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Cognitive and emotional responses to urban and nature exposures in the Brazilian Cerrado

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ABSTRACT: Contact with nature increases human health and well-being by stress reduction, positive-emotion elicitation, and attentional restoration. Despite the outstanding Brazilian biodiversity, we are unaware of studies linking nature experiences to welfare. Herein, we applied cognitive tasks and emotional self-reports in 33 subjects, before and after a 30-minute walk in a nature trail at Parque Nacional de Brasília, and compared them with the same tests applied before and after a 30-minute walk in Brasilia´s downtown. We recorded improvements in emotional self-reports after nature experience, while the urban exposure caused decreases in self-reported happiness and increases in negative emotions. These results highlight the relevance of natural settings for cognitive and emotional well-being and the need for a better understanding of the relationships between nature and human health. The recognition that mental health is an ecosystem service can improve the arguments for nature conservation, and the quality of life and public health.

Key words: cognitive improvement, ecosystem services, human health, nature contact, well-being.

RESUMO (Respostas cognitivas e emocionais à exposições a ambientes urbanos e naturais no Cerrado brasileiro): O contato com a natureza aumenta a saúde e o bem-estar humanos através da redução do estresse, elicitação de emoções positivas e restauração da atenção. Apesar da notável biodiversidade brasileira, desconhecemos estudos que vinculam experiências com a natureza ao bem-estar no país. Aqui aplicamos tarefas cognitivas e autorrelatos emocionais em 33 sujeitos, antes e depois de uma caminhada de 30 minutos em uma trilha natural no Parque Nacional de Brasília, e comparamos com os mesmos testes aplicados antes e depois de uma caminhada de 30 minutos no Centro de Brasília. Registramos melhorias nos relatos emocionais após o contato com a natureza, enquanto a exposição urbana causou diminuições na felicidade autorreferida e aumentos nas emoções negativas. Esses resultados destacam a relevância dos cenários naturais para o bem-estar cognitivo e emocional e a necessidade de um melhor entendimento das relações entre a natureza e a saúde humana. O reconhecimento de que a saúde mental é um serviço ecossistêmico pode melhorar os argumentos para a conservação da natureza, a qualidade de vida e a saúde pública.

Palavras-chave: melhoria cognitiva, serviços ecossistêmicos, saúde humana, contato com a natureza, bem-estar.

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INTRODUCTION

Natural resources, which have always sustained humankind, are undergoing severe degradation, decreasing the delivery of several ecosystem services and threatening human health and well-being (Ford *et al.* 2015, Sandifer *et al.* 2015). Humankind has had a close relationship with nature throughout its history, and most of our success as a species has come from the use of biodiversity in fulfilling our needs (Ramankutty & Foley 1999).

Most of human existence and evolution has taken place in natural environments, and we developed a deep connection with the natural world (Frumkin 2001). As might be expected, humans show an "innate emotional affiliation" with other organisms and elements of biodiversity (Wilson 1984), and have a predisposition to interact with and be integrated to the natural world, consciously or not (Bratman *et al.* 2012), including a predetermined evolutionary need for exposure to natural habitats to improve our health (Rook 2013). The complex relationships between human health and biodiversity are multidimensional, requiring integrative analytical approaches based on Ecology, Conservation, Sociology, Economy, and Psychology sciences (Lovell *et al.* 2014, Ford *et al.* 2015).

Spending time in nature allows physical and mental restoration (Stevens 2010). The evidence linking interactions in natural environments with health benefits and well-being is increasingly more robust (Bowler *et al.* 2010, Bratman *et al.* 2012, Clark *et al.* 2014). There is a wide range of beneficial effects related to exposure to green spaces. It can lead to increased immunoregulation (Rook 2013), improvement in cognitive tasks (Tennessen & Cimpricht 1995, Hartig *et al.* 2003, Berman *et al.* 2008, Bratman *et al.* 2015) and creativity (Atchley *et al.* 2012), lower blood pressure (Hartig *et al.* 2003), reduction in Attention Deficit Hyperactivity Disorder (ADHD) symptoms (Kuo & Taylor 2004), positive emotional responses and mood improvement (Hartig *et al.* 1991, Hartig *et al.* 2003, Berman *et al*. 2008), cognitive and affective amelioration in individuals with Major Depressive Disorder (MDD) (Berman *et al.* 2012), and decreases in anxiety, rumination and negative affect (Bratman *et al.* 2015). Even when subjects were only exposed to images or videos of natural environments, they also showed positive results, such as reduced heart rates (Laumann *et al.* 2003), and improved cognitive performances (Berman *et al.* 2008).

How contact with nature improves our cognitive functions and mental health is grouped into two main explanations. The Attention Restoration Theory (ART), proposed by Rachel and Stephen Kaplan (1989), is based on the perception that our attention can be voluntary or involuntary. Voluntary attention involves a conscious effort to reach focus, thus being susceptible to fatigue, whereas involuntary attention is stimulated when situations or locations are inherently interesting to the observer, demanding little or no effort to capture them (Kaplan 1995, Kaplan 2001). Prolonged mental effort leads to attention fatigue, but while the individual is in involuntary mode, voluntary attention should be able to rest (Kaplan 1995). The concept of 'restorative experiences or environments' refers to such opportunities. Natural settings are particularly likely to meet the requirements for a restorative environment (*sensu* Kaplan 1995).

The Stress Reduction Theory (SRT), proposed by Roger Ulrich (1983, 1986, 1991), states that the initial response to the environment is affective rather than cognitive. For him, restoration derives more from a reduction of arousal than from replenishment of attentional capacity. He suggests that nature is a non-taxing stimulus, and since landscapes with views of water and/or vegetation would have been more beneficial for survival throughout human history, they elicit positively-toned emotional states, conducing to well-being, and blocking negatively-toned feelings, thus causing a reduction in stress and negative thoughts (Hartig 1991).

Natural environments usually present inherently attractive stimuli and therefore activate involuntary attention mode, allowing the occurrence of restorative experiences, leading to tranquility and improved concentration abilities (Kaplan 1983). At the same time, the stressful urban environment is energetically demanding (due to annoying noises, crowding, heat, and air pollution; Evans 1984), causing negative reactions at emotional (i.e. fear, anger, sadness) and/or physiological (i.e. cardiovascular acceleration, elevated muscular tension) levels (Evans 1984, Kaplan 1995). Therefore, a lifestyle with prolonged mental effort and extended exposure to stressful situations can bring our attentional capacities to depletion (Kaplan 1995), leading to weakened cognitive abilities, and can cause negative emotional states (Ulrich 1986). This might appear as an increased difficulty to concentrate or as higher rates of irritability (Bratman *et al.* 2012).

The dramatic decrease in our exposure to natural habitats, coupled with a wide range of stimuli and information coming from many different (artificial) sources, characterizes our modern, urban lifestyle (Kareiva 2008). People are spending more and more time interacting with media and technology (Pergams & Zaradic 2006), and less time participating in activities in nature, such as visiting national parks (Atchley *et al.* 2012). Often the scarce natural remnants and/or urban green spaces, when present, are one of the few opportunities for getting some contact with a natural environment. We are reaching a critical point in our history, where biodiversity and habitat losses are accelerating due to increased human use, climate change, and rampant development (Sandifer *et al.* 2015), disconnecting us from natural environments. This disconnection brings to mind several concerns about how the absence of nature impacts our psychological well-being (Bratman *et al.* 2012) and immunological resistance (Rook 2013).

Although the roles that contact with nature plays in our mental health (cognitive skills and emotional states) are becoming clearer, further studies are necessary to understand the effects of the fast vanishing of nature on our well-being. Certain emotional and cognitive disorders (such as depression or ADHD) may become widespread and more difficult to treat in human populations in the future, especially due to the few restorative opportunities provided by contact with nature (Stevens 2010, Kuo & Taylor 2004). The combination of stressful environments in large cities and fewer opportunities for nature contact can affect negatively human well-being. For example, São Paulo, the largest South American city, with 11 million inhabitants, showed the highest rate of depression in a group of cities from 18 countries (Kessler *et al.* 2010).

Despite the biological relevance of South America and the growing number of studies on the effects of contact with nature on our well-being, none of them have been carried out in this continent (Keniger *et al.* 2013). Regarding Brazilian megadiversity and the beauty of its remaining natural landscapes, we are unaware of any research on this subject in the country.

Herein, we report differences in attentional cognitive function and self-reported psychological/emotional states caused by the exposure to a natural environment and an urban environment in a group of young adults. The Brazilian Cerrado, a global biodiversity hotspot (Myers *et al.* 2000) provided us with the experimental context of our research.

MATERIAL AND METHODS

We conducted our experiment in natural and artificial areas in the Brazilian Cerrado, the largest South American savanna, and the only savanna hotspot worldwide. The methodology was adapted from Hartig *et al.* (2003).

We compared a group of young adults (18 to 33 years old; Mean age = 23.5) exposed to two different settings (treatments), being one natural and one urban. The 33 subjects (15 females and 18 males) were mainly undergraduate students of the University of Brasília. They were randomly approached and invited to participate in the research, and they all signed a Consent Form. The duration of the experiment was of approximately two hours for a subject, including emotional and cognitive measurements taken before and after 30-minute walks in each treatment.

The natural environment chosen was a 1.2 km trail (15°44'15"S, 47°55'41"W, 1055 m a.s.l.; Figure 1A) at Parque Nacional de Brasília, an important protected area with 46 thousand hectares of natural Cerrado. The biome´s vegetation consists mostly of seasonal savanna, with corridors of mesophytic evergreen forest (gallery forests) along the rivers, forming complex mosaics. The trail was on Capivara trailhead, a patch of gallery forest, the physiognomy that presents the highest structural complexity within the Cerrado physiognomies (Felfili 1995). The urban setting was at Setor Comercial Sul, the main city's commercial and financial centers (15°47'52"S, 47°53'18"W, 1115m a.s.l.; Figure 1B), with high building density and intense traffic of vehicles and people. These are two contrasting environments considering air, visual and sound pollution.

Figure 1. Experiment settings. (A) Capivara trailhead, Parque Nacional de Brasília (natural setting); (B) Setor Comercial Sul, Brasília (urban setting). Photos (A) by ABSC and (B) from http://www.doc.brazilia.jor.br.

We applied tests in our lab at the University of Brasília before and after the walks, except for the self-report measures, which we applied following the subject´s return to the starting point of each walk, aiming to record the most accurate affective responses. We applied the cognitive tests as soon as we got back to the University. It took us approximately ten minutes by car to arrive at each setting.

We used two tests to evaluate emotional states. The Zuckerman Inventory of Personal Reactions (ZIPERS), proposed by Zuckerman (1977), is a situation-specific trait-state test for affective responses and has been used in previous studies (e.g. Hartig *et al.* 1991, 2003; Ulrich *et al.* 1991) to assess participants' emotions (i.e. attention, fear arousal, sadness, aggressiveness, positive, and negative affect). The participants rated how each statement described their mood on a 13-item Likert-type scale of 1 to 5 (1 = not at all, 5 = very much). The Overall Happiness Scale (OHS), proposed by Campbell and collaborators (1976), is a thermometer-like graph with values ranging from zero, for very unhappy, to 100, for very happy.

For measurements in attention, we first applied the Stroop Test (ST) to cause attentional fatigue. We used this test because if the subjects´ attentional abilities are initially fatigued, any restoration effect is more efficiently recorded (Hartig *et al.* 1991). The test consists of two tasks, a reading one and a name-coloring one, and is based on the Stroop effect, a slowing in color-naming when the letters form the names of other colors (e.g. BLUE printed in red ink) (MacLeod 1991).

In the Backward Digit Span Task (BDST), the subjects hear sequences of three to nine digits in increasing length (and complexity) and are asked to repeat them in backward order. Each of the seven lengths was repeated once, and every correct answer was equally scored (one point), bringing the score to a maximum of 14 points. The Necker Cube Pattern Control Task (NCPCT) is an attention test based in the drawing of a three-dimensional wire cube that can be seen in two different perspectives, duo to reversals on foreground and background (Tennessen & Cimpricht 1995). After familiarization with both patterns, subjects were asked to maintain their attention during thirty seconds in one of the perspectives, and thirty more seconds in the other perspective. The ability to maintain focus on only one perspective is related to direct attention because it demands an inhibition of the competitive stimuli to change focus. We instructed participants to give a verbal signal each time an inversion occurred, and the subject´s performance was based on the mean number of inversions in each test.

We divided the subjects into two groups. One went to the nature experience first (group 1; n=17 and the other to the urban experience first (group 2; n=16) to avoid any possible bias due to familiarization with the tests. We scheduled to meet the subjects at the lab during day hours, depending on their availability, in September and October 2014. We applied the self-report tests (ZIPERS and OHS) and the cognitive tests (ST, BDST, and NCPCT) before driving the subjects to nature and urban environments/settings. Both experiences consisted of a solitary 30-minute walk in previously projected pathways, the "Capivara trail" in Parque Nacional de Brasília, and in a pathway that crosses the middle of the Setor Comercial Sul blocks and squares. The subjects returned after approximately two weeks for repetition in the alternate setting.

To test ZIPERS´ answers, which is a Likert-type scale, we coded the answers from one to five and used Fisher´s exact test for ordinal data. As our subjects were tested twice for each treatment (i.e. their observations were not independent), we decide to test differences in OHS, BDST, and NCPCT using Generalized Linear Mixed Models (GLMM) with Poisson distribution (for OHS and BDST) and

Gamma distribution (for NCPCT), using the identity of subjects as a random effect. We used Shapiro-Wilk tests to assess data normality. All tests were performed in the R environment (R Core Team 2019), using glmm (Knudson 2018), lme4 (Bates *et al.* 2015), and MuMIn (Barton 2019) packages. We use a significance level of 5%.

We tested for differences in performance before and after the experiences (urban or natural). We also tested for differences in performance before the walks (urban or natural) to verify whether both groups were in similar initial states.

RESULTS

The 30-minute walk in an urban area increased negative feelings, including enhanced anger and sadness, fear arousal, breath acceleration, and reduced attention, happiness, and friendliness (ZIPERS´ reports). The experience in nature, on the other hand, increased positive feelings, making subjects feel more affectionate and pleased, less worried, and willing to continue the experience (Table 1). We did not find differences between self-reports taken before either of the experiences, indicating that subjects were in similar emotional states before being subjected to each treatment (Table 1).

Table 1. Summary of ZIPERS´ reports before and after each treatment (30-minute walk in urban and natural settings). The numbers on the table are the p values found for each item, using Fisher´s exact test. Statistical differences are in bold, and the arithmetical sign indicates changes in mood reports for more positive (+) or negative (-) feelings (i.e. the increase in positive or negative feelings). We included results for urban and nature before walks for check for differences in the subject's mood before the test.

Item	Statement	Treatments: Urban before vs. after	Treatments: Nature before vs. after	Treatments: Urban before vs. Nature before
1	My heart was beating fast	0.107	0.172	1
2	I was breathing fast	**0.015 (-)**	0.12	0.85
3	I felt angry or defiant	**<0.001 (-)**	1	0.145
4	I felt fearful	**<0.001 (-)**	0.263	0.672
5	I felt sad	**0.004 (-)**	0.434	0.374
6	I felt carefree or playful	0.265	**0.002 (+)**	0.783
7	I felt affectionate or warmhearted	0.095	**0.025 (+)**	0.264
8	I felt elated or pleased	**0.001 (-)**	**<0.001 (+)**	0.053
9	I felt attentive or concentrated	**0.003 (-)**	0.062	0.753
10	I felt like acting friendly or affectionate	**<0.001 (-)**	0.141	1
11	I felt like hurting or "telling off" someone	**<0.001 (-)**	1	0.492
12	I felt like getting out of this situation or avoiding it	**<0.001 (-)**	0.803	0.852
13	I felt like getting further into this situation and completing it	**<0.001 (-)**	**0.011 (+)**	0.549

Based on the self-reported overall happiness (OHS), subjects were in similar self-reported happiness before the urban or nature experiences (z value = 1.161, p = 0.246), but their happiness decreased after the urban experience (z value = -5.194; p < 0.001), and increased after the nature experience (z value = 9.053; p < 0.001) (Figure 2A).

The urban and nature walk did not result in changes in BDST performances (z value = 0.48, p = 0.63; z value = 1.68, p = 0.09, respectively). Despite an apparent increasement in BDST performance post-walk at natural trail (Figure 2B), we did not find differences in subject performances before experiences in both environments (z value = 0.346, p = 0.729) (Figure 2B). The NCPCT count decreased after nature experience (t value = 2.055, p = 0.04) (Figure 2C), suggesting attention improvement by the subjects.

DISCUSSION

We showed that experience in a natural environment, even if for a short period, improved the perception of happiness of our subjects, highlighting the beneficial effects of contact with nature. Although studies linking nature contact and well-being are becoming more frequent, few of them have taken the same subjects to natural and urban environments to test their hypotheses (Mayer *et al.* 2009). Although responses produced by the same subject for different treatments can be understood as pseudoreplication, findings produced by the same subject can minimize idiosyncratic effects circumstantially produced on the results. Our statistical approach, considering the subject identity as a random effect, reduces pseudoreplication concerns.

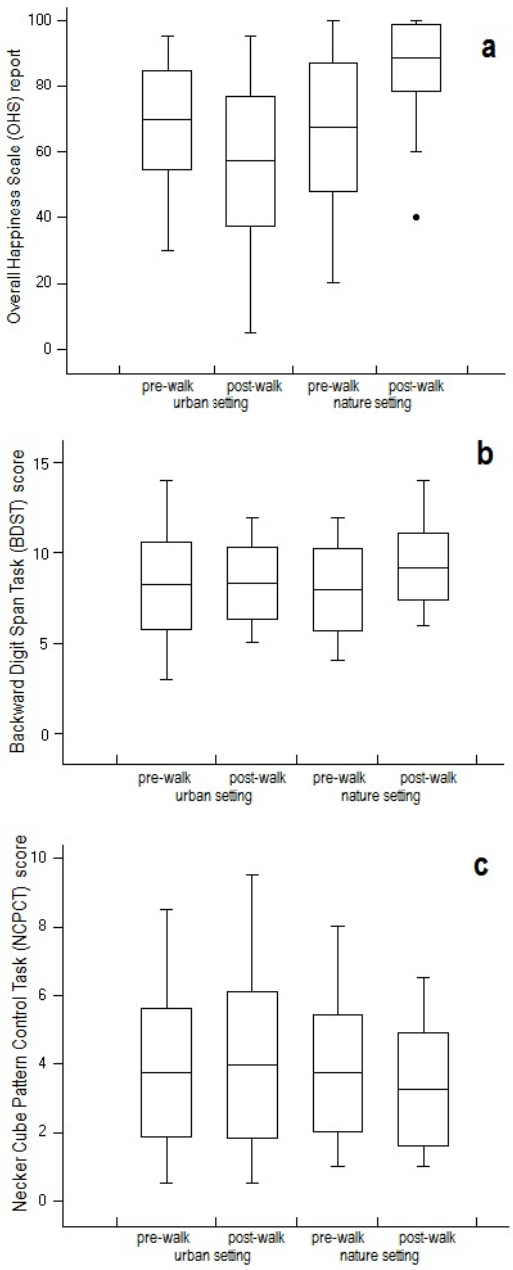

Figure 2. Box-plot showing means, standard deviation and range of pooled subjects´ performances in (A) Overall Happiness Scale; (B) Backward Digit Span Task, and (C) Necker Cube Pattern Control Task, before and after a 30-minute walk in urban and natural environments.

The exposure to urban and natural environments caused differences in the perception of subjects. Subjects not only reported improvements in their positive feelings after walking in nature but also had more negative feelings after the urban walk. Previous studies also reported similar results, showing an enhancement of positive affects after exposure to natural environments, and a negative or unresponsive effect after an urban experience (Hartig *et al.* 2003, Mayer *et al.* 2009, Bratman *et al.* 2015).

We also found differences in subjects' reports on the OHS, which increased after the natural setting and decreased after the urban walk. Hartig *et al.* (2003) did not find a significant effect of the environment on the OHS reported during their experiment, but they observed an enhancement in self-reported happiness in the natural setting for a group that had not previously been exposed to a task aiming to cause fatigue. Although we used a fast fatigue-inducing task (Stroop test), not used by Hartig *et al.* (2003), we found a significant increase in subjects´ perceived happiness in the natural setting. Evaluating how fatigue influences emotional states might help to understand these psychological reactions. Short contact with the natural environment improved the emotional state of our subjects, despite the fatigue-inducing task. Interestingly, we observed not only an enhancement in positive affect in nature but also a decrease in positive feelings and an increase in negative feelings in the urban setting (Table 1).

Berman *et al.* (2008), using BDST test scores observed improvements in subjects' performances after a natural environment exposure in comparison with exposure to urban settings (1.5 digits vs. 0.5 digits, respectively). In our study, we found an improvement of 1.2 digits after the natural treatment and 0.09 digits after the urban treatment, but these differences were not significant. We found no effects associated with the order of the experiences (no differences between the two groups), suggesting that the reported performance improvement went beyond the simple repetition of the task. We believe that the BDST could be more enlightening if the scores corresponded to the complexity of the number. That is, higher scores should be given for numbers with more digits. Another possibility is to evaluate the effects during short exposures, revealing, in more detail, what happens psychologically to subjects in different treatments. On the other hand, a solitary experience could still be more beneficial. The presence of a researcher and the repetition of tests might affect the quality of the experience.

Our results (cognitive and emotional benefits from exposure to a natural environment) support both the main theoretical explanations. ART predicts an attentional restoration in natural settings, leading to better cognitive skills, while SRT predicts an emotional and physiological improvement. Even though we did not include physiological measures, our study showed enhanced emotional well-being after the natural treatment, and a decreased one in the urban treatment.

There is an implicit sense that nature is beneficial due to restoration, without the acknowledgment that it can be beneficial for several other reasons (as an improved immunological response), beyond recovering from stress and attentional fatigue (Mayer *et al.* 2009, Sandifer *et al.* 2015). Greenspaces have a multifaceted potential to influence health (Lachowycz & Jones 2013). In our daily lives in urban environments, we are subject to several stressful situations (as annoying noises, crowding spaces, pollution), and we need alternative options that allow for mental and emotional recovery. Nature exposure is a low cost and democratic well-being source, strongly contributing to general health improvement.

How people manage their natural resources and how changes in their availability and land use affect human behavior are some of the central concerns of Conservation Biology (McNeely *et al.* 1990). If biodiversity or nature experiences promote mental health and well-being, or if they have a role in the prevention and treatment of psychological disorders, the link between nature with cognitive health and emotional well-being can contribute to nature conservation and public health-related policies, with relevant economic value and significance to society (Bratman *et al.* 2012, Clark *et al.* 2014, Sandifer *et al.* 2015). This role should be understood as a discrete ecosystem service, deserving of implementation and monitoring frameworks. This insight can help achieve the goals of the modern Conservation Biology, incorporating not only Biological/Ecological issues but also social fields, such as Environmental Psychology, Sociology, Ethics, Economy, Public Health, among others (Kareiva & Marvier 2012).

CONCLUSION

Beyond the obvious role in providing natural resources, nature is essential to human health and well-being. Enhancing human contact with natural areas can improve the quality of life of both people and ecosystems (Hansen-Ketchum *et al.* 2001, Sandifer *et al.* 2015), given that psychological benefits are positively related to biodiversity complexity (Fuller *et al.* 2007).

Both public health and conservation science require a better understanding of the role of nature in human health and well-being (Lovell *et al.* 2014, Sandifer *et al.* 2015). The recognition of this role as an ecosystem service by policy-makers and common people in different countries will enhance nature valuation and appreciation, becoming a strong argument and leading to new public policy for nature conservation and public health (Ford *et al.* 2015).

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