

HOW CAN URBAN DESIGN PROMOTE NATURE CONNECTEDNESS? A CASE FOR PHYGITALIZATION

DANIEL PAIVA¹ 

RAQUEL MAIA² 

ABSTRACT – This study reviews current knowledge on the role that urban design plays in promoting nature connectedness and discusses the underexplored value of phygitalization for the reconnection of the urban population with nature. Promoting nature connectedness in the city matters, given that most human population lives in cities, and people who feel more connected with nature tend to draw more health benefits from it and are more supportive of nature conservation action. In this study, we analyze three distinct trends in discussions about the design of urban green space and its impact on nature connectedness among urban dwellers. Firstly, we highlight literature that is concerned with the relation between the spatial qualities of urban green space, namely its dimension, diversity, connectivity, and design style, and the intensity of nature contact among the urban population. Secondly, we review studies that draw attention to the impact of the sensory and affective qualities of urban nature sites in the perception and appreciation of natural biodiversity and the health benefits of nature, and the implications of such studies for urban design. Lastly, we draw attention to the growing number of experiments that apply extended reality and digital platforms to increase engagement with urban nature sites, and we discuss what this might mean in terms of promoting nature connectedness. We conclude the study by discussing the potential and limitations of phygitalizing urban nature sites.

Keywords: Urban design; nature connectedness; urban green space; digital geographies; phygitalization.

RESUMO – COMO PODE O DESENHO URBANO PROMOVER A LIGAÇÃO À NATUREZA? UM ARGUMENTO A FAVOR DA FIGITALIZAÇÃO. Este estudo revê o conhecimento atual sobre o papel que o desenho urbano desempenha na promoção da conexão com a natureza e discute o valor da figitalização para a reconexão da população urbana com a natureza. A promoção da conexão com a natureza na cidade é importante, dado que a maioria da população humana vive em cidades, e as pessoas que se sentem mais conectadas à natureza tendem a retirar dela mais benefícios de saúde e demonstrar mais apoio a ações de conservação da natureza. Aqui, analisamos três tendências distintas nas discussões sobre o desenho do espaço verde urbano e o seu impacto na conexão com a natureza. Primeiro, destacamos a literatura que se preocupa com a relação entre as qualidades espaciais do espaço verde urbano, nomeadamente a sua dimensão, diversidade, conectividade e estilo, e a intensidade do contacto com a natureza entre a população urbana. Segundo, revemos os estudos que chamam a atenção para o impacto das qualidades sensoriais do espaço verde urbano na percepção e apreciação da biodiversidade natural e dos benefícios da natureza para a saúde, e as implicações desses estudos para o desenho urbano. Terceiro, olhamos para o número crescente de experiências que aplicam a realidade estendida e plataformas digitais para aumentar o envolvimento com a natureza, e discutimos o que isto pode significar em termos de promoção da conexão com a natureza. Concluimos o estudo discutindo o potencial e as limitações da figitalização de espaços verdes urbanos.

Palavras-chave: Desenho urbano; conexão com a natureza; espaço verde urbano; geografias digitais; figitalização.

RESUMEN – CÓMO PUEDE EL DISEÑO URBANO FOMENTAR LA CONEXIÓN CON LA NATURALEZA? UN ARGUMENTO A FAVOR DE LA FIGITALIZACIÓN. Este estudio aborda el papel del diseño urbano en el fomento de la conexión con la naturaleza y analiza el valor de la figitalización para la reconexión de la población con la naturaleza. Promover la conexión con la naturaleza urbana importa, dado que la mayor parte de la población vive en ciudades, y las personas que se sienten más conectadas con la naturaleza tienden a obtener más beneficios para su salud y apoyan más las acciones de conservación. En este artículo, analizamos tres tendencias en los debates sobre el diseño de espacios verdes urbanos y su impacto en la conexión con la naturaleza. En primer lugar, destacamos la literatura que se ocupa de la relación entre las cualidades espaciales de los espacios verdes urbanos y el contacto con la naturaleza entre la población urbana. En segundo lugar, repasamos los estudios que llaman la atención sobre el impacto de las cualidades sensoriales del espacio verde en la percepción y apreciación de la biodiversidad natural y los beneficios de la naturaleza para la salud, así como las implicaciones de dichos estudios para el diseño urbano. Por último, llamamos la atención

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¹ Laboratório Associado TERRA, Centro de Estudos Geográficos, Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Rua Branca Edmée Marques, 1600-276, Lisboa, Portugal. E-mail: daniel.paiva@edu.ulisboa.pt

² Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Lisboa, Portugal. E-mail: aldira.raquel@e-igot.ulisboa.pt

sobre el creciente número de experimentos que aplican la realidad extendida y las plataformas digitales para aumentar el involucramiento con los espacios naturales urbanos, y debatimos lo que esto significa para la promoción de la conexión con la naturaleza. Concluimos el estudio analizando el potencial y las limitaciones de la digitalización de espacios verdes urbanos.

Palabras clave: Diseño urbano; conexión con la naturaleza; espacios verdes urbanos; geografías digitales; phygitalización.

I. INTRODUCTION

Biophilic design is becoming a major topic of research in urbanism as the increment of natural features in the city is increasingly understood as a solution to many urban environmental problems, such as warming, pollution, or flooding, and as a crucial driver of positive effects for the urban population, namely in terms of health, well-being, and social cohesion (Andreucci *et al.*, 2021). Indeed, nature-based solutions are being conceived as holistic approaches that allow planners and designers to tackle multiple issues at once, integrating environmental, economic, and cultural concerns (Reeve *et al.*, 2015; Söderlund, 2019; Xue *et al.*, 2019). Among these, a central concern of biophilic urbanism is the promotion of nature connectedness among the urban population, which is not only relevant for improving health and well-being in the city, but also for gathering support for nature conservation (Beatley, 2016; Berto *et al.*, 2014). After all, why should people support the preservation of nature if they are not aware of the benefits it provides? Despite the importance of nature connectedness, studies have shown that contact with nature is in decline, as people are spending more leisure time in indoor activities such as watching television or surfing the internet (Cox *et al.*, 2017; Soga & Gaston, 2016). Countering this trend is of extreme importance to ensure that the efforts to make cities greener achieve their full potential, especially regarding their human dimension. Urban design can play a fundamental role in this matter. This has been widely acknowledged by both urban researchers and public authorities.

On the one hand, research has found that the amount of time that urban dwellers spend in nature, the immersiveness of those experiences, and the benefits drawn from them are related to the quantity and quality of green space (Apfelbeck *et al.*, 2020; Church, 2018; Shwartz, 2017). On the other, as nature-based solutions are becoming mainstream in urban planning and design, the importance of promoting nature connectedness is also increasingly acknowledged, as international institutions such as the United Nations, the European Commission, or the World Business Council for Sustainable Development have established reconnecting the urban population with nature as a planning and design priority (European Commission, 2015; UN-Habitat, 2022; World Business Council for Sustainable Development, 2021). In this context, large-scale programmes such as the European Commission's New European Bauhaus are currently supporting a series of experimentations to reconnect urban dwellers with nature through urban design (European Commission, 2021).

In line with these concerns, in this article we question the ways in which urban design can promote nature connectedness. While most research has focused on the quantity and accessibility of green space in the city, it has been put into evidence that nature connectedness is more related to the experiential and sensory qualities of the design of green space. With this in mind, in this review paper, we contend that urban design must seek innovative and creative design approaches that are sensible to the experiential dimension of green space. Such innovative and creative ways imply an understanding of urban design as a relational practice concerned with the interactions between bodies and urban materiality, rather than a purely material practice. In this sense, we explore the potential of digital technologies to expand the urban nature experience in ways that deepen nature connectedness among urban dwellers, and we reflect upon the potential of a phygital approach to the design of urban green spaces (Bataat, 2022; Neuburger *et al.*, 2018; Silva & Cachinho, 2021).

This study is further divided into three sections. First, we review and discuss current approaches to the design of places of urban nature to foster nature connectedness. While we start by highlighting the fundamental role of space in this process, in the second section we turn to the growing awareness of the importance of designing user experiences, which entails a shift from a focus on materiality toward a focus on affective interactions. In the third section, we discuss the growing awareness of the potential of digital approaches to foster nature connectedness by augmenting

affective interactions with nature, drawing on a series of experimentations in digital biophilic design. We conclude the study by reflecting upon the challenges of creating phygital urban green spaces.

II. DESIGNING FOR NATURE CONNECTEDNESS I: SPACES

It is widely acknowledged that contact with natural spaces, including green and blue spaces, has a positive effect on health, well-being, social cohesion, and willingness to support conservation action (Birch *et al.*, 2020; Prévot *et al.*, 2018; Oh *et al.*, 2022; Williams, 2017). Recently, the lockdown measures that several governments implemented to prevent the spread of the COVID-19 pandemic have highlighted the need for natural spaces within cities, in which residents can relax, exercise, and reconnect with nature. Research has found that the use of urban natural space increased during the lockdown and that urban nature experiences were associated with higher levels of mental wellbeing during this period (Robinson *et al.*, 2021). However, such benefits were not for everyone, as the lockdown also exacerbated pre-existing inequalities in access to urban nature (Astell-Burt & Feng, 2021).

It is also widely acknowledged that urban design plays a crucial role in the promotion of urban nature experiences as research has found that it is in greener urban spaces that more people engage in nature experiences with greater frequency and exhibit higher levels of nature connectedness (Shanahan *et al.*, 2017). With this in mind, research has been concerned with identifying the characteristics of urban green space that are more likely to promote urban nature experiences. It has been shown that the quantity and size of public green space is relevant (Rey Gozalo *et al.*, 2019), but different scales of natural areas are important for different reasons. While large natural areas are significant to provide immersive experiences of nature, the placement of small green areas or species within highly urbanized spaces can integrate nature into the daily routines of urban dwellers (Church, 2018). Even the subtle presence of natural elements such as homes with window views to trees and other plants can have positive effects (Kearney, 2006; Myers, 2020).

For this reason, scholars have been concerned with the connectedness between urban green spaces and their placement within the urban form. While it is unclear the degree in which the connectedness between urban green spaces affects feelings of connection with nature (Dong *et al.*, 2020), it has been shown that people tend to be more satisfied with urban green space in regions with land use diversity, rather than land-sparing regions (Soga *et al.*, 2015).

In recent years, this insight has leveraged the idea that green space should be understood as an urban infrastructure, rather than nuggets of nature spread across the city's landscape. Literature on urban green infrastructure has made the case that the development of networks of green space provides multiple benefits for both people (in terms of health and well-being) and the environment (in terms of ecosystem services) (Pauleit *et al.*, 2019). In addition to this, it has been noted that the promotion of nature connectedness depends not only on the connections between green spaces, but also on the interweaving of green spaces and the distinctive features of each city, namely its geographical context, its social and cultural background, and the morphology of its built environment (Balázsi *et al.*, 2019; Parker, 2015).

A major question in this matter has been to understand the degree to which green spaces can and should be designed, when the aim is to reconnect people with nature. At the heart of this discussion, there is a conceptual debate about what nature really means. It has been noted that designed green spaces that seem too neat are often perceived as too artificial by the public, whereas non-designed wilder spaces are understood as more 'real' or 'natural' (Myers, 2020; Rupprecht *et al.*, 2015). Such perception stems from the idea that nature or natural spaces are more than a bundle of non-human living things, that they are spontaneous ensembles that exist independently and outside human control. However, this a delicate matter as wild spaces are also often understood as more dangerous than controlled spaces such as gardens (Church, 2018).

Notwithstanding, there is increasing attention to the possibilities of introducing spontaneity in the design of urban green spaces, which has led to initiatives of 'rewilding' (Prior & Brady, 2016) or 'non-design' (Gandy, 2013, 2016; Gandy & Jasper, 2020). Integrating nature into matters of urban design implies acknowledging that design can only go so far and that a significant part of wildlife cannot be designed, but simply managed. With this in mind, scholars have called for a wildlife-inclusive urban design that not only takes into account the impact of urban design on biodiversity, but also attempts to offer places for experiences of wildlife. Such a proposal implies that the creation of urban

nature experiences in the city should not be limited to green and blue spaces, but rather be integrated into the different steps of the urban planning cycle (Apfelbeck *et al.*, 2020). In this context, urban designers have given preference to native species, both in the sense of preserving the species that remain within urban space and in the sense of replanting autochthonous species in the city. The re-introduction or increment of native species is often seen as crucial for protecting biodiversity by restoring local ecosystems. Particular attention has been given to how native species interact with the built environment (Parker, 2015). In the same line, there is increasing concern with invasive exotic species (Ernwein & Fall, 2015).

While there is significant awareness of the need to expand and diversify the green infrastructure of the city, and to improve its internal and external connectivity in order to enhance access to nature in the city, less attention has been paid to the design of the interactions between people and urban green spaces. However, literature on nature connectedness has shown that connecting with nature is an embodied and deeply affective process, and that the design of urban green spaces must take this into account. We approach these issues in greater depth in the next section.

III. DESIGNING FOR NATURE CONNECTEDNESS II: EXPERIENCES

There is a growing body of literature that is exploring human-nature relations in urban settings, which has led to relevant insights on how urban design provides nature experiences that are meaningful for the formation of nature connectedness (Liu *et al.*, 2022). The concern with interactions stems from the growing notion that the quality of green space and nature experiences plays a fundamental role in how aware people become aware of the benefits of nature, which in turn influences support for and engagement in conservation action.

Recent research has noted that appreciation of nature is more often linked to sensory and experiential elements, rather than objective assessments of the quality of green space (Myers, 2020; Souter-Brown, 2015). Indeed, studies show that most people tend to have a limited ability to assess green spaces quantitatively. For instance, Shwartz *et al.* (2014) have shown that public green spaces with higher levels of biodiversity do not necessarily produce greater nature engagement because people do not estimate biodiversity accurately and show difficulties in recognizing changes in the bi-landscape. On the other hand, Pett *et al.* (2016) have found that, while people prefer green spaces with higher biodiversity, and are capable of relating biodiversity with greater individual well-being, they generally have a limited ability to perceive the biodiversity surrounding them accurately.

In contrast, it has been shown that positive experiences in urban green spaces are mostly associated with aesthetics, sensations, and emotions (Bhatti *et al.*, 2009; Biglin, 2020; Myers, 2020; Paiva, 2020). A possible explanation for this is the insight advanced by Voigt and Wurster (2015) that people's idea of natural diversity is related to experiential sensations in nature, rather than objective and quantitative evaluations of biodiversity. That is, although people value biodiversity, they perceive it as a diversity of colours, shapes, sounds, and smells, rather than taxonomic diversity. Indeed, fascination with the sensory qualities of green spaces has been considered the foremost factor in the formation of nature connectedness (Berto *et al.*, 2014; Sato & Conner, 2013; Sonti *et al.*, 2020), which has led to calls for a greater attention to beauty and the sensory dimension in green space design (Dobson *et al.*, 2021; Lumber *et al.*, 2017; Shwartz, 2017; Souter-Brown, 2015).

Nevertheless, nature connectedness is not only linked to sensory experiences, but also mediated by the emergence of well-being, positive emotions, and meanings. First, the perception of therapeutic and positive bodily reactions to natural environments is a crucial factor for the appreciation of nature. Such reactions might include stress relief, increased attention and mindfulness, and other improvements in terms of mental health (Howell *et al.*, 2011; Howell & Passmore, 2012; Paiva, 2019; Pritchard *et al.*, 2020; Souter-Brown, 2015). Secondly, nature connectedness is linked to the formation of positive emotions such as happiness, joy, calmness and sense of freedom, and the mitigation of negative emotions such as feelings of isolation or anxiety (Birch *et al.*, 2020; Capaldi *et al.*, 2014; Passmore & Howell, 2014; Richardson *et al.*, 2016). Thirdly, nature connectedness entails the formation and attribution of existential meaning to nature experiences. That is, contact with nature becomes more valued when it is understood as a significant part of the formation and performance of personal values (Egerer *et al.*, 2019; Howell *et al.*, 2013). This means that culture plays an important part in connecting to nature. For instance, it has been noted that connection with nature is often understood not only as a bodily connection, but also as a spiritual one (Kamitsis & Francis, 2013;

Trigwell *et al.*, 2014). This implies that people frame their relationship with nature in more-than-material ways.

The insight that the experiential nuances of people's interaction with nature matters when it comes to forming bonds with the environment has led to a greater interest in attending to how people appropriate green spaces during design processes. In this context, the issue of participation has become a significant topic for the design of urban green spaces. It has been argued that the involvement of the public in the design and stewardship of urban green space is fundamental to foster a closer relation between people and nature in the city. Murphy *et al.* (2019) argue that managing urban nature areas through place-making processes – a term which refers to the personal involvement of citizens in matters pertaining to the design of places – is fundamental to foster a sense of community, belonging, and ownership among citizens, given that people who feel that they belong to the local community are more likely to take part in the protection of urban natural areas (see also Andreucci *et al.*, 2021; Oh *et al.*, 2022). On the other hand, it has been noted that while public green space is important to associate nature with a sense of community, private gardens highlight the importance of nature to elicit a sense of control, freedom, privacy, and opportunity (Cervinka *et al.*, 2016; Ginn, 2014; Ginn & Ascensão, 2018). In this sense, a diverse and inclusive approach to the design of the green city should accommodate different levels of participation and ownership of green space design.

As awareness about the role of sensory and affective experiences in the formation of nature connectedness grows, and the need to understand these experiences and incorporate them into the design process is increasingly recognized, novel creative approaches are emerging. While diverse, these approaches have mostly shared a common instrument, which is digital technology. With this in mind, we approach the growing role of digital technologies in promoting nature connectedness in urban green spaces in the next section.

IV. DESIGNING FOR NATURE CONNECTEDNESS III: TECHNOLOGIES

Digital technologies are transforming urbanism. While urban design, planning and management have been profoundly revamped by the emergence of the smart city and platform urbanism (Barns, 2019; Kitchin *et al.*, 2018), there seems to be a lesser impact of digital technologies in the design of urban green spaces, which might be related to the idea that green spaces are (and should be) restorative and therapeutic spaces in which urban dwellers can go to recover from the stress of technology-ridden bustling urban places (Williams, 2017). Nevertheless, there is increasing experimentation with the potential of digital technologies and interfaces in the making of urban green space (Gabrys, 2014, 2016, 2022), and some of this experimentation can be useful for fostering nature connectedness. Here, we focus on the potential of two types of software: (i) extended reality apps; and (ii) digital platforms for user-generated content. Rather than providing an exhaustive list of all the software options and their applications for the promotion of nature connectedness, our purpose here is to underline the main advantages that the most tested solutions provide.

1. Extended reality apps

Extended reality, which includes augmented, mixed, and virtual reality technology, is perhaps the most popular set of tools when it comes to designing urban nature experiences, given its potential to foster more immersive nature experiences and to weave storytelling into such experiences (Dogan & Kan, 2020; Prandi *et al.*, 2023). Augmented and mixed reality are particularly relevant, as they involve the superimposition of digital layers onto real-world experiences (Graham *et al.*, 2013; Lowe, 2021).

In augmented reality, the user looks at a physical space through a camera screen in which digital media is layered onto a real-time video, whereas in mixed reality the user is guided through a real-world location with cues given by digital media such as a smartphone app (Bec *et al.*, 2019). Augmented and mixed reality offer new ways to help users navigate urban green spaces and direct their attention to specific features of the natural world, which might be fascinating or therapeutic, but also difficult to find due to their reduced size, location, or duration (Cahill & Dunham, 2013). In addition, augmented and mixed reality might also become important tools for urban designers in the sense that they easily allow to weave stories and narratives onto urban green space, which might be useful for a series of purposes (McCaw *et al.*, 2014). Weaving stories into nature experiences can, for

instance, highlight the cultural significance of plant species, provide information on their conservation status, describe the natural history of the species, draw attention to bio- and geo-diversity, highlight the health benefits of urban nature, elicit certain sensorial stimuli and emotions, or promote environmentally responsible practices. In this sense, augmented and mixed reality can change the urban nature experience in profound ways, making it more significantly meaningful for urban dwellers, which is fundamental for the development of nature connectedness. In addition to this, augmented and mixed-reality apps might draw new visitors to green spaces by providing fun and exciting activities that promote also physical activity and might cater to people who prefer gamified indoor pastimes (Saaty *et al.*, 2021).

Most gardens and urban parks have been engaging with the notion of mixed reality by providing digital apps that incorporate a map of the garden or a guiding system, especially in botanic gardens. Examples include the apps Royal Botanic Garden Sydney (Australia), Denver Botanic Garden (United States of America), JBT – Jardim Botânico Tropical (Portugal), or the Jardim Botânico RJ (Brazil). While such maps help visitors to navigate the gardens and be attentive to specific features of the plants, some experiments have tried to explore the potential of augmented and mixed reality for nature engagement and connectedness in greater depth. For instance, the University Botanic Garden Jorge Enrique Quintero Arenas in Ocaña (Colombia) developed an augmented reality app that presents a digital album with information about each plant species (Rico-Bautista *et al.*, 2019). The app is fed by information gathered through a series of Internet-of-Things devices placed in the garden and it can be accessed both inside and outside the garden. To this extent, the app can enhance the experience of the visitors by providing pedagogical information about the species in an interactive and fun way, but it can also reach people who are not able to visit the garden. The Botanic Garden of Ajuda in Lisbon (Portugal), on the other hand, developed a mixed reality game with a futuristic narrative in which players take on the mission of finding endangered plant species in the garden. While the game dynamic promotes physical activity, play, and aesthetic appreciation within the garden as it guides players throughout the garden, the game's narrative also provides a learning experience about climate and ecosystem processes, environmental history, and nature conservation. This generates an emotional experience that not only bolsters engagement with the natural features of the garden, but also foments connectedness with the global environment (Paiva *et al.*, 2023). In addition to enhancing the user experience, extended reality apps have the potential of bringing new publics to urban green spaces by rendering them more accessible. For instance, the Christchurch City Council in New Zealand developed a walking track map for the app *Plan My Walk*, which signals the location of green spaces and walking tracks in the city, and includes information on accessible walking tracks, public toilets, public fountains, bus stops, and parking (Christchurch City Council, 2024). This allows people with mobility issues to plan their walks and find the most suitable routes for their needs. In this sense, navigation apps can also be understood as extended reality tools that enhance people's capabilities to experience and draw benefits from urban nature.

Experimentation with extended reality is still incipient, but the prospect of employing these technologies to draw visitors to urban nature sites and co-creating experiences that foster nature connectedness, positive emotions, aesthetic appreciation, and environmental awareness is a promising one that deserves further research.

2. Digital platforms for user-generated content

Smartphone apps are also being developed to explore the potential of user-generated content to allow urban dwellers to share and construct meaning about their own nature experiences. User-generated content encompasses the creation and sharing of different types of information by lay people in digital platforms and social media, which forms the basis of content creation in these media (Santos, 2022). It is widely acknowledged that user-generated content exponentially expands the amount of content available online, which in turn nurtures engagement among the participants in social media. A significant number of platforms allow and actively encourage the creation of geographic information (Goodchild, 2007). Indeed, smartphone apps and social media are increasingly used to share contents such as geo-tagged photos, narratives, GPS trajectories, or videos about urban places (Ballatore & Sabbata, 2020; Tu *et al.*, 2021).

Despite the idea that people spend less time in nature because they are more drawn to indoor pastimes that involve engagement with social media (Soga & Gaston, 2016), there is increasing evidence that user-generated content can also be employed to increase engagement with nature sites.

While most studies on the production of user-generated content about urban green space tends to focus on using such content to understand the experiences of visitors and tourists (Niezgoda & Nowacki, 2020; Stoleriu *et al.*, 2019), there have been interesting insights on how user-generated content can promote nature connectedness. On the one hand, it has been noted that the making of these contents allows people to construct and attribute meaning to their nature experiences as they build short narratives about their everyday contact with nature (Heikinheimo *et al.*, 2020; Muñoz *et al.*, 2020). On the other, it has been argued that the sharing of these contents allows other individuals to experience representations of nature, which might motivate them to spend more time in nature (Acuti *et al.*, 2019).

With this in mind, some green spaces are creating their own platforms for user-generated content. For instance, the city of Okayama (Japan) developed the *Korakuen Navi* app, which allows users to upload photos of flowers and trees of the Korakuen landscaped garden into a feed that users can access. The feed displays photos in the order of their upload date, which allows users to keep track of how the garden changes throughout the seasons (Seok & Kasw, 2017). In this sense, these initiatives can create online communities focused on the aesthetic appreciation of urban green spaces, which might also become important stakeholders for the conservation of such places.

The interaction with users has been further developed through the platformization of processes of environmental management in urban space, which has included the design of green space. Digital platforms consist of online structures that allow different stakeholders to connect and collaborate, which have been implemented with great success in different sectors of urban life, such as transport, retail or tourism (Capineri & Romano, 2021; Ferreira *et al.*, 2021; Rodrigues *et al.*, 2022). Indeed, authors speak of the platformization of the different sectors of the city, as such platforms deeply transform the way in which actors connect and collaborate with each other and establish themselves as important mediators in the urban realm (Ferreira *et al.*, 2022; Richardson, 2021).

Digital platforms have mostly been implemented in the city's greening with the purpose of involving urban dwellers in the management of urban nature areas through place-making processes (Murphy *et al.*, 2019). Here, the advantage of digital technology lies in the capacity to crowdsource important information for urban design and planning, while also empowering urban dwellers as they are given the capacity to play a role in the design of their living spaces (Schrammeijer *et al.*, 2022). In this context, platforms based in public participatory geographic information systems have become the most popular tools to co-manage and co-produce urban green spaces. The city of Paris (France), for instance, developed a digital platform as the medium for public participation during the consultation process for the city's Biodiversity Plan. More recently, the platform *Végétalisons Paris* allowed urban dwellers to integrate their own private natural spaces into a common geographical database to create a 'common urban nature basket' at the metropolitan level (Biase *et al.*, 2018). In Berlin (Germany), the platform *Hush City App* allowed citizens to identify, georeferenced, and classify quiet places in the city, which most often matched green spaces. With this information, the city developed the Berlin Plan of Quiet Areas, which mapped and protected the most tranquil spaces of the city, which a focus on the protection of green space (Radicchi, 2019; 2021). Such platforms widen the range of participation in the design and management of urban nature and empower urban dwellers, and in this way these platforms can contribute toward promoting feelings of control, freedom, and ownership among urban dwellers, which is significant for nature connectedness (Cervinka *et al.*, 2016; Church, 2018; Ginn, 2014; Ginn & Ascensão, 2018).

V. CONCLUSION: TOWARD PHYGITAL URBAN NATURE?

Technologies are changing the ways through which urban green space can be designed. They are underpinning a greater attention to how people experience nature, making it possible to fuse those experiences with meaningful narratives, and to engage urban dwellers in the co-creation and management of urban nature. In this sense, urban designers are finding new tools to design green spaces in ways that promote and enhance nature connectedness among urban dwellers.

As biophilic design is becoming a major topic of research in urbanism and a mainstream trend in urban policy, its underpinnings are also undergoing profound changes. While the notions that access to nature in the city must be democratized and that urban green infrastructure must be expanded and intersected with the different functional areas of the city are undisputed, there is growing acknowledgement that this might be insufficient to reconnect urban populations with nature, as the

quality of sensory experiences are fundamental to foster nature connectedness. Integrating digital technologies into the design of urban green space through the implementation of extended reality and digital platforms has led to promising interventions that can pave the way to rethinking the role that urban design might play in the promotion of nature connectedness.

The way forward, then, seems to imply thinking in the design of urban green spaces as phygital spaces, that is, spaces that emerge from the superposition of layers of physical space and layers of digital space (Batat, 2022; Neuburger, 2018; Silva & Cachinho, 2021). Such an approach implies expanding current interdisciplinary entanglements as urban designers, planners and managers must go beyond the boundaries of geography and architecture, and explore the possibilities of collaborating with computation, the arts, and the humanities. Phygital spaces allows us to balance material and digital interventions, which creates new possibilities for wild spaces in the city, while also being promising to counter the extinction of nature experiences, as these spaces might become more attractive to the growing portion of the population that prefers digital pastimes.

Notwithstanding, there are many steps to take to make phygital green spaces a common reality in our cities. Despite the growing interest by international institutions in promoting nature connectedness in urban settings, the implementation of phygital projects of urban nature remains scattered and experimental. Before phygital green spaces become mainstream, local governments require more systematic studies that evaluate the success of the ongoing experiments. While phygital solutions involve a creative approach that must be tailored to the characteristics of local green spaces, there is a need for guidelines for the implementation of such solutions, especially considering the interdisciplinarity that these projects require.

Furthermore, more research is needed to understand how phygital solutions can be implemented with different target groups in mind. Social dimensions such as age, gender and ethnicity play a significant role in how people use green space, and therefore might require tailored solutions. Here, one must be cautious regarding the shift toward phygital design, given the possibilities of intersecting existing inequalities in terms of access to urban green space, which disproportionately affects vulnerable communities and individuals, and the social divide in terms of digital skills. Biophilic design must take into account the social dimension of its interventions, to ensure that the phygital approach does not contribute towards the very exclusion that it is trying to fight.

Lastly, it is important to underline that experimentation with physical solutions has been undertaken by quite different institutions (municipalities, botanic gardens, public parks, private companies) in various scales. In this sense, more research is needed on how these entities can collaborate effectively to share knowledge, resources, and best practices, but also on how different phygital solutions that involve extended reality and digital platforms can be combined or integrated to foster people-nature interactions at the city scale.

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CONTRIBUTOS DOS AUTORES

Daniel Paiva: Conceptualization; Investigation; Resources; Writing – Original Draft; Writing – Review & Editing, Supervision; Project Administration; Funding Acquisition. **Raquel Maia:** Investigation; Writing – Original Draft; Writing – Review & Editing.

ORCID ID

Daniel Paiva  <https://orcid.org/0000-0001-9701-4705>

Raquel Maia  <https://orcid.org/0009-0003-9821-8293>

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