The Evolution of Spatial Computing and its impact on UX Designers

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Abstract

With the impending global release of the Apple Vision Pro, spatial computing has become increasingly mainstreamed in today's world. User experience (UX) design will have to adapt to new technologies, but little practical research is available for guidance as UX moves towards the new era of spatial computing. Exploring the intersection between spatial computing and UX design requires extensive research which will be guided through the research question: 'How might the evolution of spatial computing impact UX design?' Spatial computing is on a trajectory towards a more seamless integration of both digital and physical worlds. To understand the future of spatial computing, a contextual analysis of the world was launched by gathering signals and identifying trends. The trends were cross referenced with spatial computing to understand how spatial computing could evolve in the next twenty years. The futures wheel identified eight themes that demonstrated potential future scenarios that UX designers must be mindful of. The study explored the impact of spatial computing on UX designers and developed recommendations to help them proactively prepare for the future.

Spatial computing will need product designers to build ergonomic products to facilitate the easy transition between the digital and the real world. UX designers will need the skills to design for 3D and integrate spatial conceptualization when researching, prototyping, and designing. Designing to limit cognitive overload, distractions, and to visualize data safely will be the responsibility of UX designers. As AI is increasingly integrated into spatial computing, UX designers will have to understand how to utilize the personalization and data synthesis capabilities of generative AI, both responsibly and ethically. UX designers should be aware of the industries that are embracing this technology and explore opportunities in high demand sectors, such as the companies using digital twins. UX designers must learn the skill of designing collaborative spatial computing experiences to help remote work become more productive. UX designers must inform themselves of the harms and benefits of these technologies on the human brain, social life, privacy, and wellbeing, to design ethical experiences that enhance human life. Overall, UX designers have a large part to play when it comes to ensuring that this new era of spatial computing is beneficial to humanity.

Acknowledgements

To my husband

Tom, you have been there every step of the way and I cannot imagine where I would be if it was not for your constant encouragement, faith, and love. Thank you for everything.

To my family

Thank you to my family for your unending support and always encouraging me to reach for the stars. To my parents Joel and Sujani, you have paved the way for me to be here.

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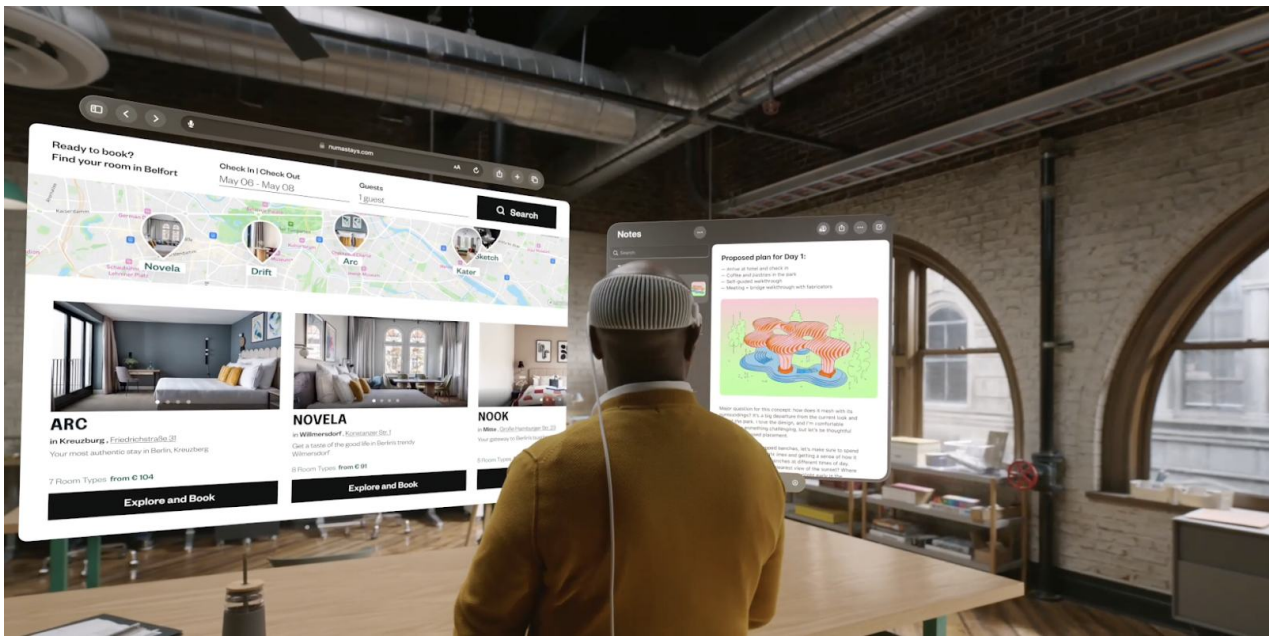
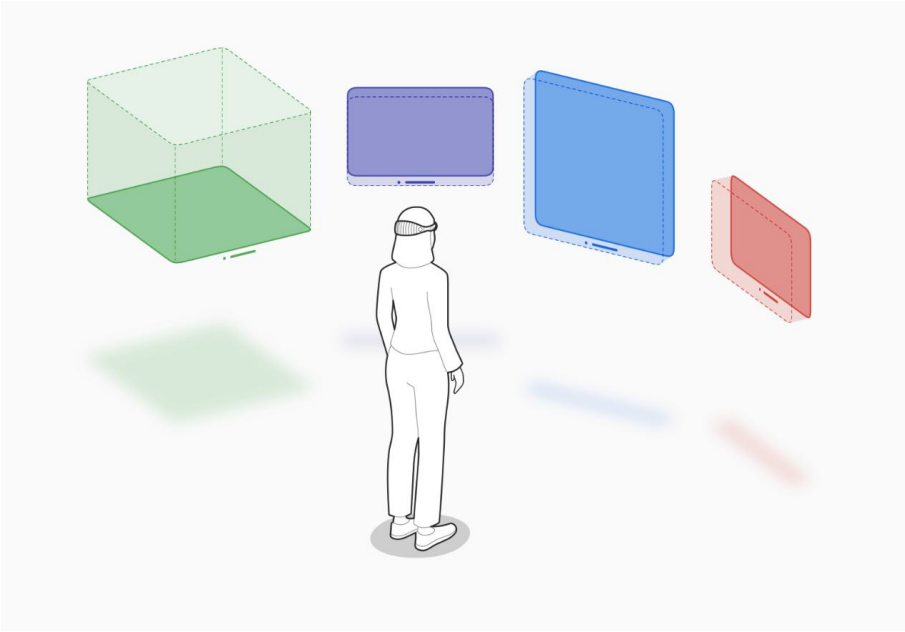
Table of contents

Introduction



(Apple, 2024)

In 2023, Apple introduced the new Vision Pro headset with the tag “welcome to the era of spatial computing”, promising to “make a computer interface a seamless part of our world” (Apple, 2023). The headset comes with the ability to use physical space around us to host digital displays. These displays are virtual screens controlled by eye tracking, gestures, and voice commands. For example, the users’ gaze and focus allows the ability to hover on an object, while touching the thumb and index finger is the way to ‘click’. Reviewer Haselton described it as, “You sit in your world while looking at a digital one, and then plop different apps around you. You can work, play games, watch movies, or surf the web all within the space of your own couch (Haselton, 2024).



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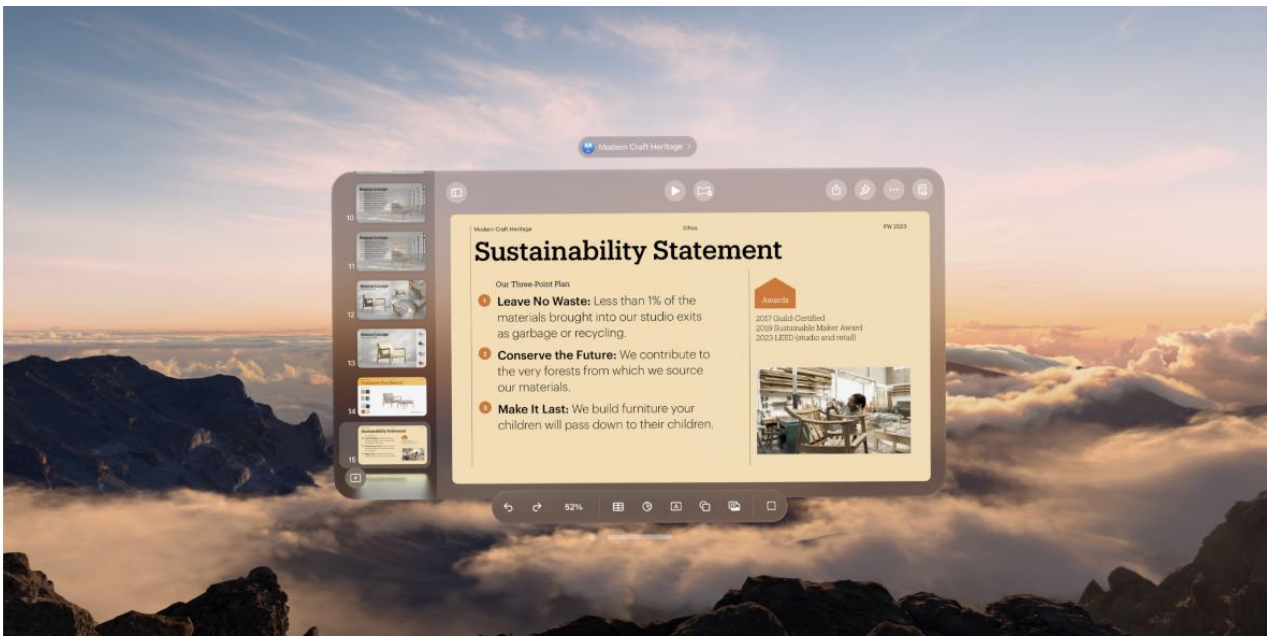


(Apple, 2024)

This image demonstrates user environments which are virtual screens in a virtual environment of choice (User environments on Apple Vision Pro, 2024). “You can work or watch movies in Hawaii, by a lake, in White Sands or at Joshua Tree. They are all relaxing environments with calming sounds and slow animations – like clouds moving across the sky — that help you feel like you are almost there” (Haselton, 2024).

Though the product itself was due to release the following year, the audience was immediately engaged. In the three months after Vision Pro was publicized, the term ‘spatial computing’ grew a search count of +5500%, an astounding 4500% increase compared to the previous year (Nifty Sparks, 2023). However, this term is not new to the English dictionary. Simon Greenwold, founder of the term ‘spatial computing’ defines it “as human interaction with a machine in which the machine retains and manipulates references to real objects and spaces” (Greenwold, 2003, p. 2). Today’s experience of spatial computing transforms our 2D computing models which require monitors, desktops, desks, keyboards, and a mouse - to a 3D infinite canvas. Apple describes the experience as allowing people to stay connected to their surroundings while they can immerse themselves completely in a new world of virtual creation. They explain that the experience can be fluid: “start in a window, bring in 3D content, transition to a fully immersive scene, and come right back” (Apple, 2024). To Greenwold, it meant to eliminate the boundaries of the physical and digital realms (Greenwold, 2003). The increasing adoption of wearables to track fitness and health goals is driving industries to build smarter devices in more portable forms (Vogels, 2020). Spatial computing centralizes the capabilities of a personal computer, mobile, watch, ring, into one wearable device. We see spatial computing gaining traction in enterprises. Meta is releasing their newest MR headset ‘Quest 3’ which can be used to supplement a virtual workspace (Facebook VR, 2023).

Magic Leap 2 is an AR device that maintains the user's view while overlaying digital content while performing surgeries (Magic Leap 2, 2023). More apps are virtualizing events, conferences, training, education, tourism, socializing, and work, to accommodate this new spatial reality (Bob, 2023). Spatial computing had a market value of around $102.1 billion in the year 2021. Projections indicate that this industry is expected to expand to around $544.6 billion by the year 2032 (FMI, n.d).

It is evident the world of technology is rapidly converging towards the convenience of having one device that combines all digital and physical experiences easily. So, what does this mean for user experience (UX) designers?

User experience can be defined as “the process design teams use to create products that provide meaningful and relevant experiences to users" (Interaction Design Foundation, 2023). User experience often combines human centred design thinking, psychology, visual design, and business requirements to improve customer satisfaction. UX designers in the corporate world research and design a company’s online experience to ensure it is as seamless and intuitive as possible for customers so that they can easily complete the transaction (Rostoll, 2018). For example, in e-commerce a typical user experience design request can ask, ‘How can we design a website to support a customer's journey to easily purchase a clothing item?’. Experience design for the corporate designer can be very two dimensional: commonly outputting designs for mobile or desktop screens. The creations that follow are usually a 2D website or app that a user interacts with via their PC device, mouse, keyboard, or phone. However, in the future of spatial computing there are several distinct factors to consider, one being that the body now acts as a cursor. Eye tracking, voice commands, hand gestures, movement, are soon to replace the mouse and keyboard to engage in tasks (Apple, 2023). Any physical space can now be someone’s monitor. In mixed reality, a screen can be virtually ‘placed’ in the top right corner of one’s field of vision without obstructing views while cooking a meal. A quick glance to the right is enough to check a recipe or overlay the YouTube cooking tutorial without needing to search for a favourite cookbook or be have attention divided between phone and stove. When visiting the zoo, instead of inputting animal search questions in Google, relevant facts can overlay one’s view as the eyes focus on their favourite animal (Kengadaran, 2020). User experience design must be able to fully integrate the body in future experiences.

Spatial UX Design poses some challenges. Studies show VR/AR headsets have complex interfaces and cognitively overload users (Michalia, 2023). User opinion surveys indicate the ways that basic tasks like typing, navigation, or scrolling are tedious and slow to accomplish (Michalia, 2023). Contextual and spatial data will be imperative to creating an experience for the new spatial computing era. Ensuring these 3D experiences are accessible to older or disabled individuals also warrants research and design (Dombrowski, Smith, Sparkman, 2019).

Chaoui, Bouzidi-Hassini, and Bellik (2022) note that designers are stranded, “concerning spatial user interaction design and development, there is no attempt to propose tools that might help designers in their task”. User experience design will have to adapt to innovative technologies, but little practical research is available for guidance as UX moves towards the new era of spatial computing. Exploring the intersection between spatial computing and UX design requires extensive research which will be guided through the research question:

‘How might the evolution of spatial computing impact UX Design?’

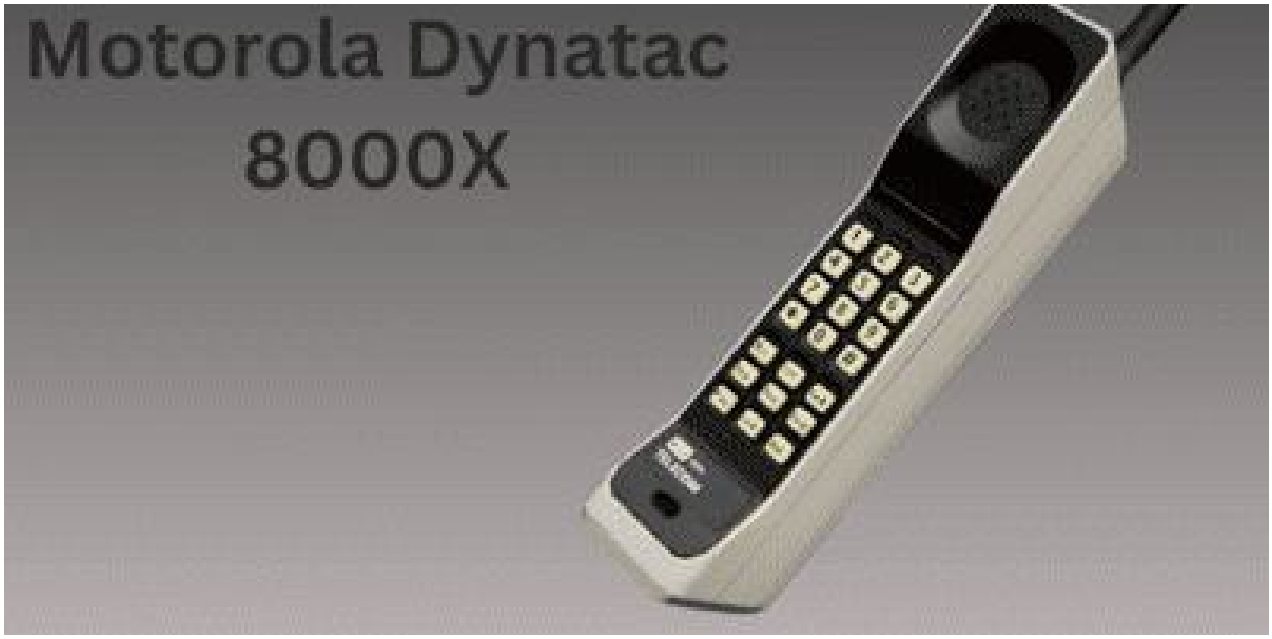
Secondary questions include:

- **What trends might influence the trajectory of spatial computing?**
- **What are the possible trajectories of spatial computing?**
- **How will lateral technologies such as ambient computing, the internet of things, the metaverse, and AI affect spatial computing?**
- **How will UX design in the next twenty years be impacted by the trajectories of spatial computing?**

This paper explores the challenges and opportunities for UX Designers to be integrated in the spatial computing world by using a strategic foresight and innovation approach. Since the technology landscape is rapidly changing, any UX recommendations regarding spatial computing will have to be future-proofed. Current trends are identified and cross referenced with spatial computing uncertainties using a futures wheel. From there, themes and recommendations are drawn to inform UX designers strategically and innovatively on the foresight of spatial computing. The purpose of the paper is to give UX designers a picture of what their future job responsibilities may look like within this impending epoch so UX designers can prepare their skills and be ready for the new era of spatial computing.

Spatial Computing: Concepts & Technologies

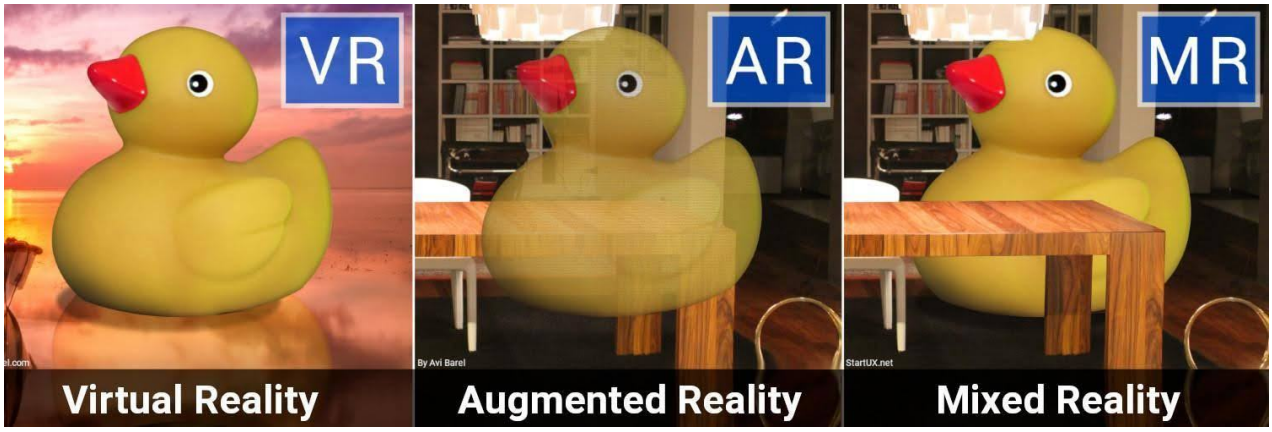
In 2003, MIT student Simon Greenwold foresaw that engineers would build consumer electronics to “shrink into near invisibility”. We see this in the way chunky personal computers have slimmed into thin, slick laptops such as the MacBook Air. Going further, the smallest PC today is the LarkBox which boasts 700 MHz at 2.4 inches (Chuwi, 2023). We observe that phones both miniaturize and move in majority from landlines to mobile phones. In the 1980s, people lined up to buy the first cellular phone, the Motorola DynaTAC 8000X which weighed two pounds and offered just a half-hour of talk time after charging, and sold for $3,995 (Sanders & Stappers, 2014). Today, the newest Motorola Razr 40 weighs only 188 grams and is 3.47 inches. The trend of minimizing the physical space taken up by computing devices has been on the rise since digital technology began. At the same time, the context of computer devices has expanded to include many aspects of the real world. Greenwold saw a gap between “the idealized spaces of computer science and the heavy, cluttered spaces of real-world” and that it was “time for a reclamation of space as a computational medium” (Greenwold, 2003, p. 8).



(Moto Smartphone, 2023).

What does that reclamation of space look like? Today, spatial computing is represented by three main technologies: Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Spatial computing uses these technologies to blend the digital and physical world, creating immersive spatial experiences where users can interact without the need for much physical equipment.

Avi Barel, UX/UI Lead and XR creator describes the differences between the three concepts of spatial computing using imagery:



(Barel, 2017).

Virtual Reality

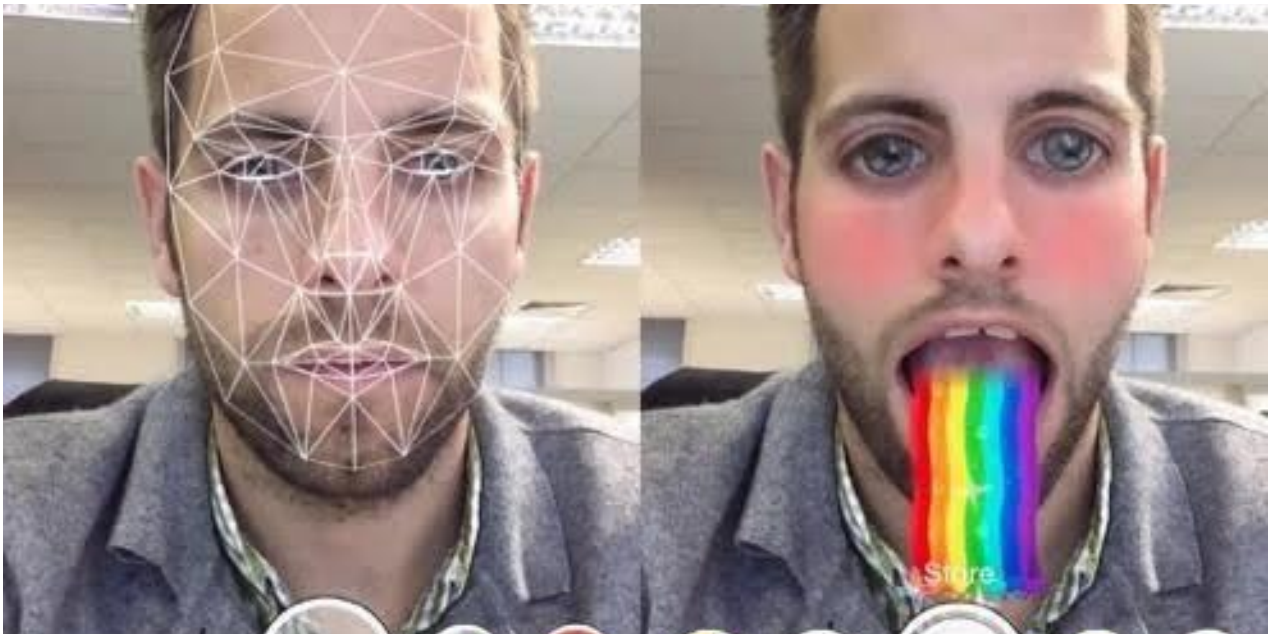
Virtual reality is a computer-generated simulated environment in which a user immerses and explores in 360 degrees, usually through a 'headset or closed head-mounted displays (HMDS)' (Ren & Adamczyk, U of T, 2022). In VR experiences, the physical or real-world environment is entirely blocked out (Tremosa, 2023). Virtual reality is often used for immersive gaming but can also be used for employee education and training in various sectors such as health, engineering, architecture, and interior design, to name a few (Sinlapanuntakul, Korentsides & Chaparro BS, 2023). This can be seen as a "risk-free way to conduct hands-on learning" (ADK Group, 2022).

A popular example of VR has been the 'metaverse' defined as "a shared space where the users can interact with each other in a computer-generated environment" (Bob, 2023). While Meta's (formerly Facebook) adoption of the word has become increasingly popular, the metaverse was coined by author Neal Stephenson in his 1992 science fiction novel about life in virtual reality, 'Snow Crash', where he described, 'a network of virtual worlds' (Stephenson, 1992). The virtual world is said to comprise thousands of smaller worlds where the user can shop, work, play, or even immerse themselves in a virtual concert (Stephenson, 1992). The metaverse can also host 'digital twins' that allow enterprises to replicate all of their physical assets and the networks and technical interactions between these, such as a business' supply chains, factories, stock inventory, retail outlets, and staff – all so there is decreased risk and disruption, meaning no delays or financial costs, and increased customer satisfaction (Abraham, Cruz, et.al, 2022). General Electric uses digital twins of aircraft parts to failure test them, increasing aviation safety (DeHae…

Augmented Reality

Augmented reality enhances a real-world environment by overlaying digital elements such as images or data on top of it (ADK Group, 2022). As Tim Cook, CEO of Apple said, “AR allows individuals to be present in the world but hopefully allows an improvement on what’s happening presently” (Pantoja, 2017). Examples of this can be seen in face filters where the real world image of a human face can be overlapped by a myriad of filters. Accuvein is an AR healthcare technology that allows the digital image created by lasers and heat to allow nurses to easily locate veins. This AR technology increases the likelihood of a successful first-time injection by 350% (AccuVein, 2019).

Augmented reality allows nurses to locate veins using lasers and heat (AccuVein, 2019).



Snapchat filters augment faces with designs, interactions, and playful images (Estela, 2021).

Mixed Reality

Mixed reality combines both VR and AR to create seamless navigation between real world and digital elements by overlaying elements and immersing the user in the experience. MR “creates a hybrid experience where physical and digital objects can co-exist in real-time” (ADK Group, 2022). The difference between AR and MR is that MR allows you to manipulate and interact with elements of both the real and the digital world. For example, you can place a digital box on your real-world bedside table, open it, see what is inside, paint it, or reconstruct it (Girnyak, 2021). It is not like VR where the user is in a completely digital universe, nor is it AR where the user can overlay a digital element but not necessarily interact with it. MR gives users the chance to continue to physically interact with their real world with superimposed digital elements.

Magic Leap is a wearable spatial computer that allows surgeons to access overlaid digital information while performing surgeries that maintain the doctor's visual connection to the physical world. Magic Leap 2 is an enterprise solution that works for many professions by maintaining its users’ actual view of their working environment while “seamlessly integrating intelligent, behaviorally realistic digital content within their field of view” (Magic Leap 2, 2023). Other use cases include remote assistance in manufacturing, assessments in healthcare, and planning and design review in construction (Magic Leap 2, 2023).

There are several other technologies that enable spatial computing.

Spatial Mapping

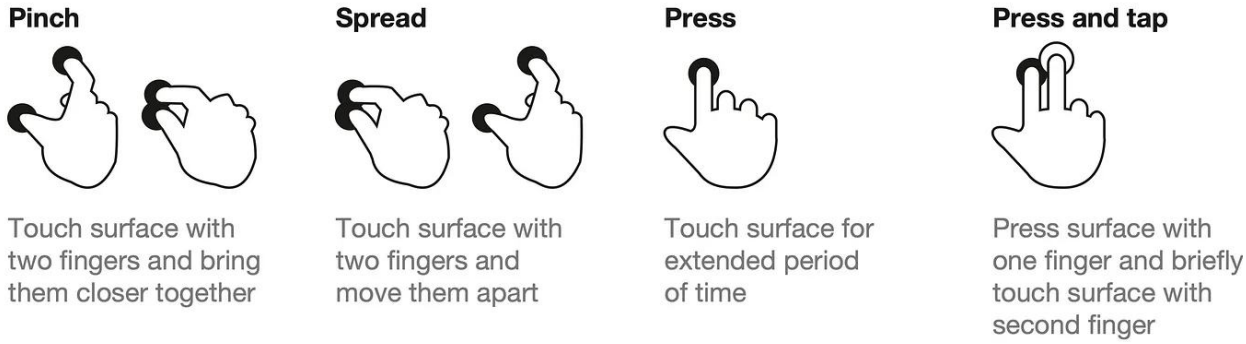
Spatial mapping is the process of creating a digital, 3D model of the physical environment. This is done through scanning, capturing, and mapping data about the geometry and features of the real-world space using sensors, cameras, and other technologies. Spatial computing then uses spatial mapping by providing real-time processing of spatial data and interactions, allowing dynamic and context-aware computing (Yenduri et al., 2024).

Location Tracking

Location tracking supports the precise tracking of the movement or position of a user. Tracking in real time allows spatial computing to be context-aware of physical objects or environments that are close by. Technologies such as GPS, accelerometers, gyroscopes, and cameras, track the user's movement and let digital content be bound to the physical world (Yenduri et al., 2024).

Gesture Tracking

Gesture Tracking captures the human trait of performing gestures either with the hands, arms, or eyes. These gestures can be seen as symbols by the computer to perform various functions such as selecting, manipulating, directing, or commanding various computer functions (Barel, 2019).



Voice Tracking

Voice tracking allows technologies to understand spoken commands. Embedded cyber-physical systems along with artificial intelligence use speech recognition to identify the primary user and complete speech-requested tasks. For example, the “VoCopilot tracker can help document meetings and generate notes, even when participants speak different languages.” It can also monitor daily conversations and extract key points to summarize their content (An & Varshney, 2023).

Haptic Feedback

Haptic feedback integrates an additional layer to interfaces by using tactile sensations to inform the user. An example today could be that your watch vibrates when you forget to pause your workout, giving you a reminder to keep moving or pause the workout to keep their pace. Since no visual or audio is required, haptic feedback plays a significant role in creating accessible experiences. Haptic feedback allows the computer to communicate back to the user through tactile sensations, bridging the gap between an immersive experience and reality (Burdea, 1999).

Overall, spatial computing is a multidisciplinary field that leverages technologies such as VR, AR, MR (XR), spatial mapping, location tracking, gesture and voice tracking, and haptic feedback to merge the physical and digital realms. These emerging technologies provide users with new ways to engage in their surroundings. They have the potential to revolutionize various industries and change the way we perceive and interact with the world. To accomplish this, the user experience of these technologies must stay human-centred, however this is not always the case. With technology advancing rapidly, it is harder to identify and address its negative effects (Humane Tech, 2022). Humane Tech notes, “By the time people understand the negative externalities of a new platform, product, or service, the harms can be difficult to reverse” (2022). In other industries, governmental policies and ethical codes of conduct exist to protect the human from harmful innovation. This unfortunately does not exist for the technology industry today, leaving the UX designer responsible for championing the human from the beginning of the innovation process. It is pertinent that with this new era of technology that the UX designers are at the forefront.

Now that we have covered spatial computing concepts and enabling technologies, it is pertinent to understand UX Design and its concepts.

UX Design

UX Design

To understand the intersection of spatial computing and user experience design, we must first understand the history, concepts, and methodologies that constitute UX design.

UX Design History

In the 1980's, research, and prototyping were used to test the market viability of a product by asking research subjects if they were likely to buy the product and at how much they would be willing to pay for it (Sanders & Stappers, 2014). Participants of testing were called 'customers' or 'consumers'. There was little to no exploration around the cognitive, emotional, or social needs of the human (Sanders & Stappers, 2014).

Usability testing rose when personal computers such as the Microsoft PC and Macintosh became widely available. The cognitive and ergonomic needs of the user began to grow (Sanders & Stappers, 2014). The description of the participants of testing moved from the market research term 'customer or consumers' to 'users' whose needs could be met by a product or interface. Design and user research became the primary focus of creating a good product, shifting the actual creation of the product to be a result of design research. This process of researching the 'why and how' before the 'what' birthed UX design. Researchers and designers focused on ways to meet the need for the user and had a say in what made a product "useful, usable, and desirable" (Buehring & Bishop, 2020). Designers and design researchers were brought in to define the product to design, and not just how to design it.

UX Design Domain Map

As the design process continues to evolve, there are several main domains that I will emphasize when referencing UX design. These four areas are illustrated in the domain map created for this research topic.

Design Thinking

Design thinking is a method of problem solving that uses a human-centred design approach to innovation by integrating “the needs of people, the possibilities of technology, and the requirements for business success” (Brown, 2009). The process of design thinking includes five main stages: empathize, define, ideate, prototype, test, and implement (Gibbons, 2016). The process is circular because it values the complexity of humans as infinite. Good design is a process that grows with our understanding of the human, rather than arriving at a singular result. Accompanying these values are qualitative research methodologies such as field studies, focus groups, and user interviews, as well as quantitative research such as usability testing, A/B tests, and surveys (Rohrer, 2022). Qualitative research methods permit direct to participant communication so the researcher can question subjects open-mindedly and empathetically, leading them to define the problem from a human perspective. “The designer or researcher needs to take account of their subjects and make observations, which is a traditional research paradigm while also understanding their impact as a participant in the process” (Bender-Salazar, 2023, p. 7). Understanding the participant means understanding the problem. While design is often thought of as visual and technical, design thinking is being increasingly used to tackle wicked problems highly diverse contexts, such as city planning, architecture, policy design, systems design, and digital design. For example, this paper references systems design and policy design, two types of design that help with social planning but may not include visual or technical skills. These roles would involve designing with the human in mind, also known as human-centred design. They utilize design thinking in methods such as co-design to ensure that all stakeholders are represented equally and equitably.

Cognitive Science

Cognitive science is the practice of study of the human mind and its processes (Ghandi, 2022). UX design is multidisciplinary and intersects with cognitive science to deeply understand users. To make experiences intuitive, UX designers must understand how humans think and behave first. In UX Design, designers study how users are taking in information, processing it, and making decisions.

Experiences that allow “cognitive ease” successfully allow humans to “enter the flow state and relinquish control over their cognitive processes” (Adamska, 2020). UX Designers use information architecture to ensure that the flow of information matches the mental model of the user, without cognitively overloading the user. Tree tests, card sorts, layout testing, leading to effective content design ensure that people can adequately find and understand information without confusion. For example, a UX designer looking to redesign a menu would use card sorting to ask participants to group menu items and title them. This gives UX designers insight into the ways that various mental models may group and name information, resulting in a more intuitive menu navigation. Accessibility is a large part of cognitive science and UX design. Designing inclusively ensures those who are visually impaired, hearing impaired, or have other disabilities can equally access an experience and utilize it successfully.

Cognitive science is an important part of designing an experience around the ways humans perceive, reason, behave, pay attention, emote, and remember.

Product Design

While many UX design positions are related to digital design work, UX design can also seek to create an intuitive experience when it comes to hardware. UX design principles ensure the product is human centered, comfortable, meets expectations of the user, and works to heighten the user’s desired life experience. UX Designers working with physical products must ensure they are creating the best user experience amidst various product limitations such as challenges with form factor and low battery life, which are challenges for MR headsets (Prasongpongchai, 2021). End to end product experiences will need to be contextually aware of the users’ lifestyle habits. An understanding of the users’ daily activities can help UX and product designers identify the gaps between expectation and reality when interacting with a product. For example, knowing that a user is on transit for 2.5 hours a day may help advocate for a product with a longer battery lifespan or an attachable charging device. Prototyping is a large part of navigating the ambiguity of product design sketches that may not work as expected in physical spaces (Prasongpongchai, 2021). They also help to materialize ideas and “evaluate your design before investing your time and resources in building the actual product” (Prasongpongchai, 2021).

Digital Design

Digital design is a widely used medium for UX Design because of an increasingly online-centered world. This includes user research, wireframing, and user interface (UI) design, and uses components of design thinking and cognitive science to holistically create for the human. UX Designers pay special attention to typography, layout, information architecture, navigation, and interaction design to ensure that the experience is seamless, meets the needs of the user, and reflects the brand or tone they are looking to encapsulate. Typography can be used to enhance the user's readability and comprehension of the information needed. Contrast, colours, and layout, among other design principles, can all increase a human's trust in a brand, elicit loyalty, and provide satisfaction (Adamska, 2020). For example, users exhibit more trust and credibility to brands with more legible fonts, making it easier for readers to believe the conveyed message (Adamska, 2020). Therefore, UX Designers need to balance the aesthetics of the experience with intuitive usability to create a seamless experience.

UX design integrates concepts from design thinking, cognitive science, product design, and digital design.

UX Design Today

UX practices today are widely interdisciplinary, inclusive, integrated, and include many actors to inform the process of creating the best user experience. Newer domains such as social systems, services, and social design are spaces where design thinking is adequately integrated. We have shifted to design with people, abandoning terms such as 'user' or 'customer' and turning to more participatory terms such as 'human', 'participants' or 'partners'. Co-design is popularized as we define participants to be experts of their own experiences and include the end user but also various teams in a business such as the engineering team, marketing team, and other relevant stakeholders. UX designers become facilitators of subject matter experts to achieve the desirable experience for the human.

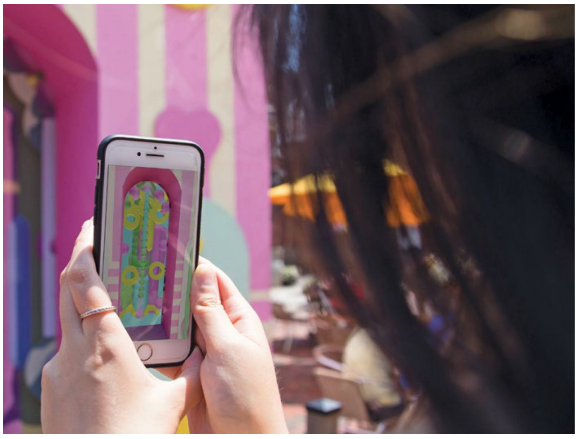
For businesses, an online presence is a substantial part of consumer decision making. Online experiences for businesses are not limited to e-commerce, but can include banking, insurance, and healthcare, among many others. These experiences can include online transactions to explore and purchase products. Hence, a user-friendly digital experience can significantly impact a company's profit. For every $1 invested in UX, the ROI is hundred-fold (Forrester Research, 2013). Businesses are motivated to expand their user base and prioritize the UX framework for user friendly designs.

A threat to good UX design for business transactions is that designers of today are primarily delivering designs for 2D screens displayed on desktops, mobiles, and watches. While certain companies on the forefront of technology such as Apple and Microsoft have innovated apps for spatial computing devices, it is not yet normalized in design culture today and many people still believe that the spatial computing era is a future consideration. As UX designers continue to focus on 2D experiences, they lack the competitive readiness to prepare themselves for the upcoming 3D and mixed reality future. While many 3D designers work in the games and entertainment industries, spatial computing has yet to normalize itself into everyday online experiences such as banking, health, and social apps. With the rise of spatial computing, all UX designers will need to learn how to design 3D immersive experiences that augment environments, visualize data, and allow for collaboration in a mixed reality world.

Spatial UX

We, as humans, live between two different worlds: one reality, and the other virtual. These online/offline experiences constantly interrupt each other through devices such as mobile phones, wearables, and the screens around us. In addition, the ever-present access to internet connectivity makes the human constantly reachable. Data, embedded in our communications and entertainment, is broadcast in seconds to mass audiences and instantly shared with friends and family. Humans use screens for remote work, online socializing, and education. However, this technology was not meant for the purpose of this level of reliance. The Covid-19 pandemic accelerated this multi-space living (Belitskaja, 2023). Being on screens for extended periods of time, we saw “the negative impact of a flattened spatial experience with the emergence of the likes of Zoom fatigue” (Belitskaja, 2023, p. 114).

The Covid-19 pandemic accelerated this multi-space living (Belitskaja, 2023). Limited to screens, we now identify a need to live in a digital and physical world with ease. Humans are built for a 3D and beyond experience, not a 2D lifestyle. Sasha Belitskaja addresses this possibility, creating multi spatial immersive mixed reality experiences through architecture, and hosting art installations where observers can see what a mixed reality future could look like. These constitute a potential future where physical and digital objects coexist, coined ‘phygital’ (physical-digital). While her exploration is architectural, the purposes of exploration for the user experience designer would be: How do we bridge the gap and experience spatiality to “feel like a natural extension to our identity?” for our day-to-day technological interactions (Belitskaja, 2023).



(iheartblob, ARc de Blob,Winter Stations, Toronto, Canada, 2021).

The overarching task for Spatial UX designers is to create the best user experience in both worlds and make it seamless enough to feel like one world. Yet, in today's corporate environment, UX Designers are not prepared for this multi-space living. As spatial computing becomes widely available to enterprises and for personal use, UX designers will need to know how to translate their knowledge of 2D experiences to 3D multi spatial thinking. UX designers need a toolkit. To ensure that this toolkit does not become outdated in the first 5 years of its publishing, it required futureproofing. This futureproofing will provide UX Designers with what they need to know about the rise of spatial computing and its future trajectory to discern what they need for today and for tomorrow. This allows us to appropriately answer the research question: How might the evolution of spatial computing impact UX Design?

Foresight

Foresight is “the discovery of a common space for open thinking on the future and the incubation of strategic approaches" (Cassingena Harper, 2003). Foresight encourages futures thinking to acutely define opportunities and future-proof strategies. To appropriately answer the research question, I had to understand the rapidly changing landscape of our world and its impact on the future of spatial computing so any recommendations to the UX designer would be future-proofed. Futurist Raphael Popper names the heart of the strategic foresight and innovation (SFI) process as the generation phase, where “(a) existing knowledge is amalgamated, analysed and synthesised; (b) tacit knowledge is codified; (c) new knowledge is generated; and (d) new visions and images of the future are created” (Popper, 2008, p. 68). In the generation phase are three main stages 1. Exploration, 2. Analysis, and 3. Anticipation. The subsequent list outlines the progression of foresight work undertaken for this research, across the three stages. It details the tasks accomplished during the generation phase to adhere to these stages:

Stage 1: Exploration

Understand the main issues, trends and drivers.

- Signals were gathered of current events both relevant and seemingly irrelevant to spatial computing.
- Signals were assembled into trends.
- Trends were created across the PESTLE sectors (see Appendix A).

Stage 2: Analysis

Understand how the context, trends, and drivers influence one another, and synthesize knowledge you learned from the exploration phase.

- Trends were placed in a futures wheel in the 1st, 2nd, or 3rd rings according to relevance to spatial computing. The futures wheel is a foresight tool which “helps identify primary, secondary, and tertiary potential consequences of a trend” created by Jerome C. Glenn in 1971 (Glenn, 2021, p. 1).
- Primary, secondary, and tertiary consequences of the trends were charted on the futures wheel, cross referenced with the central trend being ‘the rise of spatial computing’.

Stage 3: Anticipation

Considering the previous analysis, this stage is aimed at anticipating possible futures and/or suggesting desirable ones.

- Possible impacts of the cross-referenced trends were charted on the wheel, creating alternative trajectories of spatial computing and its future.

- Impacts of these trends on spatial computing were synthesized.
- Eight themes emerged when considering the future of spatial computing.
- UX recommendations based on themes from the futures wheel were identified to give UX designers a path to be ready for the new era of spatial computing.

A detailed explanation of the work done during the three stages of the generation phase is provided. During Stage 1 ‘Exploration’ phase, fundamental issues occupying our world was obtained through extensive secondary research. Using the PESTLE approach, I collected hundreds of signals across various political, economic, social, technological, legal, and environmental sectors. These signals were synthesized into trends that were both relevant and irrelevant to the topic to get an accurate picture of how the trajectories of the world may or may not impact spatial computing (see Appendix A). This constituted the first part of Stage 2: Analysis. Once these trends were identified, they were used to inform my next step of creating a futures wheel.

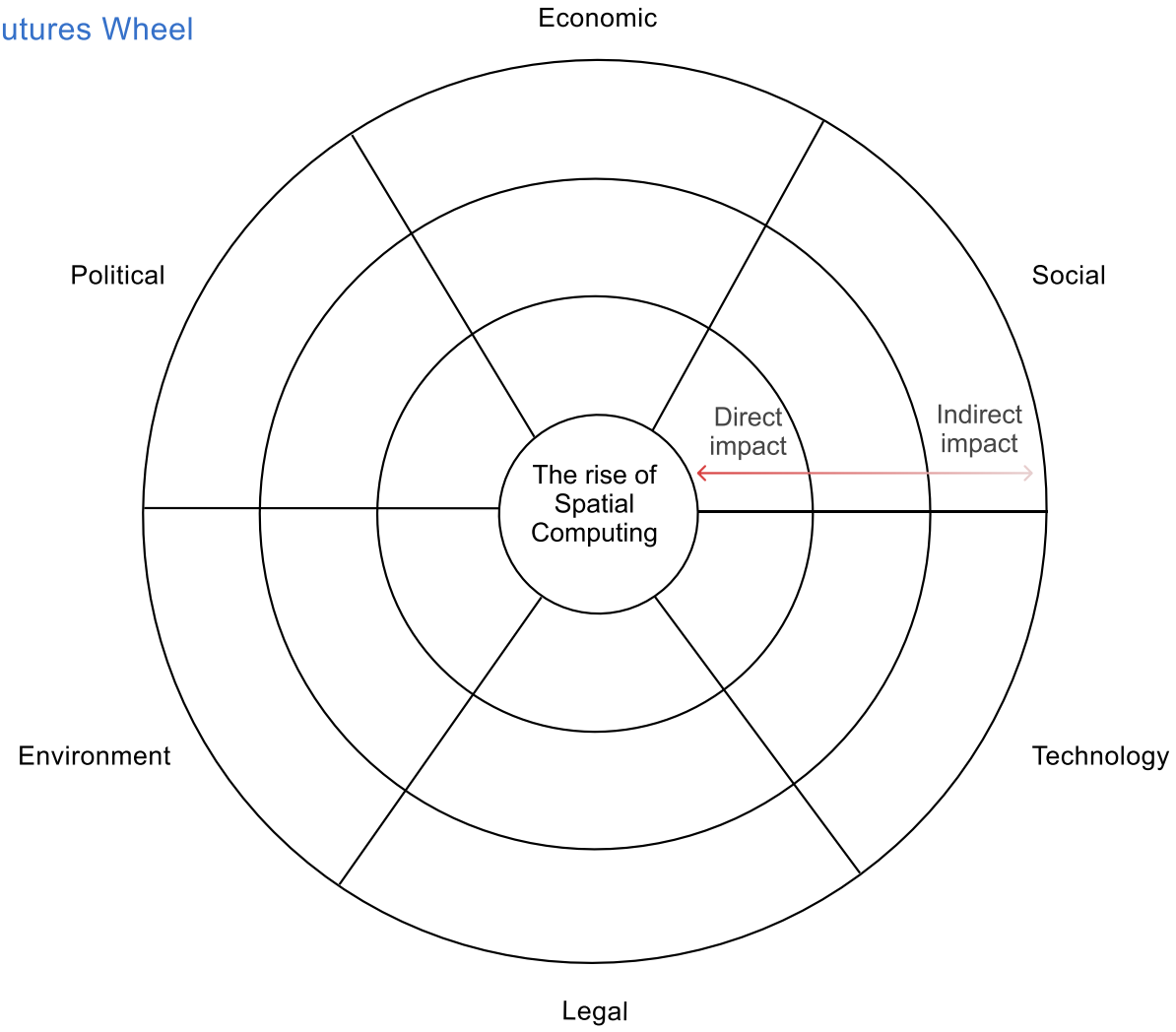
The futures wheel is purposed to “think through possible impacts of current trends or potential future events” and “show complex interrelationships” (Glenn, 2021, p. 2). By placing the contextual trends on the futures wheel and cross-referencing them with the main trend of ‘the rise of spatial computing’, I was able to generate possible consequences of how the trends could impact the future of spatial computing. This allows for outward-looking approaches that contrast the internal context which is a common practice of the generation phase (Glenn, 2021). Primary, secondary, and tertiary consequences were generated.

In the Stage 2 'Analysis' phase, the interaction between context and trends and the ways that they shape each other is investigated, utilizing a futures wheel as our method of exploration. A main trend is placed in the center of the wheel; in this case that trend was ‘the rise of spatial computing’. Contextual trends that were identified in Stage 1 were placed in the futures wheel as well. If they were relevant to spatial computing, they were placed in the inner ring. As relevance decreased, they were placed in either the 2nd or 3rd ring respectively. Relevance was determined by how closely related the trend was to spatial computing. This was decided by proximity to the contextual trends’ industry, stakeholders, technologies, and outputs, as well as tacit knowledge as Popper recommends. Technological trends were usually placed in the inner ring because they had a high relevance to spatial computing being within the same industry, having similar stakeholders, and interdependence with the technologies used. Political trends however such the rise of geopolitical volatility may have some relevance to spatial computing, but the relevance was more discreet. This placement helped guide the consequences that formed.

Stage 3: The Anticipation stage began, where the outcomes of the futures wheel and futures could be imagined, and desirable futures could be suggested. This exercise allowed me to generate the possible future outcomes of these trends and identify trajectories of spatial computing. Imagining the trajectory of spatial computing allowed me to answer its evolution as part of the research question: How might the evolution of spatial computing impact UX Design? Dozens of outcomes from cross-referencing were speculated (not predicted) (Chandler, personal communication, February 29, 2024).

The next step was to identify commonalities seen in the futures wheel outcomes. Several themes were identified when cross indexing the consequences of trends and the rise of spatial computing on the futures wheel. These themes synthesized the main products of the futures wheel and describe what the evolution of spatial computing could look like. Identifying the evolution of spatial computing allows the recommendations for UX designers to be future-proofed and relevant for a longer period. The themes and implications underwent review through personal communications interview with Spatial UX design expert, James Babarinde, who spearheaded the Microsoft Teams spatial computing user experience for the Apple Vision Pro. In the next section is a review of the themes that emerged from the futures wheel and their implications for UX designers.

Futures Wheel



Eight themes from the Futures Wheel and their UX implications

Futures Wheel Theme 1

Product design for spatial computing will get smaller and less noticeable

Futures Wheel Theme 1

Product design for spatial computing will get smaller and less noticeable

As previously discussed, Simon Greenwold wrote about the continued trajectory of heavy, cluttered computer spaces being reclaimed to “free up valuable ‘real estate’ on our desks” (Greenwold, 2003, p. 8). The public response to the Apple Vision pro echoes early responses to the first Motorola DynaTAC 8000X mobile phone being seen as clunky, heavy, inconveniently low battery life, and a hefty price of $3,995. Society could not see themselves utilizing such technology. Yet, its evolution has paved the way for one of the most widely used technologies today: the smartphone. However, just as the first Motorola evolved, so will the spatial computing displays. We can expect the product design for spatial computing to get smaller, lighter, more comfortable, and less noticeable in time.

The futures wheel brought forward this similar theme by identifying the following primary, secondary, and tertiary implications:

1. We can expect the product that provides spatial computing to evolve, miniaturize, focus on increasing comfort, and be less detectable by the user to enhance the immersive experience.

2. This means more technical effort could be devoted to creating spatial computing experiences without a headset to make the MR experience as seamless as possible for the user.

3. While headsets are the popular choice to display spatial computing today, it may not always be a head mounted device. We can expect to see various physical products emerge to display mixed reality such as holographs. The product of spatial computing will miniaturize and become increasingly embedded into our bodies and environments.

This theme appears frequently in the futures wheel, and UX designers will need to know how to design for the evolution of the spatial computing display.

UX Implications

Today, UX designers can choose to build hardware or software. Both need to keep in mind the way the user is utilizing the end product, but the UX designer focused on hardware may be challenged by physical product design to allow for spatial computing display. MR today consists of four main displays: Head-Mounted Displays (HMD), Hand-Held Displays (HHD), Ambient Projections, and Hand-Held Projectors (HHP) (Carrasco & Chen, 2021). Currently, HMDs are the most mainstream type of mixed reality display, but in the future, it can be holograms or video projections (Carrasco & Chen, 2021). For HMDs, UX designers skilled in product design will need to know how to design ergonomic spatial computing devices that are shaped around the user for lasting comfort. This could take form in a pair of Ray-Bans such as what Meta is experimenting with, a Neuralink as Musk has recently tested, or more environment based such as the Holodeck from Star Trek. Product designers will also have to keep in mind how the user can interact and navigate through physical life while still being able to turn on a spatial computing experience. UX designers will need to keep in mind the user's safety amidst their surroundings and where their attention is placed.

(Chu, K 2024).

The HMD will need to be comfortable for prolonged periods of use and design within the confines of the device's battery life. For example, a spatial computing experience that needs to be charged will mean the user is plugged in and confined to a certain space (Babarinde, personal communication, March 22, 2024). These are all implications of the future of spatial computing regarding the way it appears whether through HMD or an ambient projection. User experience designers focused on product designing the spatial computing experience must ensure that the display is comfortable, usable for lengthy periods of time, and safe.

A significant challenge that spatial computing faces is motion sickness. This "physiological issue is caused by a mismatch between visual, vestibular, and proprioceptive inputs, leading the brain to receive conflicting signals about the body's movement in space" (Yenduri et al., 2024, p. 29). Yenduri and co also suggest "installing large, transparent windows, configuring video displays to promote looking straight ahead, and eliminating swivel seats" to help with the motion sickness (Yenduri et al., 2024, p. 29). Apple is currently undergoing a patent application to utilize sensors to monitor the body's indicators such as pulse rate and sweating to reduce VR discomfort. The patent also describes the incorporation of visual anchors that synchronize with the real world movements, but more testing is needed to ensure this patent is viable (Yenduri et al., 2024). Designers will need to be cognizant of persistent motion sickness along with ensuring the technology's comfort and accessibility.

Futures Wheel Theme 2

A hyperconnected ‘phygital’ experience as the new reality

Futures Wheel Theme 2

A hyperconnected ‘phygital’ experience as the new reality

There is an increasing blend between digital and physical spaces, and this new “phygital” reality is getting smarter and more capable due to the rise of the ‘Smart everything’ era we are in.

The futures wheel primary, secondary, and tertiary implications are as follows:

1. “Spatial computing relies on various sensors and cameras integrated into the physical environment to gather data about the location of virtual objects and analyze their relationships in a spatial context” (Yenduri et al., 2024, p. 2). The phygital blend is heightened due to enabling technologies of spatial computing such as the rise of the internet of things, ambient computing, 5G, sensored environments, metaverse, Web 3.0, digital twins and more – to which this paper will refer to as ‘Smart everything’.

2. As environments get smarter, they merge digital and physical worlds seamlessly, creating immersive experiences (Yenduri et al., 2024). These smart technologies will understand how to interact with spatial computing displays to further the immersive experience of the user.

3. This era of connectivity paired with the rise of hyperconnected cities may mean more MR in physical environments such as cities.

4. These technologies are blurring the distinction between digital and physical, leading to an always connected phygital experience. Research shows that immersive virtual environments are ‘satisfactory representations’ of physical environments because people can understand them intuitively like physical spaces (Carrasco & Chen, 2021).

5. People will be fully immersed and the “phygital” world will be the new reality.

Here is a scenario that may help picture this theme: think of Times Square with its infinite billboards and screens displaying bright ads that light up the streets of New York. In the future of spatial computing experiences, physical screens may no longer exist because of their expensive physical real estate, impact on the environment, and ad pollution. The implications of a screenless city could mean when a user puts on their HMD, it reveals an augmented reality where personalized advertising content appears, and changes based on where the user's eye focuses. As the comfort of the HMD increases over time and the 'smart everything' era advances, we can expect urban AR and MR experiences, showing you ads, directions, favourites spots to eat, and the ETA of the friends you are waiting for all at the same time.

(Smart Glasses and Headsets: Revolutionizing the Way We See and Interact with the World, 2023).

“Controlling your IoT air conditioning using AR/MR glasses.” (Barel, 2018).

Avi Barrel hypothesizes that while beckoning your Tesla remotely from your home, you can adjust your smart air conditioning using your XR HMD and ensure that temperatures are set in your car and home before you leave your seat on the couch (Barel, 2023).

UX Implications

As a result of this blend of digital and physical UX designers will need to know how to design for this upcoming ’phygital‘ world. For example, how will UX research, wireframing, and design look like in this new world? Designers will need to think, role-play, and study this future of hyperconnectivity and phygital seamlessness to know how to design for the human.

If environments are smart and can communicate with the user’s spatial computing device, then it is important for UX designers to know the spatial context of the human.

Research for spatial computing may increasingly grow towards utilizing ethnographic research. Ethnographic research is a qualitative method that serves to “observe and analyze how people interact with each other, and with their environment” using a myriad of practices such as observation, journal entries, and contextual inquiry (Eriksson & Kovalainen, 2016, p. 1). Contextual inquiry is an ethnographic field study that “takes place in the humans’ natural environment as they conduct their activities the way they normally would. The context could be in their home, office, or somewhere else entirely” (Salazar, 2024). The researcher watches the user as they perform their task and asks for information to understand how and why humans do what they do (Salazar, 2024).

UX designers will also need to know how to prototype for this phygital era. Today, many prototyping apps exist such as Shapes XR and Bezi. Apples ARKit and Google's ARCore documentation also provide guidelines for designers and developers. These resources allow the UX designer to easily prototype and design for spatial computing experiences using today's technology. Learning the standards of these kits will help UX designers know what is intuitive to a user navigating MR through these HMDs. Personal practice with these resources will help the UX designer conceptualize the 2D experience to a 3D experience. Expert James Babarinde explains, "if you are building a 2D screen in a 3D environment, you don't need to know how to build in 3D or use a 3D software, but having good spatial conceptualization helps" (Babarinde, personal communication, March 22, 2024). Spatial conceptualization can mean role playing in this phygital future to understand the users journey, co-designing with humans and spatial computing experts, or studying the integration of these smart environment technologies. This future may help with today's back and forth between 2D and 3D life and improve virtual fatigue. Within a given space, UX designers need to study the relationship between spatial computing personal devices and the smart environment "interpreting virtual objects, entities, and events with respect to their physical location and the geometric relationships between them" (Yenduri et al., 2024). UX designers need to understand not just how to operate within a spatial computing environment, but also how to do so safely and responsibly, given the technology's capacity for data collection and surveillance.

There is a large amount of data around human-computer interaction relative to mixed reality. Within spatial computing, interfaces, gestures, and interaction paradigms are fundamentally different from those of traditional computing systems (Yenduri et al., 2024). Cognitive overload is also a persistent theme when being immersed in a virtual experience (Michalia, 2023). Gestures, eye tracking, spatial sound, and haptic feedback are all concepts that will aid in helping design a mixed reality experience around the nature of the human. UX designers must consider usability that is intuitive for all user demographics and digital literacy ranges. It is crucial to have excellent user education, tutorials, and onboarding processes. Offering real-time assistance can further elevate the experience. Voice navigation and gesture recognition should be easily understandable with all users, including those with disabilities. Accessibility should remain at the forefront of design and kept in mind at each step of the design process. UX designers will need to be cognizant of the effects of long wear and the length of experiences in a phygital world, keeping in mind that the human body will always stay in the reality of the physical world.

Futures Wheel Theme 3

AI will be increasingly integrated in spatial computing

Futures Wheel Theme 3

AI will be increasingly integrated in spatial computing

In recent years, Generative AI has propelled AI into a transformative global trend. AI powers spatial computing by enabling 'computer vision' which analyzes the scene around the human such as identifying objects like walls and furniture and creates a 3D representation of the environment (Yenduri et al., 2024). It ensures that virtual objects behind real-world objects create a mixed reality experience. AI also recognizes the human's gestures, detects the interaction between objects, understands, and handles object occlusion, and maps them with the real-time spatial layout (Yenduri et al., 2024). Generative AI allows humans to input prompts to produce a variety of new content such as text, images, videos, audio and more. The future of Generative AI and its role in spatial computing will produce a variety of possibilities.

The futures wheel lays out this theme using the following primary, secondary, tertiary implications:

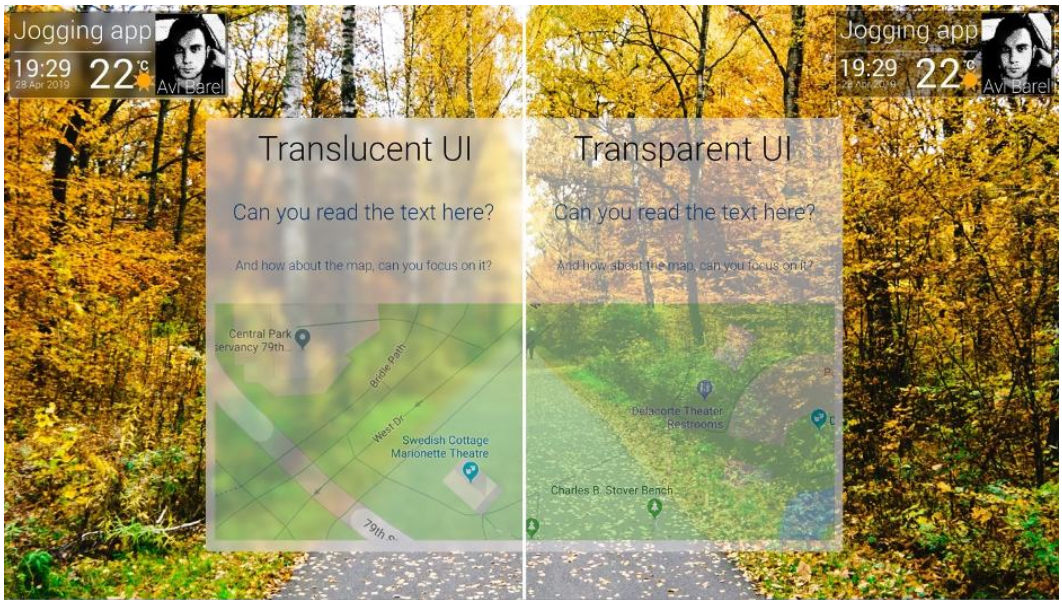
1. AI will perfect the human experience and individualize it to recognize the individual's patterns, habits, facial expressions, moods, behaviours, and body (Zhang et al., 2024).

2. Spatial computing will get smarter with AI, and precision recommendations for the human will be possible such as booking meetings for the participant, providing them with health statistics, and tips for enhancing their productivity. Visual virtual assistants can be created for the individual, which they can see and interact with, using their HMD.

3. Spaces can be augmented according to the data AI knows about the human and personalized according to their preferences. This can lead to personalized mixed reality enabled home offices, public transit directions, highlighting the appropriate bus routes to take, or even city navigation and experiences.

UX Implications

For this future of AI and spatial computing, UX designers will need a deep fluency in AI and understand personalization alongside its risks and impacts. For example, knowing where AI can be implemented to enhance a mixed reality experience will be essential. Understanding the way that AI data analysis is integrated into spatial computing will ensure it is utilized successfully. Since AI enables gesture, voice, and command recognition, understanding how AI enhances user interaction is crucial. The way these interactions are designed will either help or hinder the seamless experience for the user. For example, designing AR popups to be snoozed or dismissed through gesture or voice commands is a way UX designers can make AI prompts in a spatial computing experience usable and safe (Barel, 2019). AI also authorizes personalization in spatial computing. Knowing where and how to leverage personalized AI generated content and recommendations according to user preferences could create a seamless customer journey and help users complete tasks efficiently. Ensuring that the user's field of view is never blocked with augmented UI elements, or the user is not distracted with AR popups will keep humans safe and alert of their surroundings in the physical world (Barel, 2019). Since AI can spatially locate the user, recognize, and provide spatial context, designers can use this knowledge to comprehend the spatial limitations or opportunities for the user in their VR, MR, or AR experience. Knowing when to use translucent, transparent, or opaque screen backgrounds depending on the user's surroundings will help designers prioritize safety, readability, and accessibility.…



(Barrel, 2018)

Translucent and Opaque UI provides better readability but covers surroundings more. Thev can be better for screens when the user is not on the move.

Futures Wheel Theme 4

Enterprises are increasingly incorporating spatial computing

Futures Wheel Theme 4

Enterprises are increasingly incorporating spatial computing

Enterprises are incorporating spatial computing in several ways. Spatial computing helps through employee training, data visualization, and digital twins. The Magic Leap 2 headset is an example of this, and the company has repositioned the marketing strategy of their headset to fit enterprise needs rather than direct to consumer (Magic Leap 2, 2023). Health care professionals are being trained in VR and AR environments in preparation for the real world. VR and AR is already being used in the medical field to help surgical precision during operations by overlaying visualized data and instruction via augmented reality. The military uses spatial computing to provide training simulations. When it comes to data visualization, architectural design utilizes spatial computing to visualize proposed designs on real world environments. It also uses XR for design reviews and client approvals. MR based design reviews can effectively communicate 85% of the information to the client versus 70% provided by 2D media (Carrasco & Chen, 2021). Digital twins are being used to create virtual stores that users can ‘walk through’. Manufacturers are also using digital twins of their products and services to “provide real-time simulations for production lines and assembly processes” (Yenduri et al., 2024, p. 12). Enterprises are also using spatial computing to better their customer experiences such as Walmart releasing virtual try-on experiences for their clothes so shoppers can try on clothes from their own home and receive inputs from friends without purchasing (CES, 2024). Other industries such as education, tourism, and gaming and entertainment have followed, using spatial computing to create immersive experiences and finding cost savings in comparison to on building physical products. As we see the rise of automation in industries, we expect enterprises to adopt and automate their products and services, using spatial computing to increase the efficiency of the product or service.

1. Enterprises increasingly adopt spatial computing in their business processes such as employee training, data visualization, and digital twins to increase efficiency and sustainability (through using virtual simulations rather than costs of physical resources), decreasing risk and returning lower costs.

2. For the employee, spatial computing becomes the new norm when it comes to work, replacing the laptop and PC. Companies give HMDs to stimulate more movement during their workday, visualize data, and train using virtual scenarios in real world environments.

3. With the success of integrating spatial computing at work, there is more demand to utilize the technology. Job opportunities are added to enterprises centered around fluency with spatial computing.

UX Implications

As spatial computing integration increases in industries and enterprises, we can expect there to be more of a demand for UX design work in spatial computing enterprise solutions. This work could look like constructing digital twins for various enterprises or moving from 2D to 3D experiences. Expert James Babarinde suggests that UX designers target those industries that will use spatial computing more than others and strengthen that section of their portfolio (Babarinde, personal communication, March 22, 2024).

UX designers can utilize knowledge of AI enhancing automation in enterprise processes to improve the company's efficiency and decrease risk. For example, simulating various futures for enterprises through AI and spatial computing can both help derisk outcomes and visualize data. UX designers today can practice visualizing data in a 3D context or overlaying 2D visualizations over a 3D scene to prototype and build possibilities to undertake visual analytics in a 3D environment. Accessibility is a common theme that UX designers will continue to be cognizant about in this phygital future. Innovation for enterprise solutions is a skill that can amplify enterprise output and thinking big about how spatial computing can be integrated in enterprises and industries will keep UX designers sharp and competitive in the future job market. Overall, UX designers in the context of enterprise spatial computing play a crucial role in creating immersive, engaging, accessible, and data-driven learning experiences for enterprise users.

Futures Wheel Theme 5

Remote work environments are anticipated to utilize spatial computing

Futures Wheel Theme 5

Remote work environments are anticipated to utilize spatial computing

The location of work has undergone significant changes due to Covid-19, with remote work becoming the standard. Coming out of the pandemic in Canada, we are seeing almost 50% of companies adopt a ‘hybrid’ model compared to the 8% of fully remote companies (Canadian HR Reporter, 2024). Even though research does say hybrid or in-office work can be beneficial to mental health, Statistics Canada data shows that many workers feel they are more productive when working from home (StatCan, 2024). This trend aligns with digitally hyperconnected, physically dispersed mega cities and the globalization of project teams and indicates a persistent need when it comes to teams working from various locations. As spatial computing increasingly integrates in work processes, we can expect it to play a significant role in the way teams communicate, collaborate, and continue to evolve. Apple Vision Pro is already adopting personas and virtual workspaces to begin this implementation of MR in how humans work (Apple, 2024).

The futures wheel outlines primary, secondary, and tertiary implications of what could happen in this remote work spatial computing future:

1. Enterprises who are seeing dropping rates of employment due to preference for remote work mandate a spatial computing headset.

2. Just as laptops are provided for work, enterprises buy headsets/spatial computing technology to increase collaboration and comradery amongst employees. We may see a rise of human digital twins as virtual assistants, but even as workers.

3. Spatial computing technology becomes mainstreamed through work, and then for personal use but will still need good collaboration.

UX Implications

There are several ways UX designers can anticipate spatial computing in the way designers work. XR enables “virtual collaboration, allowing geographically dispersed individuals to convene in a common virtual space, which is particularly beneficial in fields like architecture, engineering, and remote teamwork” (Yenduri et al., 2024).

There are several ways UX designers can anticipate spatial computing in the way designers work. XR enables “virtual collaboration, allowing geographically dispersed individuals to convene in a common virtual space, which is particularly beneficial in fields like architecture, engineering, and remote teamwork” (Yenduri et al., 2024). In architectural design reviews, participants who used the Hololens could intuitively understand the designer’s ideas and save time during the process of information exchange, with lower error rates compared to the users of 2D (Carrasco & Chen, 2021). Researchers found XR replaced long and tedious explanations when presenting designs and replaced physical mock ups with immersive visuals that led to understanding the information more intuitively by 15%. (Carrasco & Chen, 2021). The capability for visualizing spatial data and 3D models is leveraged, enhancing the comprehension and analysis of spatial information (Yenduri et al., 2024).

UX designers can be confident that the future of design will continue to be collaborative and more efficiently so using spatial computing technologies. UX designers can be expected to create collaborative spatial computing experiences for the industry or product they are in. These XR experiences can include but are not limited to collaborative XR meetings, writing or drawing on boards together, prototyping, reviewing documents, and other work tasks depending on the product or service. It is important to ensure that collaborative work does not cognitively overload the user, is accessible, and still efficiently executes the task at hand. By addressing these considerations, UX designers can contribute to creating successful and impactful spatial computing experiences that enhance remote work productivity and collaboration.

Futures Wheel Theme 6

Spatial computing will have an impact on human behaviour, health, and lifestyle

Futures Wheel Theme 6

Spatial computing will have an impact on human behaviour, health, and lifestyle

The effects of spatial computing on human behaviour, health, and lifestyle are a recurring theme within the futures wheel. There has been increasing amounts of research regarding the positive and negative effects of technology on human well-being. Technology positively helps achieve tasks more efficiently, knowledgably, and faster than the human brain. However, not all technologies benefit holistic human health especially after long term use (Nikolic et al., 2023). For example, mobile phones have improved communication through long distance communication through the click of a button. However, they have also been shown to have negative effects on human attention spans, social interactions, and rise of loneliness (Golant & Holt-Lunstad, 2023). Moreover, research has shown they have been linked to issues such as digital addiction, sleep disturbances, and decreased physical activity levels (Nikolic et al., 2023). Push notifications interrupt cognitive flow and heighten stress levels while also reducing productivity (Nikolic et al., 2023).

There are also potential harmful effects of ushering into a virtual experience and out again, which Laryssa Whitaker defines as “onboarding and offboarding” (Whitaker, 2023, p.6). When returning to the real world, users encountered effects such as motion sickness, information overload or disorientation, difficulty re-entering the real world where gestures and movement did not work the same way, (Behr et al., 2005); still thinking about the VR world once returned to the physical world (Victor, interview 24 March 2020), and a jarring sense once the headset came off (Gordon, media diary, 19 February 2020) (Whitaker, 2023). Users exhibited diverse levels of “discomfort, reinterpretation, reflection, integration, or even aversion to returning to the VR world” (Whitaker, 2023, p.2). As we potentially see a shift from mobile phones being phased out and replaced with spatial computing, it becomes crucial to delve into how emerging technologies like spatial computing could impact human behaviour, health, and lifestyle.

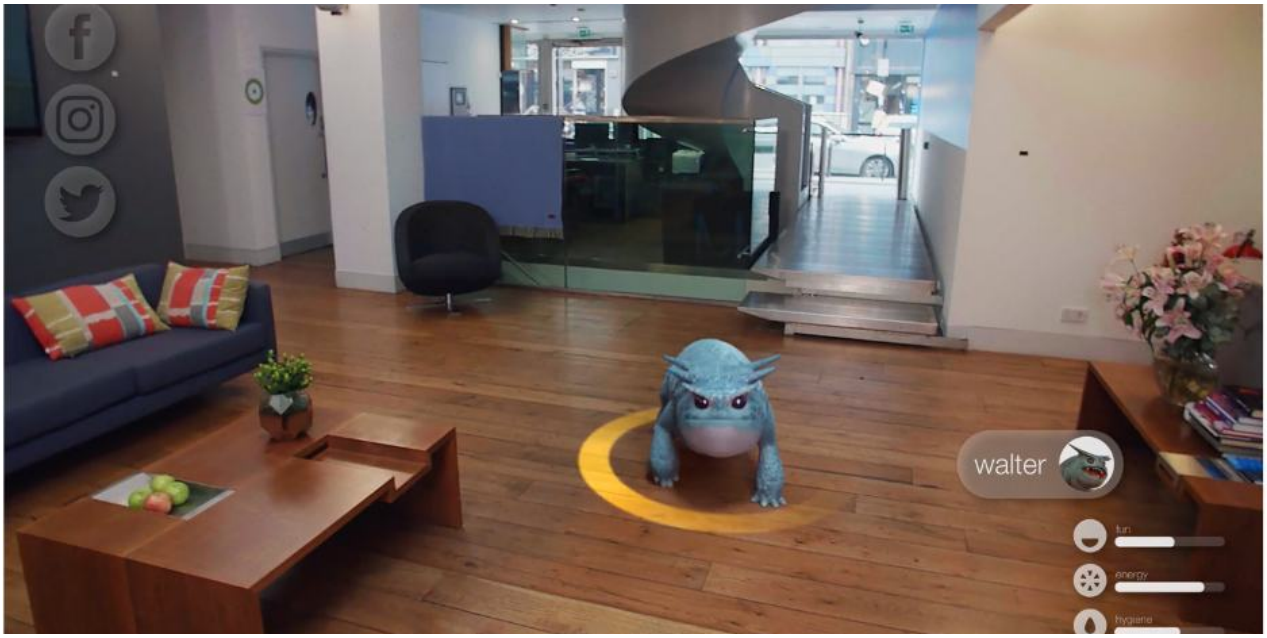
The futures wheel outlines the following primary, secondary, and tertiary implications when it comes to spatial computing's effect on humans’ mental health if a more seamless and comfortable phygital experience will result in longer amounts of time to be spent in this mixed reality and augmented world:

1. The rise of loneliness today can either be amplified or diminished in a spatial computing world. Now, HMDs (Head Mounted Displays) are built to be experienced by an individual. The act of wearing an HMD blocks the person from real life interaction serving as a visual hindrance to communicate face to face with. To share an XR experience, peers are required to have an HMD. This could amplify the rise of loneliness until spatial computing technology is improved to be able to include others easily and realistically in both the digital and physical world. Editor-in-chief of the Verge, Nilay Patel, shares this when wearing the Apple Vision Pro to the zoo with his daughter. He was able to record spatial videos with his iPhone and relive them through the headset but noticed "[the video memories] play back in a sort of ghostly white haze, and the overall effect is incredibly bittersweet — you can relive a brief memory, but you're alone in the headset and can't share it with anyone else" (Patel, 2024).

2. With the rise of loneliness, augmented friends and pets can provide substitutes for a period before people realize their needs for real relationships. Augmented family members are under ethical review.

3. Being in extended reality for long amounts of time can deplete dopamine leading to an 'XR crash' when returning to physical reality and a non-augmented world. Humans no longer want to return to a non-augmented world with no dopamine bursts and no augmented friends or pets. They vouch to stay longer in the XR world.

In a short film called *"Strange Beasts"* by Magali Barbé, she highlights the adventures of protagonist Victor having a pet in the MR world.



(Barbé, 2017)

Barbe also shows that Victor as a daughter named Anna.

(Barbé, 2017)

Later the director reveals that Anna is also part of the XR world. In this picture below, Victor is chatting to his XR daughter Anna. The film highlights the ethical concerns of highly integrated spatial computing when it comes to relationships and the rise of loneliness.

Victor talking to ‘Anna’ but in physical reality there is no one seated next to him. Anna only lives in the XR world (Barbé, 2017).

The effects of spatial computing on mental, social, emotional, and physical health are pertinent to helping UX designers know how to design spatial computing experiences ethically. While this research continues to develop, UX designers can be proactive in applying human-centred principles to the XR design world. Spatial computing merges the physical and virtual worlds to provide immersive experiences. Depending on the company, the business goal may be to make the two worlds as indistinguishable as possible. Expert James Babarinde says that awareness of the qualities of the product you are promoting should align with HCD goals. He explains that consumer targeted companies will want the human to be on their platform all the time. Enterprise products may be more focused on aiding users to get their work done (Babarinde, personal communication, March 22, 2024) and step back to the real world. Designers need to be aware of the values of the company for which they are designing. An ethical company will allow UX designers to devote time and effort to embrace and create human-centred designs. UX designers will also need to know the difference between a “seamless” experience and an “indistinguishable” experience. Humans must always remain in control of their experience and always be able to opt out of any experience. If a user chooses to stay within an XR experience, length of stay in the XR worlds will need to be monitored and studied. Designing notification reminders for how long a user has been in an XR world is one of many ways a UX designer can help an immersed user. Additionally, UX designers will need to continue research efforts to understand how humans will be affected by being in a spatial computing environment for extended periods of time.

HMDs can be a distancing experience for users and peers and family members around humans. While the Apple Vision Pro attempted a pass-through experience where surrounded peers can see an individual's eyes, many users felt this experience was still too visually distancing to have real world face to HMD conversations (Brownlee, 2024).

UX designers need to understand the implications of XR experiences while considering the trend of the rise of loneliness. Knowing how to increase collaboration, inclusivity, and peer-to-peer communication when designing spatial computing experiences will be key. When designed correctly, XR experiences should be able to be so realistic that it feels like a peer is in the room. While Apple tries to do this through 'Personas', the feature needs experimentation and design to improve its unrealistic properties (Brownlee, 2024). UX designers will need to research how spatial computing will help or hinder social experiences and design realistic digital representations of others while maintaining ethical boundaries.

Users of Apple Vision Pro have also said they felt a 'come-down' experience after removing the HMD and returning to reality, which they felt was underwhelming and under-stimulating (Haselton, 2024). Whitaker suggests having a "gentle offboarding" experience which can include meditation, yoga, spa-like environments, or dance to move the user situated in a virtual world back to the physical world (Whitaker, 2023, p. 4). An offboarding experience will need to be designed so that users can transition between the two worlds more seamlessly. Ensuring that the human is cared for in the physical world is an important way UX designers can build human centred experiences, within and without XR.

Futures Wheel Theme 7

Spatial computing will need legislation to defend human safety and privacy

Futures Wheel Theme 7

Spatial computing will need legislation to defend human safety and privacy

The implementation of spatial computing in our world presents significant challenges in the areas of privacy, security, standardisation, ethics, and health and safety issues. Data privacy poses a threat to humans in this new era of spatial computing because the technology will collect “granular, high-dimensional data about physical environments and user interactions" and upload it to a cloud to be stored indefinitely (Yenduri et al., 2024, p. 30). AI uses large language models (LLM) to generate content which in spatial computing could come from the users’ point of view: everything they see, say, talk to, and even think about is uploaded to a cloud and kept forever as an LLM (Barel, 2020).

The increasing integration of spatial computing in our world could also pose both opportunities and threats to human culture. Constantly being in an extended reality world is bound to make people feel displaced and disoriented when returning to physical reality.

The primary, secondary, and tertiary implications include:

1. As we see legislation catching up to AI and social media, we can expect that new technologies such as spatial computing will undergo the same levels of scrutiny around ethics and human safety.

2. Since spatial computing apps can mimic real life depth scale, introducing AR at an early age can confuse young brains about gravity, object depth, and permanence. Regulation or standards that define when children may be introduced to spatial computing may come into play, like the ways that we are seeing social media examined in court as harmful to children.

3. High surveillance through spatial computing technology disrupts the privacy rights of humans. Distrust in government grows and polarization amplifies. If negative effects arise around the use of spatial computing and its integration in our world, we may see a polarized view on its utilization in society. This could lead to “digital free” environments where XR use is banned, and people opt to go through life without spatial computing technology.

UX Implications

Ethical considerations should be part of the evaluation process of UX designers, ensuring that data privacy is handled with utmost confidentiality, and AI biases are vetted and removed to provide accurate outputs for the user. Implementing robust encryption and anonymization techniques will be key for UX designers and developers. Familiarizing and complying with laws such as the General Data Protection Regulation (GDPR) is a start to protecting human safety in an XR world (Yenduri et al., 2024).

In legislation design, creating policies to ensure children and adult safety will be significant and the timing of these policies will need to shape the technology proactively, rather than reactively once the technology is fully implemented in society. Researching the gaps in universal standards and privacy concerns and establishing a legal and technical framework should be considered. This framework should involve technical standards such as “interoperability, encryption, and anonymization to comply with data protection laws” (Yenduri, et al., 2024, p. 30). Design thinking should be implemented to shape policies. Research, prototyping, testing, and iterating are processes that could help laws be more human-centred, especially when technology is involved and affects humans. The Center for Humane Technology (CHT) is a coalition of designers, technologists, parents, policymakers, and ethical tech enthusiasts that lend their design thinking to align technology with humanity’s best interests (Humane Tech, 2022). The center offers a variety of resources to inform designers and non-designers alike on how to build humane tech. Their resources include a course introducing the foundations of humane tech, a podcast called Your Undivided Attention, and the movie The Social Dilemma. They also include various toolkits to help youth and policy reformers. They devote their time and effort to make a difference on a policy level and have even testified in court before U.S Congress to ensure that policies focus on humane technology and push tech companies to build products that are good for human wellbeing. In Canada, the Inclusive Design Research Centre at OCAD University undertakes similar work, establishing global standards for ethical AI application and inclusion of people with disabilities. UX designers can team up with organizations such as CHT or the IDRC to lend their design thinking, research skills, and voice to build a better future where spatial computing is helpful to humans rather than potentially harmful.

Futures Wheel Theme 8

Spatial computing content has an impact on truth and democracy

Futures Wheel Theme 8

Spatial computing content has an impact on truth and democracy

Spatial computing can either have a positive or negative impact on public truth and democracy. On one hand, spatial computing can be used to visually represent data in forms that are easy to understand by users. This could help with decision making amongst stakeholders such as policymakers and citizens. Fact-checking and detecting disinformation within the domain of AI is important for preserving news and information integrity. These tools also track misleading information in democratic processes and support transparency.

There are also downsides of spatial computing. AI algorithms may reinforce prejudices or be programmed to disseminate misinformation or disinformation. Hence, discerning fact from fiction becomes a challenge to the untrained human eye. Social media is already a critical part to shaping our discourse but these platforms “amplify extremism, increase perception gaps, and create a fertile ground for targeted disinformation during elections” (Humane Tech, 2022). Loss of confidence between citizens and their governments increases distrust has the potential to exacerbate existing issues such as geopolitical instability, wars, and racial divides. When humans lose touch with reality, anxiety, fear, and depression typically grip whole populations which can lead into further divisions that fuel the loneliness epidemic (Humane Tech, 2022).

The primary, secondary, and tertiary scenarios the futures wheel has outlined are as follows:

1. Spatial computing could replicate any physical object or environment, pair it with AI to study its natural language models and use Gen AI to create outputs. Spatial computing AI generates high-definition political images and immersive videos. They can be influential on segments of the population when they visualize a narrative which can be harmful.

2. People experience political AI-generated content in immersive, siloed environments making it hard to distinguish truth and reality creating misinformation and amplifying the current high polarization statistics.

3. Geopolitical volatility grows as misinformation grows. The world is divided, on high alert, and travel is banned until truth can be recognized.

UX Implications

In a spatial computing and AI driven world, UX designers will play a key role in promoting ethical and informed interactions. By being aware of misinformed Generative AI content, designers can consider labeling or highlighting AI-generated content that appears realistic. Understanding algorithmic decision-making is essential for ensuring transparency and fairness, guiding designers in creating systems that prioritize user trust. Systems design will be crucial in shaping the spatial computing future, necessitating co-design with stakeholders and citizens to foster inclusivity and responsiveness to user needs. UX designers can team up with the Center for Humane Technology on policy reforms demanding “political ads transparency, including purchaser identity & price transparency; scale-related transparency requirements (e.g., recommendation rates for videos, groups, posts); and mandatory transparency libraries & tools, including user-friendly APIs” (Humane tech, 2023), or collaborate with the Inclusive Design Research Centre.

The CHT also recommends focusing on 1) reducing the harms of technology and 2) creating technology that protects well-being and builds our collective capacity to address humanity’s most urgent challenges and 3) work within existing tech companies or launch humane technology products (Humane Tech, 2023). UX designers can also create a code of ethics for spatial computing design to ensure all experiences are aligned. When building experiences, UX designers must consider allowing humans to own their own data, which empowers them and enhances privacy. Algorithmic resets may be needed on social media and news platforms to mitigate misinformation. Incorporating features to track information sources and amplifying diverse viewpoints can help combat bias and echo chambers. Utilizing blockchain technology can also address issues in the information generation and attention economy, breaking causal loops and promoting accountability. Moreover, UX designers can create channels for discourse within spatial computing environments to encourage meaningful interactions between users and challenge confirmation biases. All these actions are within reach of the UX designer to help protect democracy when creating XR worlds.

Conclusion

Conclusion

It is apparent that spatial computing will continue its trajectory of being commonly integrated in our world. This paper provides a tool kit of advice to UX designers that takes the future into account. It does so by addressing these questions:

‘How might the evolution of spatial computing impact UX Design?’

Secondary questions include:

- **What trends might influence the trajectory of spatial computing?**
- **What are the possible trajectories of spatial computing?**
- **How will lateral technologies such as ambient computing, the internet of things, the metaverse, and AI affect spatial computing?**
- **How will UX design in the next twenty years be impacted by the trajectories of spatial computing?**

Spatial computing demonstrates high value in enterprise solutions through digital twins, data visualization, and simulated environments for training. With spatial computing's many enabling technologies such as AI, IoT, ambient computing, 5G, and more, we can assume spatial computing will increase in intelligence and ability. As these intelligent mixed reality experiences increase, it is apparent there is a gap between the technology and user experience needs.

The UX designer should be mindful of the evolution of spatial computing and its continued integration in our world. Ensuring a seamless integration between the digital and physical domains will be part of common UX work in the future. There are significant challenges to ensuring that the spatial computing integration is human-centred and ethical for both the user and our society. Further investigation is needed by UX designers to understand the most optimal way that spatial computing can be effectively integrated to be human centred. Until full integration, UX designers can prioritize human-centred and accessibility principles. They need to spend time immersed in spatial computing environment to understand software, hardware, design, and coding principles. Familiarizing themselves with the ergonomics of HMDs and future spatial computing displays can help product designers. Studying the ARKits of Apple and Google will allow designers to be prepared with interaction knowledge, and using current prototyping tools will build their 3D spatial mapping expertise. Gaining a deep literacy of AI will help UX designers master its intersection points in spatial computing technologies to better an experience. Researching industries more likely to adopt spatial computing and MR such as digital twins will help place UX designers in a secure role. Keeping in mind cognitive science and accessibility while designing for collaboration will keep UX designers ahead of the spatial computing game.

They must participate in ethics discussions and remain up to date with policy changes. Prioritizing privacy, encryption, and user preferences above all will help build this technology around the human. This study articulated the futures of spatial computing and its UX implications to ensure that UX designers are at the forefront of designing human-computer interaction with excellence. Knowing these UX implications will help UX designers future-proof their roles in the new era of spatial computing and create a better, smarter, and safer future for humans.

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Appendix A

Appendix A - Table of contents

Political Trends

Political

Geopolitical Volatility

Geopolitical volatility is a defining trend which shapes the whole global landscape with deep implications all across economic, political and security spheres.

It encompasses many different factors including evolving political situations, sudden shifts in power dynamics, ongoing trade disputes, regional conflicts and wars, civil unrest, and more. Geopolitical volatility mirrors the unpredictable and unstable nature of international relations, where the choices made by nations and their leaders ripple out with significant impacts. This volatility takes shape in diverse ways, spanning trade tensions between global heavyweights like the US and China to geopolitical rivalries observed in regions like the Middle East or the South China Sea. When geopolitical risks are heightened, it affects investing decisions, supply chains worldwide as well as economic stability as a whole. Most businesses have to navigate this landscape, changing and shifting strategies when such world events happen, to ensure that they mitigate risks or capitalize on opportunities that arise.

This trend can shape our public discourse, our own perceptions of national identity and our feelings towards globalization and immigration. It can fuel division, contributing to polarization within societies.

Geopolitical Volatility

Signals

- Russia and Ukraine War: With Russia invading Ukraine in 2022, the Kiel Institute for the world economy notes that approximately $278b in global aid has been given to Ukraine (Bomprezzi et al., 2022) Growing tensions between Russia and NATO as Vladimir Putin threatens nuclear war in speech (Ebel & Dixon, 2024). In 2022, Apple pauses all sales and activity in Russia due to the Russia and Ukraine war (Lerman & Albergotti, 2022).

- Israel & Gaza conflict - In October 2023, Hamas and Israel war began, over 31,000 people have lost their lives as the conflict continues (Batrawy, 2024).

- Increasing Middle-East tensions with both Iran and Israel attacking each other with missiles and drone strikes (Seddon & Palumbo, 2024).

- US/China trade war - In 2018 and 2019, the United States increased tariffs on goods imported from China and also applied higher tariffs on specific products from various other nations, notably in machinery and metals sectors. In response, China retaliated by imposing tariffs on imports from the US. (Bown & Wang, 2023). The impacts of this trade dispute between the US and China extend across economic, political, and social realms, with implications reaching beyond the borders of these two nations.

- Global technology decoupling - The U.S.- China relationship is experiencing a period of tactical stability amid targeted decoupling and intense, structural competition. Taiwan remains the most significant potential flashpoint, as the recent Taiwanese elections show (BlackRock, 2024).

- 2024 elections: The United States election is set for 2024, as US voters decide on Trump vs Biden. The effects of the elections will have both political, economical and create polarization within the country. 2024 will hold 40 national elections, key elections include: the USA, U.K, India, South Africa, Indonesia, Mexico and Russia (Ewe, 2023).

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Economic Trends

Economic

Automating Industries

Automation involves utilizing technology, machines or systems to perform tasks that minimize human input and interaction.

Some examples of automation are Generative AI (Artificial Intelligence) Machine Learning and spatial computing to name a few. With the rise of automation in today's world, businesses are looking to workforce automation to increase productivity and cut costs.

The rising trend of automation in a diverse set of industries such as manufacturing, agriculture and human resources is foreseen to result in workforce displacement, leading to significant economic challenges as well as exciting opportunities for economic growth.

Automating Industries

Signals

- Goldman Sachs predicts that the implementation of generative AI will result in a projected 7% surge (nearly $7 trillion) in global GDP and elevate productivity growth by 1.5 percentage points over the span of 10 years (Goldman Sachs, 2023).

- Next Move Strategy Consulting predicts huge growth in the artificial intelligence market over the next decade. The value currently is approaching 100 billion US dollars, and is set to surge up to 20 times that by 2030, reaching almost two trillion US dollars (Thormundsson, 2023).

- Increased company value as Tesla increased in value due to automation. The significance of automation can be seen by Tesla's Gigafactory in Nevada. They have incorporated advanced manufacturing techniques and automation and have successfully enhanced production and lowered costs. This approach enabled Tesla to expand its battery production, meeting the rising demand for electric vehicles and sustaining its competitive pricing (FasterCapital, 2024).

- Use of Digital Twins: A digital twin is a detailed and complete copy of a physical object into a digital space. It's clear from the data that digital twin technology is already saving companies millions of dollars and countless lives around the world. The Digital Twin market was estimated at 10.1b in 2023, and is set to reach up to 110.1b by 2028, which is a 61.7% CAGR growth (MarketsandMarkets, 2023).

- Workforce displacement: As per a report by Goldman Sachs, estimations suggest that approximately 300 million jobs may face the impact of Generative AI, indicating that up to 18% of the global workforce could be subjected to automation replacement. (Goldman Sachs, 2023.)

- Research by McKinsey Global Institute highlights that a projected 14% of the global workforce might have to transition to a new career by the year 2030, due to the impact of digitization, advancement in Artificial Intelligence and Robotics (Illanes et al., 2018).

- Forbes indicates that according to a report from Boston University and MIT, AI is set to replace up to two million manufacturing workers by 2025 (Johnson, 2024).

- Global market of humanoid robots is expected to reach a market size of 6bn in 10-15 years. -_Goldman Sachs Research estimates that the global market for humanoid robots may reach a market size of at least US$6bn in 10-15 years, filling 4% of the US manufacturing labour shortage gap by 2030 E and 2% of global elderly care demand by 2035E (Goldman Sachs, 2024).

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Social Trends

Social

Meetings 3.0: The Landscape of Work Shifts Post-Pandemic

The landscape of work is going through a transformative shift, urging on an era of Meetings 3.0 in the context of the ongoing hybrid work revolution.

Traditional meeting dynamics and office requirements are being redefined with technology, especially Generative AI and mixed reality, playing a pivotal role in enhancing both physical and virtual meeting spaces. Video conferencing is evolving with real-time analysis, creating breakout rooms, and introducing AI featured whiteboards that seamlessly convert notes into actionable tasks. Anticipating the year 2024, virtual meetings will evolve into immersive, XR and AI-powered experiences, turning traditional meeting rooms into flexible spaces. While the metaverse intended for enterprise work has not yet popularized, paired with the newly released Apple Vision Pro, technology companies like Meta and Apple lean towards virtual work spaces that boast connectivity with co-workers as advanced as physical work spaces (Meta, 2024).

However, the impact of hybrid and remote work on office real estate is apparent, as there is an anticipated 35% drop in office values by the end of 2025 and record-high vacancy rates globally, raising concerns about a potential commercial property financial meltdown (Singh, 2023). This trend aligns with the broader societal shift where consumers are adapting to overcome physical distances, embracing technology-driven changes in daily routines, and challenging the notion of being tied to a specific physical location for work (SAP, 2023).

More urban cities are becoming meta cities, places where there is a large outflow and inflow of talent with partnering cities that can act as a satellite or sibling location to popular cities such as New York, London, and San Francisco. As companies navigate these changes and call employees back to physical spaces, the newfound realization that work can occur from anywhere is changing how productivity and connectivity are measured and monitored (SAP, 2023).

Meeting 3.0: The Landscape of Work shifts Post-Pandemic

Signals

- Generative AI is now generating meeting minutes, assigning action items, creating Q&A meeting summaries in video conferencing tools (Bibhudatta, 2023)

- The Number of People Primarily Working From Home Tripled Between 2019 and 2021 in America (U.S Census Bureau, 2023)

- In Canada, the work landscape saw 48.04% of business adopt a hybrid model for their employees, while only 8.82% were fully remote, of which 6.86% were already remote before the pandemic (Canadian HR Reporter, 2024)

- StatCan data shows that three times as many remote workers feel they work better at home, than those who feel productivity drops (Mehdi & Morisette, StatCan, 2021)

- An August 2023 BCG survey shows that just 7% of companies have mandated full-time return to work, while only 8% have given up their offices altogether (Florida et al., 2023).

- Technology companies offer a broader availability of collaboration tools—both hardware and software—included natively with mobile phones, tablets and even cars (Brue, 2023)

- Emerging and improving technologies address meeting equity challenges with AI to help increase bandwidth in low-connectivity areas and rectify video resolution issues (Brue, 2023)

- Apple Vision Pro includes Keynote to help users feel like they are in a conference room while presenting. It also allows multiple people to share and add a live audience feed to see the user's Persona while speaking (Apple, 2024)

- 74% of people view metaverse technologies like AR as a way to commingle online and offline worlds (Meta, 2024)

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Social

Alone Together: The rise of loneliness and mental health issues

The mental health crisis continues and is now exacerbated by the “loneliness epidemic”. The topic of mental health has become popularized in the last decade and is a significant and more mature trend as mental health has been on a continued decline for decades.

Compounding this, social networks are getting smaller, time spent together in-person has drastically reduced, and people are reporting fewer confidants they can trust (). The COVID-19 Pandemic accelerated this trend and diminished trust in each other and institutions, furthering the record high levels of polarization. This growing epidemic can be correlated to social media use, but technology continues to allow accessible mental health support as well. The growing awareness of mental health is expected to lead to new treatments, interventions, and changes to social policies. However, there is still a long way to go. Mental health issues continue to rise, especially in young adults aged 18-25 (Duszynski-Goodman, 2024). As society embraces a more holistic approach to health, this trend is expected to further influence public policies, workplace practices, and individual behaviours, technology practices, ultimately shaping a more mentally resilient and supportive society.

Alone Together: The rise of loneliness and mental health issues

Signals

- There has been an increase of 24 hours per month spent alone from 2003 to 2020, and a decrease of 20 hours per month spent engaging with friends. This decline is starkest for young people ages 15 to 24 (Golant & Holt-Lunstad, 2023)

- 49% of Americans in 2021 reported having three or fewer close friends (Golant & Holt-Lunstad, 2023)

- Family size and marriage rates have been in steady decline for decades. The percentage of Americans living alone has also increased decade-to-decade (Golant & Holt-Lunstad, 2023).

- In a U.S.-based study, participants who reported using social media for more than two hours a day had about double the odds of reporting increased perceptions of social isolation compared to those who used social media for less than 30 minutes per day. However, technology has also helped online support groups allow individuals to share their personal experiences and to seek, receive, and provide social support—including information, advice, and emotional support (Golant & Holt-Lunstad, 2023).

- Nervous systems are being overloaded by technological use (Zomorodi et al., 2023)

- Employees have invested unprecedented resources in committing to mental health and wellbeing as a priority but employees are still reporting burnout symptoms, and these rates are rapidly rising around the world (McKinsey & Company, 2022).

- All in, the economic burden of mental illness in Canada is an estimated $51 billion per year including health care costs, lost productivity and reductions in health-related quality of life (CAMH, 2024)

Alone Together: The rise of loneliness and mental health issues

Signals

- The impact depression and anxiety has on the global economy can be measured in $1 trillion in lost productivity each year (National Alliance on Mental Illness, 2024)

- Young adults ages 18 to 25 in the U.S have the highest rate of experiencing any mental health concerns (33.7%) compared to adults aged 26 to 49 years, and the highest rate of serious mental illness (11.4%) (Duszynski-Goodman, 2024)

- The coronavirus pandemic led to increased diagnoses of depression, anxiety and suicidal ideation (Duszynski-Goodman, 2024)

- Depressive symptoms grew from a base of about 193 million people worldwide to 246 million, which is about 28%. Anxiety disorders grew from about 298 million people affected to 374 million, which is about a 25% increase (Santomauro et al., 2021)

- William (Bill) Bosl, PhD, in the Computational Health Informatics Program, found telltale markers of anxiety in electroencephalograms (EEGs), even in early childhood (Fliesler, 2023)

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Technology Trends

Technology

The AI Prompted Revolution

The rise of Artificial Intelligence has become a prominent and relevant trend to every industry, influencing finance, healthcare, education, transportation, manufacturing, and more.

AI has been integrated into everyday activities from smart assistants to summarize your notes, to more advanced data analytics. Generative models of AI has been trained on large amounts of data to create high quality images and videos of anyone and anything using a prompt. As data gathering becomes easier, AI gets smarter and continues to learn and adjust based on the needs of the human. Outputs are created in a mere matter of milliseconds, changing the scope and processes of work. Its easy integration into software, services, and clouds allows for it to adapt and perfect itself on any device, platform, or program. AI is a critical component to spatial computing because it allows human gestures, objects, and environments to be recognized with precision.

The AI Prompted Revolution

Signals

- Open AI creates Chat GPT, which generates immediate human-like text as a result of human prompts in a chat format (Open AI, 2021)
- Google releases Gemini, its Gen AI chatbot equivalent, who also faced scrutiny over its biases and historical inaccuracies (Nolan & Langley, 2024).
- AI development slows down due to AI chip supply constraints involving Nvidia and TMSC (Lee, 2024).
- Inaccuracy, cybersecurity, and intellectual property infringement are the most cited risks when it comes to Gen AI adoption (Chui et al., 2023)
- Less than a year after many of these AI tools debuted, one-third of McKinsey's 1,684 global respondents say their organizations are using gen AI regularly in at least one business function (Chui et al., 2023).
- 40 percent of McKinsey's 1,684 global respondents say their organizations will increase their investment in AI overall because of advances in gen AI (Chui et al., 2023).
- Figma uses Open AI to integrate its AI features for its design and prototyping service and in "Figjam" (Figma, 2024)
- Spatial computing opens the door for supercharging how we interact with Large Language Models, such as ChatGPT, and can result in having a virtual assistant who appears beside you (Torres, 2024)
- The market for AI will grow its current value of nearly 100 billion U.S. dollars to twentyfold by 2030, up to nearly two trillion U.S. dollars (Thormundsson, Statista, 2024)
- Chatbots, image generating AI, and mobile applications are all among the major trends improving AI in the coming years (Thormundsson, Statista, 2024)

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Technology

Mixed Reality Unleashed: A Spatial Computing Era Dawns

The blend of digital and physical have become more obvious as technologies such as virtual reality, mixed reality, and augmented reality become more integrated in various industries.

In the past, these technologies have been well integrated in the gaming industry, but now are working through workplaces, healthcare, entertainment, education, manufacturing, and more. These technologies allow machines to understand our surroundings, transforming the digital world into an extension of our physical environment.

Mixed Reality Unleashed: A Spatial Computing Era Dawns

Signals

- The Apple Vision Pro gets released to mass market, and encourages developers to continue building apps for their spatial computing headset, democratizing the technology and decreasing the barrier of entry by releasing it in its U.S stores providing users creative ways to interact with technology naturally and create and share experiences hands-free (Lahham, 2024).

- Saudi Arabia has recently given more than half a billion dollars to augmented reality company Magic Leap, which it hopes will rival Apple's Vision Pro mixed reality headset (Hayden, 2024)

- Magic Leap 1 sunsets its consumer targeted device, refocuses on Magic Leap 2, it's enterprise targeted device which amplifies medical training, particularly helping surgeons[HK8] perform surgery with augmented reality (Hayden, 2024).

- Recent years have also seen VR and MR headsets become more readily available at varying retail prices. (Carrasco & Chen, 2021)

- Mini's AR effect ad campaign reached 890k people, saw a 11.25x greater lift in brand favorability, and a 6x greater lift in recommendation for the brand compared with the BAU only campaign (Meta, 2024)

- Paramount ran a campaign to promote their movie Top Gun: Maverick that yielded a 16-point lift in standard ad recall and launched an AR effect to 260,000 people (Meta, 2024).

- Meta experiments with AR ad campaign templates using Spark AR to do virtual try ons for make up (ex. Lipstick), or other retail items on its Instagram shop (Meta, 2024).

- 700M users across Meta technologies already engage with immersive AR experiences each month (Meta, 2024)

- $82B is the estimated market value of AR by 2025 (Meta, 2024)

- The food service industry can leverage AR by offering consumers a menu that comes to life when scanned with their smartphones. Restaurants can use AR to present of their dishes, promote their menu, and upsell items by offering true-to-scale 3D visual representations of their food (echo3D, 2021).

- IKEA introduces augmented reality to their platform to allow you to try furniture virtually in your own home (Ikea, 2017.)

- Walmart introduces a virtual try-on feature for its clothes on its app and shares with friends for input (Incandela, 2022).

- Facebook announced its own AR program: Project Aria. (Meta, 2020)

- Gartner has noted digital twins are a 2023 top 10 strategic technology and that spatial computing in general is the biggest disruptive trend we'll see over the next five years (Groombridge, 2022).

- GE is using spatial technology to create exact digital twins of its physical assets. The company has already created more than 1.2 million digital twins and has saved $12 million dollars (GE Digital, 2020)

- Vuforia Spatial Toolbox helps speed up spatial computing prototypes and use cases (Business Wire, 2020).

- MarketsandMarkets also notes the digital twin industry will grow from roughly $3.1 billion in 2020 to approximately $48 billion by 2026 with a cost-adjusted growth rate of 58%, as reported by AiThority.com (MarketsandMarkets, 2023).

- Nokia's real-time eXtended Reality Multimedia provides 360-degree views, 3D audio, and live streaming to allow human operators to immerse themselves in a physical space many miles away (Bechtel & Briggs, 2023).

- BMW uses NVIDIA's Omniverse to pair up its legacy technologies to modern technologies that utilize AI to run simulations, possibly leading to 30% efficiency gains in the last year (Bechtel, 2022).

- Holographic workshops at Universities - (Coffey, 2024)

- - Holoconnects showcases its AI-powered holographic solution, Holobox at CES 2024 (Ortiz, 2024).

- Holoconnects showcases its AI-powered holographic solution, Holobox at CES 2024 (Ortiz, 2024).

- Kris Jenner becomes a hologram using Holobox technology in reality show The Kardashians (Hulu, 2023).

- Eye glasses team up with Rayban for MR/AR glasses (Meta, 2023).

- Magali Barbé short film shows the dystopian reality of having spatial computing integrated in our world through its potential to replace friends and family with augmented pets and family (Barbé, 2017).

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Technology

Smart Everything: The rise of ambient intelligence and the IoT

The era of connectivity amongst devices caters to the rising trend of personalization and how to make things around us “smart” devices that can communicate with each other.

The Internet of Things (IoT) plays into this transformative era where interconnected devices can communicate with each other, share data, and enhance daily tasks of life. Popular examples have included smart homes, smart cars, and smart appliances which have been coined ambient intelligence. It even expands to smart cities as a result of the growing 5G network which allows for faster and more reliable internet connections for devices to communicate. As IoT technologies advance, the capabilities are endless, ranging from predictive analytics, precision recommendations, autonomous decision making, and the vanquishing of mundane, daily tasks. With more accurate location precision, AI learning human behaviors in minutes, and spatial computing on the rise, these technologies can lead to environments that are smart, responsive, accessible, sustainable, and connected, blending the physical and digital world even more.

Smart Everything: The rise of ambient intelligence and the IoT

Signals

- FindMy network, a user mesh that leverages Bluetooth, UWB and GPS capabilities at the global scale to locate every Apple device in space (Othman, 2023).
- Mobile pods with immersive tech inside to help move people around, be wheelchair accessible, and self drive (Hyundai Canada, 2022).
- The smart city development market will grow from approximately $411 billion to roughly $821 by 2025, with a cost adjusted growth average (CAGR) of 14.8% (MarketsandMarkets, n.d).
- LG has already unveiled its cute two-legged AI robot that can walk around the home and act as an all-around independent household manager (Morrison, 2024).
- Samsung is adding AI to everything from refrigerators to cooktops. This includes a AI family hub refrigerator that uses AI vision to monitor how much you have of any item, what ingredients you have to make certain recipes, and whether you need to go grocery shopping. (Fenollol, 2024)
- Smart rings look like they are here to stay, with Samsung teasing a Galaxy Ring to launch later in 2024, and Oura ring 3 sales impressing audiences (Sawh, 2024).
- LG, Samsung, and Amazon present a 3D map view to control various smart devices in your home, presented at the 2024 Consumer Electronics Show (Tuohy, 2024).
- Generative AI continues to be adopted in smart home companies such as Govee and Aqara, for example to build routines around the home occupant (Tuohy, 2024).

- Home Copilot is a chatbot in Aqara’s app that understands natural language, allowing home occupants to set up automation to turn off lights at 11pm, lock the doors, and lower the shades (Tuohy, 2024).

- Some analysts believe the global market for digital twins could grow from US$6.5 billion in 2021 to US$125.7 billion in 2030.(Deloitte, 2023)

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Legal Trends

Legal

Ethics Empowered in AI

Artificial intelligence is undergoing a significant transformation with the rise of generative AI, which has led to legislative concerns about how the rapidly growing technology is impacting humans.

Globally, there are over 800 measures under consideration, reflecting a spotlighted focus to address ethical concerns associated with AI (Singh, 2023). As the AI development slows down due to AI chip wars, it could be the exact space needed for governments to implement ethical frameworks around the technology. This development aims to ensure responsible AI use and development, and highlights the importance of aligning technological advancements with ethical considerations to serve humans well.

Ethics Empowered in AI

Signals

- Elon Musk sues Open AI for abandoning the company's mission to help humanity and not for profit, of which Elon Musk was an investor (Nidumolu et al., 2024)

- Gemini, Google's AI model, faces backlash for displaying racial bias. When prompted, it generated historically inaccurate images of people of colour (Nolan & Langley, 2024).

- Taylor Swift deepfakes circulated on X and meta after AI generated explicit images went viral, calling for more regulations by cyber advocates and more (Contreras, 2024).

- President Biden issues an executive order to establish practices so AI is safe, secure and trustworthy (The United States Government, 2023).

- Facebook, Instagram, Threads (Meta) work toward labelling AI generated images on their platforms (Clegg, 2024).

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Legal

Social media under legislative magnifying glass

Legislative work continues around the impact of social media on society, with potential implications for politics, privacy, and mental health.

The ethics empowerment grows alongside increasing awareness of mental health issues, which could mean changes in policies to mitigate the growing numbers amidst this mental health crisis.

Social media under legislative magnifying glass

Signals

- Recent scrutiny of Meta CEO Mark Zuckerberg for Instagram's unethical algorithmic practices for child safety exemplifies the growing social concerns tied to social media. Clips of Zuckerberg apologizing to parents of children who had committed suicide due to the app goes viral, highlighting its impact on mental health and the need for regulatory measures (Yang, 2024).

- The Senate Judiciary Committee grills CEO's of TikTok, "X", Meta, Discord, Snapchat on their harmful practices around online child safety (Rosenblatt et al., 2024).

- House panel in U.S unanimously agrees on bill that could ban TikTok (Fung, 2024)

- The U.K Government experiments with limiting or banning social media for children aged 16 and under (Seal et al., 2023).

- The B.C Government is also releasing legislation to make sure social media companies are accountable to harmful online content aimed at children (Urquhart, 2024)

- TikTok is facing increasing limits and bans globally. From Nepal to India, to potentially the U.S (Navlakha, 2023).

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Environment Trends

Environment

A move towards a more sustainable future

The world is moving towards more sustainable energy sources and practices after climate change continues to pose a threat to our global wellness.

Industries, businesses, governments, and individuals are increasingly adopting sustainable practices that promote environmental responsibility. Renewable energy sources such as solar and wind are rising in utilization. Sustainable supply chain acts and eco-conscious consumer preferences direct the market, shape business models, and impact societal norms. The idea of a “circular economy” where energy is reused, wasted is reduced, and materials are recycled, are reshaping policies for greater and more sustainable economic growth. As sustainability becomes a central proponent of decision making, it fosters for cost savings, resilience to climate change, consumer preference, and global competitiveness.

A move towards a more sustainable future

Signals

- The EU bans single-use plastic bags (Cater, 2024).
- NASA and Boeing are developing the X-66, an innovative aircraft designed to advance net-zero aviation emissions by 2050 (NASA, 2024).
- A move towards cloud is a move towards sustainability
- Energy company Endesa’s 1,468 MW As Pontes coal plant will be replaced with renewable energy ventures, including a 1 GW wind project that’s set to create 1,300 jobs in the region (Elton, 2023).
- “Spain is already generating around 50 per cent of its power from renewables, and coal workers could have a bright future thanks to its Just Transition strategy,” (Adhem, 2023).
- This summer, the Spanish government also slashed the price of bus and train tickets for young people by up to 90 per cent and capped the price of high-speed train services at €30 per ticket. Interrail passes have been discounted by 50 per cent to reduce carbon emissions (Elton, 2023).
- EU countries representing more than 60 per cent of the bloc’s energy sector have committed to decarbonise their power sectors by 2035 (Frost, 2024).
- Four countries - Austria, Denmark, Lithuania and Luxembourg - have explicitly committed to replacing coal and gas with renewables (Frost, 2024).
- Electric vehicles, which accounted for one in five new car sales in 2023
- Wind and solar supply doubled in G20 countries(Jaeger, 2023) between 2017 and 2022(Bischoff, 2024).

- MIT students create a 4D smart garment that uses heat activated yarn to morph to various styles and sizes using the same garment. This innovation is used to combat the fast fashion trends of using a style of clothing and tossing it once the style trend is over (Choudhury, 2024).

- In the UK, coffee chain giant Costa is also seeing demand, recently partnering with plant-based food firm BOSH! to roll out a range of vegan-friendly wraps, paninis, and baps (Stone, 2024).

- 91% of all IKEA stores had food waste solutions in place by the end of 2022. The share of sales of the plant ball and veggie ball increased from 14% to 17% in FY22 within the HUVUDROLL range and from 24% to 26% in the Swedish Food Market (Birch, 2024).

- Formula 1 switches to Pirelli tires who leads in sustainable tire technology by focusing on reducing CO2 emissions (Jogia, 2024)

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