

# Digital Human Twins in the Age of Hyper-Personalisation and Ethical Complexity

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The rapid rise of Digital Human Twins (DHTs), essentially virtual replicas of real people that are constantly updated with real-time data, has opened up exciting possibilities while also raising significant ethical questions. Initially rooted in healthcare and precision medicine, the concept of digital twins has now branched out into areas like fitness, fashion, education, and emotional AI, all thanks to advancements in IoT, machine learning, and biometric technologies. This study dives into the intricate relationship between hyper-personalization and ethical considerations, looking at how digital human twins are transforming our sense of identity, autonomy, and social interactions. This research takes a narrative literature review approach, pulling together secondary data from peer-reviewed journals, industry reports, and ethical frameworks. The goal is to critically examine the interdisciplinary challenges that pop up at the crossroads of artificial intelligence, data science, psychology, healthcare, and law. This paper tackles important ethical issues like data privacy, surveillance, emotional manipulation, and informed consent. At the same time, it dives into the complex technology needed to maintain these real-time digital representations. Even though digital human twins are becoming more integrated into our daily lives, they are still not fully understood, particularly regarding their long-term effects on society. The existing academic literature lacks a unified, transdisciplinary framework that critically explores the intersection of emotional AI, biometric data, and digital identity. This paper aims to contribute to the academic conversation by addressing this gap, providing a comprehensive ethical-technological analysis, and emphasizing the urgent need for governance frameworks that prioritize human dignity and rights. As digital companions continue to evolve, this research lays a crucial groundwork for future studies and policymaking that seeks to balance innovation with ethical responsibility.

**Keywords:** Digital Human Twins, Hyper-personalisation, Data Ethic

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## 1. Introduction

Digital human twins are essentially virtual versions of real people, constantly updated with real-time data, and they stand out as one of the most exciting advancements in today's digital tech landscape. They first emerged in the aerospace sector and have since been fine-tuned for use in healthcare and wellness, fundamentally changing how we think about human identity, decision-making, and well-being in digital spaces. The concept of digital twins actually dates back to NASA's Apollo missions, where they created a "living model" of spacecraft systems to aid mission control (Grieves, 2016). This initial idea has transformed into a complex and immersive representation of humans, fueled by a mix of biometrics, wearable tech, motion capture, machine learning, and artificial intelligence (Gaffinet, Al Haj Ali, Naudet & Panetto, 2025). By the early 2010s, the field of precision medicine started using digital twins to simulate individual organs and forecast treatment outcomes, setting the stage for even wider applications across various fields (Papachristou et al., 2024).

The emergence of hyper-personalisation, a concept that has its roots in eCommerce and social media, has had a profound impact on how we develop and implement digital human twins. This approach leverages

real-time data, AI, and behavioural analytics to customize services and interactions based on individual preferences and behaviours (Aluwala, 2020). In the healthcare sector, it translates into targeted therapies and wellness tracking; in education, it fosters adaptive learning; and in entertainment, it creates user-focused experiences (Matcha, 2023). When combined with digital twins, hyper-personalisation enhances the depth of personal insights, crafting a digital version of ourselves that evolves in real time. This capability has the potential to transform user engagement, empower individuals, and improve decision-making (Kreuzer, Papapetrou, & Zdravkovic, 2024). However, the increasing complexity and deeply personal nature of hyper-personalised digital twins also bring up significant ethical, psychological, and social concerns.

While digital human twins hold incredible potential and innovation, they also bring along a host of ethical dilemmas that we can't ignore. Concerns around data privacy, consent, emotional manipulation, and personal autonomy are becoming more urgent, especially when these digital counterparts are involved in decision-making or providing emotional support (Quach et al., 2022). The way these digital twins engage with us particularly when enhanced by cutting-edge AI models like GPT-4.0 or Claude can blur the lines between genuine human interaction and machine-generated responses, which raises the risk of manipulation or dependency (Kreuzer, Papapetrou & Zdravkovic, 2024). The real challenge is that these systems not only analyze human data but also influence our behavior and perceptions through their feedback loops (Durango, Penichet & Gallud, 2024). On top of that, the legal and regulatory frameworks have not quite kept pace with these rapid advancements, leaving us with a patchy and mostly reactive approach to ethical governance.

This research sets out to delve into the intersection of digital human twins and hyper-personalization, all while keeping an ethical lens focused on human dignity, autonomy, and rights. The study has a few key goals: (1) to explore how digital twins operate in real-time systems from a technological standpoint, (2) to evaluate their socio-psychological effects on identity and relationships, (3) to pinpoint the ethical challenges that hyper-personalized AI systems present, and (4) to suggest a collaborative model for responsible innovation and governance. The main aim is to close the gap between what technology can do and the ethical oversight it requires, emphasizing the importance of a transdisciplinary approach to grasping the implications of digital human twins across various sectors.

To reach these objectives, the research employs a qualitative methodology that relies on secondary data analysis. This means pulling together insights from peer-reviewed academic journals, technical reports, ethical guidelines, and industry white papers to get a clearer picture of the evolving world of digital twins. Qualitative methods are particularly fitting for this study because they capture the complex and context-sensitive nature of the topic, which revolves around human behavior, perception, and societal values (Lim, 2024). By reviewing literature from areas like artificial intelligence, data ethics, psychology, healthcare, and law, the study aims to build a well-rounded understanding of these phenomena. This integrative approach not only allows for a thorough examination of the technologies themselves but also the wider sociotechnical systems they inhabit (Spector, 2015).

The current body of research highlights some notable gaps. While digital human twins are increasingly making their way into real-world applications, the academic conversation has mostly zeroed in on whether the technology works, rather than diving into the ethical or societal impacts (Papachristou et al., 2024a). There's a noticeable lack of scholarly discussion around how emotional AI and hyper-personalization affect our self-image, our relationships with others, and our participation in democracy. Additionally, conversations about the legal issues surrounding ongoing biometric data collection and predictive analytics are just starting to take shape (Migliaccio, 2024). Given the interdisciplinary nature of this field, we really need a more unified approach that brings together insights from behavioral science, media studies, digital health, cybersecurity, and human rights law. This paper aims to fill that gap by weaving together various

perspectives into a cohesive analysis that emphasizes ethical responsibility.

Another important area to consider is how our sense of presence, trust, and digital intimacy evolves when we interact with AI-driven digital twins. People might develop emotional bonds with these digital avatars that seem to understand or respond to their feelings, raising questions about the authenticity of these relationships and the potential manipulation of our emotions (Kouros & Papa, 2024). The way trust operates in digital environments becomes particularly intricate when biometric data-like heart rate, facial expressions, and voice tone are used to create emotional responses (De Keyser et al., 2021). These interactions push us to rethink traditional ideas of agency and consent, highlighting the need for new models of user education, transparency, and accountability. The possibility that such technologies could influence mental health and behavior underscores the importance of implementing safeguards and ethical design principles (De Witte, Joris, Van Assche & Van Daele, 2021).

Digital twins are fascinating, but they come with a hefty dose of complexity. To really get them to work, you need a solid grasp of real-time data processing and how to weave together various technologies like IoT devices, cloud computing, machine learning, and motion capture tools (Dingorkar, Kalshetti, Shah & Lahane, 2024). This tech mix allows digital twins to be constantly updated, mirroring the real-world status of their human counterparts. Yet, this complexity can make it tough for the general public to understand what is going on, especially in communities where digital literacy is low (Zainal Abiddin, Ibrahim & Abdul Aziz, 2022). The "black box" problem of algorithmic decision-making only adds to the confusion, leaving users in the dark about how their data is used and how AI feedback might shape their actions (von Eschenbach, 2021). That's why ethical design needs to focus on making things clear, giving users control, and ensuring inclusivity in how interfaces are built.

On a broader societal level, the rise of digital human twins brings up important issues around surveillance, power dynamics, and digital inequality. As biometric data becomes a commodity, there is a real risk of reinforcing social biases and creating new forms of discrimination (Smith & Miller, 2021). The use of digital twins in areas like data-driven elections or predictive policing shows how these personalized technologies can be misused to sway political outcomes or perpetuate systemic injustices (Attaran & Celik, 2023). Plus, without clear regulations, corporate interests often dictate how these technologies develop, often without proper oversight or accountability. To tackle these challenges, policymakers need to collaborate with stakeholders from various sectors to ensure that digital twin technologies are used fairly and ethically, especially for vulnerable populations.

In light of these complexities, this paper adopts a layered approach. It starts by outlining the historical evolution and current uses of digital human twins, laying the groundwork for understanding this technology. The following section delves into the theoretical aspects of hyper-personalization, examining its effects on autonomy, identity, and emotional health. Next, it tackles ethical issues like data privacy, surveillance, and emotional manipulation. The paper then identifies gaps in legal and academic frameworks, drawing insights from various fields. To wrap things up, it suggests guiding principles for responsible innovation and highlights key recommendations for future research, policymaking, and interdisciplinary collaboration. In doing so, it provides a timely and thorough analysis that adds to the ongoing discussions about the influence of AI and digital identity in today's society.

## 2. Conceptual Foundation of Human Twins

Digital Human Twins blend cutting-edge technology with human simulation, creating virtual replicas that reflect the actions, conditions, and traits of real people in real time. This idea, which has its roots in NASA's early work, has come a long way from monitoring astronauts' biometrics in space to the modern wearable

devices that track and mimic our actions and health. Unlike digital avatars or virtual identities that are mainly used for entertainment or social media, digital human twins focus on providing a more precise and functional representation across various fields like healthcare, urban planning, and personalized services. They utilize Internet of Things (IoT) sensors, Artificial Intelligence (AI), and real-time data processing to build dynamic models that adjust to an individual's behaviors, preferences, and health metrics. This fusion of technologies allows for ongoing monitoring and tailored interventions, representing a major advancement in how we engage with both our digital and physical worlds.

### **Definition and Technical Structure of Digital Human Twins**

Digital Human Twins are a groundbreaking idea that combines cutting-edge technologies to create a virtual version of a person. This digital counterpart is crafted to reflect real-world behaviors, physical conditions, and interactions in real-time, utilizing a mix of artificial intelligence (AI), Internet of Things (IoT) sensors, and real-time data analytics. Unlike traditional avatars or virtual representations, digital human twins serve as functional models, designed to simulate not just looks, but also the intricate physiological and behavioral characteristics of the individual they represent. These digital replicas thrive on continuous data streams, enabling them to evolve and adapt to changes in both the individual's body and their surrounding environment (Matta & Lugaresi, 2023). The main aim is to develop a tool that can boost human well-being, enhance lifestyle choices, and even forecast potential health outcomes.

The current landscape of Digital Human Twins (DHTs) is all about understanding what they can do now and what they might be capable of in the future across various fields. Right now, DHTs are able to mimic certain physical, behavioral, and cognitive traits with different levels of precision, which is really helpful in areas like research, healthcare, and personalized services. Looking ahead, improvements in AI, sensor technology, and real-time data integration could lead to even more advanced, fully autonomous digital replicas, broadening their influence in medicine, education, entertainment, and the way we interact with machines.

Digital Human Twins (DHTs) encounter some pretty hefty barriers when it comes to accessibility and cost, which really holds back their potential for widespread use. The high costs of development and maintenance, along with the need for cutting-edge hardware, software, and data infrastructure, mean that DHTs are mostly within reach of well-funded organizations or research institutions. On top of that, the requirement for technical expertise and the lack of user-friendly interfaces make it tough for more people to take advantage of this technology. Tackling these financial and accessibility issues is crucial if we want to make this technology available to a wider audience, opening the door for diverse applications in healthcare, education, and industry.

At the heart of a digital human twin lies the capability to gather extensive amounts of data. This information is typically collected through wearable devices, sensors, and other IoT-enabled technologies that keep tabs on a person's health, activity levels, environment, and even emotional state. Wearable gadgets like fitness trackers, smartwatches, and health monitors are crucial in providing ongoing input about heart rate, blood pressure, temperature, and other vital signs (Zovko et al., 2023). Smartwatch sensor inaccuracies limit data precision, directly affecting Digital Human Twin reliability by producing flawed physiological and behavioral inputs, which can compromise modeling and real-time decision-making. This data is then sent to a processing system where AI algorithms analyze it and create a real-time virtual model. The outcome is a highly personalized digital replica that can dynamically adjust to reflect the person's current condition. This constant feedback loop ensures that the digital twin stays as accurate and relevant as possible (Apte & Spanos, 2024).

The technical framework of a digital human twin is built on the seamless integration of various systems and

technologies. This encompasses everything from data collection and processing to modeling. The journey begins with capturing real-time data from the individual, which is done using sensors and devices found in wearable tech or the person's immediate environment, like smart homes and connected health gadgets (Ascone & Vanderhaegen, 2022). These devices track a range of metrics, from the user's movements and posture to environmental elements such as air quality and temperature. Once gathered, this data is sent to cloud-based systems or local servers where machine learning algorithms take over. These algorithms employ sophisticated predictive models to simulate how the individual might react to different situations or conditions, enabling a tailored experience for the digital twin (López García et al., 2020).

Artificial intelligence is crucial to how digital human twins operate. After the data is collected and sent off, AI systems dive in to create a digital version of the person's physical and behavioral traits. Thanks to machine learning techniques, the twin can learn from past data, enhancing its ability to forecast future actions, reactions, or health outcomes. For instance, if the system notices a shift in someone's heart rate or sleep patterns, the digital twin could foresee potential issues like stress or the beginning of an illness (Vallée, 2023). What truly distinguishes digital human twins from simpler avatars or static digital representations is the AI's ability to process this information in real-time and adjust its model on the fly.

Digital Human Twins (DHTs) can be divided into three distinct levels. The current prototypes are still in their infancy, showcasing basic physiological or behavioral simulations mainly for research purposes or limited applications. Then we have specialized implementations that utilize DHTs in specific fields like healthcare, manufacturing, or personalized education, making the most of advanced sensors and AI to achieve more accurate, domain-specific results. Looking ahead, the goal is to create fully autonomous, real-time digital replicas that can make complex decisions, integrate seamlessly across various industries, and bring about transformative societal changes that go beyond what we can currently achieve with technology.

The idea of a digital human twin goes way beyond just gathering data and running simulations. It's not merely a copy; it is a dynamic system that adapts to changes in the real world. Take, for example, someone going through physical therapy. The digital twin can modify its model to show either progress or setbacks, which helps in tracking improvements more accurately (Rasheed, San, & Kvamsdal, 2020). Plus, these digital twins can pull in information from various sources, like healthcare providers, to make the model even more personalized. This might involve incorporating medical histories, genetic data, or even environmental factors that influence a person's health, creating a comprehensive picture of their needs (Zhang et al., 2024). This concept also carries significant weight in health management. As digital human twins become more refined and precise, they can be crucial in healthcare, assisting both doctors and patients in monitoring health conditions and offering real-time insights into how effective treatments are. For instance, if someone is diagnosed with diabetes, a digital twin could track blood sugar levels, eating habits, and exercise routines, providing immediate feedback and suggesting changes based on the data (Papachristou et al., 2024c). Moreover, with the help of predictive algorithms, the digital twin can foresee potential health issues before they occur, paving the way for a more proactive approach to medical care. This could revolutionize preventive healthcare, where catching issues early often leads to better outcomes (Li et al., 2025).

Beyond just healthcare, digital human twins are making waves across a variety of fields, like urban planning, personalized services, and even keeping an eye on our environment. Take smart cities, for instance-digital human twins can shed light on how people engage with their surroundings, from navigating through traffic to dealing with pollution (Laso, Herrera, Galán-Jiménez & Berrocal, 2025). This valuable information can help improve city designs, public transport options, and green spaces, ultimately boosting the quality of life for everyone living there. Plus, these digital twins are not just about personal health or city life; they can also connect with larger systems, like climate data, to provide a fuller picture of how individuals affect and interact with their environment (Roman, 2024). The blend of AI, IoT, and real-time data processing creates

a dynamic ecosystem where human life is continuously monitored and fine-tuned.

### Historical Roots of Digital Human Twins

The idea of digital human twins is starting to capture people's interest in the tech world today, but it actually has some fascinating historical roots. If we look back, we can see early efforts to simulate humans and their surroundings, which can be linked to philosophical debates from the Enlightenment. Thinkers like René Descartes viewed the human body as a complex machine, which set the stage for the belief that we could replicate human functions (Manning, 2013). In the 17th and 18th centuries, anatomical models used in medical education took this idea further by visually showcasing how our bodies work. While these models were pretty static, they paved the way for the dynamic, data-driven digital representations we now refer to as digital human twins.

Digital Human Twins (DHTs) are an exciting and rapidly developing technology, but their level of maturity varies quite a bit across different fields. Right now, most prototypes are mainly used in controlled research or simulation settings, where they create digital versions of human physiology or behavior to test ideas in areas like healthcare, ergonomics, or cognitive science. While these initial models show that the concept is feasible, they still struggle with issues like scalability, interoperability, and ethical standards. On the flip side, we do see some specialized uses in specific industrial or clinical settings, such as precision medicine, rehabilitation engineering, or workplace training systems. Although these applications have real potential, they face challenges like high technical demands, fragmented data systems, and regulatory uncertainties. Looking ahead, the goal is to develop fully integrated DHTs that can interact in real-time between our physical and digital selves in fields like healthcare, urban planning, and consumer technology. Achieving this vision will rely on advancements in IoT networks, AI analytics, cybersecurity, and data governance. It is crucial to clearly differentiate between prototypes, specialized applications, and future goals to accurately evaluate the maturity and real-world potential of DHTs.

As we moved into the industrial age and then the computing revolution, the concept of simulating humans with data and algorithms started to take shape. The mid-20th century brought about the rise of cybernetics, where scholars like Norbert Wiener highlighted the significance of feedback systems in understanding both machines and living beings (Wiener, 2019). This blend of biology and engineering led to early computational models aimed at predicting and mimicking human behavior and physiological processes. The development of systems theory further reinforced this interdisciplinary approach, allowing us to view humans as systems with inputs, outputs, and internal states (Piccinini, 2004). All these intellectual movements laid the groundwork for the exciting emergence of human digital twins.

As digital computing has progressed, so has our ability to represent human life in more accurate and interactive ways. The realm of artificial intelligence (AI) has played a crucial role in this journey, working to mimic human decision-making through various algorithms. From the expert systems of the 1970s to today's advanced neural networks, AI technologies have paved the way for creating increasingly complex models of how to think and behave (Mishra, 2024). At the same time, the explosion of big data and the Internet of Things (IoT) has given us the wealth of real-time information needed to develop digital twins that can mirror the ever-changing aspects of human physiology, behavior, and context (Ahmed et al., 2017). These technological strides have transformed the once far-fetched concept of a digital human into a tangible reality.

Digital human twins are making waves in fields like healthcare, ergonomics, and behavioral sciences. Personalized medicine, for instance; it is harnessing the power of digital twin technology to create models tailored to individual patients, helping to predict health outcomes and fine-tune treatments (Zhang et al, 2024a). In the realm of industrial design and occupational health, these digital representations of workers

are being used to enhance workspaces, ensuring they're safe and productive. This shows that the digital twin concept is not just about individual health; it's about how systems interact as a whole. The COVID-19 pandemic really pushed the envelope, accelerating the adoption of digital twins in public health modeling and providing vital simulations that guide policy decisions (Kamel Boulos & Zhang, 2021). These modern applications highlight how digital human twins serve as invaluable tools for navigating complex decisions across various fields.

While digital human twins are a relatively new innovation, their roots trace back to our age-old desire to replicate, comprehend, and improve the human experience through models and simulations. The journey from anatomical dummies to sophisticated, AI-driven digital replicas showcases not just advancements in science and technology, but also the timeless philosophical questions about identity and representation. The ongoing conversation about digital twins taps into centuries of exploration regarding the connection between the human body, information, and systems thinking—now further complicated by the immense computational power we have today and the ethical dilemmas that come with it (Grieves, 2023).

### **Digital Human Twins Comparison With Digital Avatars and Virtual Identities**

Digital human twins, digital avatars, and virtual identities often come up in discussions about how we represent ourselves online, but they each have their own unique traits and purposes. A digital human twin is essentially a highly detailed, real-time digital copy of a real person. It is designed to simulate, monitor, and even predict how we behave, how our bodies function, and the choices we make. By pulling in data from sensors, biometrics, and the environment, these twins can respond dynamically, reflecting real-life processes (Ruiu et al., 2024). Unlike static images, digital twins are constantly evolving based on actual data, making them valuable in fields like medicine, industry, and behavioral studies. On the other hand, digital avatars are more like animated or graphical representations of people, often used in virtual settings like video games, online meetings, or social platforms. While they might look like their users, they don't have the same data integration or real-time modeling abilities as digital twins. Avatars are controlled by users and mainly serve to facilitate interaction and presence in a virtual world, rather than predicting behaviors.

Virtual identities bring an intriguing twist to our online world, representing the broader social and psychological roles we take on in digital spaces. These identities are shaped by our usernames, social media profiles, online behaviors, and the way we communicate. Often tied to avatars, virtual identities are influenced by how we choose to present ourselves and the algorithms that guide our interactions. Unlike digital twins, which are based on concrete biometric and behavioral data to mirror a person's physical and cognitive traits, virtual identities are more like curated snapshots of who we are—sometimes fragmented and not always complete. They span across various platforms and do not necessarily aim to provide a full or scientifically accurate portrayal of the real person. Instead, they reflect our sociocultural backgrounds, including aspects like gender, status, and emotional expression, without necessarily incorporating physiological data or real-time feedback (Barresi, Pacchierotti, Laffranchi & De Michieli, 2022). Essentially, virtual identities are more about representation, interaction, and performance in the digital realm rather than strict simulation or optimization.

The key difference between digital human twins and avatars or virtual identities is all about how deeply they integrate data and what they're designed to do. A digital twin is all about real-world applications like predicting disease progression, boosting workplace safety, or tailoring healthcare to individual needs. It creates a detailed model that closely mimics human biology and behavior (Papachristou et al., 2024c). This concept is grounded in system theory and cybernetics, working hand-in-hand with machine learning and sensor tech to provide real-time adaptability and support for decision-making. In contrast, avatars and virtual identities are more about the virtual world and social interactions. While avatars might look like a

person or be completely imaginative, and virtual identities show how people want to be seen, they typically do not simulate bodily systems or cognitive responses based on real data. This makes them great for self-expression and engagement, but not so much for situations that need accurate predictions or physiological relevance.

Despite their unique characteristics, digital human twins, avatars, and virtual identities are increasingly overlapping, particularly within metaverse platforms, telehealth, and AI-driven social media. As technology continues to evolve, we're seeing the rise of hybrid forms like avatars that use biometric data for fitness tracking or emotional analysis, and virtual identities shaped by behaviors collected through wearable tech. These developments indicate a blending of representation and simulation, blurring the lines between a person's digital presence and their physical self (Ruiu et al., 2024a). However, the ethical, psychological, and ontological implications differ widely. Digital twins bring up concerns about surveillance, autonomy, and consent since they rely on sensitive health and behavioral information. On the other hand, while virtual identities and avatars are less intrusive, they spark discussions about authenticity, disembodiment, and how we construct our digital selves. Grasping the differences and connections among these forms is essential for navigating the future of human representation in our digital society, where identity, agency, and embodiment are constantly being redefined.

### **Role of IoT, AI, Real-Time Data Processing for Digital Human Twins**

The creation of digital human twins is closely linked to the use of advanced technologies like the Internet of Things (IoT), artificial intelligence (AI), and real-time data processing. Together, these technologies allow for a lively, data-driven simulation of people by constantly feeding, analyzing, and updating digital replicas with information about their physiology, behavior, and environment. The IoT plays a crucial role in this setup. With a variety of connected sensors and devices—everything from fitness trackers to smart home gadgets—IoT delivers a steady flow of biometric and contextual data about individuals. This information includes heart rate, temperature, movement, sleep patterns, and surrounding environmental conditions, all of which are vital for accurately mirroring the physical human in its digital version (Domínguez-Bolaño et al., 2022). Without this rich sensory input, the digital twin would be static or too abstract, which would diminish its usefulness for predictive analysis and real-time monitoring.

Artificial intelligence is incredibly important as it processes the vast amounts of data produced by the Internet of Things (IoT) and turns that data into useful insights. AI algorithms, especially those that utilize machine learning, can spot patterns, anomalies, and connections that would be nearly impossible for humans to catch on their own. This means that a digital twin can evolve from just being a simple data storage tool to an intelligent entity that can mimic physiological responses, recommend interventions, and even foresee potential health issues or changes in behavior (Wu, Ji, Ma & Xing, 2023). In healthcare, for example, AI-powered digital twins can assist doctors in customizing treatment plans for individual patients by predicting how someone might react to a specific medication based on real-time data and past trends. In the realm of workplace safety and ergonomics, they can model stress reactions to changes in the environment, giving managers a heads-up about risks before they actually happen.

The combination of IoT and AI really shines when it comes to real-time data processing, which is essential for ensuring that digital twins provide timely and relevant outputs. Real-time processing means analyzing data and providing feedback the instant new information comes in. This is especially important for situations that require quick decision-making, like remote health monitoring, emergency responses, and adaptive learning environments. If we do not have real-time processing, the effectiveness of a digital twin takes a hit, as delays in data analysis can lead to outdated or irrelevant insights (Es-haghi, Anitescu & Rabczuk, 2024). Take chronic disease management, for instance: monitoring glucose levels in diabetic patients

through IoT devices, paired with AI algorithms that track these changes, can lead to timely dietary or insulin adjustments before any serious issues arise. Plus, real-time capabilities can greatly enhance the use of digital human twins in training and rehabilitation, where immediate feedback can make a world of difference in outcomes.

When we think about health, it is not just about individuals; the way to use these technologies can really change the game for public health monitoring, understanding behaviors, and tailoring education. Imagine digital human twins that can be expanded to represent entire populations, using collected sensor data to forecast disease outbreaks, track behavioral patterns, or even customize educational materials based on how people think and respond (Kamel Boulos & Zhang, 2021). Take education, for example-digital twins powered by AI and real-time feedback can adjust the learning experience to fit a student's focus or emotional state, making personalized learning a real possibility. In the realm of behavioral science, these constantly monitored digital twins open up exciting new paths to investigate how we make decisions and how we can improve mental health support, especially for those who might not feel comfortable sharing their thoughts or aren't fully aware of their own behaviors.

While digital human twins hold incredible promise, their implementation brings up important ethical and legal questions about who owns the data, how consent is obtained, and the transparency of the algorithms involved. As AI delves deeper into our personal and intricate data, concerns about bias, privacy violations, and potential misuse become more pronounced (Martin & Zimmermann, 2024). It is vital that the application of digital twins honors human dignity and autonomy, especially in sensitive areas like healthcare and employment. Striking a balance between technological advancements and ethical oversight will be key as IoT, AI, and real-time data play an increasingly significant role in shaping our future and well-being.

### 3. Results and Discussion

#### Hyper-Personalisation and Digital Human Twins

Hyper-personalisation has come a long way since it first made waves in eCommerce, evolving into more intricate applications in fields like healthcare, education, and human-computer interactions, especially with the rise of digital human twins. In its early days, hyper-personalisation in eCommerce was all about customizing content, ads, and product suggestions using user data like browsing habits and purchase history. Companies like Amazon and Netflix really changed the game by setting new consumer expectations, delivering a highly tailored experience that leaned heavily on algorithms and user profiles (Hong, 2024). As technology has progressed, particularly in artificial intelligence (AI), big data, and machine learning, this idea has expanded into areas like healthcare. Now, personalisation includes real-time monitoring, predictive diagnostics, and customized treatment plans (Ho et al., 2020). Digital human twins, which are virtual replicas of people created from real-time data, have become a pivotal technology in this transformation. They represent a cutting-edge form of hyper-personalisation, merging physiological, behavioral, and psychological data into practical models (Gaffinet, Al Haj Ali, Naudet & Panetto, 2025).

Emotional AI and behavioral tracking are at the heart of how hyper-personalization is evolving, especially when it comes to digital human twins. Emotional AI has the ability to read facial expressions, voice tones, body language, and even biometric signals to gauge how someone is feeling (Clement, 2025). This technology is essential for a variety of applications, from customer service chatbots to mental health assessments. Pairing it with behavioral tracking which keeps tabs on user interactions, preferences, and habits-digital human twins can react not just to physical health data but also to emotional and psychological signals. This creates a level of personalization that goes beyond simple profiles, allowing for responses that adapt as the individual changes. This flexibility is particularly important in healthcare, where digital twins

can simulate how patients might respond to different medications or therapies, leading to more tailored interventions (Ringeval, Etindele Sosso, Cousineau & Paré, 2025). By merging emotional AI with behavioral tracking, we ensure that the digital human twin is more than just a static representation; it becomes a dynamic, evolving simulation of the person it mirrors.

While hyper-personalization and digital human twins offer some impressive advantages, they also raise serious questions about autonomy, identity, and agency. When systems start to predict, influence, or even make decisions for individuals, the line between helpful assistance and controlling oversight gets pretty fuzzy. Users can find their autonomy at risk when they are nudged or manipulated based on algorithmic predictions, which brings up valid concerns about digital paternalism (Lembcke, Engelbrecht, Brendel & Kolbe, 2019). The way we construct our identities also gets tricky, as the tailored feedback loops from hyper-personalized systems can reinforce certain behaviors or self-views while sidelining others. With digital human twins, the data-driven portrayal of oneself might not always match how a person sees themselves, leading to a disconnect in identity. Moreover, an agency takes a hit when a user's behavioral data is used to automate decisions without clear transparency or consent. This becomes especially concerning in medical contexts, where the stakes are high, and the intricacies of data-driven decision-making can hinder patients' understanding and involvement in their own care (Subías-Beltrán et al., 2024).

The real-world uses of hyper-personalization and digital human twins are becoming more apparent in consumer tech, particularly in areas like fitness, health coaching, and smart assistance. Take fitness apps like Fitbit or Apple Health, for instance; they create digital profiles for users by tracking their activity levels, heart rates, sleep patterns, and other biometrics. Over time, these profiles develop into basic digital twins that can forecast fatigue, suggest training plans, or warn users about potential health issues (Vallée, 2023). Then there are virtual health coaches, like those found on platforms such as Noom or Lark, which take things a step further. They use conversational AI and behavioral psychology to help users navigate their personalized health journeys. These systems tap into emotional AI to assess motivation and offer timely encouragement or interventions. Smart assistants like Alexa and Google Assistant also learn from user behavior, providing increasingly tailored experiences from setting reminders based on daily routines to recommending products or services that match the user's preferences. The real power of these systems comes from their ability to combine data from multiple sources, acting as early-stage digital twins that adapt to and influence user behavior in real time (Elahi, 2021).

The rise of digital human twins brings with it a pressing need for strong ethical guidelines and data governance policies. Since these systems rely on ongoing data collection often involving sensitive physiological and emotional details issues surrounding privacy, surveillance, and data ownership become incredibly important. It is essential to have clear data practices that empower individuals to know how their information is gathered, processed, and utilized in creating their digital twins (Ikezuruora, 2024). Consent should be informed, continuous, and relevant to the context, particularly in healthcare, where mishandling data can lead to serious repercussions. Additionally, the ownership of the digital twin whether it belongs to the individual, the platform provider, or a third party remains a complex issue with significant legal and philosophical challenges. Ethical considerations also mean that individuals should have the right to opt out, change, or delete their digital twin, ensuring these representations do not turn into instruments of control or discrimination. Without clear regulatory standards, there is a real danger that digital human twins could be misused for commercial or political purposes, rather than genuinely serving the interests of the people they represent (Khazanchi & Saxena, 2025).

One important aspect to consider is how widespread hyper-personalization through digital human twins could impact society. If access to these systems is limited to those who can afford it or have the right tech skills, it could deepen existing inequalities. Relying on data-driven models might unintentionally reinforce

systemic biases, especially if the training data for AI reflects past injustices or lacks diversity. For example, health-related digital twins might not perform equally well for different demographic groups, which could lead to unequal care (Hanna et al., 2025). Additionally, the assumptions built into these systems—like what defines healthy behavior, ideal emotional states, or the best decision-making—might not capture the rich variety of human experiences. While hyper-personalization might seem neutral or even helpful, it can carry hidden value judgments that shape how people see themselves and others. This highlights the importance of inclusive design principles and participatory methods that engage a diverse range of users in creating and assessing digital human twin systems (Interaction Design Foundation, 2016).

The way hyper-personalization and digital human twins are coming together is really changing our human experience, both in exciting and concerning ways. On one side, these technologies promise incredible insights, efficiency, and support, helping us lead healthier, more informed, and connected lives. However, they also bring about new kinds of surveillance, behavioral control, and a sense of identity fragmentation. As we engage more with our digital counterparts, the line between what's virtual and what is real starts to blur, raising important questions about authenticity, trust, and how we see ourselves. The path these technologies are taking hints at a future where the digital twin is not just a tool but a partner in our lives, influencing our decisions, behaviors, and even how we perceive ourselves. To navigate this future successfully, we need a collaborative effort that brings together technologists, ethicists, legal experts, and the public to make sure that hyper-personalization through digital human twins enhances dignity and freedom, rather than undermining them (Khazanchi & Saxena, 2025).

### **Ethical Dilemmas and Interdisciplinary Challenges of Digital Human Twins**

The rapid growth of digital human twins (DHTs) has sparked some serious discussions across various fields, especially when it comes to the ethical, legal, psychological, and societal impacts of using them. DHTs create digital replicas of real people by combining biometric data, behavioral insights, and real-time tracking, which makes it hard to distinguish between what's simulated and what's real life. A key issue here revolves around privacy, consent, and data ownership. These ideas get even trickier when DHTs pull in data from various, often unclear sources. While we have established norms for consent in traditional healthcare and consumer contexts, the ever-changing and inferred nature of data collection by DHTs raises important questions. Experts argue that the usual models of informed consent just do not cut it when it comes to DHTs, where personal data is not just gathered but also interpreted, altered, and even anticipated in real-time by AI systems (Wiertz & Boldt, 2022; Kondrup, 2025).

DHTs are more than just tools for personalizing services; they signify a shift towards a model of surveillance capitalism, where behavioral data is turned into a commodity and manipulated. As Lipartito (2025) points out, surveillance capitalism uses predictive analytics to change user behavior for profit. DHTs, seamlessly woven into our daily routines through fitness apps, smart home gadgets, or digital assistants, can create feedback loops that subtly influence our choices and habits without us even realizing it. This kind of manipulation raises significant ethical concerns about our autonomy and decision-making power. The subtlety of this control becomes even more concerning when the digital twin starts to imitate, suggest, and anticipate our desires, turning what seems like convenience into behavioral manipulation.

Right now, proto-DHT technologies are mostly in the hands of well-funded research institutions, tech companies, and healthcare organizations because of the hefty costs involved in development and maintenance. These financial hurdles really limit how widely these technologies can be used. If we want to see broader adoption, we need to be careful; otherwise, we could end up deepening global inequalities, giving an edge to wealthier regions while leaving under-resourced areas behind. It's crucial that we tackle issues around accessibility, affordability, and infrastructure to make sure everyone can benefit equally in

education, healthcare, and beyond.

Autonomy is closely linked to emotional dependency, especially as digital human twins (DHTs) become more attuned to our feelings. These systems can read and mimic human emotions, adjusting their interactions based on our moods and psychological patterns (Adarsh, 2024). While this can be a game-changer in therapeutic settings like virtual companions for mental health support or eldercare-it also raises concerns about emotional reliance. People might start turning to their DHTs for emotional support above all else, which could complicate their real-life relationships and weaken their ability to cope in social situations. Moreover, this dependency could create exploitative situations, particularly if the DHT's responses are driven more by profit than by ethical considerations. If we do not adapt our legal and clinical frameworks to recognize DHTs as significant emotional players, the psychological impact of these dependencies might go unnoticed.

Looking at it from a legal perspective, digital human twins bring about some pretty unique challenges. The laws, especially those around privacy and data protection, were not really designed with these kinds of technologies in mind. The General Data Protection Regulation (GDPR) in the European Union, for instance. It offers some protections, like the right to be forgotten and the need for informed consent, but it can be a bit unclear how these rules apply to the ongoing and changing datasets that make up digital human twins (DHTs) (European Parliament and Council of the European Union, 2016). Legal experts emphasize the need for new frameworks that not only clarify ownership and control over digital twins but also establish ways to seek redress and protect against potential harm (Fontes, Carpentras & Mahajan, 2024). This issue is especially urgent considering the significant influence DHTs could have in critical areas like predictive healthcare and criminal profiling.

Interdisciplinary perspectives offer valuable insights into tackling these ethical challenges. In the realm of healthcare ethics, we see a strong emphasis on beneficence, autonomy, and non-maleficence-principles that often clash when it comes to using AI-driven digital health technologies (DHTs) for diagnosing or influencing patients (Mennella, Maniscalco, De Pietro & Esposito, 2024). In these contexts, informed consent needs to be redefined to not only consider the risks of data exposure but also the psychological and social effects of constant digital monitoring. On a similar note, AI ethics highlights the need for transparency, explainability, and fairness in how algorithms make decisions. However, these ideals can be tough to achieve when DHTs function within black-box systems that learn and adapt without human oversight. Adding to the complexity, human rights law emphasizes the inherent dignity of each individual. As DHTs become more integrated into public services-ranging from social welfare to criminal justice-it's crucial to ensure that they promote non-discrimination and equitable access (Gaffinet, Al Haj Ali, Naudet & Panetto, 2025). It must be cautious that DHTs do not perpetuate or exacerbate existing systemic biases, as current datasets frequently reflect and amplify these inequalities.

The psychological effects of digital human twins (DHTs) are incredibly important. Having a digital version of ourselves-constantly active and always being watched-can really change how we see ourselves and how we act. This idea, often called the "looking-glass self" in a digital context, brings up concerns about how our identities can become fragmented and how we perform authenticity. People might start to shape their behaviors based on how they think their DHT will interpret and share them, which can ironically lead to a loss of spontaneity and true self-expression (Papachristou et al., 2024d). Additionally, as DHTs become more intertwined with emotional AI and behavioral nudges, individuals might start to take machine feedback as the norm, which can alter their self-esteem or sense of competence based on artificial standards. Psychologists caution that these dynamics could heighten anxiety, diminish social trust, and foster a reliance on validation from technology.

At the end of the day, the ethical and interdisciplinary hurdles posed by digital human twins call for strong, varied solutions. Tackling issues of privacy and consent means we need to fundamentally rethink data rights when it comes to these living, evolving digital representations. It is crucial for legal experts and AI ethicists to team up and redefine concepts like liability, transparency, and user empowerment. Meanwhile, psychologists and sociologists should dig deeper into how our emotional ties and sense of identity are shaped by algorithmic companionship. Only by engaging in this kind of cross-disciplinary conversation can we ensure that the development and use of DHTs align with our core values of human dignity, autonomy, and justice. As DHTs become a bigger part of our daily lives, it is up to institutions, researchers, and developers to make sure that our technological progress does not outstrip our ethical protections or legal responsibilities.

### **Gaps in Literature and the Need for Transdisciplinary Frameworks**

Digital human twins (DHTs) are essentially digital copies of people, and they hold incredible promise in areas like healthcare, urban planning, education, and personalized services. However, the journey to develop and implement DHTs is still quite scattered. There are noticeable gaps in the research, particularly a lack of unified frameworks that pull together insights from various fields such as computer science, ethics, law, psychology, and sociology. Most current studies tend to focus on one area—either the technical side or the ethical concerns without really connecting the dots between the two. This separation makes it tough to fully grasp and navigate the wider societal impacts of DHTs. For instance, while data scientists and AI experts are busy figuring out how to enhance predictive models within DHTs, they often overlook important principles from human rights law or public health ethics. This can lead to a tech-driven approach that races ahead of necessary moral and legal protections (Gaffinet, Al Haj Ali, Naudet & Panetto, 2025a).

Moreover, the policies and legal frameworks have not kept pace with the swift evolution of DHT technologies. The current regulations surrounding digital identities, health records, and AI systems are frequently outdated or simply do not address the unique challenges that DHTs present. Unlike traditional data systems, DHTs deal with dynamic, real-time data that reflects a person's physical, emotional, and behavioral states. This raises new and complex questions about who owns the data, how consent is managed, and who is accountable (Ascone & Vanderhaegen, 2022). The lack of clear regulations becomes even more critical in international contexts, where DHT data might be handled in places with varying legal standards. This regulatory gap not only hinders the responsible growth of DHTs but also puts individuals at risk of surveillance, manipulation, and exploitation.

It is quite alarming that long-term studies lack on the social impact of adopting and normalizing Digital Human Twins (DHTs). The psychological, cultural, and interpersonal effects of engaging with a digital version of ourselves are still mostly up in the air, mainly because there is a lack of solid research. Some early studies suggest that having these hyper-personalized digital counterparts could change how we see ourselves, how to behave socially, and even our expectations around privacy (Fontes, Carpentras & Mahajan, 2024a). But these findings are pretty limited and often overlook differences across various demographics and cultural backgrounds. The absence of cohesive conceptual models and cross-disciplinary collaboration only adds to the challenges to face with DHTs. For example, traditional biomedical ethics frameworks might not fully capture the relational and performative elements of DHTs, especially when they are integrated into everyday tech like fitness trackers, smart assistants, and social media algorithms. Likewise, legal concepts based on fixed ideas of personhood and property may struggle to keep up with the fluid and co-created nature of our digital identities. There is an urgent need to create interdisciplinary frameworks that bring together insights from phenomenology, systems theory, critical data studies, and regulatory science to guide the design, governance, and assessment of DHTs.

We need frameworks that tackle not just the technical and ethical aspects but also dive into the wider societal stories surrounding our data-driven lives. Often, the mainstream conversation about Digital Health Technologies (DHTs) focuses on efficiency and personalization, while glossing over critical issues like power imbalances, digital inequality, and emotional reliance. For instance, how corporate narratives around DHTs in health and wellness apps highlight empowerment, yet conveniently overlook exploitative data practices and reinforce the neoliberal push for self-optimization (Wilson et al., 2024). By engaging in transdisciplinary research, we can unpack these narratives and shed light on the political and economic forces that influence the evolution of DHTs. This means bringing in insights from media studies, gender studies, and postcolonial theory to examine how DHTs might perpetuate existing social hierarchies and biases while masquerading as innovation (Fontes, Carpentras & Mahajan, 2024b).

To bridge these gaps, future research should focus on participatory methods that involve a variety of stakeholders in the design and evaluation of DHTs. It's crucial to engage marginalized communities-like people with disabilities, the elderly, and ethnic minorities-not just as end-users but as co-creators of digital health and identity solutions. This kind of engagement calls for methodologies that are inclusive and reflective, acknowledging the real-life experiences of different groups while challenging prevailing assumptions about technology and progress (Ascone & Vanderhaegen, 2022a). Moreover, researchers and policymakers need to work together to develop common languages and metrics for evaluating the social, ethical, and psychological impacts of DHTs in various contexts.

Policy development needs to shift from just reacting to regulations and start embracing anticipatory governance. This means we should be on the lookout for emerging risks and ethical challenges before they actually happen, using tools like scenario planning, foresight methods, and ethics-by-design principles to guide us. Current efforts in data ethics, like the EU's General Data Protection Regulation (GDPR), provide a solid foundation, but they need to be adapted to keep up with the ever-changing, interconnected nature of digital health technologies (DHTs). Both national and international organizations should create regulatory sandboxes to test out DHTs governance, allowing for flexible policy responses while still protecting individual rights (OECD, 2023). It's crucial that these initiatives are shaped by ongoing conversations among technologists, ethicists, legal experts, and the communities impacted by these technologies.

The pressing need for transdisciplinary frameworks for DHTs is highlighted by their increasing influence on our everyday lives. From virtual consultations in telemedicine to AI-powered career coaching, DHTs are becoming a part of essential daily activities. Therefore, we can't just leave their development to market forces or technological determinism. We need a united effort from academia, industry, civil society, and government to define shared values and norms that will steer the ethical development of DHTs. This also means rethinking core concepts like identity, consent, agency, and justice in the context of digital embodiment and datafication (Gaffinet, Al Haj Ali, Naudet, & Panetto, 2025a).

### **Towards Responsible Innovation and Governance**

The rise of digital human twins has really taken off, bringing with it a mix of exciting possibilities and some tricky ethical dilemmas. This surge calls for us to rethink how we balance innovation with governance in our digital age. As these technologies find their way into fields like healthcare, education, and personal wellness, it is crucial to set up guiding principles that resonate with our societal values and safeguard human rights. Ethical frameworks that emphasize transparency, accountability, and giving users control over their personal data and digital identities is crucial. It is vital for policymakers, industry leaders, and academics to work together to create inclusive strategies that respect individual autonomy while also fostering technological advancement. Given how quickly digital landscapes can change, our governance models must be flexible enough to adapt to new risks and societal issues. This section will highlight the key principles

and cross-sector recommendations for ensuring the ethical and socially responsible growth of digital human twins.

### **Principles for Ethical Digital Human Twins Development**

Digital Human Twins (DHTs) bring up some pressing ethical dilemmas that call for thoughtful solutions grounded in teamwork across various fields, respect for human rights, and accountability in technology. As DHTs become more advanced and are utilized in areas like precision medicine, predictive analytics, virtual environments, and urban planning, it's crucial to weave ethical considerations into their development. Privacy is a key principle that needs to be safeguarded from the very beginning, right through to deployment. Since a DHTs inherently involves sensitive data that reflects not just biometric and behavioral traits but also predictive profiles, preferences, and social patterns, it is essential to secure informed consent for every piece of data that goes into building and operating the DHTs. Moreover, the idea of "informed consent" should evolve from a simple one-time agreement into a more dynamic, ongoing process that offers clear, accessible information and options for opting out (Gesualdo et al., 2021). Without these measures, individuals could find themselves losing control over their most personal digital representations.

Transparency is absolutely essential for the ethical governance of digital human twins. It is crucial for users to grasp how their digital twins are created, what data is involved, how the models are validated, and the purposes for which their twins are used. The lack of clarity in algorithmic systems often adds to ethical dilemmas, especially when individuals can't access or understand the reasoning behind automated decisions that impact them. Ethical DHTs systems should embrace explainable AI (XAI) techniques to bridge the understanding gap between developers and users (Nannini, Marchiori Manerba & Beretta, 2024). Moreover, transparency promotes accountability, ensuring that both public and private organizations are held responsible for the outcomes generated by digital twins. In cases where harm or discrimination arises, there should be clear and accessible mechanisms for redress. Regulatory frameworks, particularly data protection laws like the GDPR, provide a legal foundation, but they need to be strengthened to tackle the complex nature of DHTs that mimic dynamic human traits in real-time and across various contexts.

Another key ethical principle we need to consider is autonomy, especially when it comes to emotional AI integrated into digital health technologies (DHTs). These systems can try to predict, influence, or even nudge our emotional reactions, which raises some serious red flags about manipulation and behavioral conditioning. To develop ethical DHTs, it is crucial to put safeguards in place that protect user autonomy and guard against any coercive or subliminal interactions (Iqbal & Biller-Andorno, 2022). This is especially important in areas like mental health support, education, or customer service, where there are already imbalances of power. The idea of autonomy is closely linked to user agency. Developers should create designs that give users real control over their digital twins, from how they're set up to when they're deleted. Data governance should empower individuals to decide what data feeds their twin, who gets to see it, and how it can be used. These user-centered approaches align with broader digital ethics principles that promote participatory design, fairness in algorithms, and respect for the context in which data is used (Parlangeli & Liston, 2023).

Justice and non-discrimination should be at the heart of ethical frameworks for digital health technologies (DHTs). Since these digital tools often play a role in predictive decision-making and resource distribution, there's a real risk that biases lurking in the data or algorithms could lead to unfair outcomes. If we are not careful, historical disparities in areas like health, education, or employment could be perpetuated. That's why it's crucial for developers and regulators to focus on fairness audits and to include a variety of datasets to prevent the continuation of systemic discrimination. The stakes are especially high when DHTs are used in public policy or insurance, where profiling can impact access to vital services. To create more equitable

models, ethical development needs to involve interdisciplinary teams that bring in insights from law, sociology, psychology, and voices from marginalized communities (Bitomsky, Pfitzer, Nißen & Kowatsch, 2024). So, bias mitigation should not just be an afterthought; it has to be a fundamental ethical principle that shapes the very foundation of DHTs systems.

### **The Role of Transparency, Accountability, and User Control of Digital Human Twins**

The swift advancement and use of digital human twins (DHTs) have unlocked exciting new opportunities in healthcare, personal data management, and a host of other fields. Yet, this surge in tech innovation brings with it a range of significant ethical and practical issues, particularly around transparency, accountability, and user control. Transparency is vital for ensuring that users are well-informed about how their data is collected, utilized, and shared. DHTs, transparency means not just giving users clear and easy-to-understand information about data practices, but also making sure that the underlying data models are comprehensible and accountable. As DHTs increasingly incorporate real-time data, machine learning, and AI, it is crucial that the algorithms are transparent, allowing users to grasp how decisions are made especially in matters that affect their health, privacy, or autonomy (Graili & Farhoudi, 2025).

Development and use of Digital Human Twins (DHTs), accountability is a major concern, especially when things go wrong. As these digital replicas of people become more advanced and play a bigger role in decision-making across fields like healthcare, law enforcement, and personalized marketing, it is crucial to have clear accountability measures in place. For example, if a DHTs system gives a wrong recommendation about someone's health treatment, who takes the blame? Is it the designers, the software company, or the person who provided the data? These questions highlight the complexities of today's technology and the urgent need for governance frameworks that can offer straightforward answers in these situations. Without such frameworks, there is a real risk of causing harm to individuals, particularly those who are vulnerable or may not fully understand the potential risks of using these technologies (Gaffinet, Al Haj Ali, Naudet & Panetto, 2025b). Tackling accountability will require a blend of legal, technical, and ethical oversight to ensure that digital twins are not just effective, but also safe and trustworthy.

User control is a key principle to keep in mind when we think about the role of Digital Human Twins (DHTs) in both personal and professional settings. As we increasingly depend on digital systems that monitor our personal data, health stats, and behavior patterns, it is crucial that we maintain control over how our information is accessed and utilized. The emergence of DHTs brings up complicated questions about data ownership and user consent. Often, people might not fully grasp the extent of data collection, how it is analyzed, or what it could mean for them. This is why the idea of informed consent is so vital in the realm of DHTs. Users need to be not just aware of what data is being gathered, but also understand why it is being used and the potential benefits and risks that come with it (Asad, Khan, Khalid & Lughmani, 2023).

One of the major hurdles in achieving transparency, accountability, and user control is the intricate nature of the systems at play. Decentralized Health Technologies (DHTs) often depend on extensive networks of interconnected devices and platforms that are constantly collecting and sharing data. This data travels through a range of third-party services, which can lead to a muddled understanding of where the data comes from, how it is utilized, and who has control over it. For example, an individual's health data that might be used by a digital twin for predictive healthcare analysis; this information can be shared with various stakeholders, including healthcare providers, insurance companies, and tech firms. Each of these players has its own interests and practices regarding data management, making it even more challenging to ensure that the individual's needs are prioritized. This fragmentation can diminish user control, as people may struggle to keep track of where their data is going, ultimately making it harder to give informed consent effectively (Yew, Trivedi, Adanan & Chew, 2024).

For transparency to truly matter, the information shared with users about their digital twin needs to be clear, easy to access, and straightforward. This means giving detailed insights not just about how data is collected, but also about the algorithms that drive these systems. For instance, a Digital Health Tool (DHT) that makes health predictions or offers recommendations. Users should be able to grasp what influences those suggestions, like their medical history or lifestyle choices. This kind of understanding is essential for building trust in these systems and helping users make informed choices about their interactions with them (Burton et al., 2022). So, when we work on improving transparency, we should focus on empowering users to comprehend the inner workings of the technologies they use and the potential impacts of sharing their personal data.

Accountability goes beyond just legal obligations; it also encompasses the ethical aspects of creating and using digital twins. As digital health technologies (DHTs) keep advancing, their application in sensitive fields like healthcare and law enforcement brings up important questions about how we handle personal data ethically. We can't overlook the potential for manipulation or bias in AI systems, especially those that depend on personal information. For instance, if a digital twin is used to forecast someone's chances of developing a specific health issue or getting involved in criminal activities, how can we guarantee that these predictions are fair, accurate, and unbiased? To ensure that digital twins are accountable for their outcomes, we need to maintain constant oversight and regulation, along with a strong focus on the ethical duties of developers and organizations to minimize risks (Burton et al., 2022a).

User control over their digital twins hinges on how easily individuals can access, modify, and delete their data. This level of control plays a crucial role in building user trust, which is key for the broader acceptance of Digital Human Twins (DHTs). Looking ahead, it's essential to create systems that empower people to manage their digital identities and oversee the data linked to their digital twins. These systems might feature user-friendly interfaces that allow individuals to track how their data is being utilized and to make changes or remove it when needed. By giving users more control, we can reduce the risks of data misuse or exploitation, enabling individuals to make more informed choices about their digital identities (Sirigu, Carminati & Ferrari, 2025). As DHTs keep evolving, it is crucial to weave in principles like transparency, accountability, and user control into the design and regulation of these technologies. These principles are vital not just for safeguarding individual privacy and autonomy, but also for making sure that digital twins are created and utilized in ways that truly benefit society. With the right frameworks in place, digital twins could become an incredible asset for enhancing healthcare, improving user experiences, and streamlining public services. But for this to happen, we need to prioritize ethical considerations throughout their development and deployment.

### **Recommendations for Policy, Industry, and Academic Collaboration**

As digital technologies keep advancing, it's becoming more crucial for policymakers, industry leaders, and academics to work together, especially in fields like digital human twins and artificial intelligence (AI). Crafting thorough policies is vital to ensure that these emerging technologies are used in an ethical and responsible way. Policymakers need to create regulations that not only tackle the current situation but also look ahead to future challenges. This means setting up frameworks for data privacy, user consent, and accountability, especially when it comes to sensitive personal information. Governments should collaborate closely with industry leaders to make sure that regulatory measures are both practical and effective, all while considering the rapid pace of technological change. On the flip side, industry players need to be proactive in following these policies and engaging with policymakers to share real-world insights that can shape future regulations. A teamwork approach between these sectors helps ensure that policies stay flexible and responsive to the ever-evolving tech landscape (Langås, Zafar & Sanfilippo, 2025).

From an academic standpoint, research institutions and universities play a vital role in guiding the ethical and practical growth of emerging technologies. Scholars can make a difference by carrying out thorough studies on the implications of digital human twins, AI, and related areas, especially when it comes to ethical, legal, and sociological viewpoints. Research should not only delve into the technical side of these technologies but also consider their wider social, cultural, and economic effects. This kind of research will create the solid evidence needed to shape industry practices and inform policy decisions. Additionally, academic institutions ought to foster interdisciplinary collaborations, uniting experts from various fields like law, ethics, computer science, psychology, and healthcare to tackle the complex challenges that new technologies present. This collaborative approach ensures that we fully grasp the intricacies of digital human twins and can examine them from multiple perspectives, promoting innovation while reducing potential risks (Sharma et al., 2022).

Collaboration among industry, academia, and policymakers is crucial, especially when it comes to creating standards and best practices for designing and implementing digital twins and AI systems. The industry has a significant part to play by developing voluntary standards that emphasize transparency, accountability, and user control, which can serve as benchmarks for how these technologies should be created and used. These standards ought to be integrated into government regulations, fostering a unified and thorough approach to technology governance. Academia's role is vital in researching and crafting these standards, ensuring they are based on solid evidence and adhere to ethical guidelines. Beyond just setting standards, industry and academic institutions can join forces to develop training programs that inform both developers and users about the responsible use of new technologies. This initiative will help cultivate a workforce ready to tackle the ethical and technical challenges that come with digital human twins and similar technologies (Evans, Miklosik & Du, 2023).

To truly foster collaboration among these sectors, we need to create platforms that encourage ongoing dialogue and knowledge sharing. Events like conferences and workshops can serve as great venues for stakeholders from different areas to gather and discuss the latest trends, challenges, and opportunities in the realm of digital human twins and AI. These gatherings not only promote the sharing of insights but also help build trust among the various players involved, motivating them to unite towards shared objectives. It is essential for policymakers, industry experts, and academic researchers to collaborate regularly, as this will be key to navigating the intricate landscape of technological innovation. By doing so, we can ensure that advancements in AI and digital human twins are beneficial to society while minimizing any potential downsides. When these three sectors join forces, they can cultivate an environment that supports responsible innovation, ensuring that new technologies are developed and utilized in ways that resonate with our societal values and ethical standards (Zheng, Yan & Xu, 2025).

### **The Importance of Adaptive Governance in a Fast-Evolving Digital Human Twins**

The world of digital human twins is an exciting and fast-changing landscape, where technology is advancing at lightning speed. This rapid evolution poses a real challenge for governance structures, which often struggle to keep up with new tech developments. Digital human twins, essentially virtual versions of people that reflect their real-life selves are being increasingly utilized in areas like healthcare, education, and personalized marketing. However, these innovations also bring up important ethical, privacy, and legal issues, especially since they gather and handle large amounts of sensitive personal information. To make sure that the creation and use of digital human twins align with our societal values and ethical standards, we need adaptive governance. Traditional governance models, which depend on fixed rules and frameworks, just can't keep up with the fast-paced changes these technologies bring, which can have wide-ranging effects. We need a more flexible and responsive approach to regulation and oversight to stay in sync with the rapid progress in digital human twins and similar technologies (Yeong, 2021).

Adaptive governance is all about being flexible and responsive to new challenges and the fast-paced changes in technology, instead of sticking to strict, pre-set rules. A standout aspect of adaptive governance is its emphasis on continuous learning and feedback loops. This means that regulators and policymakers are constantly tweaking their strategies based on fresh data, new tech developments, and input from the public. When it comes to digital human twins, this approach is crucial because the speed of innovation in AI, machine learning, and data processing often leaves policymakers scrambling to create laws and regulations that can keep up with the wide array of ethical, legal, and social issues that arise. An adaptive governance model empowers regulators to stay in sync with technological advancements, allowing them to address emerging concerns about privacy, data security, and the potential for misuse of these technologies in real-time (Janssen & van der Voort, 2016). Achieving this requires a strong partnership between regulators, industry leaders, and academic researchers, who can offer valuable insights and recommendations based on the latest trends and data.

In the context of digital human twins, adaptive governance becomes crucial, especially when it comes to privacy and consent issues. These digital twins depend on vast amounts of data, including personal health information, biometric details, and behavioral trends, to accurately mirror individuals. This data often comes from wearable tech, mobile applications, and various other sources, which raises important questions about how this information is stored, accessed, and utilized. Traditional governance models, which typically emphasize data protection and privacy laws like the GDPR in Europe, often struggle to keep up with the complexities of real-time data collection and processing. Adaptive governance offers a more dynamic solution by integrating principles such as user consent, data sovereignty, and transparency into the regulation of digital human twins. By allowing for continuous updates to regulatory frameworks, adaptive governance helps ensure that privacy protections stay strong, even as technology advances (Janssen & van der Voort, 2016a). This approach also fosters the creation of privacy-enhancing technologies that can reduce the risks tied to collecting and using sensitive data.

One crucial aspect where adaptive governance really shines is in tackling the ethical challenges posed by digital human twins. These technologies have the power to change how we engage with the digital landscape, sparking important discussions about autonomy, identity, and personal agency. For instance, digital human twins might be used to forecast and sway our behaviors, opening the door to potential manipulation and exploitation, especially in fields like advertising and personalized healthcare. A strict, one-size-fits-all regulatory approach might fall short in addressing the complex ethical issues these technologies bring to the table. Adaptive governance offers a way for regulators to develop frameworks that are flexible enough to consider the various applications of digital human twins and the unique ethical dilemmas they introduce. This includes tackling concerns like the risk of emotional dependency on virtual avatars, the danger of perpetuating societal biases, and the necessity for transparent algorithms that can be held accountable (Bhat et al., 2025). By fostering ongoing dialogue and feedback among all parties involved, adaptive governance can help ensure that ethical considerations are woven into the development of digital human twins as they evolve.

Lastly, adaptive governance plays a crucial role in ensuring that digital human twins are developed with a focus on social equity and inclusivity. As these technologies become more woven into the fabric of our society, there's a real concern that they might deepen existing inequalities, especially regarding access to healthcare, education, and other vital services. For instance, people from marginalized communities might find it harder to access the cutting-edge technologies necessary for creating and maintaining digital human twins, leading to a digital divide that could further entrench social disparities. Adaptive governance empowers policymakers to spot these challenges early on and tweak regulations to make sure the advantages of digital human twins are shared fairly. This approach encourages collaboration among

governments, private companies, and civil society organizations, ensuring that technological progress benefits everyone, not just a select few. By keeping a close eye on the social impact of digital human twins and adjusting policies as needed, adaptive governance helps to reduce the risk of worsening social inequalities.

#### 4. Conclusion

The rise of digital human twins is opening up exciting new possibilities in technology and ethics, paving the way for hyper-personalization in areas like healthcare, fitness, and entertainment. But with this innovation comes a tangled web of ethical responsibilities that we need to navigate carefully. While the potential for digital human twins to transform personalization is huge, we also have to grapple with serious issues like privacy, consent, autonomy, and the risk of behavioral manipulation. The real challenge is to make sure these technologies are created and used in ways that honor individual rights and reflect our societal values. Finding a middle ground between innovation and ethics is absolutely crucial. Digital human twins can enhance personalization, but we must tackle the ethical dilemmas that come with them, especially regarding data privacy and user autonomy. It's vital for policymakers and industry leaders to work together to weave ethical guidelines into the fabric of these technologies right from the start. Striking a balance between technological advancement and ethical responsibility is key to preventing exploitation and harm. This highlights the importance of interdisciplinary research and policymaking. The fast-paced development of digital human twins calls for insights from various fields like law, ethics, technology, and healthcare to build a solid regulatory framework that can handle the complexities of this new technology. Collaboration among academic institutions, industry players, and government agencies will be essential in crafting effective governance models. It is crucial for future research to dive into the long-term effects of digital human twins. We need to examine how they influence social dynamics, mental health, and human rights. Gaining a clear understanding of the societal impacts of these technologies, especially concerning autonomy and identity will be vital for crafting policies that not only safeguard individuals but also encourage innovation.

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