PhD defence: Matt P. Stevenson

Green Matter: How exposure to natural environments improves cognitive functioning in children with and without Attention Deficit/Hyperactivity Disorder

Friday 18 January 2019 at 13:00 in the auditorium

Forest and Landscape College

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SUMMARY

Modern childhoods are associated with high technology use and urbanisation. These trends may be associated with higher levels of cognitive fatigue due to the increasing amount of attention-grabbing stimuli present in a child's life. Previous research has demonstrated that prolonged exposure to urban environments may be detrimental to mental health, while exposure to natural environments may promote mental health and support cognitive development.

Attention Restoration Theory (ART) proposes that natural environments support cognitive functioning by inducing a period of restoration that is necessary for overcoming the effects of mental fatigue. ART proposes that the restoration process is fostered by the activation of an effortless form of attention that is evoked by the intrinsically fascinating stimuli found within natural environments. Environments may be particularly restorative when they also evoke a sense of being away or separated from cognitively fatiguing situations; are extensive enough to offer a rich experience; and are compatible with the individual's desires and goals. The restoration effect seems to be well-supported by evidence involving primarily adult participants. However, studies of the effect in children are rare. Therefore, the current thesis aimed to investigate how natural environments influence the cognitive processes of children with and without attention deficit/hyperactivity disorder (ADHD).

In Article I, a systematic review and meta-analysis is presented that revealed a sharp increase in the number of studies exploring the restoration effect in recent years. However, there was a marked absence of publications involving children. Random-effects meta-analyses were performed to calculate pooled mean effect size estimates for eight cognitive domains covered in the literature. Results showed that working memory (Hedges' $g = 0.162$), cognitive flexibility (Hedges' $g = 0.317$), and to a less-reliable degree, attentional control (Hedges' $g = 0.156$) were improved after exposure to natural environments or natural stimuli. Moderator analyses found that effect sizes were significantly larger when participants were exposed to actual environments, rather than virtual environments; however, this may also be explained by the typical durations of the two exposure types. The moderating effect of restoration potential, such as fatigue induction, was less clear. A framework is proposed from which future researchers can quality the involvement of directed attention during cognitive tasks in an attempt to move towards a more homogenous evidence base using relevant outcome measures.

To extend the limited research in children, a semi-randomised crossover trial is presented in Article II that explored the effect of exposure to a natural environment on the cognitive performance of Danish school children, using the Attention Network Task (ANT). 33 participants (m = 12.03 years) were recruited to perform the ANT before and after a 30-minute walk in a natural and built environment. Cognitive fatigue was induced prior to baseline measurements to compare the restoration effects associated with the two environments. Linear-mixed models (LMMs) revealed a significant improvement in stability of performance and response speed after exposure to the natural environment, but not directed attention ability. This pattern of results contradicts adult data derived from the same task that showed a restoration effect specific to directed attention. However, the results were in line with a recent natural experiment that suggested children may benefit from natural environments through different mechanisms than adults, based on divergent results on the ANT. Performance stability is more likely to be maintained by self-regulatory processes, such as effort allocation, rather than cognitive mechanisms such as directing attention. This suggests that cognitive resources related to self-regulation may be particularly sensitive to the restoration effect in children. Additionally, an explorative sub-study using mobile eye-tracking glasses revealed that children fixated more often while walking in the natural environment compared to the built environment. This finding may reflect greater visual exploration of the natural environment due to heightened fascination or an increased ease in shifting visual attention while perceiving the environment.

To assess the clinical relevance of the restoration effect, a double-blinded, placebo-controlled, randomised, two-by-two crossover trial is presented in Article III that compared the effects of 30-minute walks in a natural environment (natural versus built) with a dose of medication (medication versus placebo) on performance of the ANT in children with ADHD. LMMs revealed no significant improvements in performance due to exposure to the natural environment; however, there were significant main effects of medication on response speed, stability of performance, and accuracy. The interaction of environment and medication was significant for accuracy; however, contrary to the hypothesis, the treatment combination of medication and built environment was associated with higher accuracy. Post-hoc power analysis suggested that comparing the effects of medication and environment within the same study may be problematic.

Finally, a theoretical extension of ART is presented in Article IV that was devised to align current accounts of the restoration effect with the existing evidence base that was described and contributed to in the thesis. The cognitive-energetic model of restoration (CEM-R) was inspired by Sanders' (1983) original cognitive-energetic model and was based on evidence that suggests both executive functioning and self-regulatory processes are sensitive to the restoration effect, while stress recovery is also likely to play a role. The CEM-R puts specific emphasis on energetic factors,

effort and arousal, to explain the restoration effect, particularly for outcome measures that require self-regulation. It is proposed that the CEM-R may be particularly suitable for describing the restoration effect in children.

In summary, the work presented in the current thesis contributes to the knowledge gap regarding the restorative effect natural environments have on children's cognitive processes. Specifically, it appears that children can benefit from acute exposure to natural environments; however, they may do so through mechanisms distinct to their stage of cognitive development. Whether cognitive resources related to self-regulation play a more central in restoration effect in children remains tentative but presents a viable hypothesis for future studies comparing children and adults. The restoration effect was not demonstrated in children with ADHD; however, a better understanding of the effect, using the knowledge presented in this thesis, may lead to more reliable studies involving this participant group in the future. Based on the relatively few well-conducted studies investigating how natural environments affect children's cognition, recommendations for practice and policy should await further verification. However, interventions involving lifestyle choices, such as the use of natural environments, present intriguing avenues for future initiatives in the fields of education and mental health. Such initiatives may serve as a buffer against the fatiguing effects of urbanisation and technology use associated with modern childhoods.