Virtual Nature: A Psychologically Beneficial Experience

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Abstract. This study sought to determine which, if any, of the benefits conferred by experiences in nature are conferred by an equivalent Virtual Reality (VR) experience. To this end, previous VR users were immersed in a virtual forest environment. Post-immersion, participants were measured on a variety of metrics including stress level, relaxation level, and directed attention abilities – metrics that have been shown to be significantly modulated by exposure to physical nature. Our results indicate that experiences in virtual nature afford much the same psychological benefits of exposure to physical nature, but they did not show the same kinds of attentional benefits. Experiencing nature in VR significantly decreased self-reported anxiety levels.

Keywords: Virtual Reality · Nature · Directed attention · Stress reduction · Immersive environments · Attentional fatigue

1 Introduction

Virtual Reality (VR), as implied in the name, immerses users in digitally created or captured environments. Enthusiastically embraced by the world of gaming, entertainment, and marketing, the relationship between "really real" and "virtually real" experiences is not yet fully understood. In addition, ethnographic research has found that non-gamer consumers were interested in VR, but they struggle to see the benefits of this technology (Sherman 2016). Aside from being "cool," what can VR really accomplish?

Experimentation and literature exploring the relationship between virtual and physical reality offerings is growing, and largely divides into three bodies of work. One body of work explores psycho-social aspects of VR and addresses how VR and similar technologies can be used to change users' social attitudes by placing them in new kinds of virtual social roles, physical bodies, or exposing them to immersive documentary material (Maister et al. 2013; Maister et al. 2015; Peck et al. 2013; Tettegah et al. 2006). A second body of work explores the cognitive relationship between virtual and physical realities with a primary focus on spatial cognition (Bohil et al. 2011). Finally, an emerging third body of work documents psycho-therapeutic benefits enabled by VR. Experiments have looked at the uses of VR for treating mental health, phantom limbs, chronic pain, Alzheimers, and even remapping for neuromuscular pathways of paralyzed patients (Lugrin et al. 2016; Serino et al. 2017; Tsirlin et al. 2009). This study contributes

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to the latter two bodies of work by exploring the extent to which exposure to nature in VR mirrors the well-documented effects of being in nature in the physical world.

A plethora of studies document the beneficial effects of human exposure to nature. Many of these studies have focused on the psychological benefits, including increased relaxation and diminished stress and anxiety levels (Ulrich et al. 1991; Brown et al. 2013; Keniger et al. 2013; Tennessen and Cimprich 1995). Nature has been shown to significantly decrease stress according to many measures: whether qualitative or quantitative, biometric or participantive (Keniger et al. 2013). In a thorough review of the nature literature, Keniger et al. also noted that many studies demonstrated increased academic performance, increased ability to perform mentally challenging tasks, decreased mental fatigue, and increased attentional resources (Herzog et al. 1997; Keniger et al. 2013; Taylor et al. 2002; Berman et al. 2012; Cimprich et al. 1992).

Such research has led to the “Attentional Restoration Theory” (ART). The basis of this theory is that nature relieves one’s focusing overload, thus restoring directed attention, which is used to perform highly-focused and detail-oriented tasks, such as proof-reading (Herzog et al. 1997; Atchley et al. 2012). Certain experiences replenish one’s ability to perform these highly-attentive tasks. The underlying cause of such restoration is involuntary fascination, by which an individual’s attention is naturally– rather than consciously– directed. Furthermore, environments that offer “soft” involuntary fascination, where one’s focus may wander (i.e. on a nature walk) are even more restorative than situations that evoke “hard” involuntary fascination, where one’s focus is more specific (i.e. a racecar race). Neuroscientists suggest that soft involuntary fascination relieves the pre-frontal cortex, which is responsible for directing an individual’s attention (Herzog et al. 1997).

Indeed, Hartig et al. demonstrated that nature is particularly evocative of soft involuntary fascination, and also especially effective at attentional restoration. Participants were assigned to either urban, nature, or relaxing indoor environments. Participants’ self-reported levels of fascination with their surroundings were highest for the nature condition participants. The nature condition participants also scored the highest on a directed attention task (in this case, a proof-reading task), as ART would predict (Hartig et al. 1991).

Additionally, Tennessen and Cimprich showed that students who were simply placed in dorms with a nature view likewise scored higher on directed attention tasks than their non-nature-facing peers (Tennessen and Cimprich 1995). One of these tasks was the Necker Cube Pattern Control Task– or NCPCT– which sought to deduce student’s level of top-down control of bistable perception. In other words, students attempted to “hold” the amount of times that a bistable illusion flipped in their view.

Similarly, Atchley et al. demonstrated that four days of full nature immersion yields a full 50% increase in performance on creativity and problem-solving tasks, which utilize directed attention (2012). The question remained open: was this outcome spurred by the increase in exposure to nature or the decrease in exposure to technology? ART would predict that a technology-absent, nature-present environment would improve attention relative to a technology-absent, nature-absent environment. What about a technology-present, nature-present environment? The present study directly addresses this case by incorporating nature within a technological experience.

2 Methods

In previous literature on the effects of nature, participants were (a) exposed to a stressful experience, surveyed about their mood, immersed in nature, and then asked about their mood again or (b) immersed in nature and then given directed attention tests, the results of which were compared to participants who were not immersed in nature. This study replicated such methodologies.

We controlled for experience with VR; all participants were first-time users of VR. Additionally, we controlled for gender: half of our participants were female, while the other half were male. Similarly, all participants were in the same age range: between 18–25 years old. Lastly, we controlled for general technological experience and daily exposure to screens: all participants were generally familiar with technology, and self-reported high levels of comfortability using devices such as smartphones and computers. All participants held day jobs that consisted of 5+ h of screen time; in this way, we sought to control for daily levels of screen exposure across participants.

First, participants were subjected to a "stressful experience" intended to mimic equivalent experiences utilized in previous studies that examined the effect of nature on the psyche. In many of these psychological experiences, "It Didn't Have to Happen," a workshop safety video, was used to induce stress. We used a modern version that depicts driver safety, which we believed to be more relevant to our participants.

After this stressor, an 8-question survey was administered. Utilizing a Leickert scale, participants were asked to indicate how stressed, happy, busy, relaxed, tired, and anxious they felt, among other questions. We clarified that the participants should answer the questions on the basis of "how they are feeling today," rather than basing their answers on how the video clip made them feel. It is important to note that we were primarily interested in participants' relaxation and anxiety levels, and the other self-report measures (e.g. happiness, business, tiredness, etc.) acted as distractor measures.

Next, participants in the experimental condition were fitted with an HTC Vive headset. Using SteamVR, NatureTreks VR was launched. In NatureTreks VR, participants are able to explore a natural VR environment via armswinger locomotion; thus, they progress through the natural experience in a simulation that feels as if one is walking. We limited the participants' options to five specific environments, all of which resembled forest-like landscapes so as to ensure the level of foliage and greenery touted in previous nature studies. Amongst these five options, we allowed participants to choose the experience that most interested them. The primary difference between the experiences was time of day: some experiences occurred at dawn, others during the daytime, and others at sunset.

During this phase, control participants read simple, short biographies on a computer screen indoors. The reading task and VR task were planned so as to occupy the same length of time and the same physical location. In both situations, the participants were looking at a screen, albeit at different distances.

After the experimental or control experience, participants were administered the same set of qualitative questions about their mood and stress levels. Again, the participants were instructed to indicate how they were feeling "today," such that the answers would be expected to be identical, unless a large shift had occurred. The participants responded to each question using a Leickert scale, and the questions were re-ordered to reduce memory effects.

Finally, participants were given a battery of directed attention tests. First, participants completed the Necker Cube Pattern Control Task (NCPCT). Participants received a blank sheet with a line drawing of a three-dimensional cube. They were told that their perspective of the cube would shift, with the front and back faces of the cube reversing their relative positions. Once they familiarized themselves with this property of the Necker cube, they were instructed to look at the cube and tap audibly on a hard surface when the pattern reversed. We counted the number of reversals that occurred during two consecutive 30-s "hold" periods during which the participant was to focus on one pattern for as long as possible. Reversals that occur despite the effort to hold a pattern are thought to be due to attentional fatigue (Kaplan 1995). We used the average number of reversals across the two hold periods as a dependent variable in our analyses (cf. Tennessen and Cimprich 1995). The NCPCT has been shown in previous studies to be a sensitive measure of restored attention due to natural environments (Cimprich 1993; Tennessen and Cimprich 1995).

Next, participants engaged in a Backward Digit Span task. The participants were given series of numbers, asked to hold them in their memory, and then instructed to repeat the numbers aloud in reverse order. The series of numbers increased in length and difficulty as the task continued. We recorded the maximum digit span that participants were able to correctly repeat, as well as their accuracy level across numerical series of all lengths. This task involves active attention to retain the numbers in working memory and directed modification of memory in order to reverse the order of the numbers upon recall. Therefore, it fits well within a battery of highly-focused directed attention tasks.

Finally, participants were given a Remote Association Test, as created by Bowden & Beeden. Participants were given a multitude of triplets of words and asked to find the linking word amongst as many triplets as possible. This linking word, for example, would be "cheese" for "cottage, swiss, cake;" it is the one word that can be cohesively added to the beginning or end of each word in the triplet. We recorded the number of triplets that each participant was able to accurately complete in a two-minute timespan. Across participants, the triplet prompts and task length were kept constant.

3 Results

3.1 Psychological Effects

Data analyses indicate a significant decrease in anxiety ratings for experimental participants– those who had been immersed in virtual nature– compared to control participants, who completed a reading task. We performed a one-way ANOVA between experimental and control groups' change in anxiety pre-to-post task (Δ anxiety). The results demonstrated a significant effect of the VR experience as compared with the control experience: $F(1, 8) = 7.0$, $p = 0.0294$ (Fig. 1).

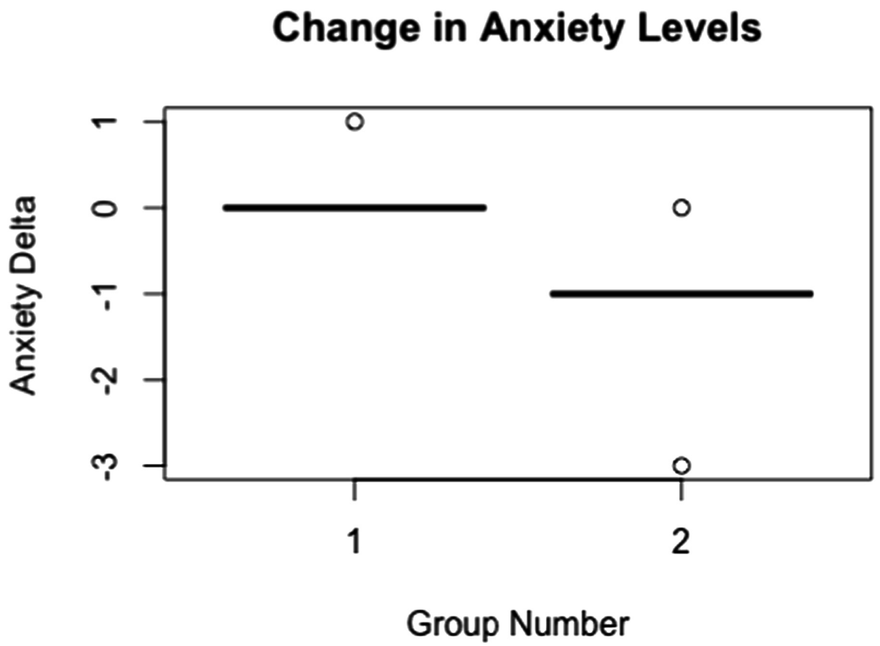

Fig. 1. This graph shows the anxiety level delta for both groups. Group 1 is the control group, who completed a reading task. Group 2 is the experimental group, who participated in a Virtual Reality nature experience. The anxiety level delta (on the y-axis) represents the difference between participants self-reported anxiety levels before and after their experience: either reading or being in VR. As demonstrated, participants who experienced virtual nature experienced a significant decrease in anxiety.

Surprisingly, the data did not show a significant change in relaxation levels between experimental and control participants. A one-way ANOVA between experimental and control groups' change in relaxation levels demonstrated an insignificant effect of the VR experience as compared with the control experience: $F(1, 8) = 0.615$, $p = 0.455$ (Fig. 2).

Participants' self-response ratings of their happiness, business, and tiredness showed no effect of the experience. As expected, these distractor measures were unchanged, in contrast to the change in anxiety for experimental participants.

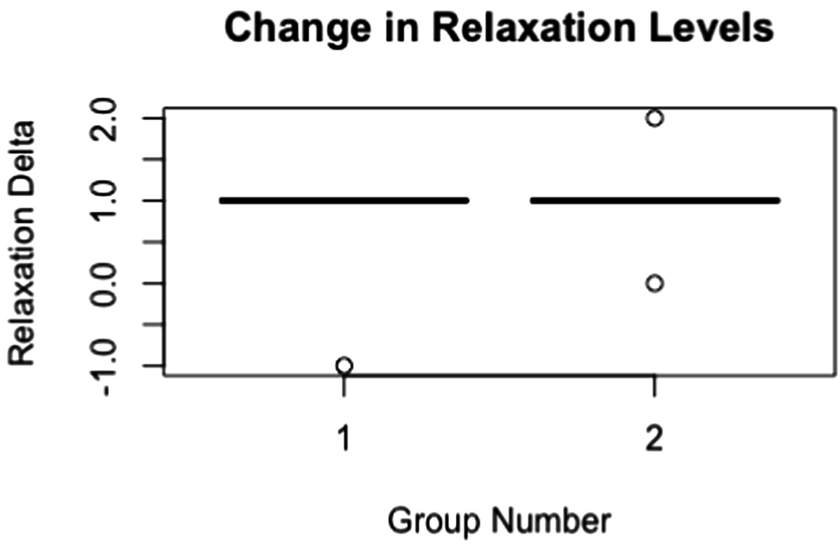

Fig. 2. This graph shows participants' changes in relaxation before and after the experiment. Group 1 represents the control group, whose experience included reading biographies on a screen; Group 2 represents the experimental group, who participated in a Virtual Reality nature experience. The relaxation delta (on the y-axis) indicates the participants' change in relaxation levels before and after their experience. As demonstrated, participants in both groups experienced an increase in relaxation, without a significant difference between groups.

3.2 Directed Attention Effects

Additionally, there were negligible differences in success between experimental and control participants on all three directed attention tasks. In fact, for one task, control participants outperformed experimental participants, albeit by an insignificant margin.

For the Necker Cube Pattern Control Task (NCPCT), a one-way ANOVA between the experimental and control groups' respective "number of flips" during a 30-s top-down "hold" period revealed an insignificant effect of group: $F(1,8) = 0.435, p = 0.528$.

Within the digit span task, there were not significant results for either the digit span achieved or for the digit accuracy achieved. A one-way ANOVA between the experimental and control groups' respective "digits missed" during the digit span task revealed an insignificant effect: $F(1,8) = 0.021$, $p = 0.89$. Similarly, a one-way ANOVA between the experimental and control groups' respective "maximum digit span" revealed a whoppingly insignificant effect: $F(1,8) = 0$, $p = 0.1$. As shown in the plot below, the two groups performed nearly identically on this task (Fig. 3).

Lastly, a one-way ANOVA between experimental and control groups' performance on the Remote Association Test, measured by the number of triplets correctly completed, showed an insignificant effect of group: $F(1,8) = 0.036, p = 0.854$. According to this data, it is clear that none of the directed attention tasks showed an effect of group.

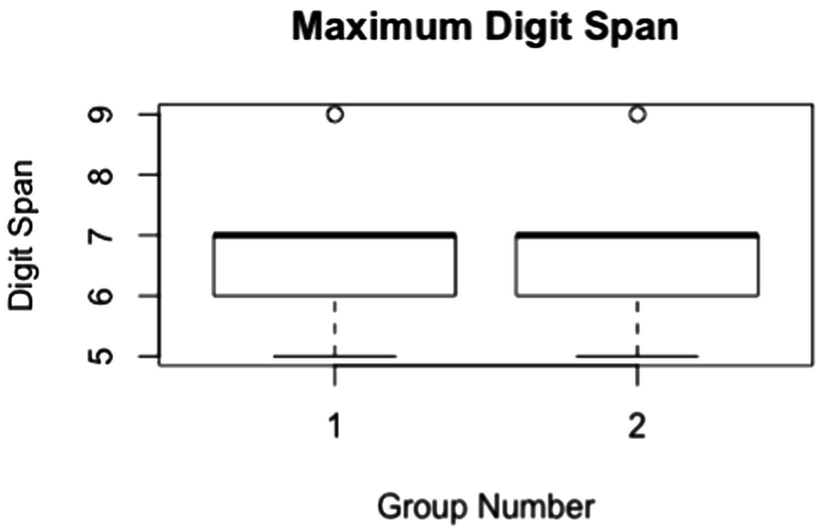

Fig. 3. This graph represents the maximum number of numerical digits that participants were able to hold in active memory and subsequently recite. Group 1 represents participants in the control group, who read biographies on a screen. Group 2 represents the experimental participants, who participated in a Virtual Reality nature experience. As represented by this graph, the two groups performed quite similarly on this task: that is, there were able to remember similar amounts of numerical digits after their respective experiences.

4 Discussion

This study shows that virtual nature reduced anxiety in a way that mirrors exposure to physical nature. However, unlike exposure to physical nature, the VR nature experience did not produce the attentional restoration that others have observed after exposure to physical nature.

This presence of one set of benefits (reduced anxiety levels) and the absence of the other (increased attentional resources) is surprising and somewhat puzzling. It raises a series of questions as to why this is so, and indeed raises questions about what facets of physical nature effectively restore attention. Is it that the novelty of VR promotes “hard” rather than “soft” fascination? Could current VR display technologies, known to induce visual fatigue, be at fault? Would light field or other technologies that more closely mimic physiological properties of spatial vision enable the attentional benefits of nature in VR? Are the attentional tests themselves part of the problem; would attentional tasks less dependent on a visual system potentially taxed by compensatory processes induced by current VR display technologies show different results? Or perhaps the answer lies in other sensory or cognitive aspects of being in physical nature– perhaps UV spectrum, wind, or smell contribute to attentional improvement. Further, it may be the case that mindful recognition of the vastness of nature in comparison to the smallness of one’s individual existence enhances fascination levels, which in turn restore attentional capacity. Certainly, the results of this study suggest that further research is needed to fully understand the relationship between nature and attentional restoration, as well as how virtual experiences relate to physical experiences.

It is particularly interesting that– while anxiety levels significantly decreased for those in the experimental condition– relaxation levels were not different across the two groups. In previous experiments on the psychological benefits of nature, reduced anxiety levels co-varied with increased relaxation levels. Perhaps this fine-tuned difference is informative in and of itself: though nature maintains its anxiety-reducing abilities in VR, it loses its soft, calming effect. This may contribute both to the lack of relaxation effects as well as to the lack of soft fascination, which subsequently contributes to the minimal attentional restoration found in this study.

Here, it is important to note a limitation of our research: as mentioned previously, all participants were new to VR. It is likely, therefore, that they were eagerly adjusting to their new environment. As they explored their new perceptual space, it is quite possible that they were excited. Excitement would certainly diminish relaxation levels and could lead to "hard" fascination, rather than the requisite soft fascination necessary for attentional restoration. A future study with avid VR users may address this discrepancy.

Such limitations aside, this study clearly demonstrates that virtual nature carries one of the most substantial benefits of physical nature: anxiety reduction. In a world of increasing urban density and development, immersion in nature can be challenging at best, involving significant investments in time and access to transportation resources. In addition, there are many for whom physical mobility is a considerable challenge. For those with limited access to nature, whether due to time, money, or physical limitation, the benefits of accessing nature in VR could be a significant benefit. Even for those with greater access, the immediacy of VR is an advantage. Simple 10-min sessions of immersion in virtual forests at work, at home, or clinical settings could be used to effectively and reliably reduce anxiety.

References

Atchley, R.A., Strayer, D.L., Atchley, P.: Creativity in the wild: improving creative reasoning through immersion in natural settings. PLoS ONE **7**(12), e51474 (2012)

Berman, M.G., Jonides, J., Kaplan, S.: The cognitive benefits of interacting with nature. Psychol. Sci. **19**(12), 1207–1212 (2008)

Berman, M.G., et al.: Interacting with nature improves cognition and affect for individuals with depression. J. Affect. Disord. **140**(3), 300–305 (2012)

Bohil, C.J., Alicea, B., Biocca, F.A.: Virtual reality in neuroscience research and therapy. Nat. Rev. Neurosci. **12**(12), 752–762 (2011)

Bratman, G.N., Hamilton, J.P., Hahn, K.S., Daily, G.C., Gross, J.J.: Nature experience reduces rumination and subgenual prefrontal cortex activation. Proc. Natl. Acad. Sci. **112**(28), 8567–8572 (2015)

Brown, D.K., Barton, J.L., Gladwell, V.F.: Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress. Environ. Sci. Technol. **47**(11), 5562–5569 (2013)

Cimprich, B.: Attentional fatigue following breast cancer surgery. Res. Nurs. Health **15**(3), 199–207 (1992)

Cimprich, B.: Development of an intervention to restore attention in cancer patients. Cancer Nurs. **16**(2), 83–92 (1993)

Faber Taylor, A., Kuo, F.E.: Children with attention deficits concentrate better after walk in the park. J. Atten. Disord. **12**(5), 402–409 (2009)

Hartig, T., Mang, M., Evans, G.W.: Restorative effects of natural environment experiences. Environ. Behav. **23**(1), 3–26 (1991)

Hartig, T., Mitchell, R., De Vries, S., Frumkin, H.: Nature and health. Annu. Rev. Public Health **35**, 207–228 (2014)

Herzog, T.R., Black, A.M., Fountaine, K.A., Knotts, D.J.: Reflection and attentional recovery as distinctive benefits of restorative environments. J. Environ. Psychol. **17**(2), 165–170 (1997)

Kaplan, S.: The restorative environment: nature and human experience. In: Role of Horticulture in Human Well-Being and Social Development: A National Symposium, pp. 134–142. Timber Press, Arlington (1992)

Kaplan, R.: The nature of the view from home: psychological benefits. Environ. Behav. **33**(4), 507–542 (2001)

Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A.: What are the benefits of interacting with nature? Int. J. Environ. Res. Public Health **10**(3), 913–935 (2013)

Lugrin, J.L., Polyschev, I., Roth, D., Latoschik, M.E.: Avatar anthropomorphism and acrophobia. In: Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology, pp. 315–316. ACM, November 2016

Maister, L., Sebanz, N., Knoblich, G., Tsakiris, M.: Experiencing ownership over a dark-skinned body reduces implicit racial bias. Cognition **128**(2), 170–178 (2013)

Maister, L., Slater, M., Sanchez-Vives, M.V., Tsakiris, M.: Changing bodies changes minds: owning another body affects social cognition. Trends Cogn. Sci. **19**(1), 6–12 (2015)

Peck, T.C., Seinfeld, S., Aglioti, S.M., Slater, M.: Putting yourself in the skin of a black avatar reduces implicit racial bias. Conscious. Cogn. **22**(3), 779–787 (2013)

Serino, S., et al.: A novel virtual reality-based training protocol for the enhancement of the "Mental Frame Syncing" in individuals with alzheimer's disease: a development-of-concept trial. Front. Aging Neurosci. **9**, 240 (2017)

Tennessen, C.M., Cimprich, B.: Views to nature: effects on attention. J. Environ. Psychol. **15**(1), 77–85 (1995)

Tettegah, S., Taylor, K., Whang, E.W., Meistninkas, S., Chamot, R.: Can virtual reality simulations be used as a research tool to study empathy, problems solving and perspective taking of educators?: Theory, method and application. In: ACM SIGGRAPH 2006 Educators Program, p. 35. ACM, July 2006

Tsirlin, I., Dupierrix, E., Chokron, S., Coquillart, S., Ohlmann, T.: Uses of virtual reality for diagnosis, rehabilitation and study of unilateral spatial neglect: review and analysis. Cyberpsychol. Behav. **12**(2), 175–181 (2009)

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A., Zelson, M.: Stress recovery during exposure to natural and urban environments. J. Environ. Psychol. **11**(3), 201–230 (1991)

White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H.: Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. Psychol. Sci. **24**(6), 920–928 (2013)