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Aug 6th, 9:00 AM - Aug 8th, 5:00 PM

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Citation

Ianniello, A.,and Bendor, R.(2025) Everywhere, all at once: Speculative layering of multiple temporalities with Augmented Reality, in Morrison, A., Culén, A. & Habib, L. (eds.), *Nordes 2025: Relational Design*, 6-8 August, Oslo, Norway. https://doi.org/10.21606/nordes.2025.11

EVERYWHERE, ALL AT ONCE: SPECULATIVE LAYERING OF MULTIPLE TEMPORALITIES WITH AUGMENTED REALITY

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ABSTRACT

This paper considers the design of Augmented Reality experiences that allow the interrogation of multiple temporalities to foster engagement with More-than-Human worlds. While Augmented Reality has traditionally been used to layer different spatial contexts onto the physical environment, we explore its potential to visualize alternative temporalities, offering users unique ontological perspectives on time and its role in shaping interconnected human and non-human futures. Drawing from futures studies, experiential futures, and speculative design, we examine how Augmented Reality's capacity to represent temporal layers can deepen understanding of More-than-Human interdependencies. We report on a pilot experiment where participants engaged with an Augmented Reality experience, analyze their reflections, and propose design insights for integrating Augmented Reality into speculative design practices.

INTRODUCTION

Speculative design practices offer ways to critically inquire about and deconstruct the current state of things by imagining and bringing to life alternative – possible and preferable – futures (Auger, 2013; Dunne & Raby, 2013). Making futures tangible implies rendering alternative future possibilities experienceable, translating abstract calculations of future probabilities into tangible forms (Candy & Dunagan, 2017; Candy & Kornet, 2019).

Key to futures studies – and by extension speculative design – is the recognition that time does not flow linearly and therefore the future is both open and plural (List, 2004; Rovelli, 2018). Instead of talking about "the future", design fiction, experiential futures, and speculative design – popular forms of design futuring – refer to "futures" as a linguistic reminder of the world's malleability. In this sense, the conceptualization of time as a plurality carries important consequences for how humans imagine their capacity to act and, indeed, their very sense of "futurity" (Fry, 2009).

In recent years, design futures' pluralization of the future has undergone an "ontological expansion" (Tuomi, 2019) by taking on additional dimensions. In line with the suggestion that "the past, much like the future, can be approached as a plurality and a repository of potentiality" (Bendor et al., 2021, p. 2), designers have called to pluralize not only the future but also the past and the present, under the assumption that temporal pluralization unleashes agentic modalities regardless of its directionality (Light, 2021). Designers have also questioned this very directionality, arguing for the value of non-Western ways to relate to and represent time (Howell et al., 2021). This appears to us a crucial part of any attempt to decolonize design – to "unlearn" or "unmake" how temporality is enacted in and through design activities (Song et al., 2024). It is also an important step toward moving away from human-centered notions of time.

https://doi.org/10.21606/nordes.2025.11

In this context, the aim is not to assess the plausibility of these pasts but to engage with them critically, opening spaces for reflection, dialogue, and the reconsideration of dominant narratives (Zeitlyn, 2015). Treating pasts and presents – not just futures – as plural repositories of untapped possibilities can stimulate the realization of equitable and inclusive alternatives (Auger & Hanna, 2023; Forlano & Halpern, 2023). Integrating perspectives on the past into speculative design practices holds transformative potential by amplifying marginalized viewpoints (Álvarez & Coolsaet, 2020). Furthermore, as Morley (2019, p. 607) writes, past-focused counterfactuals can allow us to "evaluate the conditions under which these [past] alternatives could reasonably be considered to have been possible or, even likely, as a means of alerting ourselves to contingency and possibility and to our habit of assuming that the present is the only possible world and hence is the measure of the past".

Nevertheless, the role of the past remains underexplored in speculative design practices (Nooney & Brain, 2019), and as Bendor et al. (2021) observe, the lack of structured methods to clarify relationships between pasts, presents, and futures limits the effectiveness of such integration. Bendor et al. try to overcome this gap by proposing past-facing futuring approaches that encourage critical reflection on historical trajectories and illuminate overlooked assumptions, offering a language and a framework to articulate alternative presents that challenge prevailing norms (Figure 1).

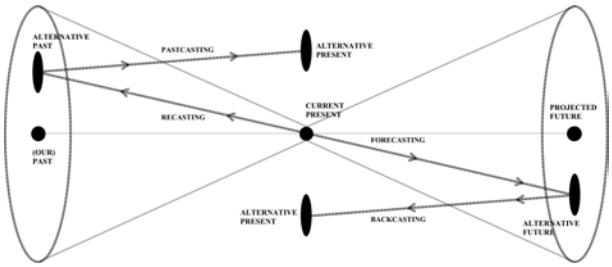

Figure 1 (adapted from Bendor et al. 2021): Comparison between future-facing and past-facing approaches.

While speculative designers seek to pluralize temporality, the question of how to effectively enact this plurality through design remains open. In our research, we turn to immersive technologies – specifically Augmented Reality (AR) – as a critical medium for enabling this enactment. As we argue here, AR's inherent ability to layer digital elements onto the physical world offers a unique way to make multiple temporalities experiential, fostering a critical inquiry into the present reality.

Experiencing alternative temporalities requires immersion, a state of deep mental engagement in which individuals feel absorbed in a crafted environment (Lee, 2020). Immersion can emerge from sensorial experiences that replicate the feeling of being elsewhere or from narrative-driven strategies that draw users into action-oriented interactions (Lam et al., 2012; Murray, 1998). Over time, digital technologies – from early CAVE systems to contemporary Virtual Reality (VR) – have been employed to create immersive experiences that promote social, political, and environmental awareness (Bendor, 2018). Crucially, these experiences do not exist in isolation; they embed symbols, memories, histories, and values drawn from both individual and collective practices (Malpas, 2018).

However, technology alone does not guarantee immersion. The level of engagement is shaped by how well an experience is designed and made accessible. When designed effectively, immersive experiences can foster empathy and encourage meaningful action (Douglas & Hargadon, 2000), and even extend their influence beyond the experience itself, shaping users' perceptions and behaviors in the real world (Bendor, 2018). As Murray (1998) notes, such experiences contribute to a sense of possibility, giving rise to felt alternative worlds (Bendor, 2018; Candy & Kornet, 2019) and creating spaces for reflection and engagement. It is in this capacity that immersion becomes particularly relevant to speculative design.

Among immersive technologies, AR occupies a unique position. By overlaying digital elements onto the physical world, it enables users to simultaneously engage with both physical and digital realities. Thus, AR maintains a continuous relationship between digital and physical layers, one that is most effective when those elements remain cognitively and physically consistent. This relationship is often described as "diegetic", referring to the coherence between different elements within a single fictional world (Bleecker, 2009).

In this paper, we present an AR experience designed to explore counterfactual presents that foster engagement with More-than-Human (MtH) worlds. We analyze insights from a pilot study conducted with 10 participants, reflecting on both the outcomes and the design process. Through this, we aim to provide an initial response to the following question: How can we design AR-mediated experiences that enable the exploration of multiple temporalities and foster engagement with MtH worlds?

In what follows, we first outline related work on how AR has been leveraged in speculative design. We then describe the AR experience we designed and the methods used in our investigation, followed by the results of our pilot study. Finally, we discuss our design insights and considerations, the limitations of our investigation, and future directions for integrating AR into speculative design practices.

BACKGROUND

CONTEXT: MORE-THAN-HUMAN

The concept of the MtH refers to an ensemble or "assemblage" of both organic and mechanical entities that share the planet with humans (Giaccardi & Redström, 2020; Wakkary, 2021). At its core lies an acknowledgement that human-centric ways of being are no longer tenable – if they ever were (Latour, 1993) – and stand in the way of developing a post-anthropocentric, sustainable and equitable world. In Felix Guattari's words: "Now more than ever, nature cannot be separated from culture; in order to comprehend the interactions between ecosystems, the mechanosphere and the social and individual Universes of reference, we must learn to think 'transversally'" (Guattari, 2014, p. 28).

The ontological symmetry promoted by MtH perspectives stands in stark contrast with Western ontologies that center on (a very particular notion of) the human and thus fail to consider other agencies and perspectives. Despite the fact that we humans are but a single group of actors within a complex world, much of the West's cultural milieu and nearly all of its economic activities are oriented by ideological constructs and hierarchies that situate certain beings (and therefore temporalities) as more valid and valuable than others (Bastian, 2009; Bernardes da Souza, 2021).

MtH perspectives, in contrast, embrace notions of diversity and multiplicity (Price & Chao, 2023) and see temporalities as co-constituted by constant encounters between humans, nonhuman actors, and their environments (Álvarez & Coolsaet, 2020). Thus, relationality emerges as a foundational MtH ontological principle by positing that beings exist through their relationships (Escobar et al., 2024), rather than as isolated entities. Embracing relationality decouples existence from human exclusivity, highlighting the co-constitution and interdependence of diverse human and nonhuman agencies across entangled life worlds (de la Bellacasa, 2017). In Bendor's words (2025, p. 2), relationality deeply contributes to the making of an "emerging sustainability imaginary [...] that moves away from the established truths of modernity [...] significantly distinguishing it from modernist sustainability imaginaries, which tend to promote individualized, efficiency-driven solutions".

Providing discursive space to types of agencies and temporalities that were repressed in dominant history, epistemology, and ontology (Álvarez & Coolsaet, 2020), allows those agencies to take a more intentional, direct part in co-shaping future imaginaries, and, therefore, futures alongside humans (Bessai et al., 2024). Accordingly, other-than-humans become allies in envisioning radical alternatives (Bastian, 2009). Given the strong relationship between being and temporality (Bergson, 2007; Heidegger, 1962), to perceive time otherwise is to open up to unknown possibilities with radical potential and, returning to Guattari's words, to seed transversal thinking.

SPECULATIVE EXPERIENCES WITH AR

AR technologies can generate meaningful experiences of alternative worlds – social, spatial, temporal reconfigurations of unrealized possibilities – as evident in Tamiko Thiel's pioneering AR art installations (Thiel, n.d.). In *Gardens of the Anthropocene* (Figure 2), for instance, viewing the physical environment through an AR app reveals multiple post-anthropocentric lifeforms that have evolved to survive the changing climate.

Figure 2: Gardens of the Anthropocene, AR installation, Tamiko Thiel, 2016. Commissioned by Seattle Art Museum Olympic Sculpture Park.

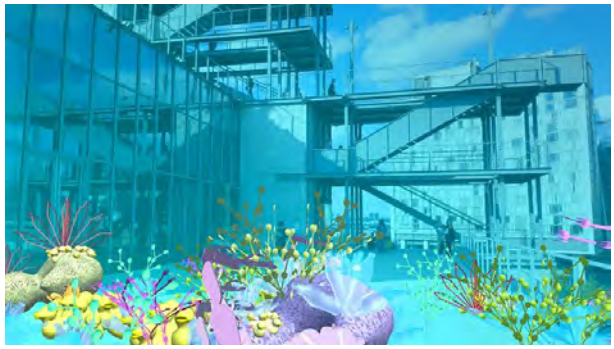

Figure 3: Unexpected Growth, AR installation, Tamiko Thiel and /p, 2018. In the collection of the Whitney Museum of American Art, New York.

In *Unexpected Growth* (Figure 3), the presence of users triggers the transformation of what first appears as a coral reef into an array of plastic detritus, giving tangible, immediate form to human–nature relations.

Despite AR's capabilities, increased accessibility, and relatively low cost, it is rarely used in speculative design practice, and when it is, it remains largely undertheorized. While the technology has been examined from various angles – its future ethical implications (Eghtebas et al., 2023; Harrington et al., 2022), potential domain-specific applications (Colombo et al., 2018; Palmieri et al., 2020), possible near-future

developments (Baumann et al., 2017; Vlachokyriakos & Abosaleh, 2022), and use as a medium for staging alternative futures (Matos Tuna et al., 2023; Ylipulli et al., 2016) – its use as a speculative design tool remains largely unexplored. Notable exceptions include Clarke (2021) and Wanick (2019), who describe and leverage AR as a means for shaping alternative dimensions and places, respectively.

METHODS

The pilot experience we designed focused on counterfactual presents that lend themselves to MtH worlds, and was situated in the Netherlands. In our scenario, the Netherlands has developed and applied an alternative water management strategy that considers the perspectives and interests of nonhumans. This alohistorical (i.e., counterfactual) bifurcation resulted in a higher degree of local biodiversity, which was reflected in the selection of digital elements (nonhuman beings) – including rabbits, otters, birds, and plants – chosen because they are currently endangered due to past (and ongoing) ecosystem changes caused by flood control operations (Troost et al., 2012). We further placed spatialized audio (animal calls, wind, and water sounds) within the scene. These elements became more or less audible depending on the user's distance from each sound's source in the augmented environment.

The key to the experience is the overlay of an alternative present on top of the current one, intended to foster engagement with both the outcomes of modernist socio-technical policies and the value of opening up to nonhuman actors.

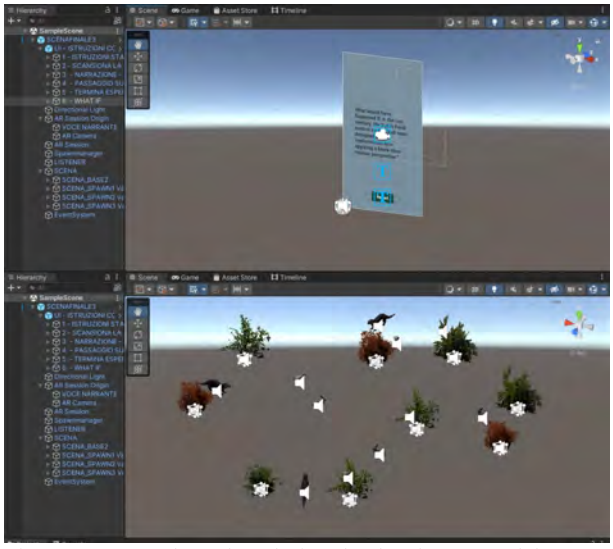

Figure 4: Screenshot taken during the development of the application with the software Unity.

We staged the experience outdoors, taking advantage of a nearby green space as our "canvas" to provide visual coherence between the digital elements and the physical setting. This green space was positioned next to a built area that remained visible during the experience, providing a visual cue of the alternative past's overlaying over the current present. For reasons detailed in the Discussion section, we opted to use a smartphone (handheld device) to ensure accessibility and chose Unity as our software platform (Figure 4). Lastly, both the digital models and the spatialized audio were programmed to appear based on where the user points the handheld device's camera at the start of the experience. Their behaviors – such as movement patterns or the duration of sounds – were designed to remain consistent throughout the entire experience. This approach ensures that all users share a similar "digital experience", with minimal variation caused by their initial position in the physical space.

The experience unfolded as follows (Figure 5 provides interface and scene screenshots and Figure 6 shows participants during the experience): First, the user is invited to discover the digital beings by moving around and looking at the physical environment through the handheld device. Users are stimulated primarily through two senses – sight and hearing.

After an initial instructional phase, the user is introduced to the alternative scenario via audio, from the perspective of a nonhuman narrator. The user is then invited to explore the setting (moving through the space) using only the sense of hearing (the screen remains dark), discovering the spatialized sounds around them as a trigger for engagement with the narrative. Following this 30-second audio-only phase, the device's screen activates and the user is invited to explore the scene visually, moving through it and observing the digital flora and fauna overlaid on the physical setting. This visual exploration phase lasts about one minute.

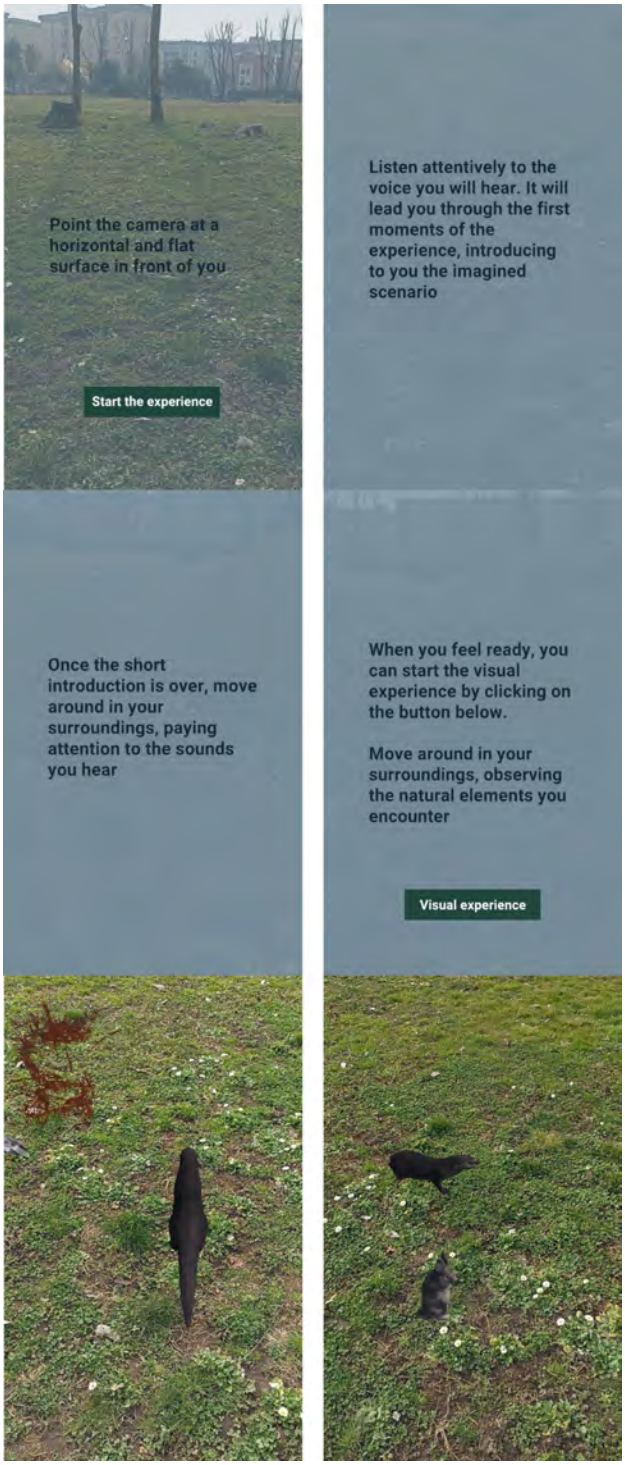

Figure 5: Screenshots of the interface and the augmented scene.


Figure 6: Photos of participants during the experience.

METHODOLOGY AND METHODS

Given the experimental nature of our investigation, we adopted Research through Design (RtD) as our overarching methodological approach. RtD allows new knowledge to emerge through an iterative movement between design action and reflection, where designing is understood not as problem-solving but as a form of material inquiry (Stappers & Giaccardi, 2017).

The AR experience described above was tested with 10 participants, including MSc students, PhD researchers, and design faculty members. Some participants were partially aware of the research, while others had no prior knowledge of it, but all had at least heard of MtH approaches to design.

To help us make sense of the experience, we used two evaluation methods: personal meaning maps and unstructured interviews.

Personal meaning mapping is a qualitative technique that allows individuals to represent their interpretations of specific topics or experiences (Hay et al., 2008). All participants completed a pre-experience personal meaning map to capture their initial familiarity with MtH concepts and vocabulary. After the experience, participants updated their maps with any new findings, ideas, or thoughts that emerged. We collected each participant's pair of maps (pre- and post-experience) and compared them to identify what new ideas and thoughts emerged after the experience. We digitally transcribed the reflections written on the maps and summarized them, as discussed in the Results section.

We used unstructured interviews as the second method to evaluate the AR experience. The interviews began with a broad question: Did you discover something new through the experience?

All interviews lasted between 10 and 15 minutes. We recorded, transcribed, and analyzed them through thematic analysis (Braun & Clarke, 2006). Similar to the personal meaning maps, we grouped and summarized

key reflections from the interviews, which we discuss in the Results section.

RESULTS

We now delve into the results of our investigation, starting from the personal meaning maps and then moving to the interviews.

PERSONAL MEANING MAPS

A comparison of the pre- and post-experience personal meaning maps reveals that all participants added new and relevant insights, ideas, or concepts after the experience.

For instance, P1 added the concept of "multiplicity", which was absent from their initial map, describing it as "multiple perspectives and worlds that can co-exist at the same time". P3 reflected on the notion of "change" and emphasized "how we should incorporate diverse worldviews into our own practices". Similarly, P4 expanded on the concept of "change" by considering how human actions have shaped "landscapes". P6 reflected on "abundance" in relation to the "several digital elements [in the augmented scene]" and used the term "co-emergence" to describe "new types of relations between humans and nonhumans".

Other participants highlighted themes of "coexistence" and "relationality". P7 noted that the experience enhanced their "curiosity toward nonhuman actors" and underscored the need for "peaceful coexistence [between humans and nonhumans]". This theme was echoed by P5 and P10, who connected it to ideas of "harmony" and "relationships", respectively. P8 emphasized "awareness" as a critical means of fostering meaningful relations with others, while P9 explicitly reflected on AR as a "tool to experience other worlds and perspectives".

Although more anecdotal, P2 offered an insightful reflection prompted by the experience, recalling childhood memories of encounters with MtH worlds.

INTERVIEWS

During the interviews, participants shared new reflections that further enriched what they had noted on the personal meaning maps.

P1 reflected on "the risk we pose to other agents", linking anthropocentric actions to their impact on landscapes and questioning "how the landscape would look if a MtH perspective had been applied to design the Dutch built environment". Similarly, P4 contemplated "new ways to imagine the landscape if a MtH perspective were integrated into these processes", envisioning "peculiar spaces characterized by chaotic beauty". In the same vein, P9 questioned "how a space could have been transformed if humans had embraced MtH perspectives".

In addition to reflecting on broader implications, some participants noted the experience as a motivator for further exploration of the issue depicted in the augmented counterfactual scenario. P1 expressed a desire to investigate "the Dutch flood management strategy" in greater depth. This sentiment was echoed by P5, P7, and P8, who described the alternative present as a "trigger to discover more about the topic", including biodiversity challenges currently faced by the Netherlands (Smit, 2021).

Sensory immersion emerged as a significant aspect of participants' reflections. P3 and P7 emphasized the role of sensory elements in shaping their engagement – particularly the auditory elements. P7 noted that sound heightened their "curiosity", especially "during the transition between the auditory and visual experience". P7 further remarked that sound helped to "make the environment more alive and truly natural".

Participants also reflected on the temporal dimensions conveyed through the AR experience. P6 described the digital elements as "ghosts of a past" and "remnants of the past brought back digitally", suggesting that the experience evoked "a sense of a more livable past". They considered AR a valuable tool for making alternative temporalities tangible. Similarly, P9 affirmed that the "AR experience was useful in raising curiosity about the consequences of this potential shift in perspective".

Despite knowing that interaction with the digital elements was not possible, P10 attempted to engage with them and described this as a way to create "a bond with the nonhumans in the scene". This prompted them to reflect on "sustainable relations between humans and nonhumans".

DISCUSSION

In a broader context, our findings contribute to ongoing discussions in MtH design research about how to make this approach more concrete and actionable as a design practice (Giaccardi et al., 2025; Lindley et al., 2023; Nicenboim et al., 2024; Poikolainen et al., 2024). They offer a practical method for incorporating nonhuman perspectives and alternative temporalities into the design process, supporting efforts to decenter the human within design (Giaccardi & Redström, 2020; Wakkary, 2021). By using AR to foster "transversal" thinking across species and timescales (Guattari, 2014), our work contributes to grounding speculative design within a MtH framework of inquiry (Nicenboim et al., 2025; Oktay et al., 2024; Tironi et al., 2023).

Indeed, our research indicates that AR holds potential to render counterfactual, multiple temporalities

experientially accessible. By bridging these temporal layers with real-world concerns, AR can foster critical reflections on how – in our case – MtH perspectives could have informed and reshaped (and may yet inform and reshape) current reality. This process, in turn, has the capacity to enhance engagement with the themes depicted in the experience.

Participants engaged with multiple temporalities and worlds in diverse ways, facilitated by the experiential cues embedded within the augmented scenario, which they experienced as sensorially present, abundant, and rich. These digital cues – and the act of observing/interacting with them – enabled participants to draw intellectual connections between the augmented experience and the real-world issue under exploration. Some participants traced their reflections back to the scenario's thematic focus, expressing heightened curiosity about the topic and demonstrating how they linked the physical present with the digital past. This suggests that the counterfactual scenario successfully engaged them with its core subject, illustrating AR's capacity to foster critical engagement with the themes at hand.

Other participants reflected on temporal dynamics, such as the notion of change over time, or explicitly referenced the "past" and its role in shaping present realities, suggesting the experience as a form of hauntology (Fisher, 2012).

However, it is important to note that AR is not a magic wand. Our research underscores that its effectiveness hinges on careful design. Based on that, we present key insights that speculative designers might employ to leverage AR as a tool for exploring temporal pluralities and fostering engagement with pressing topics. Specifically, we propose the concept of AR layering as a valuable design principle for speculative practices, followed by a discussion of interaction design considerations critical to achieving this aim.

AR LAYERING AS A KEY SPECULATIVE DESIGN PRINCIPLE

The research presented here makes a case for the value of multi-temporal experiences as part of speculative design practices. If the critical thrust of speculative design is an effort to demonstrate that any single reality is only one of many possible ones, it seems relevant that the pluralization of reality would extend in all temporal directions – not only a plurality of futures but also of pasts and presents (Bendor et al., 2021). This approach allows users to explore histories where certain voices were silenced (Ryding et al., 2021). Practically, the "hegemonic" present remains anchored in the physical world, always visible beneath the AR layers, while alternative pasts, presents, and futures unfold on top of the physical setting. Providing experiential cues to the act of temporal pluralization seems to us a valuable contribution to speculative design practice. The experience of inhabiting alternative pasts, presents, or futures can give the critical aspect of speculation an omnidirectional, embodied grounding by situating it in lived experience. This experiential dimension additionally contributes to unveiling the relationality between multiple temporalities and, in turn, multiple agencies, emphasizing the intertwined formation and mutual dependency of diverse human and nonhuman agencies across entangled life worlds (de la Bellacasa, 2017).

Our choice to focus on AR technologies was driven by the intuition that they are not only adequate but optimal for conveying experiences of multiple temporalities because of their capacity to layer various spatiotemporal realities on top of each other. Layering and overlaying alternative "worlds" (specific spatiotemporal configurations) allows multiple alternatives to be explored simultaneously, provoking a confrontation between past, present, and future possibilities – each potentially represented with one or more layers. This approach undermines linear perceptions of time by creating a situation in which plural temporalities coexist experientially, stimulating shifts in perspective, engagement, and attitudes.

INTERACTION DESIGN FOR SPECULATIVE AR LAYERING

When designing the AR experience, we were guided by a set of key questions that helped us balance immersion, engagement, and accessibility. These questions were not fixed at the start, but emerged through our use of RtD, and are, therefore, presented as outcomes of the process itself. We see them as useful design considerations for others working in similar contexts.

In this section, we explain how we approached each issue by responding to these questions and reflecting on the decisions we made. While this question-driven method is similar to other AR design frameworks (e.g., Clarke, 2021), our focus is specifically on speculative, multi-temporal, and MtH engagement.

How much of the narrative should be predefined, and how much should be left open for user interpretation?

A primary consideration when designing AR experiences is the structure of the narrative underpinning the experience, which can strongly influence user engagement, imagination, and sense-making (Lingan et al., 2021). Rather than providing a fixed storyline, we opted for a loose narrative that allowed participants to discover connections between digital elements and the counterfactual scenario on their own. This decision aligns with the concept of "unfinishedness" (Bendor, 2018) and the speculative design principle of using ambiguity to spark imagination (Encinias et al., 2021). By intentionally incorporating gaps in the narrative, we encouraged users

to co-create meaning, making the experience more personally relevant (Wong & Khovanskaya, 2018).

How can sensory and cognitive cues be designed in ways that enhance engagement with the theme?

Another crucial factor we considered was the sensory and cognitive aspects of the experience, which can impact the overall degree of immersion (Irshad et al., 2020). This meant carefully balancing the sensory cues embedded in the augmented scene and managing the user's attention level and cognitive/emotional load (Aromaa et al., 2020). To leverage these aspects, we integrated digital flora and fauna, spatialized sound, and other sensory elements to create a rich, layered environment. Participants' reflections confirmed that these elements heightened curiosity and emotional connection with nonhuman entities, therefore demonstrating an increased level of engagement with the theme.

Where should the AR experience be situated, and how will the environment affect immersion?

The effectiveness of immersion also depends on the physical setting, since AR overlays digital entities on top of physical reality. We deliberately staged the experience "in the wild", embedding it in an uncontrolled public environment rather than a closed, curated space. While this approach increased spontaneity, it also introduced the potential for disruptions (e.g., interference from passersby) that could break diegetic consistency and diminish engagement.

How much agency should users be given over the interactive experience?

Interactivity is a key factor in creating immersive experiences. User performance, defined by the type and complexity of interactions with digital elements (Papakostas et al., 2021), and point of view – whether synaptic external (third-person) or embodied (first-person), or a combination of both (Normand et al., 2012; Sereno et al., 2022) – can significantly impact immersion. To prevent overwhelming users and potentially hinder their personal exploration of the experience and its themes, we deliberately minimized interaction complexity. Rather than assigning users an active role in the scenario, we positioned them as observers. While higher interactivity can enhance engagement, it also increases cognitive demands that may detract from reflection and interpretation (Markman & Brendl, 2005). Our approach prioritized an exploratory mindset, allowing users to engage with the speculative scenario at their own pace.

What type of display best balances immersion, accessibility, and ease of use?

When it comes to accessibility, the choice of hardware – displays and interfaces – plays a significant role in shaping the experience. Different display types come with trade-offs. Handheld mobile devices are widespread and easy to carry, yet they allow more of the real-world background to remain visible, potentially reducing immersion (Zhang et al., 2017). Head-mounted displays offer a higher degree of immersion but may introduce usability challenges (Zollmann et al., 2021). Since accessibility and mobility were central to our design goals, we opted for handheld mobile displays, accepting certain limitations in terms of diegetic consistency.

Which software capabilities will best serve the desired interactive and visual qualities of the AR experiences?

Lastly, software constraints influence the fidelity and depth of the experience. Different AR development tools offer varying levels of rendering capability and interactivity, and they require different levels of programming expertise (Davidavičienė et al., 2020). More user-friendly platforms enable quick design and deployment but often limit customization, while more complex tools demand greater technical effort but allow richer interactivity. Because our experience involved managing multiple digital elements in a procedurally structured scene, we selected Unity as our development platform. This choice introduced trade-offs in the time and technical expertise required to implement and refine the experience.

By addressing these key design questions – narrative structure, sensory/cognitive cues, physical setting, interactivity, hardware, and software – we shaped an AR experience that sought to balance engagement and accessibility while encouraging users to critically engage with a counterfactual present. The choices we made, while effective in fostering curiosity and reflection, also introduced specific limitations and challenges.

LIMITATIONS

Reflecting on our investigation, we identified several limitations and opportunities for future work.

There is room (and need) to account for different user groups in the design of speculative AR experiences. While some design decisions are difficult to anticipate in advance of a concrete design context, more generic placeholders (or prompts) could be introduced regarding accessibility, ability, cultural background, and intersectionality. As Encinias et al. (2021, p. 99) note, "Every design excludes, to a higher or lesser degree and more or less explicitly, particular individuals or groups from accessing the possibilities that such design brings forward. Speculative designs are no exception and hence, it is paramount that designers consider how they negotiate exclusion as a tension during their design process".

The pilot experience we designed tested only one possible path through the myriad of options AR affords

in our context. Given more time and resources, we would have liked to attempt additional – perhaps more complex – designs and to evaluate them more broadly (not only with design students and researchers).

The participants we recruited were very helpful in providing evidence of AR's usefulness in bringing multiple temporalities to life. However, several of them were also quite knowledgeable about the specific topic (MtH), and so their comments should be interpreted accordingly. In other words, just how much of what they reported was exclusively elicited by the AR experience remains unclear.

On a more technical note, although AR is becoming increasingly widespread and fairly easy to implement, one still needs a certain degree of expertise to develop a successful AR experience. This applies to both coding/programming and UX design skills, which not all speculative designers possess. That said, some software and platforms are easier to use than others, allowing even novices to develop engaging experiences. The choice of software is therefore particularly critical, since it greatly influences both the design process and the final output. We encountered this challenge firsthand: lacking proficiency with this type of software, we faced complex design requirements that ultimately forced us to seek assistance from a programmer.

This raises another limitation – perhaps a more general reflection on AR. Compared to other immersive technologies (such as VR), AR is characterized by a lower degree of realism, simply because the physical layer always contrasts with the digital layer(s). While this may present a hard limit to how realistic AR experiences can be, the lack of fidelity can also be considered an advantage, providing users with blank spaces to fill in themselves, thus triggering even more powerful imaginative processes (Bendor, 2018). For instance, we decided to stage our experience outdoors, taking advantage of a green space adjacent to a built area. We thought this might help create a cue for reflection, given the friction between "nature" and "culture" (mapped onto "alternative now" and "current now"). However, we suspect it may have reduced the realism and immersiveness of the experience.

CONCLUSION

This paper began with the premise that speculative design practices can be enriched by engaging not only plural futures but also plural pasts and presents. In this context, multi-temporality emerges as a critical dimension of speculative design's aim to challenge dominant views of reality and reveal alternative possibilities. Building on principles of experiential futures, we emphasized the importance of using experiential cues to bring multiple temporalities to life and identified AR as a promising medium for doing so, thanks to its inherent capacity for layering realities.

To explore this potential, we focused on MtH worlds as a compelling case study to examine how AR-mediated experiences of multiple temporalities can foster engagement with specific topics and concepts. We developed a pilot AR experience, tested it with 10 participants, and analyzed their responses through personal meaning maps and interviews. The findings illustrated the value of AR in fostering critical reflection and meaningful engagement with MtH principles – relationality, care, interdependence to cite some – through the staging and overlaying of alternative, multiple temporalities. Our primary contribution lies in introducing AR layering as a design principle for speculative, MtH design, demonstrating how AR can pluralize temporal experience, prompt new perspectives.

We also offer a set of reflective design considerations (posed as guiding questions and answers) that can inform the creation of future multi-temporal AR experiences.

We believe the research we presented provides a useful starting point for other designers to build upon. However, we recognize there still exists considerable room for future development and refinement, and significant potential to include a broader spectrum of user groups to ensure our approach is equitable, inclusive, and representative of diverse perspectives.

We conclude by reaffirming our view that AR holds great potential for unlocking users' imaginations, pointing them toward alternative realities and thus seeding radical, transformative possibilities.

REFERENCES

Álvarez, L. & Coolsaet, B. (2020). Decolonizing Environmental Justice Studies: A Latin American Perspective. *Capitalism Nature Socialism* 31(2), pp. 50–69.

Aromaa, S. et al. (2020). Awareness of the Real-World Environment when Using Augmented Reality Head-Mounted Display. *Applied Ergonomics* 88, 103145.

Auger, J. (2013). Speculative Design: Crafting the Speculation. *Digital Creativity* 24(1), pp. 11–35.

Auger, J. & Hanna, J. (2023). Counterfactual and Alternative Histories as Design Practice. *Temes de Disseny* 39, pp. 20–39.

Bastian, M. (2009). Inventing Nature: Re-writing Time and Agency in a More-than-Human World. *Australian Humanities Review* 47, pp. 99–116.

Baumann, L., Stokes, B., Bar, F., and Caldwell, B. (2017). Infrastructures of the Imagination:

Community Design for Speculative Urban Technologies. In *Proceedings of the 8th International Conference on Communities and Technologies*, June 26, 2017. Troyes, France, pp. 266–269.

Bendor, R. (2018). *Interactive Media for Sustainability*. Cham: Springer International Publishing.

Bendor, R. (2025). Sustainability Imaginaries by Design. *Sustainability: Science, Practice and Policy* 21(1), 2443998.

Bendor, R., Eriksson, E., and Pargman, D. (2021). Looking Backward to the Future: On Past-Facing Approaches to Futuring. *Futures* 125, 102666.

Bergson, H. (2007). *The Creative Mind: An Introduction to Metaphysics*. Mineola, New York: Dover Publications.

Bernardes da Souza, C. R. (2021). More-Than-Human Cultural Geographies Towards Co-Dwelling on Earth. *Mercator - Revista de Geografia da UFC* 20, pp. 1–10.

Bessai, R., Bendor, R., and Balkenende, R. (2024). Designing with More-than-Human Temporalities. In *Proceedings of the DRS Conference*, June 23-28, 2024. Boston, USA, pp. 23–28.

Bleecker, J. (2009). Design Fiction: A Short Essay on Design, Science, Fact and Fiction. [online] Available at: http://drbfw5wfjlxon.cloudfront.net/writing/DesignFiction_WebEdition.pdf [Accessed 16 July 2024].

Braun, V. & Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology* 3(2), pp. 77-101.

Candy, S. & Dunagan, J. (2017). Designing an Experiential Scenario: The People Who Vanished. *Futures* 86, pp. 136–153.

Candy, S. & Kornet, K. (2019). Turning Foresight Inside Out: An Introduction to Ethnographic Experiential Futures. *Journal of Futures Studies* 23(3), pp. 3–22.

Clarke, P. (2021). Future Places Toolkit: Engaging Communities through Augmented Reality and Performance. *Research for All* 5(2), pp. 205–226.

Clarke, R., Heitlinger, S., Light, A., Forlano, L., Foth, M., and DiSalvo, C. (2019). More-than-Human Participation: Design for Sustainable Smart City Futures. *Interactions* 26(3), pp. 60–63.

Colombo, S., Lim, Y., and Casalegno, F. (2018). Augmented Health and Safety: Exploring Future Scenarios through Design Fiction. In *Proceedings of the 11th PErvasive Technologies Related to Assistive Environments Conference*, June 26, 2018. Corfu, Greece, pp. 363–370.

Coskun, A., Cila, N., Nicenboim, I., Frauenberger, C., Wakkary, R., Hassenzahl, M., Mancini, C., Giaccardi, E., and Forlano, L. (2022). More-than-Human Concepts, Methodologies, and Practices in HCI. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems* (CHI EA '22), April 28, 2022. New Orleans, LA, USA, pp. 1–5.

Davidavičienė, V., Raudeliūnienė, J., and Viršilaitė, R. (2020). Evaluation of User Experience in Augmented Reality Mobile Applications. *Journal of Business Economics and Management* 22(2), pp. 467–481.

de la Bellacasa, M. P. (2017). *Matters of Care: Speculative Ethics in More than Human Worlds*. Minneapolis, Minnesota: University of Minnesota Press.

Douglas, Y. & Hargadon, A. (2000). The Pleasure Principle: Immersion, Engagement, Flow. In *Proceedings of the eleventh ACM on Hypertext and hypermedia*, May 30, 2000. San Antonio, Texas USA, pp. 153–160.

Du Vignaux, M. M., Léger, P. -M., Charland, P., Salame, Y., Durand, E., Bouillot, N., Pardoen, M., and Sénécal, S. (2021). An Exploratory Study on the Impact of Collective Immersion on Learning and Learning Experience. *Multimodal Technologies and Interaction* 5(4), pp. 1–17.

Dunne, A. & Raby, F. (2013). *Speculative Everything: Design, Fiction, and Social Dreaming*. Cambridge, Massachusetts: The MIT Press.

Eghtebas, C., Klinker, G., Boll, S., and Koelle, M. (2023). Co-Speculating on Dark Scenarios and Unintended Consequences of a Ubiquitous(ly) Augmented Reality. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, July 10, 2023. Pittsburgh, PA USA, pp. 2392–2407.

Encinias, E., Božanić, S., and Šuran, O. (2021). Methods, Approaches and Tools: Ambiguity, Tensions and Scopes. In Mitrović, I., Auger, J., Hanna, J., and Helgason, I. (eds.) *Beyond Speculative Design: Past - Present - Future*. Split: SpeculativeEdu, pp. 94–165.

Escobar, A., Osterweil, M., and Sharma, K. (2024). *Relationality: An Emergent Politics of Life beyond the Human*. London, UK: Bloomsbury Publishing.

Fisher, M. (2012). What Is Hauntology? *Film Quarterly* 66(1), pp. 16–24.

Forlano, L. & Halpern, M. K. (2023). Speculative Histories, Just Futures: From Counterfactual

Artifacts to Counterfactual Actions. *ACM Transactions on Computer-Human Interaction* 30(2), pp. 1–37.

Fry, T. (2009). *Design Futuring: Sustainability, Ethics and New Practice*. London, UK: Bloomsbury Publishing Plc.

Giaccardi, E. & Redström, J. (2020). Technology and More-Than-Human Design. *Design Issues* 36(4), pp. 33–44.

Giaccardi, E., Redström, J., and Nicenboim, I. (2025). The Making(s) of More-than-Human Design: Introduction to the Special Issue on More-than-Human Design and HCI. *Human–Computer Interaction*, 40(1-4), pp. 1-16.

Guattari, F. (2014). *The Three Ecologies*. London, UK: Continuum.

Harrington, C. N., Klassen, S., and Rankin, Y. A. (2022). All that You Touch, You Change: Expanding the Canon of Speculative Design Towards Black Futuring. In *CHI Conference on Human Factors in Computing Systems*, April 29, 2022. New Orleans, LA USA, pp. 1–10.

Hay, D. B., Wells, H., and Kinchin, I. M. (2008). Quantitative and Qualitative Measures of Student Learning at University Level. *Higher Education* 56(2), pp. 221–239.

Heidegger, M. (1962). *Being and Time*. San Francisco, California: Harper San Francisco.

Hirskyj-Douglas, I., Kantosalo, A., Monroy-Hernández, A., Zimmermann, J., Nebeling, M., and Gonzalez-Franco, M. 2020. Social AR: Reimagining and Interrogating the Role of Augmented Reality in Face to Face Social Interactions. In *Companion Publication of the 2020 Conference on Computer Supported Cooperative Work and Social Computing*, October 17, 2020. Online, pp. 457–465.

Howell, N. et al. (2021). Calling for a Plurality of Perspectives on Design Futuring: An Un-Manifesto. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems* (CHI EA '21). Yokohama, Japan, pp. 1–10.

Irshad, S., Rambli, D. R. A., and Sulaiman, S. (2020). Design and Implementation of User Experience Model for Augmented Reality Systems. In *Proceedings of the 18th International Conference on Advances in Mobile Computing & Multimedia*, November 30, 2020. Chiang Mai, Thailand, pp. 48–57.

Lam, H., Bertini, E., Isenberg, P., Plaisant, C., and Carpendale, S. (2012). Empirical Studies in Information Visualization: Seven Scenarios. *IEEE Transactions on Visualization and Computer Graphics* 18(9), pp. 1520–1536.

Latour, B. (1993). *We Have Never Been Modern*. Cambridge, Massachusetts: Harvard University Press.

Lee, H. (2020). A Conceptual Model of Immersive Experience in Extended Reality. [online] Available at: https://osf.io/preprints/psyarxiv/sefkh [Accessed 16 July 2024].

Light, A. (2021). Collaborative Speculation: Anticipation, Inclusion and Designing Counterfactual Futures for Appropriation. *Futures* 134, 102855.

Lindley, J. et al. (2023). Productive Oscillation as a Strategy for Doing More-than-Human Design Research. *Human–Computer Interaction*, 40(1–4), pp. 117–142.

Lingan, C. L., Li, M., and Vermeeren, A. P. (2021). The Immersion Cycle: Understanding Immersive Experiences through a Cyclical Model. *Proceedings of the Design Society* 1, pp. 3011-3020.

List, D. (2004). Multiple Pasts, Converging Presents, and Alternative Futures. *Futures* 36(1), pp. 23–43.

Malpas, J. (2018). *Place and Experience: A Philosophical Topography*. New York, New York: Routledge.

Markman, A. B. and Brendl, C. M. (2005). Constraining Theories of Embodied Cognition. *Psychological Sciences* 16(1), pp. 6–10.

Matos Tuna, I., Rafael, S., Almeida, V. M., and Henriques, A. O. (2023). Gender Stereotypes in Interaction Design. Render Me – Augmented Reality Masks to Inhabit the Metaverse. In Chen J. Y. C. & Fragomeni, G. (eds.) *Virtual, Augmented and Mixed Reality*. Cham: Springer Nature Switzerland, pp. 43–57.

Morley, N. (2019). Counterfactualism and Anticipation. In Poli, R. (ed.) *Handbook of* Anticipation. Cham: Springer International Publishing, pp. 595–613.

Murray, J. H. (1998). *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*. Cambridge, Massachusetts: The MIT Press.

Nicenboim, I., Lindley, J., Zaga, C., Berger, A., Forlano, L., and Giaccardi, E. (2024). More-Than-Human Design in Practice. In *Proceedings of the DRS Conference*, June 23-28, 2024. Boston, USA, pp. 2-9.

Nicenboim, I., Oogjes, D., Biggs, H., and Nam, S. (2025). Decentering through Design: Bridging

Posthuman Theory with More-than-Human Design Practices. *Human–Computer Interaction*, 40(1-4), pp. 195-220.

Nooney, L. & Brain, T. (2019). A 'Speculative Pasts' Pedagogy: Where Speculative Design Meets Historical Thinking. *Digital Creativity* 30(4), pp. 218–234.

Normand, J. -M., Servières, M., and Moreau, G. (2012). A New Typology of Augmented Reality Applications. In *Proceedings of the 3rd Augmented Human International Conference*, March 8, 2012. Megève, France, pp. 1–8.

O'Brien, H. L. & Toms, E. G. (2008). What is User Engagement? A Conceptual Framework for Defining User Engagement with Technology. *Journal of the American Society for Information Science and Technology* 59(6), pp. 938–955.

Oktay, G., Lee, M., Barati, B., and Wakkary, R. (2024). Caring through: Engaging with Temporality of Care in More-than-Human Design. In *Proceedings of the Halfway to the Future Symposium*, October 21-23, 2024. Santa Cruz CA, pp. 1-8.

Palmieri, S., Righi, A., Bisson, M., and Ianniello, A. (2020). Training with a World Champion: Augmented Reality Applications in Sport Design-Led Research. In *2020 IEEE International Conference on Artificial Intelligence and Virtual Reality*, December 14-18, 2020. Online, pp. 366–370.

Papakostas, C., Troussas, C., Krouska, A., and Sgouropoulou, C. (2021). Exploration of Augmented Reality in Spatial Abilities Training: A Systematic Literature Review for the Last Decade. *Informatics in Education* 20(1), pp. 107–130.

Poikolainen Rosén, A., Salovaara, A., Botero, A., and Juul Søndergaard, M. L. (Eds.). (2024). *More-than-Human Design in Practice* (1st ed.). New York, New York: Routledge.

Preuß. A. K. (2021). The Learning Process in Live-Action Simulation Games: The Impact of Personality, Motivation, Immersion, and Flow on Learning Outcome in a Simulation Game. *Simulation & Gaming* 52(6), pp. 775–795.

Price, C. & Chao, S. (2023). Multispecies, More-Than-Human, Nonhuman, Other-Than-Human: Reimagining Idioms of Animacy in an Age of Planetary Unmaking. *Exchanges: The Interdisciplinary Research Journal* 10(2), pp. 177–193.

Rovelli, C. (2018). *The Order of Time*. London: Allen Lane, an imprint of Penguin Books.

Ryding, K., Jørgensen, S. H., and Tsaknaki, V. (2021). Sensing Places: Making Room for More-Than-Human Encounters in the City. In *Proceedings of Politics of the Machines - Rogue Research*, September 14-17, 2021. Berlin, Germany, pp. 330–335.

Sereno, M., Wang, X., Besancon, L., Mcguffin, M. J., and Isenberg, T. (2022). Collaborative Work in Augmented Reality: A Survey. *IEEE Transactions on Visualization and Computer Graphics* 28(6), pp. 2530–2549.

Smit, A. (2021). More Life in Streams and Ditches. [online] Available at: https://edepot.wur.nl/553780 [Accessed 16 July 2024].

Song, K. W. et al. (2024). Unmaking & HCI: Techniques, Technologies, Materials, and Philosophies Beyond Making. *ACM Transactions on Computer-Human Interaction* 31(6), pp. 1–6.

Stappers, P. J. & Giaccardi, E. (2017). Research through Design. In Soegaard, M. & Friis-Dam, R. (eds.) *The Encyclopedia of Human-Computer Interaction*. The Interaction Design Foundation, pp. 1–94.

Thiel, T. (nd.). Artworks Exploring the Intersection of Space, Place and Cultural Memory. [online] Available at: https://tamikothiel.com/ [Accessed 16 July 2024].

Tironi, M., Chilet, M., Marín, C. U., and Hermansen, P. (Eds.). (2023). *Design for More-than-Human Futures: Towards Post-Anthropocentric Worlding*. Milton Park, UK: Taylor & Francis.

Troost, K., Tangelder, M., van den Ende, D., and Ysebaert, T. (2012). From Past to Present: Biodiversity in a Changing Delta. [online] Available at: https://repository.tudelft.nl/record/uuid:7a2da3d0-9a93-4a9e-913e-1af48eab4eb7 [Accessed 16 July 2024].

Tuomi, I. (2019). Ontological Expansion. In Poli, R. (ed.) *Handbook of Anticipation*. Cham: Springer International Publishing, pp. 37–71.

Vlachokyriakos, V. & Abosaleh, A. H. S. (2022). Civic Fictions: Exploring the Socio-technical Implications of Augmented Reality in Future Cities through Science Fiction Prototyping. In *2022 7th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference*, September 23, 2022. Ioannina, Greece, pp. 1–8.

Wanick, V. (2019). Exploring the Potential of the Fourth Dimension as a Speculative Design Element: Reflections and Applications. [online] Available at: https://eprints.soton.ac.uk/434795/ [Accessed 16 July 2024].

Wakkary, R. (2021). *Things We Could Design: For More than Human-Centered Worlds*. Cambridge, Massachusetts: The MIT Press.

Wong, R. & Khovanskaya, V. (2018). Speculative Design in HCI: From Corporate Imaginations to Critical Orientations. In Filimowicz, F. & Tzankova, V. (eds.) *New Directions in Third Wave Human-Computer Interaction: Volume 2 – Methodologies*. Cham: Springer International Publishing, pp. 175–202.

Ylipulli, J., Kangasvuo, J., Alatalo, T., and Ojala, T. (2016). Chasing Digital Shadows: Exploring Future Hybrid Cities through Anthropological Design Fiction. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, October 23, 2016. Gothenburg, Sweden, pp. 1–10.

Zeitlyn, D. (2015). Looking Forward, Looking Back. *History and Anthropology* 26(4), pp. 381–407.

Zhang, C., Perkis, A., and Arndt, S. (2017). Spatial Immersion Versus Emotional Immersion, Which is More Immersive? In *Proceedings of the 9th International Conference on Quality of Multimedia Experience*, May 31 – June 2, 2017. Erfurt, Germany, pp. 1–6.

Zollmann, S. et al. (2021). Visualization Techniques in Augmented Reality: A Taxonomy, Methods and Patterns. *IEEE Transactions on Visualization and Computer Graphics* 27(9), pp. 3808–3825.