to indoor exercising (control condition), while controlling for the exercise component. Our findings suggest that soundscape videos of natural environments do not trigger immediate positive cognitive and emotional effects, while controlling for submaximal physical effort levels. Therefore, soundscape videos of natural environments are unlikely to reproduce the beneficial effects of direct exposure to nature or the ones of more immersive simulations. Future research should investigate the minimal degrees of immersion that trigger the positive mental and emotional benefits in both regularly active individuals and in the general population.

ACKNOWLEDGEMENTS

We have no known conflict of interest to disclose. This study was the result of an Erasmus Traineeship founded by the European Commission. We thank Prof. Daniel Sanabria[2 3], Prof. Mikel Zabala, and MSc Manuel Sola Arjona from the Faculty of Sport Sciences, University of Granada, Spain for their support. The Mind, Brain, and Behavior Research Center, University of Granada, Spain for allowing us to conduct this research.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, LVP, upon reasonable request.

REFERENCES

Aarts, E., Roelofs, A., Franke, B., Rijpkema, M., Fernández, G., Helmich, R. C., & Cools, R. (2010). Striatal dopamine mediates the interface between motivational and cognitive control in humans: evidence from genetic imaging. *Neuropsychopharmacology, 35*(9), 1943–1951. https://doi.org/10.1038/npp.2010.68

Alexandrowicz, R. W., Fritzsche, S., & Keller, F. (2014). A psychometric view on the applicability of the BDI-II in non-clinical populations. *Neuropsychiatrie: Klinik, Diagnostik, Therapie und Rehabilitation: Organ der Gesellschaft Osterreichischer Nervenarzte und Psychiater, 28*(2), 63–73. https://doi.org/10.1007/s40211-014-0104-z

Basner, M., & Dinges, D. F. (2011). Maximizing sensitivity of the psychomotor vigilance test (PVT) to sleep loss. *Sleep, 34*(5), 581–591. https://doi.org/10.1093/sleep/34.5.581

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*(6), 893. https://doi.org/10.1037//0022-006x.56.6.893

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Beck depression inventory-II*. https://doi.org/10.1080/00223890802248919

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science, 19*(12), 1207–1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x

Beute, F., & De Kort, Y. A. W. (2014). Natural resistance: Exposure to nature and self-regulation, mood, and physiology after ego-depletion. *Journal of Environmental Psychology, 40*, 167–178. https://doi.org/10.1016/j.jenvp.2014.06.004

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Human Kinetics.

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health, 10*(1), 456. https://doi.org/10.1186/1471-2458-10-456

Brancato, G., Van Hedger, K., Berman, M. G., & Van Hedger, S. C. (2022). Simulated nature walks improve psychological well-being along a natural to urban continuum. *Journal of Environmental Psychology, 81*, 101779. https://doi.org/10.1016/j.jenvp.2022.101779

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning, 138*, 41–50. https://doi.org/10.1016/j.landurbplan.2015.02.005

Bratman, G. N., Hamilton, J. P., & Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences, 1249*(1), 118–136. https://doi.org/10.1111/j.1749-6632.2011.06400.x

Depledge, M. H., Stone, R. J., & Bird, W. J. (2011). Can natural and virtual environments be used to promote improved human health and wellbeing? *Environmental Science & Technology, 45*(11), 4660–4665. https://doi.org/10.1021/es103907m

Ekkekakis, P., & Brand, R. (2019). Affective responses to and automatic affective valuations of physical activity: Fifty years of progress on the seminal question in exercise psychology. *Psychology of Sport and Exercise, 42*, 130–137. https://doi.org/10.1016/j.psychsport.2018.12.018

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fuegen, K., & Breitenbecher, K. H. (2018). Walking and being outdoors in nature increase positive affect and energy. *Ecopsychology, 10*(1), 14–25. https://doi.org/10.1089/eco.2017.0036

Gatersleben, B., & Andrews, M. (2013). When walking in nature is not restorative—The role of prospect and refuge. *Health & Place, 20*, 91–101. https://doi.org/10.1016/j.healthplace.2013.01.001

Hauser, D. J., Ellsworth, P. C., & Gonzalez, R. (2018). Are manipulation checks necessary? *Frontiers in Psychology, 9*, 998. https://doi.org/10.3389/fpsyg.2018.00998

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Lahart, I., Darcy, P., Gidlow, C., & Calogiuri, G. (2019). The effects of green exercise on physical and mental wellbeing: A systematic review. *International Journal of Environmental Research and Public Health, 16*(8), 1352. https://doi.org/10.3390/ijerph16081352

Magán, I., Sanz, J., & García-Vera, M. P. (2008). Psychometric properties of a Spanish version of the Beck Anxiety Inventory (BAI) in general population. *The Spanish Journal of Psychology, 11*(02), 626–640. https://doi.org/10.1017/S1138741600004637

MacIntyre, T. E., Beckmann, J., Calogiuri, G., Donnell, A. A., Jones, M. V., Madan, C. R., ... & Gidlow, C. J. (2020). Human-nature interactions: Perspectives on conceptual and methodological issues. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.607888

McMahan, & Estes (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology, 10*(6), 507–519. https://doi.org/10.1080/17439760.2014.994224

McSweeney, J., Rainham, D., Johnson, S. A., Sherry, S. B., & Singleton, J. (2015). Indoor nature exposure (INE): A health-promotion framework. *Health Promotion International, 30*(1), 126–139. https://doi.org/10.1093/heapro/dau081

Niedermeier, M., Grafetstätter, C., Hartl, A., & Kopp, M. (2017). A randomized crossover trial on acute stress-related physiological responses to mountain hiking. *International Journal of Environmental Research and Public Health, 14*(8), 905. https://doi.org/10.3390/ijerph14080905

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention restoration theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B, 19*(7), 305–343. https://doi.org/10.1080/10937404.2016.1196155

Pasanen, T. P., Tyrväinen, L., & Korpela, K. M. (2014). The relationship between perceived health and physical activity indoors, outdoors in built environments, and outdoors in nature. *Applied Psychology: Health and Well-Being, 6*(3), 324–346. https://doi.org/10.1111/aphw.12031

Pasca, L., Carrus, G., Loureiro, A., Navarro, Ó., Panno, A., Tapia Follen, C., & Aragonés, J. I. (2022). Connectedness and well-being in simulated nature. *Applied Psychology: Health and Well-Being, 14*(2), 397–412. https://doi.org/10.1111/aphw.12309

Plante, T. G., Aldridge, A., Su, D., Bogdan, R., Belo, M., & Kahn, K. (2003). Does virtual reality enhance the management of stress when paired with exercise? An exploratory study. *International Journal of Stress Management, 10*(3), 203. https://doi.org/10.1037/1072-

5245.10.3.203

Rogerson, M., Gladwell, V. F., Gallagher, D. J., & Barton, J. L. (2016). Influences of green outdoors versus indoors environmental settings on psychological and social outcomes of controlled exercise. *International Journal of Environmental Research and Public Health, 13*(4), 363. https://doi.org/10.3390/ijerph13040363

Sandín, B., Chorot, P., Lostao, L., Joiner, T. E., Santed, M. A., & Valiente, R. M. (1999). Escalas PANAS de afecto positivo y negativo: validación factorial y convergencia transcultural [The PANAS Scales of Positive and Negative Affect: Factor analytic validation and cross-cultural convergence]. *Psicothema, 11*(1), 37–51. https://www.redalyc.org/articulo.oa?id=72711104

Sanz, J., Perdigón, A. L., & Vázquez, C. (2003). Adaptación española del Inventario para la Depresión de Beck-II (BDI-II): 2. Propiedades psicométricas en población general. *Clínica y Salud, 14*(3), 249–280.

Sartor, F., Vernillo, G., De Morree, H. M., Bonomi, A. G., La Torre, A., Kubis, H. P., & Veicsteinas, A. (2013). Estimation of maximal oxygen uptake via submaximal exercise testing in sports, clinical, and home settings. *Sports Medicine, 43*(9), 865–873. https://doi.org/10.1007/s40279-013-0068-3

Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). Attention Restoration Theory II: a systematic review to clarify attention processes affected by exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B, 21*(4), 227–268. https://doi.org/10.1080/10937404.2018.1505571

Tokowicz, N., Michael, E. B., & Kroll, J. F. (2004). The roles of study-abroad experience and working-memory capacity in the types of errors made during translation. *Bilingualism: Language and Cognition, 7*(03), 255–272. https://doi.org/10.1017/S1366728904001634

Ulrich, R. S. (1981). Natural versus urban scenes: Some psychophysiological effects. *Environment and Behavior, 13*(5), 523–556. https://doi.org/10.1177/0013916581135001

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), https://doi.org/1063. 10.1037/0022-3514.54.6.1063

Yao, W., Zhang, X., & Gong, Q. (2021). The effect of exposure to the natural environment on stress reduction: a meta-analysis. *Urban Forestry & Urban Greening, 57*, 126932. https://doi.org/10.1016/j.ufug.2020.126932

Yu, C. P., Lee, H. Y., & Luo, X. Y. (2018). The effect of virtual reality forest and urban environments on physiological and psychological responses. *Urban Forestry & Urban Greening, 35*, 106-114. https://doi.org/10.1016/j.ufug.2018.08.013

RECEIVED 10.03.2023 | ACCEPTED 05.11.2023

APPENDIX A

Descriptive Statistics for Regular Physical Activity, Perception of Exertion, Duration of Training Time

Variable	Session	*N*	*M*	*SD*
Age	1	21	27.05	5.71
Aerobic test (W: submaximal)	1	21	233.81	54.61
70% of Aerobic test (70%W)	2 & 3	21	163.67	38.23
Relative maximal power (W/kg)	1	21	3.46	0.81
RPE Evaluation session	1	21	17.62	1.53
RPE Simulated Nature session	2 or 3	21	12	2.14
RPE Control session	2 or 3	21	12.05	2.38
Sport training (h/day)	1	21	2.30	0.68
Sport training (h/week)	1	21	10.38	4.61
Sport training (days/weeks)	1	21	4.57	1.50

Note. W = Watts (power energy unit); RPE = rating of perceived exertion, h = hours.

APPENDIX B

Procedure – Step by Step

Steps	Session 1 (Pre-test)	Session 2	Session 3
1. Basal Heart Rate Variability (HRV)	-	-	5 min. resting state
2. Cycling time & collected measures	20.38 min.	55 min.	55 min.
	HRV & RPE	HRV & RPE	HRV & RPE
3. Cognitive tasks & collected measures	-	AW	
PVT			
OSpan	AW		
PVT			
OSpan			
	HRV & RPE	HRV & RPE	HRV & RPE
Break	-	10 min.	10 min.
4. Affective questionnaires	-	PANAS	
BAI			
BDI-II	PANAS		
BAI			
BDI-II			
Total time	≈ 1 h 30 min.	≈ 3 h	≈ 3 h

Note. Time of cycling is written without considering the 3 to 5 minutes of warm up. In Pre-test the time varied between participants depending on their aerobic power; Minimum = 12 min., Maximum = 30 min., Mean = 20.38 min.). HRV – Heart Rate Variability; RPE – Rating of Perceived Exertion score; AW – Arrows and Words task; PVT – Psychomotor Vigilance Test; OSpan – Working Memory Task; PANAS – Positive and Negative Affect Schedule-Positive Affect score; BAI – Beck Anxiety Inventory score; BDI-II – Beck Depression Inventory II score.

Session 1 (Pre-test). Incremental Effort Test (VO2 Submax; Sartor et al., 2013)

To assess participants' submaximal aerobic power, we employed the submaximal oxygen consumption test. This incremental effort test, conducted using a bicycle ergometer, determines the fitness level of each participant by measuring the amount of oxygen the body needs during vigorous physical activity. The initial workload was at 30 Watts (W) with an incremental protocol of 30 W every 3 minutes, until 90 W. If at any time the researchers noticed that the participants' continuously monitored heart rate reached 85% of their age-predicted maximal heart rate (calculated as 220-age), they were required to completely stop the activity from that moment onward (this was the case for 5 participants). The criteria to finish the test were either to reach 85% of 220-age, or to not be able to maintain the pedaling cadence between 60 and 90 W. In addition, the Rating of Perceived Exertion scale (RPE; Borg, 1998) was used after every physical effort as a measure of control. The question, "rate your perceived exertion for the past 3 minutes" was administrated by the researcher after each incremental of power with 30 Watts (W).

APPENDIX C

Cyclers Perform Under Similar Laboratory Conditions

Moment of assessment		Session 2	Session 3
Before Physical Effort	Temperature °C	23.35	23.46
	Humidity %	44.43	45.05
	Atmospheric Pressure mbar	907.95	907.90
After Physical Effort	Temperature °C	23.51	23.66
	Humidity %	47.90	47.57
	Atmospheric Pressure mbar	907.71	907.67
After Cognitive tasks	Temperature °C	23.66	24.25
	Humidity %	45.05	44.71
	Atmospheric Pressure mbar	907.81	907.43

APPENDIX D

Individual Heart Rate Variability, RR Interval Differences (RR-MS) – Across the Two Conditions: Simulated Nature Condition and Control

Task	Condition	*N*	*M*	*SD*	Statistic	*df*	*p*
Arrow Word Switching Task	Simulated Nature	21	179.01	271.72	1.00	40	.332
	Control	21	113.55	125.24			
PVT1 (1-3 minutes)	Simulated Nature	21	103.41	161.63	0.46	40	.651
	Control	21	83.37	120.42			
PVT2 (3-6 minutes)	Simulated Nature	21	85.82	160.81	0.38	40	.709
	Control	21	69.17	123.45			
PVT3 (6-9 minutes)	Simulated Nature	21	97.42	158.57	0.81	40	.425
	Control	21	62.16	122.31			
Working Memory	Simulated Nature	21	120.7	177.02	0.21	40	.833
	Control	21	110.5	131.2			

Note. PVT – Psychomotor Vigilance Test.

APPENDIX E

In-Depth Description of Cognitive Tasks

ARROWS AND WORDS TASK

Arrows and Words task (AW; Aarts et al., 2010) is designed to measure executive attention by assessing task-switching behavior using incongruent arrow-word combinations as targets. Participants were presented with a screen and had to fixate on an asterisk in the middle of the screen after a task-cue came and they had to respond either to the direction of the arrow (arrow task) or to the direction indicated by the word (word task), which were sometimes congruent (arrow pointing to the left and the word left) and other times in conflict (incongruent: arrow pointing to the right and the word left displayed). The cues for the arrow task were the Spanish words for *arrow* (*flecha*) and the letter *f*. The cues for the word task were the Spanish words for *word* (*palabra*) and the letter *p*. The task-cue switched on every trial, whereas the task itself switched (from arrow to word or vice versa) or was repeated (from arrow to arrow or from word to word) in a random manner. In this way, a task switch (the manipulation of interest) was never confounded with a task-cue switch. The critical measure of interest, the switch cost, was calculated by subtracting performance (errors and reaction times) on repeat trials from that on switch trials. This task was programmed with E-prime 2.0 and the main experiment consisted of 120 trials. The factors of task (arrow/word), trial type (switch/repeat), and response (right/left) were equally distributed over the trials in a random manner. The whole task lasted for about 15 minutes starting with a familiarization trial and including a 30 seconds break after every 24 trials.

PSYCHOMOTOR VIGILANCE TEST

Psychomotor Vigilance Test (PVT; Basner, & Dinges, 2011). Vigilance and sustained attention were measured using a precise computer-based version of the 9-minute PVT, followed after a familiarization session. Participants were instructed to monitor a red circle on the computer screen and press a response button as soon as a red stimulus counter appeared on the computer screen, which stopped the counter and displayed the reaction time (RT) in milliseconds for a 1-second period. The inter-stimulus interval varied randomly from 2 to 10 seconds. The participants were instructed to press the button as soon as each stimulus appeared in order to keep the RTs as low as possible, but not to press the button too soon (which yielded a "false start" on the display).

OPERATION SPAN WORKING MEMORY TASK

Operation Span Working Memory Task (OSpan, Tokowicz et al., 2004) was used to measure individual differences in working memory capacity. The task involves solving mathematical expressions while maintaining sets of words in memory. For example, a participant may see "(4 + 2) – 3 = 10," after which they should press the "no" button, and then the word tiger would appear. The sets ranged in size from two to six operation-word pairs and were presented in increasing order of size with three sets of each size. Each set contained an approximately equal number of expressions requiring "yes" (Y) and "no" (N) responses. Each trial began with a fixation point (+) for 1000 ms, then a mathematical expression for 2500 ms. Participants responded to the expressions using the keys marked either "Y" or "N" during the presentation of a question mark (?), which was displayed for 1250 ms. Participants then saw a word for 1250 ms, and then the fixation point reappeared, which started the next trial. After the last word in the set was displayed, a "RECALL" prompt appeared, at which time participants wrote the words from that set in a booklet. Participants were instructed to respond as quickly and accurately as possible. The whole task lasted for about 10 minutes, including a familiarization trial in the beginning. Working memory capacity was defined as the set size at which a participant was able to recall all the words from at least two of three sets. The accuracy of word order was not factored into the calculation of span.

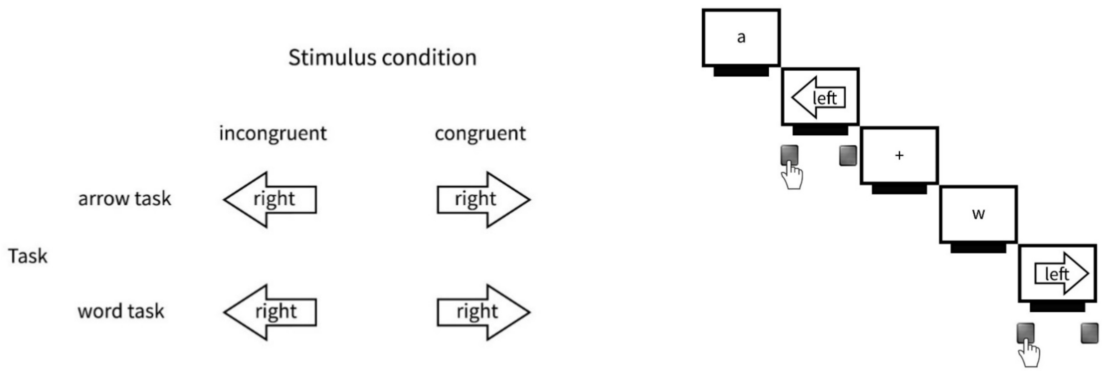


FIGURE 1E.

Left: Examples of incongruent and congruent stimuli in the AW task (Aarts et al., 2010). Right: Visual display of the AW task (adapted from Aarts et al., 2010)

APPENDIX F

Correlations for Simulated Nature Condition Above the Line and Correlations for Control Condition Below the Line

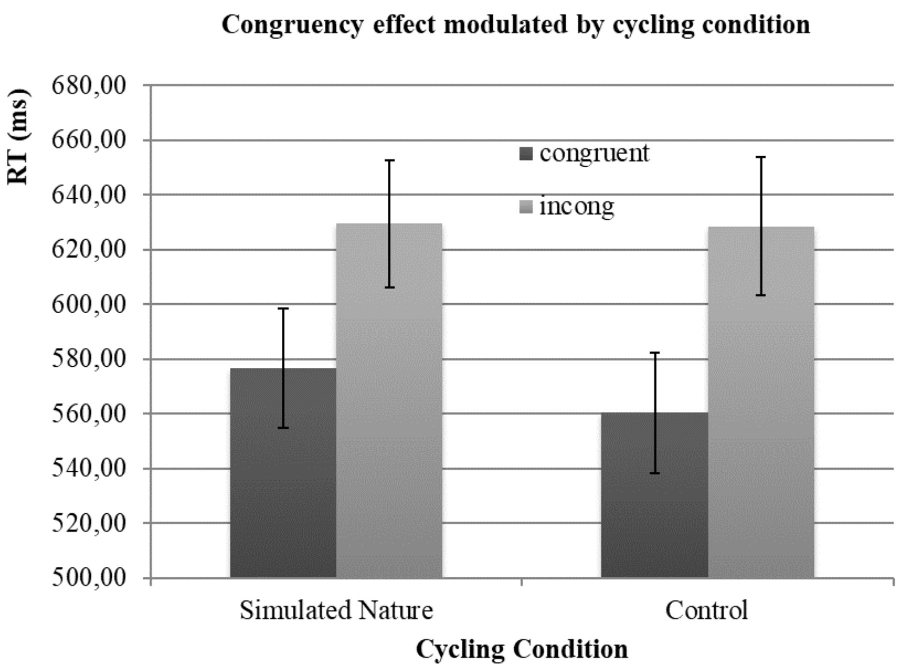
Variable	1.	2.	3.	5.	6.	7.	8.	9.
1. PANAS-PA	-	.19	.05	−.09	−.13	−.19	−.33	−.20
2. PANAS-NA	−.39	-	.54*	.54*	.42	−.12	.06	.02
3. BAI	−.35	.58	-	.58**	.24	.10	.02	.01
5. BDI	−.60**	.63**	.74***	-	.66**	.39	.11	−.12
6. AW RT	−.42	.25	.20	.59**	-	.16	.21	.04
7. AW conflict	−.26	.33	.63**	.48*	.37	-	−.14	−.12
8. PVT mean RT	−.02	.01	−.25	.29	.52*	−.05	-	.45*
9. OS total RT	−.44*	.52	.10	.26	.24	.25	.09	-

Note. PANAS-PA – Positive and Negative Affect Schedule-Positive Affect; PANAS-NA – Positive and Negative Affect Schedule-Negative Affect; BAI – Beck Anxiety Inventory; BDI – Beck Depression Inventory II; AW RT – Arrow Word Reaction Time (ms); AW conflict effect = Arrow Word incongruent – congruent Reaction Time (ms); PVT mean RT – Psychomotor Vigilance Test mean Reaction Time (ms); OS total RT – Operation Span total Reaction Time (ms). Bivariate correlations above the line correlations for Simulated Nature condition and below the line correlations for Control condition.

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

APPENDIX G

Arrow-Word Switching Task Results According to Congruency in Simulated Nature and Control Conditions



APPENDIX H

Arrow-Word Switching Task Results for Conflict Effect in Simulated Nature and Control Conditions