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Digital forest recreation in the metaverse: Opportunities and challenges

Wanggi Jaung

Division of Social Sciences, Duke Kunshan University, China
Environmental Research Center, Duke Kunshan University, China

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ABSTRACT

The metaverse could provide a new way of interacting with nature through immersive three-dimensional virtual worlds. This digital nature recreation has the potential to shape users' perceptions, knowledge, and behavior toward nature. Despite this potential, its user demand is currently unknown. This study analyzes the demand for digital forest recreation in the metaverse by conducting a discrete choice experiment with university students as potential metaverse users to fill this knowledge gap. The study results revealed that users preferred digital forest recreation to experience outdoor adventure and a nature-based digital twin in the metaverse, indicating that digital forest recreation has the potential to influence human-nature interactions. The students required responsible and immersive metaverse platforms for digital forest recreation that were not subject to invasions of user privacy (e.g., selling big data of users), biased algorithms (e.g., racism), algorithms selling virtual goods, cyberaggression (e.g., trolling), and less immersive virtual experiences. These findings highlight both opportunities and challenges for creating user-centered digital forest recreation in the metaverse. The research contributes to understanding potential interactions between technological, social, and ecological systems.

1. Introduction

The metaverse, which is thought to be the evolution of the Internet, has become a popular term in the technology industry (Metz, 2021; Oremus, 2021). The term "metaverse" originated from the sci-fi novel "Snow Crash" (Stephenson, 1992) and it refers to three-dimensional virtual worlds that are interactive, immersive, and collaborative (Caulfifld, 2021; Meta, 2021). Users in the metaverse are expected to participate in virtual live concerts with other users, do virtual shopping for the real world, collaborate with other coworkers in a virtual office, play games, and even attend class using virtual avatars in the virtual worlds (Caulfifld, 2021; Gent, 2021; Meta, 2021; Roach, 2021). These anticipated activities suggest that the metaverse concept could encompass all digital technologies and cultures, including extended reality (virtual, augmented, and mixed reality), social media, online shopping, digital games, mirror world, digital twins, big data, and artificial intelligence (Caulfifld, 2021; Gent, 2021; Meta, 2021; Murgia, 2021; Park and Kim, 2022; Pesce, 2021; Roach, 2021). The metaverse, in turn, is a new digital phenomenon that incorporates all digital technologies and cultures. Indeed, the metaverse is facing increased criticism and concerns due to the lack of clear definitions, its potential for hype due to its fuzzy scope overlapping with many existing digital platforms (e.g., social media and online games), technological barriers to building immersive virtual realities in order to support massive users simultaneously, cybersecurity issues, privacy invasion of big data applications, and cyberaggression (Cass, 2021; Frenkel and Browning, 2021; Gent, 2021; Oremus, 2021; Park and Kim, 2022). Despite these concerns and uncertainties, many technology companies and businesses, including Meta, Microsoft, Nvidia, and Epic Games, have increased their investments in metaverse-related business models and technologies to pioneer metaverse platforms that could integrate major digital industries, such as online shopping, social media, entertainment, education, big data, and artificial intelligence (Bambysheva, 2021; Metz, 2021; Murgia, 2021). These increased market efforts indicate that these platforms will influence our society in the future (Dwivedi et al., 2022), even if their disruptiveness is not certain.

By allowing people to experience nature in interactive, immersive, and collaborative virtual worlds or digital nature recreation in the metaverse, the metaverse has the potential to change human-nature interactions. According to studies on technological nature (Kahn et al., 2009), simulated nature (Annerstedt et al., 2013; Browning et al., 2020a), and digital games that help players learn nature, this digital nature recreation may alter users' perceptions, attitudes, and behaviors toward nature (Fox et al., 2020; McCauley, 2017; Sandbrook et al., 2015). This digital nature recreation potential is contingent on user demand for experiencing nature in the metaverse. However, because the

E-mail address: wanggi.jaung@dukekunshan.edu.cn.

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metaverse is still in its infancy, this demand is unknown, limiting our understanding of the potential of this digital nature recreation to influence human-nature interactions. This study examines potential metaverse users' demand for digital forest recreation in the metaverse to fill this knowledge gap. University students were investigated as potential metaverse users because their social values could influence metaverse development (Park and Park, 2022). To elicit their stated preferences, a discrete choice experiment was used. Furthermore, structural equation modeling was employed to assess the potential of digital forest recreation to promote their diverse metaverse activities. The research would help identify opportunities and challenges for developing user-centered digital forest recreation in the metaverse. Furthermore, the study would contribute to the literature on technological and simulated nature by revealing the potential demand for digital nature in the metaverse, as well as the literature on social-ecological systems by demonstrating the metaverse's potential to become a technological system influencing human-nature interactions.

2. Relevant work

2.1. Metaverse

Although the term "metaverse" has only recently gained popularity, it has been investigated by the digital world and virtual reality researchers. For example, studies investigated users' trust, intention, and acceptance of digital platforms by employing psychological theories that explain user behavior, such as the technology acceptance model (Sahut et al., 2022). Barnes et al. (2015) assessed the value of real-life brands in the virtual world of Second Life using value theory. The study revealed that creating emotional brand value in a virtual world is complicated. Barnes and Pressey (2016) demonstrated that "market mavens," or super consumers who disseminate market information and are influential in real markets, would be similarly effective in virtual world environments. Herz and Rauschnabel (2019) demonstrated using a technology acceptance model that fashionable designs and wearable comfort can influence the utilitarian and hedonic values of virtual reality glasses. Choi and Kim (2017) proposed a concept of virtual exhibitions in a museum that visitors can access via a head-mounted display.

There have recently been several studies that explicitly investigated the metaverse. Park and Kim (2022) argued that the current metaverse is embedded in the social value of Generation Z by analyzing metaverse taxonomy. This new version of the metaverse differs from previous concepts in that it has a more immersive environment, a real-time connection with users, and interconnection with real life and the virtual economy. The study demonstrated that the metaverse comprises hardware, software, and content components and can be analyzed through user interactions, metaverse implementation, and metaverse applications. Dwivedi et al. (2022) investigated experts' perspectives on the metaverse's expected societal impacts, highlighting that the metaverse would provide enormous marketing opportunities for businesses, more immersive educational experiences, more travel opportunities by allowing tourists to work in a virtual workspace and a virtual space where patients can remotely communicate with healthcare professionals. Tlili et al. (2022) asserted after reviewing metaverse applications for education that the metaverse is capable of assisting students in visiting historical sites in an immersive virtual world. More research is needed, however, to investigate the lifelogging applications of the metaverse for education and the metaverse's ability to support students with disabilities. Akour et al. (2022) used the technology acceptance model to demonstrate that perceived usefulness is a key factor influencing university students' intention to use a metaverse system for their education. Pamucar et al. (2022) investigated potential metaverse transportation systems, such as AI-based autonomous driving, public transportation for metaverse users, AI-managed traffic, and vehicles that metaverse users can rent or borrow. In the Sandbox metaverse, where virtual lands are established and traded as non-fungible tokens, Nakavachara and Saengchote (2022) discovered that cryptocurrency units can influence users' willingness to pay for real estate. Despite these studies, the potential demand for digital forest recreation in the metaverse remains unknown, even though this demand is necessary to explore the impact of this digital nature on metaverse users and its potential to alter their interactions with nature.

2.2. Digital nature

Digital nature has been studied as a subset of technological nature (Kahn et al., 2009) and simulated nature (Browning et al., 2020a). Technological nature refers to technologies that mediate, augment, or simulate the natural world in various ways, and its scope is broader than simulated nature because technological nature includes both simulated nature and robots that mimic nature, such as robot dogs (Kahn et al., 2009) (Fig. 1). Simulated nature has a broader scope than digital nature because it represents both digital and non-digital nature, including printed nature images (Browning et al., 2020a). According to this study, digital nature recreation in the metaverse is a subset of simulated nature because simulated nature represents both nature displayed on 2-dimensional (2D) plasma screens and nature in 3-dimensional (3D) extended reality (Browning et al., 2020a).

Despite the conceptual differences, the literature on technological nature and simulated nature suggests that digital nature recreation in the metaverse has the potential to change human-nature interactions by influencing users' emotions, nature-related perceptions and knowledge, and environmental behavior, as well as by advancing our understanding of human-nature interactions with big data. Technological nature, for example, on a 2D plasma screen, can provide an enjoyable experience for office workers, even if it is less restorative than observing real nature (Kahn et al., 2009). Experiencing simulated nature in virtual reality has similar restorative effects on viewers (Annerstedt et al., 2013; Browning et al., 2020a) and could reduce the ecological footprint in a national park by reducing physical visits (Sánchez et al., 2021). A virtual reality treadmill that simulates nature can provide users with an enjoyable experience, though users may experience cyber sickness and lag between treadmill movements and virtual reality (Calogiuri et al., 2018). Serious games, designed for education and training purposes, also help players learn about nature and develop pro-environmental behavior, such as energy conservation (Fox et al., 2020; McCauley, 2017; Sandbrook et al., 2015). Nature-related entertainment games, such as Pokémon Go and Animal Crossing, can help players learn about wild species, even if game-based hunting experiences can encourage players to exploit wildlife in real life (Dorward et al., 2017; Fisher et al., 2021). Nature photos shared on social media can be used as big data to investigate nature's socioeconomic values (Chang et al., 2020a; Ghermandi and Sinclair, 2019). 3D modeling, the Internet of Things, and remote sensing technologies (such as Unity and Lidar drones) would aid in the creation of a nature-based digital twin, allowing for accurate ecosystem monitoring (Brock et al., 2021; Gabrys, 2020; Galle et al., 2019; Keeler et al., 2019; Voosen, 2020). As a result, the European Union attempted to create a digital twin Earth to simulate ecosystems and forecast global environmental changes (Bauer et al., 2021; Voosen, 2020). As a result, these studies suggested that digital nature recreation in the metaverse has the potential to alter human-nature interactions. Despite this potential, digital nature recreation in the metaverse has received little attention in the literature thus far. To fill this gap, this study investigates potential metaverse users' preferences for digital forest recreation in the metaverse, as well as the potential impact of this forest recreation on their preferences for metaverse activities.

3. Material and methods

3.1. Conceptual framework

The study's research question was, "*Do potential metaverse users prefer*

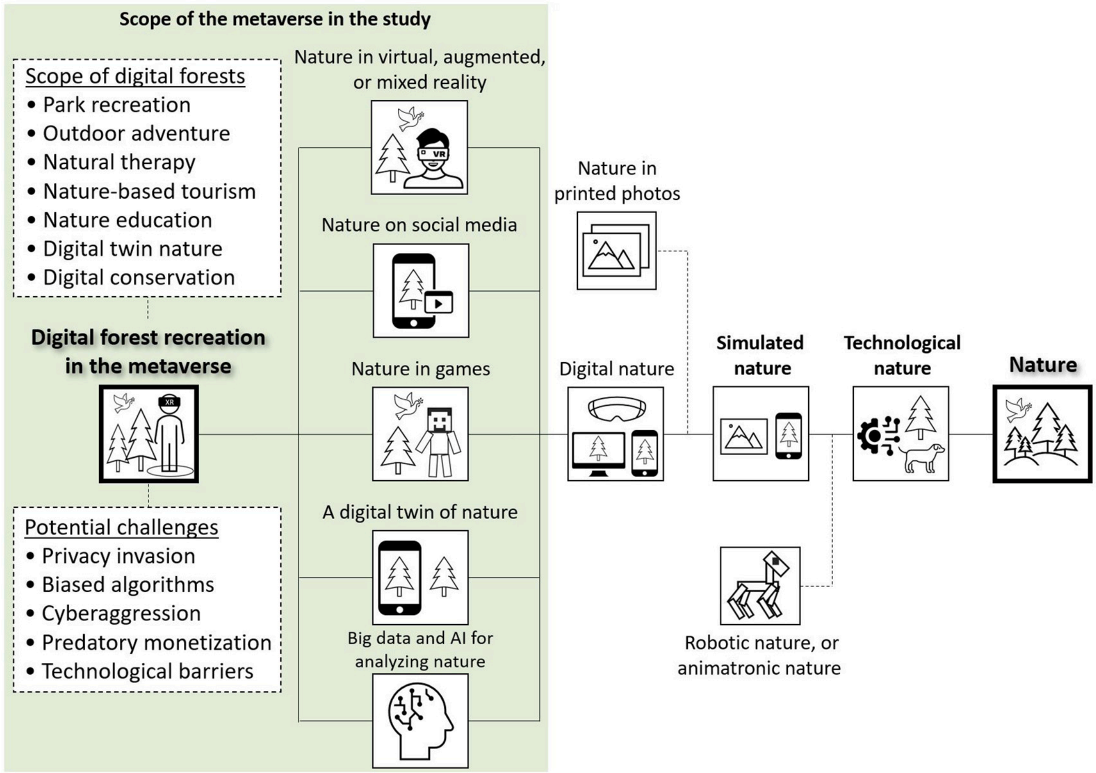

Fig. 1. A conceptual framework of digital forest recreation in the metaverse. The framework replies on the concepts of technological nature (Kahn et al., 2009), simulated nature (Browning et al., 2020a), and the metaverse (Park and Kim, 2022; Tlili et al., 2022).

digital forest recreation in the metaverse?" This study established a conceptual framework defining the scope of digital nature in the metaverse to address this research question (Fig. 1). This study's scope reflected the metaverse's scope, which included extended reality, social media, digital games, a digital twin, big data, and artificial intelligence (Park and Kim, 2022; Tlili et al., 2022). For example, digital nature recreation in the metaverse represents digital nature in extended reality, representing virtual, augmented, and mixed reality, which can have rehabilitative effects on users (Annerstedt et al., 2013; Browning et al., 2020a; Calogiuri et al., 2018nature posted on social media that is used as big data to measure socioeconomic values of natural places (Chang et al., 2020a; Ghermandi and Sinclair, 2019); serious games and gamification related to nature that help players learn about nature (McCauley, 2017; Sandbrook et al., 2015); a digital twin nature, such as a digital replication of the Earth (Bauer et al., 2021; Voosen, 2020); big data and artificial intelligence that support the metaverse, as well as social media and online games related to nature (Chang et al., 2020a; Ghermandi and Sinclair, 2019; Nitoslawski et al., 2019; Rodgers, 2021). In addition to examining user preferences for digital forest recreation, the study explored its potential as metaverse content that encourages users' diverse metaverse activities. This study conducted an online survey to investigate university students as potential metaverse users from Generation Z, who are considered digital natives (Mohr and Mohr, 2017) and influence metaverse development (Park and Kim, 2022). The term "users" was used in this study to refer to these potential metaverse users. A discrete choice experiment was used in this study to elicit user preference for digital forest recreation in the metaverse. Furthermore, structural equation modeling was used to assess the potential of this digital forest recreation to serve as metaverse content to encourage diverse metaverse activities.

3.2. Preference for digital forest recreation

A discrete choice experiment was used in this study to investigate user preferences for digital forest recreation in the metaverse. A discrete choice experiment, as a stated-preference technique, allows eliciting study subjects' potential market demand for non-market goods or services in terms of the expected characteristics (or attributes) of these goods and services (Bateman et al., 2002; Hensher et al., 2005; Louviere et al., 2000). This study analyzed digital forest recreation in the metaverse as a non-market service that is not yet available on the market. By reviewing the user-oriented attributes of the conceptual framework, we established nine attributes of this digital forest recreation (Fig. 1 and Table 1). These nine attributes included forest and technological attributes of digital forest recreation. Forest attributes included the following: 1) *themes*, 2) *landscapes*, 3) *wildlife*, and 4) *natural risks* associated with digital forest recreation content. In addition, the following technological characteristics were identified: 5) *user types*, 6) *algorithms*, 7) *commercial activities*, 8) *access points*, and 9) *costs* associated with metaverse platforms supporting digital forest recreation.

Themes were identified as an attribute influencing user preference for metaverse digital forest recreation. Themes of digital forest recreation were analyzed and compared with playing games in the metaverse because digital games represent a theme supported by the mainstream digital entertainment and digital cultures, with a market size of approximately $24.9 billion as of 2019 (Ahn et al., 2020; Daniel and Garry, 2018; Monahan, 2021). In other words, if users prefer digital games over digital forest recreation, it will have a lower chance of reaching a large population. Forest recreation themes included general recreation, adventure, and natural therapy (Huddart and Stott, 2019; Pomfret and Bramwell, 2016; Rajoo et al., 2020). Although there were some similarities between these themes (for example, adventure in open-world games and outdoor adventure in nature), they each had their focus. Other forest recreation activities, unlike games that give users specific missions (Charsky, 2010), allow users to freely explore the digital forest without specific missions. Natural outdoor adventure, such as climbing, is generally more difficult than a general forest recreation theme (e.g., walking on trails) (Pomfret and Bramwell, 2016). In contrast to general recreation themes, natural therapy is more closely

Table 1
Attributes of the choice experiment.

Attribute	Level	Code
a. Nature in the metaverse		
1. Theme	- Game in nature (a baseline)	ThGame
	- General recreation in nature	ThRecreation
	- Adventure in nature	ThAdventure
	- Natural therapy	ThTherapy
2. Landscape	- Fictional urban parks (a baseline)	LaFicPark
	- Existing urban parks	LaExistPark
	- Fictional forests	LaFicForest
	- Existing forests	LaExistForest
3. Wildlife	- Anime characters (a baseline)	WildAnime
	- Urban species	WildUrban
	- Iconic species	WildIconic
	- Endangered species	WildEndan
4. Natural risk	- No risk in nature (a baseline)	RiskNone
	- Natural disasters	RiskDisater
	- Mosquitos	RiskMosquito
	- Animal attacks	RiskAniAttack
b. Metaverse platform		
5. Users	- Anyone (a baseline)	UserAny
	- Only you	UserAlone
	- Verified members	UserVerified
	- Users invited by you	UserInvited
6. Algorithm	- No algorithm impacts (a baseline)	AlgoNone
	- Encouraging sustainable behaviors	AlgoSustain
	- Biased by developers	AgloBiased
	- Encouraging to buy items	AlgoItems
7. Commercial activities	- None (a baseline)	ComNone
	- Displaying ad	ComAd
	- Exposing brands	ComBrand
	- Selling users' big data	ComBigdata
8. Access points	- 2D screens (a baseline)	Access2D
	- Virtual reality (VR)	AccessVR
	- VR and sensor gloves	AccessGloves
	- VR treadmill	AccessTreadmill
9. Cost[a]	- 10 RMB per month	MonthCost
	- 20 RMB per month	
	- 30 RMB per month	
	- 40 RMB per month	

[a] As of 2021, RMB 10, 20, 30, and 40 are equivalent to about USD $0.16, $3.20, $4.80, and $6.70, respectively.

linked with natural healing experiences (Rajoo et al., 2020).

Landscape and *wildlife* were used to determine whether digital forest recreation that reflects real nature is preferable to digital forest recreation that is based on fiction. Gamification, which incorporates game components into non-game activities (Hamari et al., 2014), can be integrated into digital forest recreation using fictional landscapes (for example, fictional forests in the movie, Avatar) or fictional species (e.g., Totoro). Because fantasy is an important component of digital games (Charsky, 2010), these fictional creatures in the digital forest could indicate potentially popular digital forest recreation content. Digital forest recreation, however, could be built using existing natural landscapes and wild species. For example, some serious games are being developed to highlight the importance of conserving the Amazon rainforest (McCauley, 2017; Sandbrook et al., 2015), and Nintendo's Animal Crossing features endangered species from the IUCN Red List (Fisher et al., 2021). Digital forests in the metaverse could be digital replications of natural forests based on 3D modeling, game engines, and spatial analysis (Brock et al., 2021; Gabrys, 2020; Galle et al., 2019; Keeler et al., 2019; Voosen, 2020). Such digital forests in the metaverse would be a "digital twin nature" (Bauer et al., 2021; Voosen, 2020). Thus, this study used the *landscape* attribute to compare user preferences for existing parks, existing forests, and fictional forests to fictional parks (the baseline). Compared to anime characters (the baseline), the attribute of *wildlife* was created to elicit user preferences for iconic, endangered, and urban species.

Natural risks were used to test the feasibility of incorporating nature's negative contributions to people, or ecosystem disservices, into metaverse digital forest recreation. Forests provide a variety of benefits to visitors as part of cultural ecosystem services (Daniel et al., 2012), including aesthetic beauty, natural therapy, improved mental health, learning about nature, social gathering, and supporting cultural heritage (Milcu et al., 2013; Nghiem et al., 2021; Rajoo et al., 2020; Rojas-Rueda et al., 2019). Forest visitors, however, are exposed to several hazards during their outdoor activities, such as animal attacks (e.g., monkeys and bears), bite from harmful insects (e.g., mosquito bites), and natural disasters (e.g., hurricanes or flooding) (Gstaettner et al., 2018; Rosselló et al., 2020). These negative contributions of nature, referred to as ecosystem disservices (Blanco et al., 2019), are a part of natural forests. Thus, if users only want to experience enjoyable recreational components of forests, integrating a digital twin nature into the metaverse may be difficult because this digital twin could reflect unexciting recreational components of real forests, such as forests with unappealing scenery or non-flagship species. As a result, the attribute of *natural risk* was used in this study to test whether ecosystem disservices would decrease user preferences for digital forest recreation in the metaverse.

User types were investigated as a metaverse platform attribute influencing user preferences for digital forest recreation. Because interactions among multiple users are a key feature of the metaverse (Park and Kim, 2022; Tlili et al., 2022), digital forest recreation in the metaverse may face cyberaggression from other users, as it does on many other online platforms (Frenkel and Browning, 2021). Many studies showed that cyberaggression, such as trolling (e.g., trashing, talking, and spamming) and sexual harassment, can occur on online platforms with many users (Hilvert-Bruce and Neill, 2020; Nguyen et al., 2022; Seering et al., 2019). Although some users consistently express their toxic behavior on online platforms, even normal users have a high potential to reveal toxic behavior, such as having a bad day (Maher, 2016), which complicates managing cyberaggression on online platforms. This study used the attribute of *user types* to examine how different types of metaverse users, including random users, verified users, users invited by other users, and a single user, would affect user preference for digital forest recreation. Any user was analyzed as the baseline of this attribute.

Algorithms and *commercial activities* were investigated as metaverse attributes that would influence the development of responsible metaverse platforms for digital forest recreation. Although algorithms and commercial activities are essential components of metaverse platforms, these attributes could render these platforms unethical (Park and Kim, 2022; Tlili et al., 2022). Machine learning algorithms trained on big skewed data and used to automate social and business sectors would lead to invasions of privacy, social inequality, and systematic social discrimination (Boyd and Crawford, 2012; Pencheva et al., 2020; Rodgers, 2021; Ulnicane et al., 2021a; Ulnicane et al., 2021b). Furthermore, metaverse platforms would be susceptible to aggressive commercial activities, such as predatory monetization of online games (King and Delfabbro, 2019; King et al., 2019). Online games with a "free-to-play" business model are free to play, but they constantly encourage players to make microtransactions by selling rare virtual goods (e.g., avatars' clothes) only through a random selection, a practice known as "loot boxes" (Hamari et al., 2017; King and Delfabbro, 2019; Macey and Hamari, 2018). Such business models could become common in the metaverse because they could bring enormous profits to platform developers. Metaverse algorithms, however, can be purposefully designed to encourage users' environmental behavior, similar to serious games that help players learn about nature and pro-environmental behavior (McCauley, 2017; Sandbrook et al., 2015). As a result, this study investigated how different metaverse platform algorithms and commercial activities influence user preference for digital forest recreation. The *algorithm* attribute was examined in terms of no algorithm impact (baseline), algorithms encouraging users to engage in sustainable behaviors, algorithms biased by developers' social stereotypes, and algorithms motivating users to purchase items in the metaverse. *Commercial activities* attribute was investigated as no commercial activities (a baseline), advertisement in the metaverse, metaverse platforms exposing commercial brands (e.g., avatars wearing Nike-branded shoes), and metaverse platforms selling users' big data to a third party.

Access points to metaverse platforms were used to test the effects of immersive experiences on user preference for digital forest recreation. The current virtual reality technologies are still insufficient to support immersive virtual reality experiences. For example, head-mounted display devices can cause motion sickness in users (Calogiuri et al., 2018; Chang et al., 2020b). These devices would also need to be used in conjunction with other devices to provide immersive sensory experiences, such as touching and sensing virtual objects in virtual reality with wearable sensing gloves (Demolder et al., 2021) and walking in a natural environment with virtual treadmills (Calogiuri et al., 2018; Nilsson et al., 2018). However, these devices are not yet widely available to the general public. As a result of these technological limitations, metaverse users would be unable to have immersive experiences in digital forest recreation. As a result, this study aims to analyze how these constraints influence user preference for digital forest recreation. The *access points* attribute included a 2D plasma display (a baseline), a head-mounted display device with two stick controllers, a head-mounted display device with wearable sensing gloves, and a head-mounted display device with a virtual treadmill.

Costs would influence user preference for digital forest recreation in the metaverse. Many social media platforms, such as Instagram, do not charge users for their services, and "free-to-play" business models are common in online games (Hamari et al., 2017; King and Delfabbro, 2019; Macey and Hamari, 2018). As a result, this study assumed that digital forest recreation in the metaverse would not necessitate user subscription fees. Rather, the average cost of purchasing virtual items in the metaverse, such as avatar clothing, would determine users' costs of using digital forest recreation. Consequently, the following costs were examined as average monthly costs to users: 10 RMB (approximately \$0.16 as of 2021), 20 RMB (\$3.20), 30 RMB (\$4.80), and 40 RMB (\$6.70). This study explored a low range of costs because many university students are low-income individuals.

The effects of these nine attributes on user preference for digital forest recreation in the metaverse were investigated using random utility theory (Table 1). Based on Train (2009), we developed a random utility model to investigate the effects of these attributes on user preference for digital forest recreation in the metaverse. This model was expressed as the following equation:

$$U_{ni} = V_{ni} + \varepsilon_{ni} \forall j \tag{1}$$

U_{ni} is a random utility of a metaverse user n with a digital forest recreation scheme i. The utility consists of V_{ni} and ε_{ni}, where V_{ni} represents a metaverse user's observable random utility and ε_{ni} represents the unobservable random utility. This model assumes that a metaverse user is a rational decisionmaker who will select a digital forest recreation scheme that maximizes the random utility. For example, suppose there are J schemes for digital forest recreation. In that case, the metaverse user is expected to choose scheme i with the highest random utility among the J schemes for digital forest recreation. The likelihood of a metaverse user preferring scheme i over scheme j is depicted as follows:

$$P_{ni} = \text{Prob}\left(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \quad \forall j \neq i\right)$$
$$\int_{\varepsilon} I\left(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \forall j \neq i\right) f(\varepsilon_n) d\varepsilon_n \tag{2}$$

where $I(\bullet)$ denotes the probability function and $f(\bullet)$ denotes an n-dimensional distribution function of ε_n. If $f(\varepsilon_n)$ is logistically distributed, this probability can be expressed as follows:

$$P_{ni} = \frac{exp^{Vni}}{\sum_j exp^{Vnj}} \tag{3}$$

A multinomial logit model assumes that ε_n is distributed independently and identically (iid) extreme value type 1, whereas a mixed logit model assumes that ε_n is distributed randomly (Hensher et al., 2005). The coefficients of these models indicated part-worth utilities of users associated with digital forest recreation attributes in the metaverse (Hensher et al., 2005).

Discrete choice experiment questions were developed using an optimal orthogonal design to elicit these part-worth utilities of potential metaverse users (Walker et al., 2018). The experimental design was created using Ngene 1.2. (ChoiceMetrics, 2018). A total of 40 alternative sets were created. Each participant was asked to complete 10 choice sets (=40 choice sets / 4 blocks) using four blocks. Each choice set asked, "*Which metaverse nature theme do you prefer*?" and provided the following three options: "Scheme A," "Scheme B," and "None of them" (or the status quo) (Fig. 2). The study used pre-tests of choice experiment questions to determine whether the participants understood the questions. Furthermore, the survey provided several examples of metaverse activities and expected shortcomings and advantages of digital forest recreation to help participants become acquainted with the digital nature of the metaverse. Because the Hausman test indicated that the iid assumption was not met, a multinomial logit model was not applicable; therefore, the study established a mixed logit model simulated by Halton draws (Hensher et al., 2005). With the exception of the cost variable, all attributes of the choice experiments were coded as dummy variables (Daly et al., 2016) because they were designed as discrete variables. As a continuous variable, the cost variable was examined. NLOGIT 6 software was used to analyze the results of the discrete choice experiment results (Econometric Software, 2016).

3.3. Potential to influence metaverse activities

A pilot study was conducted using structural equation modeling to test the potential of digital forest recreation on user preference for various metaverse activities. Because digital forest recreation in the metaverse is not yet available, this potential was measured in terms of the impacts of users' digital forest recreation experiences and perspectives. For this pilot study, 43 questions (or items) were measured. These items represented 1) frequency of visits to natural places, 2) metaverse-related digital platform experiences, 3) preferred metaverse activities, 4) expected shortcomings of digital forest recreation, and 5) its expected strengths. The first and second item groups were evaluated using a five-point Likert scale with the options of never (1), rarely (2), sometimes (3), often (4), and always (5). The third group was given the options of very low (1), low (2), medium (3), high (4), and very high (5). The fourth and fifth groups were scored using the following criteria: strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5). The study tested common method biases (Fuller et al., 2016) as well as the normality of these items (Kline, 2015). Using these items, a metaverse preference model was developed to test whether user preferences for metaverse activities would be influenced by their online experiences watching nature videos and pictures, as well as their perceptions of the good and bad aspects of digital forest recreation. This model was created using the measurement and structural models (Hair et al., 2017). A factor analysis was used to develop the measurement model. Cronbach's alpha, composite reliability, and average variance extracted (AVE) were calculated to evaluate the model's internal consistency and convergent validity (Hair et al., 2017). The structural model eventually included constructs representing users' preferences for metaverse activities, experiences watching nature videos and pictures online, and positive perceptions of digital forest recreation (Table 2). However, the construct of bad things was excluded from the model due to its statistically insignificant impact. Fornell-larcker criterion and heterotrait-monotrait ratio (HTMT) were used to assess the model's discriminant validity (Hair et al., 2017). (Table 3). The root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean squared residual (SRMR) were used to assess the model's global fit (Kline, 2015).

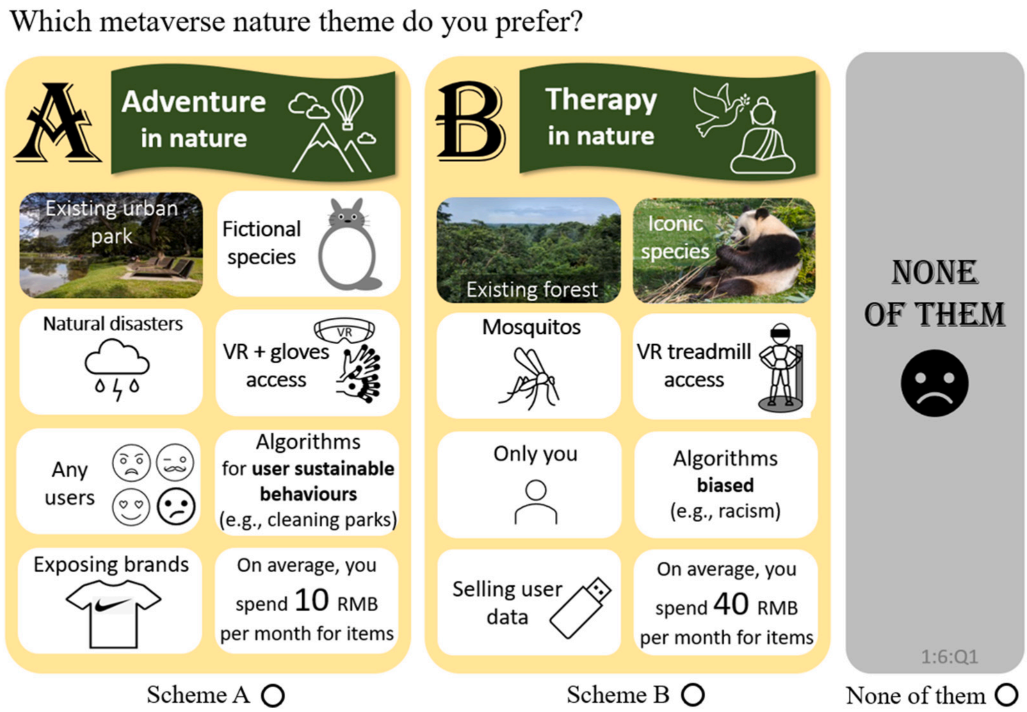

Fig. 2. An example of the discrete choice experiment questions.

Table 2
Constructs of the metaverse preference model.

Constructs	Items	Cronbach's alpha	Composite reliability	Average variance extracted
Preferences for metaverse activities (P)	[20] Art museums [22] Visiting natural places [25] University courses [26] Traveling	0.778	0.801	0.521
Watching nature online (W)	[05] Watching nature photos online [06] Watching nature videos online	0.822	0.826	0.705
Good things about digital nature (G)	[37] No harmful insects [38] Learning new natural places [40] No animal attacks	0.728	0.842	0.585

Table 3
Validity of the metaverse preference model.

		W	G	P
Fornell-larcker scale	W	*0.840*		
	G	0.438	*0.722*	
	P	0.291	0.427	*0.765*
Heterotrait-monotrait ratio	W			
	G	0.486		
	P	0.349	0.481	

These italics indicate "Square root of AVEs".

3.4. Data collection

In August 2021, undergraduate students at Duke Kunshan University participated in an online survey. When the survey was conducted, approximately 1260 undergraduate students were enrolled at this liberal arts university. All undergraduate students in the university were invited by email to join the survey. The survey had 113 participants, yielding a response rate of approximately 9 %. These undergraduate students ranged in age from 18 to 22 years old. The survey was divided into two sections. The first section asked about their experiences and perspectives on digital forest recreation, as well as their preferences for metaverse activities. This section was designed to familiarize survey participants with the choice experiment questions and to investigate the potential of digital forest recreation as metaverse content that encourages users' diverse metaverse activities. The discrete choice experiment questions in the second section were designed to elicit user preference for digital forest recreation in the metaverse.

4. Results

The results of the discrete choice experiment were used to develop a mixed logit model (Table 4). This model was estimated using 200 Halton draws because this draw provided the lowest log-likelihood among draws between 100 and 1000 times with an interval of 100. McFadden pseudo-R^2 for the model was 0.23. Except for access points and cost, all attributes were randomized using a triangular distribution. All the randomization outcomes were statistically significant (Table 5).

The mixed logit model demonstrated the effects of forest attributes on metaverse preferences for digital forest recreation (Fig. 3 and Table 4). There was no statistically significant preference for playing games in the metaverse (the baseline) compared to experiencing nature-based recreation (part-worth utility of 0.249) and therapy in the metaverse (0.144). Outdoor adventure in nature (0.415) was preferred over gaming. Among different natural landscapes, fictional forests (0.871) and existing forests (0.742) were preferred over fictional parks in digital forest recreation (the baseline). There was no difference in preferences between existing parks (0.300) and fictional parks. In terms of the

Table 4
Results of the mixed logit model analysis.

Variables	Coeff.	Std. error
ASC	0.459	0.554
ThAdventure	0.415*	0.237
ThRecreation	0.249	0.241
ThTherapy	0.144	0.266
LaFicForest	0.871***	0.294
LaExistForest	0.742***	0.254
LaExistPark	0.300	0.270
WildIconic	0.176	0.262
WildEndan	−0.365	0.247
WildUrban	−0.481*	0.262
RiskDisater	0.395	0.271
RiskAniAttack	−0.043	0.266
RiskMosquito	−0.534**	0.246
UserInvited	0.879***	0.256
UserVerified	1.234***	0.305
UserAlone	0.244	0.243
AlgoSustain	0.171	0.242
AlgoItems	−0.561**	0.234
AgloBiased	−1.029***	0.292
ComBrand	0.307	0.234
ComAd	−0.282	0.242
ComBigdata	−1.423***	0.354
AccessVR	0.422*	0.246
AccessGloves	0.716***	0.254
AccessTreadmill	0.782***	0.262
MonthCost	−0.005	0.007
Log-Likelihood (LL)	−900.86	
LL ratio test	$\chi^2 = 417.08$, $p < 0.001$	
McFadden *pseudo*-R^2	0.23	

***, **, * indicate significance at a 1 %, 5 %, and 10 % level, respectively.
ASC: alternative specific constant.

Table 5
Randomization results of the mixed logit model.

Variables	Coeff.	Std. error
ASC	3.636***	0.515
ThAdventure	0.312	0.225
ThRecreation	0.516***	0.194
ThTherapy	1.711***	0.281
LaFicForest	2.076***	0.343
LaExistForest	0.610*	0.288
LaExistPark	1.260***	0.307
WildIconic	0.428	0.265
WildEndan	0.575**	0.257
WildUrban	0.579***	0.222
RiskDisater	1.311***	0.363
RiskAniAttack	1.670***	0.292
RiskMosquito	0.744***	0.286
UserInvited	1.195***	0.244
UserVerified	1.409***	0.333
UserAlone	0.369	0.313
AlgoSustain	0.829***	0.252
AlgoItems	0.393	0.257
AgloBiased	1.067***	0.232
ComBrand	0.161	0.269
ComAd	0.487**	0.231
ComBigdata	2.612***	0.423

***, **, * indicate significance at a 1 %, 5 %, and 10 % level, respectively.

wildlife attribute, anime characters (the baseline) were not preferred over iconic (0.176) and endangered species (−0.365). However, anime characters outperformed urban species (−0.481). There were no statistically significant preferences for natural disasters (0.395) or animal attacks (−0.043) among the various natural risks. These potential metaverse users, however, did not prefer experiencing mosquitos (−0.534) in digital forest recreation.

The technological attributes of metaverse platforms influenced user preferences for digital forest recreation in the metaverse in various ways (Fig. 3). Among the different types of metaverse platform users, verified users (1.234) and invited users (0.879) were preferred to any user (the baseline). However, only a single user (0.244) was not preferred over any user. Regarding different algorithms, algorithms encouraging users to buy items (−0.561) and biased by developers (−1.029) significantly reduced user preference for digital forest recreation in the metaverse. However, algorithms encouraging sustainable behavior (0.171) did not affect this preference. Among the various commercial activities of metaverse platforms, a platform selling big user data to a third party (−1.423) significantly reduced user preference for digital forest recreation. Platforms that expose brands (0.307) and display advertisements (−0.282) did not affect this preference. In terms of different access points to metaverse platforms, treadmill-based virtual reality (0.782) outperformed gloves-based virtual reality (0.716). Glove-based virtual reality (0.716) outperformed a head-mounted display with only two stick controllers (the baseline). Despite the negative part-worth utility (−0.005), the low-cost range did not influence user preference for digital forest recreation in the metaverse.

The pilot study with structural equation modeling suggested that digital forest recreation could increase user preferences for various metaverse activities (Fig. 4 and Fig. 5). Harman's one-factor test revealed that the highest variance is 8 % (≤50), indicating that the items did not suffer from severe common method biases (Fuller et al., 2016). The items' normality was supported by their skewness and kurtosis having absolute values of <10 (Kline, 2015). Although three items yielded standardized factor loadings >0.4, the rest items achieved the loadings >0.7 (Hair et al., 2017) (Fig. 5). All constructs had composite reliability >0.7 and AVE >0.5 (Hair et al., 2017) (Table 2). Supporting the Fornell-larker criteria, the AVEs and square roots of the constructs were higher than their correlations with other constructs, and their HTMT ratios were <0.85 (Hair et al., 2017) (Table 3). The model's global fit revealed that it was acceptable ($\chi^2 = 33.481$, $p = 0.073$, df = 23; CFI = 0.979; RMSEA = 0.053; SRMR = 0.046) (Kline, 2015). According to the established model, watching nature videos and photos online (a coefficient of 0.414) and the good things about digital forest recreation (0.468) had a positive impact on user preferences for various metaverse activities (Fig. 5).

5. Discussion

5.1. User preference for digital forest recreation

The study's findings demonstrated user preference for digital forest recreation in the metaverse, implying that it has the potential to influence users and their interactions with nature. As potential metaverse users, university students revealed statistically significant preferences for experiencing outdoor adventure and existing forests in the metaverse (Fig. 3). Although these preferences cannot represent public preferences, these findings indicate that digital forest recreation in the metaverse could influence these young adults who are familiar with digital technologies. This, in turn, could alter users' interactions with nature, as evidenced by studies showing that serious games help players learn about nature (McCauley, 2017; Sandbrook et al., 2015); entertainment games encourage players to learn or exploit wild species (Dorward et al., 2017; Fisher et al., 2021); digital nature in virtual reality provides a sense of restoration to users (Browning et al., 2021; Browning et al., 2020b); film-induced tourism increases tourists in natural environments (Dubois and Gibbs, 2018; Singh and Best, 2004); virtual tours might reduce visits to natural sites by allowing them to indirectly experience these places (Sánchez et al., 2021). Furthermore, users preferred experiencing the digital twin nature in the metaverse. In this study, they preferred existing forests over fictional parks by a significant margin, and anime characters were not preferred over existing iconic and engendered species in digital forest recreation (Fig. 3). These findings suggest that these users are interested in experiencing digital nature that reflects real nature or a digital twin nature. A digital twin nature could help users learn about nature while monitoring and analyzing nature in

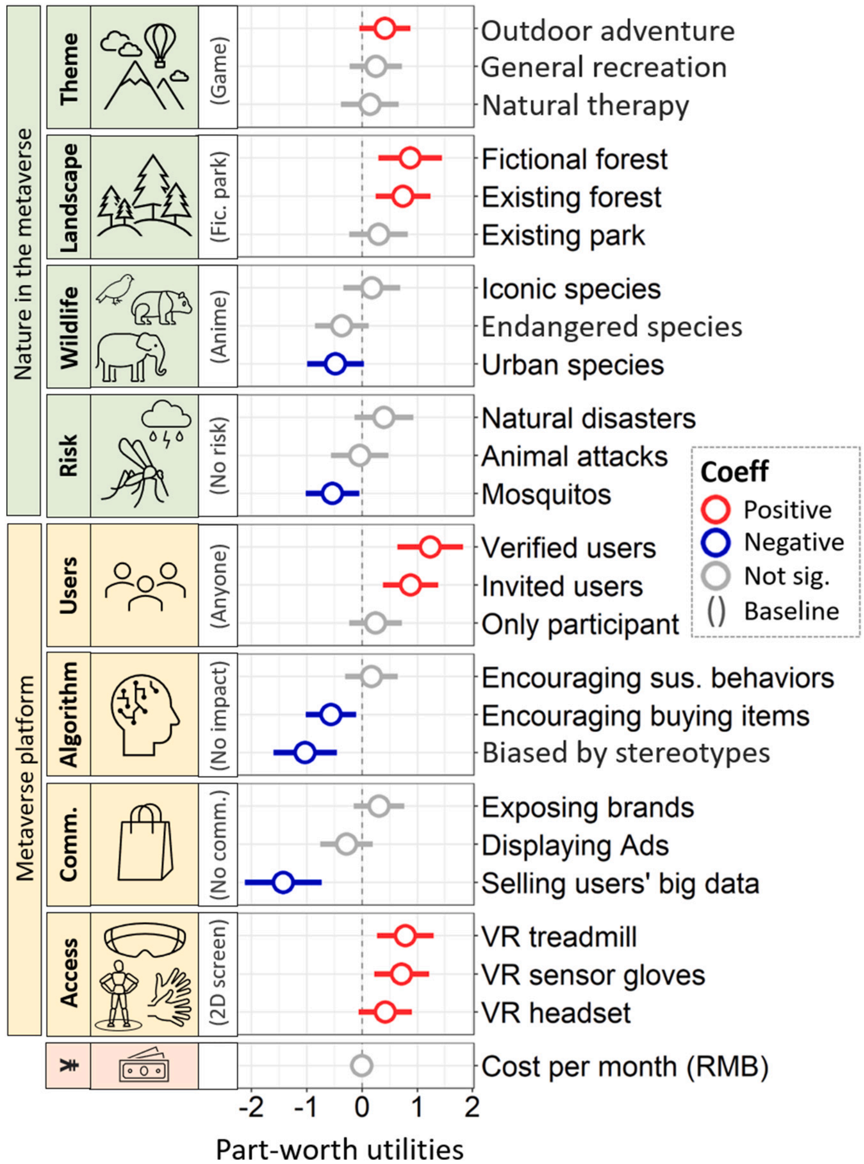

Fig. 3. Results of the mixed logit model from the discrete choice experiment.

the real world (Bauer et al., 2021; Voosen, 2020). By monitoring changes in nature (e.g., illegal deforestation) in the metaverse, a digital twin nature could further encourage public participation in digital conservation. Developing metaverse platforms that support a digital twin nature still faces many technological challenges (Gent, 2021), such as monitoring changes in nature in real-time, instantly processing large amounts of data, and facilitating massive user access to metaverse platforms. Despite these obstacles, the study's findings revealed that there would be a demand for digital forest recreation in the metaverse; this digital nature would influence human-nature interactions as metaverse-related technologies advanced.

5.2. Importance of responsible and immersive metaverse platforms

Cyberaggression in the metaverse would be a barrier to widespread digital forest recreation. According to the findings of this study, verified and invited users were preferred to any user (Fig. 3), potentially reflecting concerns about users' toxic behavior in digital forest recreation. Cyberaggression, such as trolling (e.g., trash talking, spamming, and attacking other players' characters) and harassment (e.g., racism and sexual harassment) are common in online games and platforms (Hilvert-Bruce and Neill, 2020; Nguyen et al., 2022; Seering et al., 2019). Users' toxic behavior would also affect digital forest recreation with multiple users, but taming toxic behavior is challenging. It not only necessitates platform developers' efforts to prevent such user behavior (Matias, 2019; Seering et al., 2019), but it also necessitates the development of individual and social norms that can assist users in recognizing toxic behavior (Cary et al., 2020; Hilvert-Bruce and Neill, 2020). Furthermore, because the metaverse allows users to engage in activities ranging from shopping to social gatherings, it could give users more freedom to develop abnormal behaviors than other online platforms (e.g., social media). Taming toxic behavior in the metaverse would thus be a critical enabling condition for mainstreaming digital forest recreation.

Metaverse platform business models would influence user preferences for digital forest recreation. The study's findings revealed that users have strong preferences for responsible metaverse platforms that do not force them to purchase virtual goods (such as avatar fashion items) (Fig. 3). These findings are supported by previous studies that addressed concerns regarding in-game purchasing systems that force players to spend indefinitely (King and Delfabbro, 2019; King et al., 2019). In addition, many online games sell valuable items (for example, rare armor for game avatars) by utilizing a “loot box” mechanism that

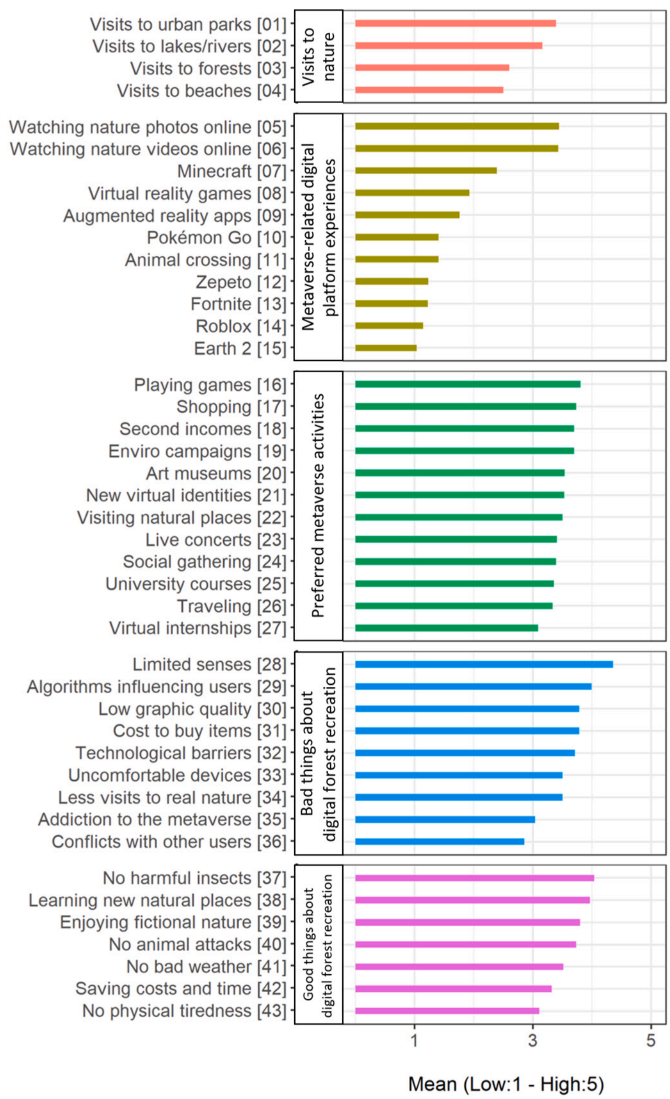

Fig. 4. User experiences and preferences related to digital forest recreation in the metaverse.

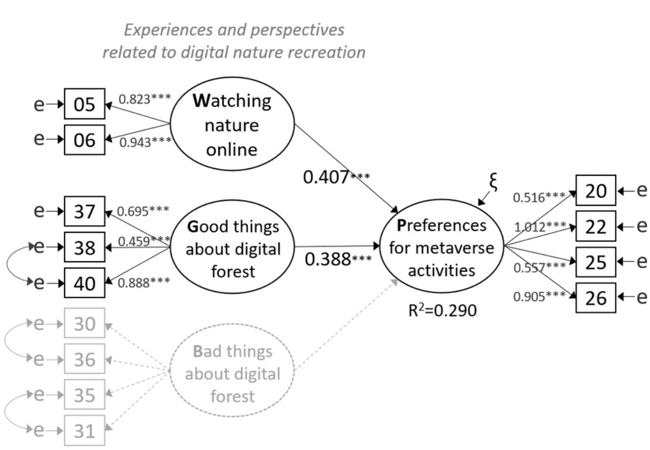

Fig. 5. A metaverse preference model.

provides purchased items at random (King and Delfabbro, 2019; King et al., 2019). This business model with a gambling component has resulted in significant financial losses for gamers, including children, while generating enormous profits for game publishers (King and Delfabbro, 2019; King et al., 2019). Consequently, gamers, industries, and governments call for responsible game designs that protect virtual goods consumers, make loot box systems transparent by sharing their probabilities, and limit the amount consumers can spend on a loot box (King et al., 2019). Establishing compliant platforms, however, is complicated due to the difficulty in defining "fairness" that is acceptable to all stakeholders (e.g., game users vs. publishers), developing consumer protection policies across multiple countries with different statutory laws, and motivating game publishers to support responsible game designs (Hamari et al., 2017; King and Delfabbro, 2019; King et al., 2019). These lessons from online games suggest that to establish responsible metaverse platforms, the development of digital forest recreation in the metaverse would need to overcome these challenges.

User preference for digital forest recreation would be influenced by metaverse algorithms and user privacy protection. According to the findings, when metaverse platforms were subjected to biased algorithms (e.g., racism) or the selling of users' big data to third parties, user preference for digital forest recreation decreased (Fig. 3). These findings are corroborated by concerns about potential social inequality, discrimination, and privacy invasion as a result of biased big data and artificial intelligence (Boyd and Crawford, 2012; Pencheva et al., 2020; Taeihagh, 2021; Ulnicane et al., 2021a; Ulnicane et al., 2021b). In addition, these biased technologies would undermine businesses and social sectors by systematically integrating social biases into hiring processes, business models, health care systems, and social services (Cirillo et al., 2020; Raghavan et al., 2020; Taeihagh, 2021; Ulnicane et al., 2021b). As a result, global efforts have been made to develop responsible and ethical big data and artificial intelligence regulations (Pencheva et al., 2020; Ulnicane et al., 2021a; Ulnicane et al., 2021b). However, regulating these technologies is difficult because it necessitates overcoming uncertainties associated with these evolving technologies, encouraging collaboration among multiple stakeholders, and dealing with social transitions caused by these technologies (Kuhlmann et al., 2019; Morley et al., 2021; Ulnicane et al., 2021b). Metaverse platforms for digital forest recreation will face similar challenges if they rely on big data and artificial intelligence (Murgia, 2021).

Immersive experiences would be essential for adopting digital forest recreation in the metaverse. The study findings demonstrated that virtual experiences of digital forest recreation were preferred over 2D experiences on a plasma screen (Fig. 3). In addition, access points with enhanced immersive virtual reality experiences increased user preference for digital forest recreation as follows: VR treadmill > VR gloves > VR headset. However, several technological challenges must be overcome before developing digital forest recreation. Head-mounted display devices, for example, can cause motion sickness, eye fatigue, disorientation, and nausea (Calogiuri et al., 2018; Chang et al., 2020b). These symptoms are caused by both technological and human factors, such as poor optics and hardware calibration (Iskander et al., 2018), virtual reality content, and user ages (Chang et al., 2020b). In addition, wearable and virtual reality walking devices (Demolder et al., 2021; Nilsson et al., 2018) could cause physical fatigue and a movement lag between real and virtual worlds (Calogiuri et al., 2018). Another challenge is making these technologies affordable. To provide users with immersive experiences, digital forest recreation in the metaverse would also need to overcome these challenges.

5.3. Potential to encourage metaverse activities

Digital forest recreation could serve as metaverse content that encourages users to engage in various metaverse activities. This study discovered that user preferences for metaverse activities could be positively influenced by their online experiences watching nature videos and pictures, as well as their perceptions of the benefits of digital forest recreation (Fig. 3). Furthermore, this pilot study indicated that the potential of digital forest recreation could be tested and described by the technology acceptance model, which is used to identify psychological factors influencing metaverse user acceptance (Akour et al., 2022). The positive effects of the benefits of digital forest recreation in this study demonstrated that perceived usefulness would play an essential role in the test. Future research should investigate the psychological effects of digital forest recreation on user acceptance of various metaverse activities to better understand the contributions of digital forest recreation to the metaverse.

5.4. Limitations and future directions

The limitations of this study point to future research directions. First, the study only analyzed the perspectives of university students. Although the social values of these students could influence the development of the metaverse (Park and Kim, 2022), they do not represent the general public; future research should look at different user groups. Second, despite its negative part-worth utility, the cost attribute was statistically insignificant (Table 2). This indicated that monthly costs <40 RMB (or $6.70) could be affordable to students; future studies can apply a broader cost range to identify the most affordable prices for users. Third, the digital forest recreation themes employed in this study were rather broad. As a result, more specific recreation themes, such as digital forest hiking vs. digital mountain climbing, can be investigated in the future. Fourth, because this digital forest recreation is not yet available, this study elicited users' stated preferences. When such metaverse content is established, future studies will use actual digital forest recreation. Fifth, this study analyzed only a few key attributes of metaverse platforms, indicating the need to test other potential attributes, such as private vs. open-source metaverse platforms (Gent, 2021). Sixth, the metaverse concept is rapidly evolving; future studies will analyze digital forest recreation using more concrete definitions of the metaverse. Seventh, this study focused on attributes of digital forest recreation influencing users' stated preferences; psychological factors influencing these preferences should be investigated using various theories, such as the technology acceptance model (Akour et al., 2022). Finally, despite analyzing undergraduate students, this study did not test how sociodemographic factors, such as age, would influence preferences for digital forest recreation.

6. Conclusion

This study analyzed the potential demand for digital forest recreation in the metaverse from the perspective of university students who are potential users. The findings of the study revealed their preferences for outdoor adventure and a digital twin nature in the metaverse. These findings suggested that this digital forest recreation could influence users and their interactions with nature in the future by providing a new opportunity for people to learn about nature and experience digital twins of existing nature in the metaverse. However, these potential metaverse users did not want to encounter unpleasant natural organisms, such as mosquitos, which would make integrating a digital twin nature into the metaverse difficult. Furthermore, when the metaverse platforms were subjected to user privacy invasions (e.g., selling of users' big data to third parties), biased algorithms (e.g., racism), aggressive monetization (e.g., root box), cyberaggression (e.g., trolling), and less immersive virtual experiences, users' preference for digital forest recreation decreased. As a result, responsible and immersive metaverse platforms will be essential in adopting digital forest recreation in the metaverse. According to the findings of structural equation modeling, digital forest recreation could serve as metaverse content that boosts users' interest in various metaverse activities. This study contributed to both empirical and theoretical literature. It empirically contributed to identifying opportunities and challenges for developing and managing user-centered digital forest recreation in the metaverse. It theoretically contributed to the literature on technological and simulated nature by investigating a new type of digital nature in the metaverse and to the literature on social-ecological systems by investigating the metaverse as a technological system that could influence human-nature interactions (or social-ecological systems). Other potential factors influencing user preference for digital forest recreation in the metaverse will be studied in the future, such as psychological factors influencing user acceptance of digital forest recreation (e.g., the technology acceptance model), specific recreational activities in nature (e.g., digital hiking vs. climbing), and user sociodemographic factors.

CRediT authorship contribution statement

Wanggi Jaung: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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References

Ahn, J., Collis, W., Jenny, S., 2020. The one billion dollar myth: methods for sizing the massively undervalued esports revenue landscape. Int. J. Esports 1 (1). https://www.ijesports.org/article/15/html.
Akour, I.A., Al-Maroof, R.S., Alfaisal, R., Salloum, S.A., 2022. A conceptual framework for determining metaverse adoption in higher institutions of gulf area: an empirical study using hybrid SEM-ANN approach. Comput. Educ. Artif. Intell. 3, 100052 https://doi.org/10.1016/j.caeai.2022.100052.
Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, Å.M., Währborg, P., 2013. Inducing physiological stress recovery with sounds of nature in a virtual reality forest—results from a pilot study. Physiol. Behav. 118, 240–250.
Bambysheva, N., 2021. Welcome to the Metaverse. Forbes.
Barnes, S.J., Pressey, A.D., 2016. Cyber-mavens and online flow experiences: evidence from virtual worlds. Technol. Forecast. Soc. Chang. 111, 285–296. https://doi.org/10.1016/j.techfore.2016.07.025.
Barnes, S.J., Mattsson, J., Hartley, N., 2015. Assessing the value of real-life brands in virtual worlds. Technol. Forecast. Soc. Chang. 92, 12–24. https://doi.org/10.1016/j.techfore.2014.10.017.
Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R., Swanson, J., 2002. Economic Valuation With Stated Preference Techniques: A Manual. Edward Elgar Publishing Limited.
Bauer, P., Stevens, B., Hazeleger, W., 2021. A digital twin of earth for the green transition. Nat. Clim. Chang. 11 (2), 80–83.
Blanco, J., Dendoncker, N., Barnaud, C., Sirami, C., 2019. Ecosystem disservices matter: towards their systematic integration within ecosystem service research and policy. Ecosyst. Serv. 36, 100913.
Boyd, D., Crawford, K., 2012. Critical questions for big data: provocations for a cultural, technological, and scholarly phenomenon. Inf. Commun. Soc. 15 (5), 662–679.
Brock, E., Huang, C., Wu, D., Liang, Y., 2021. Lidar-based real-time mapping for digital twin development. In: 2021 IEEE International Conference on Multimedia and Expo (ICME).
Browning, M.H., Mimnaugh, K.J., van Riper, C.J., Laurent, H.K., LaValle, S.M., 2020a. Can simulated nature support mental health? Comparing short, single-doses of 360-degree nature videos in virtual reality with the outdoors. Front. Psychol. 10, 2667.
Browning, M.H., Shipley, N., McAnirlin, O., Becker, D., Yu, C.-P., Hartig, T., Dzhambov, A.M., 2020b. An actual natural setting improves mood better than its virtual counterpart: a meta-analysis of experimental data. Front. Psychol. 11, 2200.

Browning, M.H.E.M., Saeidi-Rizi, F., McAnirlin, O., Yoon, H., Pei, Y., 2021. The role of methodological choices in the effects of experimental exposure to simulated natural landscapes on human health and cognitive performance: A systematic review. Environ. Behav. 53 (7), 687–731. https://doi.org/10.1177/0013916520906481.
Calogiuri, G., Litleskare, S., Fagerheim, K.A., Rydgren, T.L., Brambilla, E., Thurston, M., 2018. Experiencing nature through immersive virtual environments: environmental perceptions, physical engagement, and affective responses during a simulated nature walk. Front. Psychol. 8, 2321.
Cary, L.A., Axt, J., Chasteen, A.L., 2020. The interplay of individual differences, norms, and group identification in predicting prejudiced behavior in online video game interactions. J. Appl. Soc. Psychol. 50 (11), 623–637.
Cass, S., 2021. Silicon Valley's metaverse problem. IEEE Spectr. Retrieved on 5 Oct 2022 from https://spectrum.ieee.org/silicon-valleys-metaverse-problem.
Caulfifld, B., 2021. What is the Metaverse? Nvidia. https://blogs.nvidia.com/blog/2021/08/10/what-is-the-metaverse/.
Chang, C.-C., Cheng, G.J.Y., Nghiem, T.P.L., Song, X.P., Oh, R.R.Y., Richards, D.R., Carrasco, L.R., 2020. Social media, nature, and life satisfaction: global evidence of the biophilia hypothesis. Sci. Rep. 10 (1), 4125. https://doi.org/10.1038/s41598-020-60902-w.
Chang, E., Kim, H.T., Yoo, B., 2020. Virtual reality sickness: a review of causes and measurements. Int. J. Hum. Comput. Interact. 36 (17), 1658–1682.
Charsky, D., 2010. From edutainment to serious games: a change in the use of game characteristics. Games Cult. 5 (2), 177–198.
Choi, H.-S., Kim, S.-H., 2017. A content service deployment plan for metaverse museum exhibitions—centering on the combination of beacons and HMDs. Int. J. Inf. Manag. 37 (1), 1519–1527.
ChoiceMetrics, 2018. Ngene 1.2 User Manuel & Reference Guide.
Cirillo, D., Catuara-Solarz, S., Morey, C., Guney, E., Subirats, L., Mellino, S., Gigante, A., Valencia, A., Rementeria, M.J., Chadha, A.S., 2020. Sex and gender differences and biases in artificial intelligence for biomedicine and healthcare. NPJ Digit. Med. 3 (1), 1–11.
Daly, A., Dekker, T., Hess, S., 2016. Dummy coding vs effects coding for categorical variables: clarifications and extensions. J. Choice Model. 21, 36–41.
Daniel, M., Garry, C., 2018. Video Games as Culture: Considering the Role and Importance of Video Games in Contemporary Society. Routledge.
Daniel, T.C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J.W., Chan, K.M.A., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P.H., 2012. Contributions of cultural services to the ecosystem services agenda. Proc. Natl. Acad. Sci. 109 (23), 8812–8819.
Demolder, C., Molina, A., Hammond, F.L., Yeo, W.-H., 2021. Recent advances in wearable biosensing gloves and sensory feedback biosystems for enhancing rehabilitation, prostheses, healthcare, and virtual reality. Biosens. Bioelectron. 190, 113443 https://doi.org/10.1016/j.bios.2021.113443.
Dorward, L.J., Mittermeier, J.C., Sandbrook, C., Spooner, F., 2017. Pokémon go: benefits, costs, and lessons for the conservation movement. Conserv. Lett. 10 (1), 160–165.
Dubois, L.-E., Gibbs, C., 2018. Video game–induced tourism: a new frontier for destination marketers. Tour. Rev. 73 (2), 186–198.
Dwivedi, Y.K., Hughes, L., Baabdullah, A.M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M.M., Dennehy, D., Metri, B., Buhalis, D., Cheung, C.M., 2022. Metaverse beyond the hype: multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. Int. J. Inf. Manag. 66, 102542.
Fisher, J.C., Yoh, N., Kubo, T., Rundle, D., 2021. Could Nintendo's Animal Crossing be a tool for conservation messaging? People Nat. 3 (6), 1218–1228. https://doi.org/10.1002/pan3.10240.
Fox, J., McKnight, J., Sun, Y., Maung, D., Crawfis, R., 2020. Using a serious game to communicate risk and minimize psychological distance regarding environmental pollution. Telematics Inform. 46, 101320 https://doi.org/10.1016/j.tele.2019.101320.
Frenkel, S., Browning, K., 2021. The Metaverse's Dark Side: Here Come Harassment and Assaults. The New York Times.
Fuller, C.M., Simmering, M.J., Atinc, G., Atinc, Y., Babin, B.J., 2016. Common methods variance detection in business research. J. Bus. Res. 69 (8), 3192–3198. https://doi.org/10.1016/j.jbusres.2015.12.008.
Gabrys, J., 2020. Smart forests and data practices: from the internet of trees to planetary governance. Big Data Soc. 7 (1), 2053951720904871.
Galle, N.J., Nitoslawski, S.A., Pilla, F., 2019. The internet of nature: how taking nature online can shape urban ecosystems. Anthr. Rev. 6 (3), 279–287.
Gent, E., 2021. Why the Metaverse Needs to Be Open Making virtual worlds as interconnected as the internet will be tough. IEEE Spectr. Retrieved on 5 Oct 2022 from https://spectrum.ieee.org/open-metaverse?utm_campaign=post-teaser&utm_content=n7rqkquk.
Ghermandi, A., Sinclair, M., 2019. Passive crowdsourcing of social media in environmental research: A systematic map. Global Environmental Change 55, 36–47. https://doi.org/10.1016/j.gloenvcha.2019.02.003.
Gstaettner, A.M., Lee, D., Rodger, K., 2018. The concept of risk in nature-based tourism and recreation–a systematic literature review. Curr. Issue Tour. 21 (15), 1784–1809.
Hair, J., Hollingsworth, C.L., Randolph, A.B., Chong, A.Y.L., 2017. An updated and expanded assessment of PLS-SEM in information systems research. Ind. Manag. Data Syst. 117 (3).
Hamari, J., Koivisto, J., Sarsa, H., 2014. Does gamification work?–a literature review of empirical studies on gamification. In: 2014 47th Hawaii International Conference on System Sciences.
Hamari, J., Alha, K., Järvelä, S., Kivikangas, J.M., Koivisto, J., Paavilainen, J., 2017. Why do players buy in-game content? An empirical study on concrete purchase motivations. Comput. Hum. Behav. 68, 538–546.
Hensher, D.A., Rose, J.M., Greene, W.H., 2005. Applied Choice Analysis: A Primer. Cambridge University Press.
Herz, M., Rauschnabel, P.A., 2019. Understanding the diffusion of virtual reality glasses: the role of media, fashion and technology. Technol. Forecast. Soc. Chang. 138, 228–242. https://doi.org/10.1016/j.techfore.2018.09.008.
Hilvert-Bruce, Z., Neill, J.T., 2020. I'm just trolling: the role of normative beliefs in aggressive behaviour in online gaming. Comput. Hum. Behav. 102, 303–311.
Huddart, D., Stott, T., 2019. Outdoor Recreation: Environmental Impacts and Management. Springer.
Iskander, J., Hossny, M., Nahavandi, S., 2018. A review on ocular biomechanic models for assessing visual fatigue in virtual reality. IEEE Access 6, 19345–19361.
Kahn Jr., P.H., Severson, R.L., Ruckert, J.H., 2009. The human relation with nature and technological nature. Curr. Dir. Psychol. Sci. 18 (1), 37–42.
Keeler, B.L., Hamel, P., McPhearson, T., Hamann, M.H., Donahue, M.L., Prado, K.A.M., Arkema, K.K., Bratman, G.N., Brauman, K.A., Finlay, J.C., 2019. Social-ecological and technological factors moderate the value of urban nature. Nat. Sustain. 2 (1), 29–38.
King, D.L., Delfabbro, P.H., 2019. Video game monetization (eg, 'loot boxes'): a blueprint for practical social responsibility measures. Int. J. Ment. Heal. Addict. 17 (1), 166–179.
King, D.L., Delfabbro, P.H., Gainsbury, S.M., Dreier, M., Greer, N., Billieux, J., 2019. Unfair play? Video games as exploitative monetized services: an examination of game patents from a consumer protection perspective. Comput. Hum. Behav. 101, 131–143.
Kline, R.B., 2015. Principlesand Practice of Structural Equation Modeling. Guilford publications.
Kuhlmann, S., Stegmaier, P., Konrad, K., 2019. The tentative governance of emerging science and technology—a conceptual introduction. Res. Policy 48 (5), 1091–1097.
Louviere, J.J., Hensher, D.A., Swait, J.D., 2000. Stated Choice Methods: Analysis and Applications. Cambridge University Press.
Macey, J., Hamari, J., 2018. Investigating relationships between video gaming, spectating esports, and gambling. Comput. Hum. Behav. 80, 344–353. https://doi.org/10.1016/j.chb.2017.11.027.
Maher, B., 2016. Can a video game company tame toxic behaviour? Nat. News 531 (7596), 568.
Matias, J.N., 2019. Preventing harassment and increasing group participation through social norms in 2,190 online science discussions. Proc. Natl. Acad. Sci. 116 (20), 9785–9789.
McCauley, D.J., 2017. Digital nature: are field trips a thing of the past? [Article]. Science 358 (6361), 298–300. https://doi.org/10.1126/science.aao1919.
Meta, 2021. Melcome to Meta. Retrieved December 19 from. Meta. https://about.facebook.com/meta/.
Metz, C., 2021. Everybody Into the Metaverse! Virtual Reality Beckons Big Tech. The New York Times.
Milcu, A., Hanspach, J., Abson, D., Fischer, J., 2013. Cultural ecosystem services: a literature review and prospects for future research. Ecol. Soc. 18 (3).
Mohr, K.A., Mohr, E.S., 2017. Understanding generation Z students to promote a contemporary learning environment. J. Empower. Teach. Excell. 1 (1), 9.
Monahan, S., 2021. Video games have replaced music as the most important aspect of youth culture. The Guardian. Retrieved on 5 Oct 2022 from https://www.theguardian.com/commentisfree/2021/jan/11/video-games-music-youth-culture.
Morley, J., Floridi, L., Kinsey, L., Elhalal, A., 2021. From what to how: an initial review of publicly available AI ethics tools, methods and research to translate principles into practices. In: Ethics, Governance, and Policies in Artificial Intelligence. Springer, pp. 153–183.
Murgia, M., 2021. Facebook to build metaverse with start-up that had US military contracts. In: Financial Times. https://www.ft.com/content/18d50b48-f11d-49b2-9287-e5595b25f656.
Nakavachara, V., Saengchote, K., 2022. Does unit of account affect willingness to pay? Evidence from metaverse LAND transactions. Financ. Res. Lett. 49, 103089.
Nghiem, T.P.L., Wong, K.L., Jeevanandam, L., Chang, C.C., Tan, L.Y.C., Goh, Y., Carrasco, L.R., 2021. Biodiverse urban forests, happy people: experimental evidence linking perceived biodiversity, restoration, and emotional wellbeing. Urban Forestry & Urban Greening 59, 127030. https://doi.org/10.1016/j.ufug.2021.127030.
Nguyen, S.H., Sun, Q., Williams, D., 2022. How do we make the virtual world a better place? Social discrimination in online gaming, sense of community, and well-being. Telematics Inform. 66, 101747 https://doi.org/10.1016/j.tele.2021.101747.
Nilsson, N.C., Serafin, S., Steinicke, F., Nordahl, R., 2018. Natural walking in virtual reality: a review. Comput. Entertain. 16 (2), 1–22.
Nitoslawski, S.A., Galle, N.J., Van Den Bosch, C.K., Steenberg, J.W., 2019. Smarter ecosystems for smarter cities? A review of trends, technologies, and turning points for smart urban forestry. Sustain. Cities Soc. 51, 101770.
Oremus, W., 2021. In2021, Tech Talked Up 'the Metaverse.' One Problem: It Doesn't Exist. The Washingdon Post.
Pamucar, D., Deveci, M., Gokasar, I., Tavana, M., Köppen, M., 2022. A metaverse assessment model for sustainable transportation using ordinal priority approach and aczel-alsina norms. Technol. Forecast. Soc. Chang. 182, 121778.
Park, S.M., Kim, Y.G., 2022. A metaverse: taxonomy, components, applications, and open challenges. IEEE Access 10, 4209–4251. https://doi.org/10.1109/ACCESS.2021.3140175.
Park, C.S.-Y., Park, N.J.-Y., 2022. In: Adaptingto Cutocracy: A Survival Strategy for Prospective Health Professions Educators inthe Era of the Metaverse, 41, pp. A1–A4.
Pencheva, I., Esteve, M., Mikhaylov, S.J., 2020. Big data and AI–a transformational shift for government: so, what next for research? Public Policy Adm. 35 (1), 24–44.
Pesce, M., 2021. The Metaverse Could Help Us Better Understand Reality. The killer app for ambitious virtual reality could be our world. IEEE Spectr. Retrieved on 5 Oct

2022 from https://spectrum.ieee.org/the-metaverse-could-help-us-better-understand-reality.
Pomfret, G., Bramwell, B., 2016. The characteristics and motivational decisions of outdoor adventure tourists: a review and analysis. Curr. Issue Tour. 19 (14), 1447–1478.
Raghavan, M., Barocas, S., Kleinberg, J., Levy, K., 2020. Mitigating bias in algorithmic hiring: evaluating claims and practices. In: Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency.
Rajoo, K.S., Karam, D.S., Abdullah, M.Z., 2020. The physiological and psychosocial effects of forest therapy: a systematic review. Urban For. Urban Green. 54, 126744 https://doi.org/10.1016/j.ufug.2020.126744.
Roach, J., 2021. Meshfor Microsoft Teams Aims to Make Collaboration in the 'Metaverse' Personal and Fun. Retrieved December 19 from. Microsoft. https://news.microsoft.com/innovation-stories/mesh-for-microsoft-teams/.
Rodgers, S., 2021. In: ThemedIssue Introduction: Promises and Perils of Artificial Intelligence and Advertising, 50. Taylor & Francis, pp. 1–10.
Rojas-Rueda, D., Nieuwenhuijsen, M.J., Gascon, M., Perez-Leon, D., Mudu, P., 2019. Green spaces and mortality: a systematic review and meta-analysis of cohort studies [Article]. Lancet Planet. Health 3 (11), e469–e477. https://doi.org/10.1016/S2542-5196(19)30215-3.
Rosselló, J., Becken, S., Santana-Gallego, M., 2020. The effects of natural disasters on international tourism: a global analysis. Tour. Manag. 79, 104080 https://doi.org/10.1016/j.tourman.2020.104080.
Sahut, J.-M., Schweizer, D., Peris-Ortiz, M., 2022. Technological forecasting and social change introduction to the VSI technological innovations to ensure confidence in the digital world. Technol. Forecast. Soc. Chang. 179, 121680 https://doi.org/10.1016/j.techfore.2022.121680.
Sánchez, M.R., Palos-Sánchez, P.R., Velicia-Martin, F., 2021. Eco-friendly performance as a determining factor of the adoption of virtual reality applications in National Parks [Article]. Sci. Total Environ. 798, 148990 https://doi.org/10.1016/j.scitotenv.2021.148990.
Sandbrook, C., Adams, W.M., Monteferri, B., 2015. Digital games and biodiversity conservation. Conserv. Lett. 8 (2), 118–124.
Seering, J., Wang, T., Yoon, J., Kaufman, G., 2019. Moderator engagement and community development in the age of algorithms. New Media Soc. 21 (7), 1417–1443.
Singh, K., Best, G., 2004. Film-induced tourism: motivations of visitors to the Hobbiton movie set as featured in the Lord of the rings. In: International Tourism and Media Conference Proceedings.
Software, Econometric, 2016. NLOGIT Version 6 Reference Guide.
Stephenson, N., 1992. Snow crash. Penguin Random Houses.
Taeihagh, A., 2021. Governance of artificial intelligence. Policy Soc. 40 (2), 137–157. https://doi.org/10.1080/14494035.2021.1928377.
Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A.H.S., Wang, H., Denden, M., Bozkurt, A., Lee, L.-H., 2022. Is metaverse in education a blessing or a curse: a combined content and bibliometric analysis. Smart Learn. Environ. 9 (1), 1–31.
Train, K., 2009. Discrete Choice Methods with Simulation. Cambridge University Press.
Ulnicane, I., Eke, D.O., Knight, W., Ogoh, G., Stahl, B.C., 2021. Good governance as a response to discontents? Déjà vu, or lessons for AI from other emerging technologies. Interdisc. Sci. Rev. 46 (1–2), 71–93. https://doi.org/10.1080/03080188.2020.1840220.
Ulnicane, I., Knight, W., Leach, T., Stahl, B.C., Wanjiku, W.-G., 2021. Framing governance for a contested emerging technology: insights from AI policy. Policy Soc. 40 (2), 158–177.
Voosen, P., 2020. Europe builds 'digital twin' of earth to hone climate forecasts. Science 370 (6512), 16–17. https://doi.org/10.1126/science.370.6512.16.
Walker, J.L., Wang, Y., Thorhauge, M., Ben-Akiva, M., 2018. D-efficient or deficient? A robustness analysis of stated choice experimental designs. Theor. Decis. 84 (2), 215–238. https://doi.org/10.1007/s11238-017-9647-3.

Wanggi Jaung is an assistant professor of environmental policy at Duke Kunshan University. His research focuses on sustainable human-nature relations, including technology impacts on social-ecological systems, big data analysis, and nonmarket valuation.