

Brain capital, ecological development and sustainable environments

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ABSTRACT

The importance of improving brain and mental health and developing sustainable environments is increasingly recognised. Understanding the syndemic interactions between these processes can help address contemporary societal challenges and foster global innovation. Here, we propose a green brain capital model that integrates environmental drivers of brain health and green skills necessary for long-term sustainability and discuss the role of interdisciplinary approaches in promoting individual and collective behavioural changes. We draw on existing literature and research to highlight the connections between brain health, environmental factors and green skills. Environmental factors and exposome can have long-lasting adverse effects on brain health, particularly in vulnerable populations. Investing in green brain capital can prepare societies to address global crises. Green skills, including creativity, ecological intelligence and digital literacy, are critical for promoting sustainable environments. Access to nature improves brain and mental health, and interdisciplinary fields such as neurourbanism can inform urban planning to benefit citizens' well-being. Building brain capital and environmental sustainability interactions requires increasing future generations' awareness, education and training. A comprehensive approach to green brain capital can enable greater societal scaling, synergistically protecting brain health and environmental sustainability.

TIME TO BRING TOGETHER BRAIN AND ENVIRONMENTAL HEALTH

Improving mental health and developing sustainable environments are perhaps two of the most crucial revolutions required to foster the future of humankind. The syndemic interactions of these two processes are usually not well appreciated. Moreover, the links between mental health and brain health are pervasive,¹ despite the scientific literature not usually integrating them. In turn, both psychiatric and neurological disorders are affected by different environmental exposures across the lifespan (or exposome²), from pollution of social determinants of health and socioeconomic disparities.^{1–3} We offer a model (figure 1) of green brain capital that could improve brain and mental health through a sustainability-focused strategy, taking into account both the environmental drivers of brain health and the green skills necessary for long-term sustainability.

According to the WHO,⁴ brain health is the state of brain functioning that allows individuals to realise their full cognitive, sensory, social-emotional, behavioural and motor potential. Brain

health is a determinant of mental and neurological disorders.⁵ A transformational framework called brain capital combines information, skills, competencies and tools to recognise brain health and skills as key factors in the modern knowledge economy.⁶ How can the brain capital framework help develop a more integrated framework with environmental health? Here, we suggest that syndemic models of brain/environmental health and green brain capital represent two complementary avenues to enable a significant societal scaling, synergistically protecting brain health and ecological sustainability.

HOW ENVIRONMENT IMPACTS BRAIN HEALTH

The connection between the environment and brain health is becoming more widely understood, with the environment posing direct socioenvironmental determinants of brain health that may have long-lasting negative effects, especially on populations with lower levels of resilience and coping mechanisms.⁷ These factors include the effects of environmental pollution on physical health, as well as the psychological effects of mass migration or disasters linked to the climate.

The exposome can be understood in term of both physical and social forces that externally impact health.² The current industrialised global food system, which affects human health by promoting poor diets that harm brain health, is a major cause of environmental pollution. The health of the environment is also harmed by environmental toxins and pollutants. Building materials and consumer products (phthalates, polychlorinated biphenyls) can have negative whole-body and brain health impacts, including cancer, and psychiatric, neurodevelopmental and neurological conditions. Pesticides and related chemicals that poison insects and mammals also have neurotoxic effects regarding chronic toxicity and even low-level exposure, especially in developing organisms. Brain health is adversely affected by the loss of microbial diversity in both individual and environmental settings. But these physical conditions are not the only environmental contributors to brain health. Socioeconomic disparities, including low socioeconomic status and negative social determinants of health, impact brain health and contribute to the development of cumulative burden of diseases like dementia.^{8–10} The negative impact of environmental and socioeconomic disparities can be observed in brain health diseases across levels including clinical severity, biomarkers, neurodegeneration, altered brain dynamics, heightened proteinopathy and allostatic overload.^{1–3 8–14}



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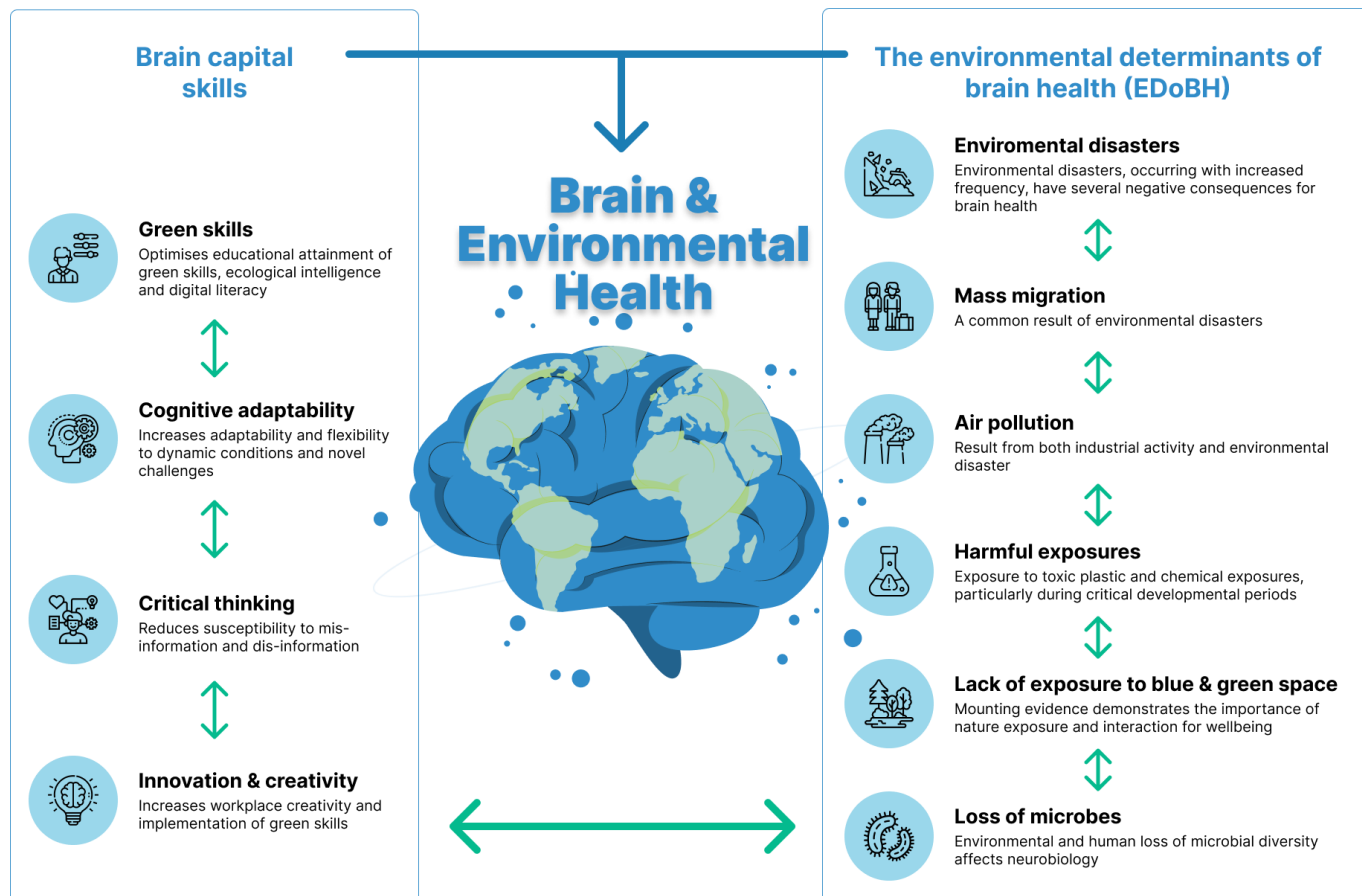


Figure 1 The green brain capital model. The figure highlights the interdependence of improving brain health and developing sustainable environments. The model emphasises the importance of a sustainability-focused strategy that considers both the environmental drivers of brain health and the necessary brain skills, particularly green skills that promote long-term sustainability. By prioritising sustainability, the model aims to enhance brain health and promote a healthier and more sustainable future. Green arrows represent bidirectional connections between subcomponents, and the blue arrow represents the combined influence of brain and environmental factors on health.

The field of environmental public health, which is rapidly expanding, offers opportunities for addressing the global, regional, national and local environmental factors that have an impact on human health.⁷ However, addressing these brain–environmental syndemics requires more holistic, systemic and complex models of health. The phenomena emerging from non-linear interactions between environmental and brain dynamism can be approached by synergetic models such as the renewed allostatic interoceptive overload.^{1–3 11 15 16} These models integrate different sources of exposomes and their impact on multiple physiopathological pathways that, in turn, modify neurocognitive processes associated with brain health and disease. These approaches provide a more ecological understanding of environment–body–brain interactions.

HOW THE GREEN BRAIN HEALTH IMPACTS ENVIRONMENT

Brain health also impacts environmental health. Investing in brain health, particularly green brain capital, may be vital to prepare societies to cope with uncertainty inherent in global crises. Current initiatives support a green brain capital model, include the mental health action as an integral part of climate response and a focus on the delivery of human and ecological well-being as part of modern development. Brain capital skills include abilities like cognitive flexibility, critical thinking and creativity, among others, that are necessary to thrive in a changing and uncertain world. To address contemporary societal

concerns and spur global innovation, it is essential to invest in strategies for increasing brain capital. An important step forward for programmes targeted at improving and preserving brain health should include a green component that takes into account how human activity affects the environment.

Green skills are the set of knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable, resource-efficient society and planetary ecosystem.¹⁷ The transition to a low-carbon, resource-efficient economy requires systemic changes, which involve individuals, institutions and whole societies that will result in not only innovations but also changes to production and consumption processes, policies and business models. Across these skills, three green mental skills are critical to favour sustainable environments. Promoting creativity at institutional levels can strategically boost urban and natural development. In addition to cities being efficient and fair, a creative city that provides places, experiences and opportunities to foster creativity among its citizens offers a unique alignment opportunity for cross-sector priorities, like the United Nations Sustainable Development Goals,¹⁸ through a common set of human factors identified by the World Economic Forum. Creative solutions to improve global climate targets and overcome challenges are critical to develop a sustainable planetary ecosystem. Ecological intelligence, the ability to understand the impact of behavioural change in the natural environment, allows to develop a healthier and sustainable lifestyle. Digital

literacy, or the ability to access, understand, communicate and create digital information safely and appropriately, is essential in an increasingly digitised world, especially to combat climate misinformation and disinformation. The European Union has developed a Digital Literacy Index in an attempt to measure and track such skills across the continent. These three combined green skills can help to nurture present and future generations of brain capital builders.

New disciplinary approaches are needed to account for individual and collective behavioural changes promoting creative, action-research and transdisciplinary solutions that protect the health of human and ecosystems. The brain health states determine the ability of key skills to flourish, and the presence of these skills affects the environmental conditions that determine brain health, creating a feedback loop.

CONCLUSION: A CALL TO SYNDEMIC ACTIONS

The green brain capital model highlights a symbiotic relationship between environmental and brain health, emphasising that sustainability-focused strategies improve both domains. Environmental influences, including pollution and socioeconomic disparities, impact brain health negatively, while a healthy brain, furnished with green skills, plays a crucial role in driving sustainability. Moreover, tackling brain–environment syndemics using systemic models will enhance societal resilience and long-term sustainability.

Brain health is important for the effective development of environmental sustainability, through the deployment of green skills. Conversely, interdisciplinary fields such as neurourbanism¹⁹ call for cross-sectional approaches to optimise the effects of the urban environment on citizens' brains. Access to nature, including green spaces, water features and proximity to living things, has been shown to improve brain and mental health.²⁰ Nature exposure can protect against mental strain and stress-related diseases, including age-related memory decline. Such findings can inform urban planning to create more accessible green areas and adapt urban environments to benefit citizens' mental health. Additionally, exposure to nature has been shown to benefit cognitive function and overall well-being, promoting motivation for climate action.

Building brain capital and environmental sustainability interactions requires an increase in the awareness, education and training of future generations. A comprehensive approach to building literacy includes not just sectoral skills but a transdisciplinary continuum from awareness to green brain health knowledge and skills. Engaging young people is important for envisioning the future, and we need to create programmes to train teachers to deliver content related to green brain capital. Enhancing public literacy of green brain capital can create the means to enable greater scaling across society. As human growth continues to increase, a focus on the interaction between nature capital and brain capital can inform strategic actions to synergistically protect both brain health and environmental sustainability.

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