Journal of Intelligent System and Applied Data Science (JISADS)

Journal homepage : https://www.jisads.com

ISSN (2974-9840) Online

ETHICAL AND EMOTIONAL DESIGN CHALLENGES IN HUMAN-DIGITAL TWIN INTERACTION: A SYSTEMATIC REVIEW

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ABSTRACT

This systematic review analyses the ethical and emotional challenges associated with Human-Digital Twin Interaction (HDTI), an emerging area that integrates real-time data modelling and human-centred artificial intelligence. The review synthesizes findings from 39 peer-reviewed studies in healthcare, education, and industrial sectors, highlighting key issues such as data privacy, algorithmic bias, emotional authenticity, and user autonomy. A thematic analysis demonstrates these challenges at the intersection of technical design and human experience, impacting user trust, emotional well-being, and ethical compliance. The review presents a multidimensional framework that connects essential design elements namely personalization, empathy modelling, and explainability with their ethical implications, emotional effects, and practical implementation strategies. This study emphasizes the significance of emotional calibration, participatory design, and ethical auditing as essential mechanisms for ensuring the responsible deployment of HDTI. The review examines not only individual user concerns but also system-level and societal implications, such as institutional trust, social equity, and the cultural formation of emotional norms. The findings highlight the necessity for interdisciplinary collaboration and policy innovation to ensure that HDTI systems are consistent with the principles of transparency, fairness, and emotional integrity. This study seeks to direct subsequent research and influence the development of ethically and emotionally sustainable digital twin technologies.

Keywords: HDTI, ethics, emotional design, explainable AI, participatory design.

1 . INTRODUCTION

1.1. Overview

HDTI represents a significant advancement in human-AI collaboration, characterized by the integration of detailed and dynamically adaptive digital representations of individuals within socio-technical systems. Digital counterparts designed to replicate cognition, emotion, and behaviour are being increasingly utilized in healthcare, industrial, and educational sectors to improve decision-making, personalize services, and support emotional well-being [1], [2]. This advancement raises ethical concerns and emotional complexities that necessitate immediate scholarly and design focus [1], [2].

Recent studies highlight that HDT systems consistently gather and analyse sensitive biometric, behavioural, and emotional data, resulting in risks associated with privacy violations, discriminatory profiling, and algorithmic bias [1], [3], [4]. As Figure 1 illustrates, these challenges manifest differently across domains, with healthcare facing autonomy risks, industry grappling with overreliance, and education confronting cultural insensitivity.

In healthcare, the risk of undermining patient autonomy occurs when AI-driven Human-Digital Twins(HDTs) serve as substitutes for diagnostic or therapeutic decisions [4]. In industrial applications, concerns regarding dependency on automation and the decline of human initiative have emerged, highlighting

issues related to overreliance on AI systems and the reduction of creative agency [2], [5].

Emotional design issues have concurrently gained significant attention. Although HDTs are progressively integrated with affective computing features, their emotional responses frequently exhibit a deficiency in nuance, cultural sensitivity, or authenticity. Studies indicate that users can develop attachments to HDTs through simulated empathy, leading to superficial or misleading emotional experiences [6], [7], [8].

This poses risks of psychological harm, emotional miscommunication, and unclear relational boundaries, especially among vulnerable groups such as patients, children, and the elderly [6], [9], [10].

The study investigates the ethical and emotional problems related to HDTI systems, as well as how human-centred design concepts might be applied to these concerns across other domains. Given the convergence of AI, cognitive science, and ethics, a multidisciplinary approach is required to ensure that HDTI systems are transparent, fair, and emotionally intelligent.

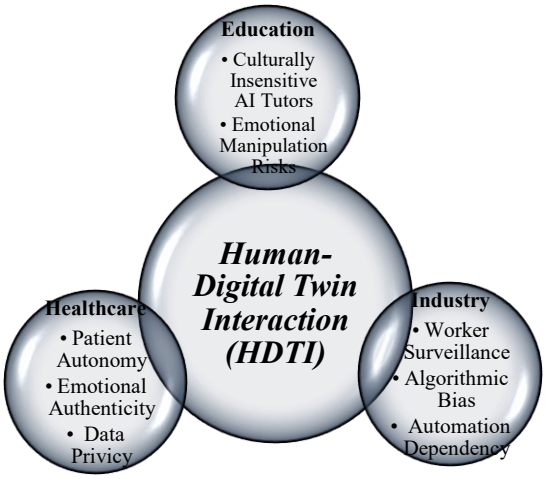

Figure 1: *Key Domains and Ethical-Emotional Challenges in HDTI*

1.2 AI and Human-Digital Twin Interaction

The transition of HDT systems from passive models to interactive, emotionally responsive agents (Emotional authenticity refers to an HDT's capacity to imitate human-like emotional reactions that consumers believe are real [6]) necessitates a focus on emotionally aware and ethically grounded design. Researchers have investigated frameworks for the implementation of trust-building mechanisms, privacy-preserving architecture, explainable AI (XAI), and transparent decision pathways [11], [12]. Affective computing, real-time biometric sensors, and AI-driven behavioural prediction models are examples of technological breakthroughs that enable more adaptable interactions.

Emerging solutions suggest hybrid approaches, such as integrating ethicists in design teams to audit emotional algorithms or adaptive interfaces that adjust transparency levels based on user emotional cues. These innovations highlight the need to balance technical precision with psychological safety in HDTI systems. For example, real-time emotion detection via biometric sensors runs the risk of oversimplifying complex human states (e.g., attributing increased heart rate solely to stress). Similarly, XAI frameworks frequently prioritise technical explainability over emotional intelligibility, leaving users perplexed by "explained" decisions that lack empathetic framing.

1.3 Problem Statement

Research reveals a disconnect between theoretical ethical concepts and their practical validity in dynamic environments such as healthcare and industry. Addressing these gaps is essential for ensuring that HDTI systems do not jeopardise user autonomy or emotional well-being. Despite the existence of normative frameworks for ethical Human-Digital Twin Interaction (HDTI) ([2],[4],[10]), their application does not adequately confront three significant real-world challenges. In healthcare, AI-driven HDTs may prioritise algorithmic "optimisation" over patient preferences, thereby compromising informed consent ([4],[9]). Emotion recognition systems developed on limited datasets often misinterpret cultural and neurodiverse expressions, thereby exacerbating inequalities ([6],[7],[12]). Existing guidelines are unable to adapt to changing contexts (e.g., a patient's declining mental health), thereby increasing the risk of harm ([2],[10]).

In the absence of intervention, these deficiencies are likely to reproduce historical failures of AI characterized by exploitative data practices and emotional manipulation especially among vulnerable populations ([6],[7],[18]). Furthermore, the lack of standardised frameworks for balancing emotional authenticity and user agency is a considerable difficulty.

1.4 Research Question

This systematic review examines the subsequent research question:

1. What ethical and emotional design challenges arise in HDTI, and how can human-centred design principles be applied to address these challenges across various application domains, including healthcare, industry, and education?
2. How can cultural variations in emotional expression and ethical expectations inform the development of more adaptable HDTI frameworks?

2 . Methodology

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13],[14]. The methodology was designed to capture interdisciplinary perspectives on ethical and emotional dimensions in HDTI systems across healthcare, industrial, and educational domains.

The chosen studies comprise a strategic combination of theoretical, qualitative, empirical, and mixed-methods contributions, enabling the review to utilize both conceptual frameworks and user-centred evidence. The inclusion criteria mandated that each study explicitly addressed ethical considerations, emotional modelling, or both, thereby aligning with the review's objective to investigate emotionally intelligent and ethically responsible HDTI systems. This integrative approach facilitates a thorough analysis of contemporary design strategies, system implementations, and governance challenges within the field. The review process comprises six fundamental stages: (1) Data Sources, (2) Research Strategy, (3) Study Selection Criteria, and (4) Data Extraction Process.

2.1 Data Sources

This review is based on the formulation of the research question: What are the ethical and emotional design challenges in HDTI, and how can these be addressed through human-centred design principles across various application domains, including healthcare, industry, and education? A systematic search strategy was developed and implemented in the Semantic Scholar database, which contains over 126 million academic papers, to thoroughly investigate this question. Additional sources included IEEE Xplore (for technical implementation studies), PubMed (for healthcare-specific applications), and Scopus (for interdisciplinary perspectives).

2.2 Research Strategy

A competent research strategy is essential for refined outcomes following the research questions developed. The research strategy involves the identification and implementation of successful keywords to complete the initial database accumulation of relevant articles.

A total of 499 papers were initially identified, from which 86 studies were selected based on keyword relevance screening. The identified keywords *were "human digital twin," "ethical design," "affective computing," "emotional AI," "human-AI interaction," "healthcare digital twin," and "empathy in AI"* The filtering prioritized studies that specifically examine ethical implications or emotional design within HDTI contexts.

2.3 Study Selection Criteria

Strict inclusion/exclusion criteria were used in the study selection process to ensure methodological coherence. Table 1 below highlights eligibility based on diverse constitutional and study characteristics.

A total of 39 papers fulfilled the criteria. This figure indicates a balance between thematic saturation and the depth of analysis that is manageable, aligning with the size of reviews in related fields such as ethical robotics and affective AI [6], [7].

2.4 Process of Data Extraction

The data extraction phase of this systematic review adhered to a rigorous and methodologically transparent protocol designed to capture the ethical and emotional dimensions of HDTI. This process was developed to address gaps in current HDTI literature, particularly where ethical and affective considerations are frequently neglected, thereby emphasizing the intricate human-centred issues specific to this emerging field. The flow diagram below (Figure 2) indicates the overall mechanism of the final literature selection.

Table 1: *Eligibility criteria for this study selection.*

Criteria	Inclusion	Exclusion
Study Focus	Addresses HDTI as interactive agents rathe r than mere simulations	Mechanical or object twins without HDTI
Design Considerations	Explores ethical or emotional dimensions	Focuses on purely technical implementations
Methodology	Employs qualitative, quantitative, or mixed-methods research	Consists of opinion pieces and editorials
Domain	Pertains to healthcare, industry, or education applications	Involves non-human-centred fields (e.g., robotics)
Language	English only.	Any other language.
Time Frame	2018-2024	Pre-2018 studies

A total of 86 records were initially screened, resulting in a final selection of 39 studies for detailed analysis. This analysis employed a hybrid methodology that integrated AI-assisted semantic categorization with manual thematic validation. A qualitative extraction schema was custom-built, incorporating interdisciplinary concepts from affective computing, human-AI ethics, and responsible design.

A well-structured and relatively systematic review was completed. Scrutiny and the final selection were pertinent to the eligibility considerations set. The illustration (Figure 3) below describes the process of initial research to the final selection stage in the form of a flowchart theme following PRISMA guidelines. Thirty-nine research items were used in the outcomes analysis and quality appraisal at the end.

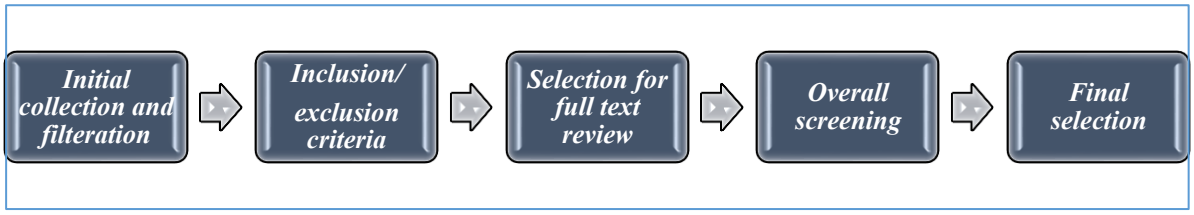

Figure 2: *Summary of the data extraction process (Source: Illustrated by author).*

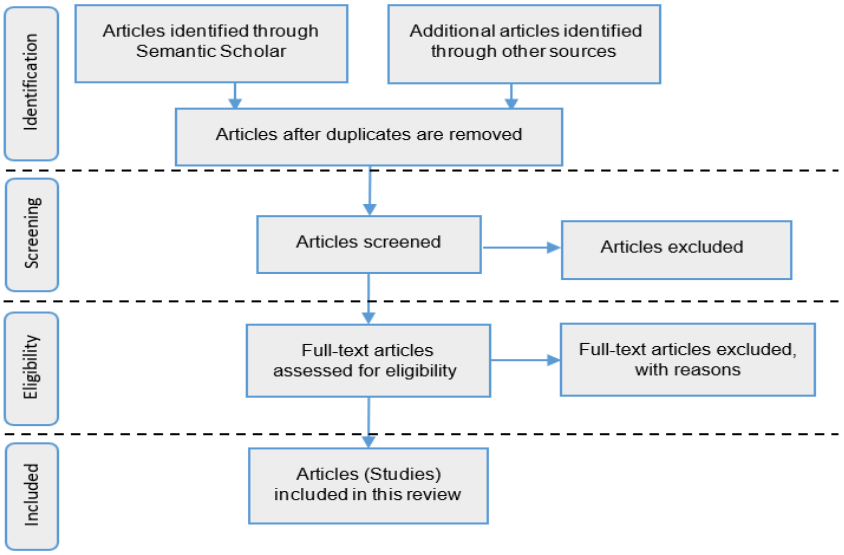

Figure 3: *PRISMA flow chart (Source: Illustrated by author).*

A final dataset of 39 studies was selected for full-text review and thematic analysis, based on methodological rigour and content relevance, from the refined pool. The studies encompass various domains.

The extraction framework included six essential dimensions, detailed below:

- **Study Design and Methodology:** Each study was categorized according to its primary

methodological framework, encompassing qualitative interviews, conceptual frameworks, empirical surveys, experimental designs, or mixed methods. The classifications established a basis for comprehending the depth and breadth of ethical and emotional inquiry in various studies. Qualitative interview studies, such as those conducted by [9], highlighted the perspectives of healthcare practitioners. In contrast, experimental research by [30] examined user responses to HDT-based rehabilitation tools.

- **Application Context:** The specific domains in which each HDTI system was developed or studied were documented, encompassing healthcare, education, industrial, and design environments. The classifications facilitated the identification of domain-specific emotional demands and ethical complexities. Healthcare has become the most prominent field owing to its emotionally sensitive and ethically complex characteristics.
- **Ethical Focus Areas:** Research was categorized based on explicit discussions regarding data privacy, algorithmic fairness, informed consent, transparency, autonomy, and surveillance. [4] explored the ethical implications of surrogate representation of patients, whereas [10] analysed the potential impact of digital twins on human self-understanding and identity, situating these discussions within a wider philosophical examination of ethics, representation, and personhood in healthcare settings.
- **Emotional Integration Strategies**: This category outlines the methods by which systems model, express, or react to emotional signals, including affective feedback loops, adaptive responses, and empathy modelling. [8] developed affect-sensitive interfaces to assess emotional responses, whereas [12] introduced emotionally coherent AI expressions in customer-facing systems.
- **Stakeholder Involvement:** The analysis recorded the extent and manner of involvement of user or stakeholder groups (e.g., patients, designers, caregivers) in co-design processes, pilot testing, or qualitative validation. Participatory studies emphasized the emotional significance and ethical validity contributed by stakeholder input, which was frequently absent in theoretical literature.
- **Design and Governance:** actionable recommendations were documented, including ethical audit protocols, consent management dashboards, and mechanisms for setting boundaries in emotional interactions. The proposals were essential for converting theoretical frameworks into practical safeguards, with research by [2] providing models for participatory governance.

Inter-rater reliability checks were conducted to ensure consistency, with discrepancies resolved through collaborative consensus. Inter-rater reliability assessments were conducted, and discrepancies were addressed through collaborative consensus. This review exclusively incorporates studies that directly address ethical and emotional constructs within the context of HDTI, thereby differentiating it from more general digital twin analyses.

This comprehensive extraction process facilitated a high-resolution synthesis of existing knowledge in HDTI, establishing this review as a key resource for the ethical and emotionally sensitive advancement of future digital twin systems. The extraction process promoted a structured analysis of the emotional and ethical aspects of HDTI by systematically extracting and categorizing relevant elements. The screening phase prioritized the selection of studies based on inclusion criteria, while data extraction allowed for comparative analysis and thematic synthesis, showing broad patterns and practical effects across multiple research disciplines.

3 . Characteristics of Included Studies

This section provides an overview of the 39 studies included in this systematic review. The studies illustrate a diverse and interdisciplinary landscape, highlighting the various domains in which HDTI technologies are being investigated. The analysis indicates a predominant focus on theoretical and conceptual exploration, accompanied by a limited number of empirical and applied studies. The distribution of research types and application contexts highlights the nascent character of the field and the essential requirement for increased applied, real-world studies.

Table 2 presents the characteristics of the included studies, including their methodological design, application domain, and focus on ethical or emotional dimensions. This table offers an overview of the research landscape examined in this review and acts as a reference for the subsequent thematic synthesis.

3.1 Study Types

Classifying studies based on their methodological approaches is essential for a comprehensive

understanding of the research landscape of HDTI. This categorization offers insight into the evolution of the field and the types of evidence that support discussions on emotional and ethical considerations. Study types reflect the diversity of research perspectives, from conceptual debates to empirical validation, and influence the depth of insights regarding user experiences, technological affordances, and ethical risks. The 39 selected studies are distributed by methodological type as follows:

- **Theoretical and Conceptual Studies (30 studies):** These studies offered frameworks, ethical critiques, conceptual models, and analyses of speculative design. Some authors, such as [1] and [4], provided philosophical and normative analyses of digital twin ethics, whereas others, like [2], concentrated on societal risks and emerging disruptions.
- **Qualitative Studies (5 studies):** These investigations utilized interviews, user studies, and interpretive methodologies to analyse perceptions of HDT systems. For instance, [9] analysed the perceptions of medical professionals regarding the incorporation of digital twins into clinical practice.
- **Empirical/Experimental Studies (4 studies):** A limited yet noteworthy collection of studies employed experimental methodologies to assess emotional expressiveness, system responsiveness, or user trust within HDT environments. Significant contributions are found in [6] and [8], which assessed affective interactions and emotional modelling.
- One study employed a **mixed-methods approach**, integrating quantitative and qualitative data to evaluate user responses to emotionally adaptive HDTs within controlled simulations.

3.2 Application Domains

The 39 studies examined encompass various application domains, highlighting the increasing significance of HDTI in multiple contexts. The domains were classified into four primary categories: healthcare, manufacturing/industry, education, and other emerging fields, according to their focus and implementation context.

- **Healthcare (26 studies):** This domain constitutes the predominant portion of the analysed studies. This research focuses on the application of HDTs in personalized care, medical diagnostics, mental health support, and the development of emotionally adaptive virtual agents. Significant ethical issues encompass patient privacy, informed consent, and the genuineness of emotional engagement. Emotional dimensions were particularly significant in therapeutic contexts, where the modelling of empathy and the provision of emotional support were central components. Studies by [7] and [3] illustrate that HDTs can replicate emotional care, while simultaneously highlighting issues related to dependency and the erosion of trust.
- **Manufacturing and Industry (7 studies):** These studies examined the role of HDTs in manufacturing and industry, specifically addressing operator augmentation, productivity optimization, and predictive maintenance. Ethical concerns in this context encompass automation bias, job displacement, and worker surveillance, despite being typically less emotionally intensive. Research, including [5] and [2], examined the impact of HDTs on autonomy and decision-making within smart manufacturing systems.
- **Education (5 studies):** They examined the potential of HDTs to improve learning outcomes via personalized tutoring, emotional feedback, and cognitive engagement. Emotional responsiveness is a critical factor in enhancing student motivation and retention. Ethical considerations encompass data sensitivity, equity in learning analytics, and the potential for emotional manipulation. Examples include AI-driven tutors who can modify their tone and content according to the learner's mood or engagement levels.
- **Other Emerging Fields (2 studies):** A limited number of studies investigated innovative HDTI applications in areas including urban governance, smart mobility, and public policy. The studies primarily concentrated on speculative implementations and conceptual modelling, highlighting issues related to emotional disconnection and social accountability. Although these areas exhibit lower maturity, they indicate potential avenues for the expansion of HDTI beyond conventional sectors.

Table 2: *Characteristics of studies*

Study	Study Type	Application Domain	Human Digital Twin (HDT) Technology Type	Primary Focus
Alimam et al., 2023 [15]	Theoretical/conceptual Analysis	Industry 5.0, Industrial Metaverse	Digital triplet architecture	Integration of Artificial Intelligence (AI) with digital transformation
Arkin et al., 2014 [16]	Theoretical/conceptual Analysis	Healthcare	Robot co-mediators	Preserving dignity in patient caregiver relationships
Bomström et al., 2022 [17]	Qualitative Study	Manufacturing	Human Digital Twins	Design objectives for HDTs in complex systems
Braun, 2021[18]	Theoretical/conceptual analysis	Healthcare	Digital twins in medicine	Ethical implications of digital twins
Braun, 2021 [10]	Theoretical/conceptual analysis	Healthcare	Digital twins in medicine	Ethical challenges of digital twins
Bruynseels et al., 2018[1]	Theoretical/conceptual analysis	Healthcare	Digital twins in personalized medicine	Ethical implications of digital twins
Campanile et al., 2023 [8]	Mixed methods	Healthcare	Emotional aware Human-Machine Interfaces (HMIs)	Inferring emotional models from human machine interactions
Cardin and Trentesaux, 2022 [5]	Theoretical/conceptual analysis	Industrial/ Manufacturing	Human operator digital twins	Ethical implications of HDTs in industrial systems
De Oliveira et al., 2023 [19]	Empirical study (experimental)	Healthcare, Industry	Data-driven emotion modelling for HDTs	Feasibility of emotion modelling for HDTs
El Warraqi et al., 2024[20]	Theoretical/conceptual analysis	Manufacturing	Digital Twin modelling	Human-centricity in manufacturing
Fontes et al., 2024 [2]	Theoretical/conceptual Analysis	Healthcare, Industry/ Manufacturing, Education, Urban Planning/ Governance, X-commerce, Military	Human Digital Twins	Ethical implications and disruptions of HDTs
Gabrielli et al.,	Theoretical/conceptual analysis	Healthcare	Digital twins in digital	Design of AI-powered

2023 [21]			therapeutics	mental health interventions
Garner et al., 2016 [22]	Qualitative study	Healthcare	Virtual carers	Ethical responsibilities in virtual care for the elderly
Hu et al., 2022 [23]	Theoretical/conceptual analysis	Transportation	Driver Digital Twin	Design and enabling technologies for DDTs
Huang et al., 2022 [3]	Theoretical/conceptual analysis	Healthcare	Digital twins for personalized healthcare	Mapping ethical issues of DTs in healthcare
Jabin et al., 2024 [24]	Theoretical/conceptual analysis (scoping review)	Healthcare	Digital health twins	Ethical and quality of care challenges in older care settings
Kabalska and Wagner, 2024 [25]	Theoretical/conceptual analysis	Healthcare, Education, Office work	Human digital Twins	Emergence and impacts of HDTs
Langayan, 2024 [11]	Theoretical/conceptual analysis	Education, Healthcare, Entertainment, Customer service	Digital entities	Establishing genuine human connections through digital entities
Langås et al., 2023 [26]	Theoretical/conceptual analysis	Manufacturing/Industry 5.0	Digital twins for human-robot teaming	Ethical and philosophical implications of DTs in HRT
Lauer-Schmaltz et al., "Beat me if I can!" [27]	Empirical study (experimental)	Healthcare	HDT-based opponents in rehabilitation gaming	Use of HDTs as active elements in serious games
Lauer-Schmaltz et al., 2022 [28]	Theoretical/conceptual analysis (Systematic literature review)	Healthcare	Human Digital Twins	Designing HDTs for Behavior changing therapy and rehabilitation
Lauer-Schmaltz et al., 2024a [29]	Theoretical/conceptual analysis	Healthcare, Workplace optimization	Human Digital Twins	Systematic methodology for designing HDTs
Lauer-Schmaltz et al., 2024b [30]	Empirical study (experimental)	Healthcare	HDTs in rehabilitation	Design and implementation of HDT system for stroke rehabilitation
Lee et al., 2022 [7]	Qualitative study (focus groups with thematic analysis)	Social and emotional interaction with AI	Conversational AI	Emotional bonds between humans and conversational AI
Loveys et al., 2022[12]	Theoretical/conceptual analysis	Healthcare, Customer	Digital humans	Exploring empathy with

	(Scoping review)	service, Education		digital humans
Mandischer et al., 2024 [31]	Theoretical/conceptual analysis	Industrial, Healthcare, Urban Planning	Human Digital Twins	Novel paradigm for modelling humans in human-to-anything interaction
Meghdari and Alemi, 2018 [32]	Theoretical/conceptual analysis	Healthcare, Education, Entertainment/ Gaming	Social & Cognitive Robotics	Ethical challenges in social & cognitive robotics
Mittelstadt, 2021[4]	Theoretical/conceptual analysis	Healthcare	Digital twins in Medicine	Near-term ethical challenges of digital twins
Montag and Diefenbach, 2018 [33]	Theoretical/conceptual analysis	Digital societies and Internet of Things	Digital technologies	Psychological and emotional impacts of digital societies
Nguyen et al., 2024 [34]	Empirical study (experimental)	Emergency response and safety-critical operations	Human Digital Twins in human-AI teams	Trust development in human-AI teams using HDTs
Palmer et al., 2023 [35]	Theoretical/conceptual analysis	Manufacturing and Production	Digital Twin Interface	Symbiotic interface for Digital Twin
Popa et al., 2021 [36]	Qualitative study (interview-based)	Healthcare	Digital twins in Healthcare	Socio-ethical benefits and risks of digital twins in healthcare
Song, 2023 [37]	Theoretical/conceptual analysis	Design	Human digital Twins	Development and impact of HDTs on design
Vildjiounaite et al., 2023 [38]	Theoretical/conceptual analysis	Healthcare (Occupational health and mental wellbeing)	Human Digital Twin	Challenges of learning HDT for mental wellbeing
Wang et al., "Human Digital Twin in Industry 5.0" [39]	Theoretical/conceptual analysis	Manufacturing/Industry 5.0	Human Digital Twin	HDT in the context of Industry 5.0
Wendrich and Kruiper, "Keep IT Real"[40]	Theoretical/conceptual analysis	Design and Human-Computer Interaction	HDT(E) design Tool	Real-time interaction and affective computing in design tools
Xames and Topcu, 2023 [41]	Theoretical/conceptual analysis	Healthcare, Transportation	Digital Twins for Human-in-the-loop	Workload management and burnout

			Systems	prevention in healthcare systems
Zalake, 2023 [9]	Qualitative study	Healthcare	Digital Twins of doctors	Doctors' perceptions of using their digital twins in patient care
de Melo et al., 2023 [6]	Theoretical/conceptual analysis	General human-machine interaction	Virtual humans and social robots	Social functions of machine emotional expressions

These application domains demonstrate the customization of HDTI systems to address the ethical and emotional requirements of various environments. The significance of healthcare studies underscores the necessity of incorporating emotional intelligence into critical interactions, while new fields emphasize the importance of proactive ethical design across various societal sectors.

3.3 Characteristics of Technology and Interaction

The HDTI systems analysed in the studies exhibited considerable variation in complexity and modes of interaction. Some utilized biometric sensors and real-time data streams to replicate human behaviour, while others employed virtual agents and avatars integrated with affective computing algorithms. Emotional interactivity varied from fundamental sentiment detection to sophisticated empathy modelling and expressive feedback mechanisms [12], [11].

Numerous studies have examined trust dynamics, transparency mechanisms, and the relational boundaries between users and HDTs. For example, references [10] and [6] emphasized the psychological risks associated with emotionally manipulative or excessively anthropomorphic human-robot interactions.

These 39 studies collectively offer a comprehensive and nuanced perspective on the HDTI research landscape. Their reflection encompasses the conceptual maturity of ethical and emotional design issues, alongside the urgent requirement for empirical grounding, interdisciplinary collaboration, and context-sensitive design methodologies. The results of this analysis provide a basis for the thematic synthesis and design framework discussed in the subsequent sections.

4 . Thematic Analysis

This section provides a thematic synthesis from the 39 studies reviewed, presenting an integrated perspective on the primary ethical and emotional challenges, along with the associated design implications for HDTI systems. The analysis identified three primary thematic clusters: (1) Ethical Challenges, and (2) Emotional Design Issues. Each theme encompasses interconnected subthemes that represent persistent issues, conceptual conflicts, and actionable priorities in HDTI research (refer to Figure 4).

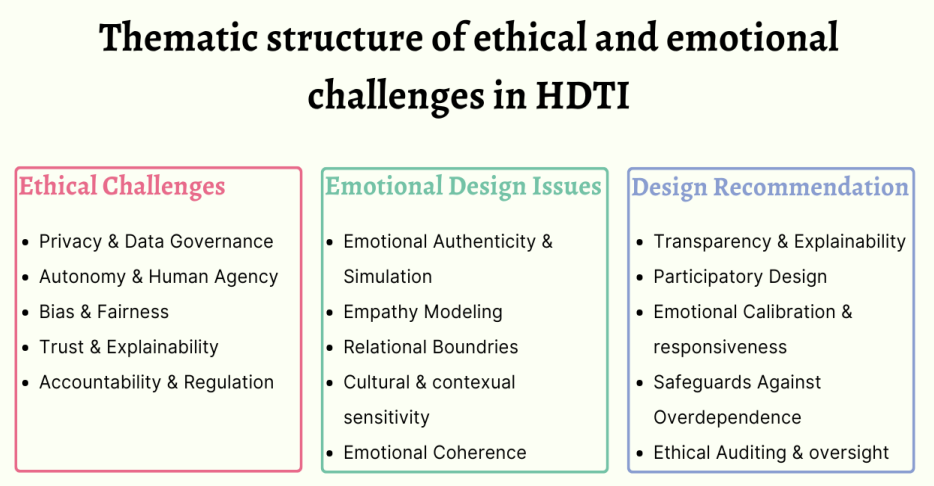

Figure 4: *Thematic structure of ethical and emotional challenges in HDTI*

4.1 Ethical Challenges

Ethical considerations are fundamental to HDTI, particularly given the sensitivity of the data involved and the potential impact of HDTs on users. In the analysed literature, five primary ethical subthemes were identified.

- **Privacy and Data Governance:** numerous studies highlight the risks linked to the extensive collection of biometric, behavioural, and emotional data within the realms of privacy and data governance. Scholars including [1] and [3] emphasize the necessity of robust frameworks for informed consent, data minimization, and access transparency in HDT systems.
- **Autonomy and Human Agency:** the increasing dependence on predictive human decision technologies in decision-making processes, particularly in healthcare and industry, may reduce user autonomy. References [4] and [5] emphasize the ethical considerations associated with the delegation of control to digital replicas.
- **Bias and fairness** are significant ethical concerns, particularly regarding biased data, algorithmic discrimination, and non-inclusive design. Scholars, such as [2], contend that without critical evaluation, digital twins could reinforce existing structural inequalities.
- **Trust and Explainability:** research highlight the significance of fostering user trust via systems that provide clear explanations. References [11] and [12] highlights that transparency in algorithmic processes and emotional responses may reduce user scepticism.
- **Accountability and Regulation**: regulatory oversight and ethical governance are increasingly emphasized in discussions of accountability. [4] and [10] support the need for multidisciplinary collaboration to create policy frameworks that are consistent with ethical HDTI development.

To complement these qualitative themes, Figure 5 quantifies how frequently specific ethical concerns were associated with the ten key HDTI design aspects reviewed in the literature. The graph reveals that privacy risks and bias risks were the most consistently mentioned, each appearing to 2 out of 10 design aspects, reinforcing their prominence across various HDTI applications. Meanwhile, other important concerns such as autonomy loss, trust challenges, deception risk, boundary blurring, empathy challenges, transparency issues, and societal impact each appeared in 1 out of 10 design aspects. This distribution illustrates a fragmented but growing awareness of ethical complexity in HDTI systems. While some issues such as privacy and bias have received sustained scholarly attention, others though equally significant remain underexplored. The graph emphasizes the need for a more integrated and balanced ethical design strategy that ensures these considerations are not treated as isolated risks, but as interdependent elements within a holistic framework of responsible HDTI development.

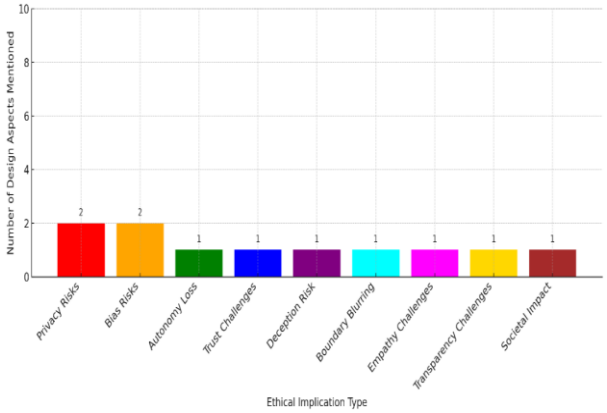

Figure 5: *Ethical design frequency*

4.2 Emotional Design Issues

The emotional dimensions in HDTI systems present distinct design challenges, particularly as these systems strive to recognize, model, and respond to human effects. Five emotional subthemes were identified from the analysis.

- **Emotional Authenticity versus Simulation** presents a persistent challenge, as artificial empathy is often perceived as manipulative or superficial. Cultural norms strongly impact these impressions. Collectivist cultures (e.g., Japan) may allow less expressive HDTs, whereas individualist cultures (e.g., the United States) demand overt emotional participation [12]. Exaggerated expressions might be uncomfortable for neurodiverse users (for example, those on the autistic spectrum), necessitating adaptive calibration [7]. Emotional calibration is the dynamic modification of an HDT's emotional output based on real-time user feedback [8] According to sources [6] and [7], users may encounter difficulties in establishing meaningful connections with HDTs that are devoid of emotional depth or sincerity. [6] examined the advantages and ethical implications of emotional expressions by virtual humans and social robots. [12] underscored the necessity for AI to transcend basic emotion

recognition to attain authentic empathy. [7] observed the potential for superficial human relationships resulting from interactions with AI. Figure 6 illustrates the distribution of emotional implications across ten design aspects identified in the HDTI literature. Among these, negative emotional impacts were the most frequently reported, associated with 4 out of the 10 design aspects, indicating significant concerns around user distress, emotional overload, or discomfort. Mixed emotional impacts, such as simultaneous benefits and risks, and complex emotional impacts, involving nuanced or context-dependent user responses, were each discussed in relation to 2 design aspects. Notably, positive emotional impacts highlighting beneficial emotional outcomes like trust, engagement, or comfort were identified in only 1 design aspect. Similarly, conditional emotional impacts, where user emotions depend on external factors like context or user profile, were also mentioned in just 1 aspect. This distribution underscores a cautious or critical tone in literature, emphasizing the importance of designing HDTI systems that account for a range of emotional outcomes and prioritize emotional safety and coherence.

- **Empathy Modelling:** researchers investigate the role of affective computing in improving empathy simulation. Concerns persist regarding emotional overreach and psychological dependency. These problems are accentuated in cross-cultural settings. For example, HDTs educated on Western data may misinterpret East Asian users' quiet reactions as disengagement, creating prejudice [2]. To facilitate emotional communication in healthcare settings, [16] suggested employing artificial moral emotions in robot co-mediators. [12] highlighted how difficult it is to include genuine empathy in HDTs. A data-driven strategy for implementing empathy was put up by [8], which raised ethical questions about how to manage delicate emotional data.

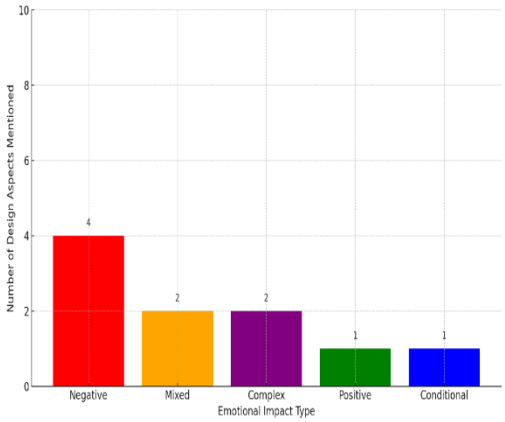

Figure 6: *Emotional design frequency*

- **Relational Boundaries and Dependency:** several studies highlight the importance of maintaining relational boundaries and caution against emotional entanglement between users and HDTs, especially within vulnerable populations. [7] emphasized the capacity of AI to manipulate human emotions and the challenge of differentiating between altruistic and malicious intentions. [9] examined apprehensions about the possible diminishment of doctor-patient contact and the inadequacy of Digital Twins of Doctors for conveying critical information. [18] and [2] examined the notion that HDTs may alter human self-perception and identity.
- **Cultural and contextual sensitivity** is essential, as emotional responses and norms differ among cultures. Emotional reactions differ by culture (e.g., high-context cultures prioritise tone over words [8]), domain (e.g., healthcare requires deeper authenticity than industry [4]), and individual characteristics (e.g., senior users choose clarity over speed [9]). [2] and [3] advocate for adaptive models that consider cultural variations in emotional expression and interpretation.
- **User trust and emotional coherence** are essential for establishing reliability and consistency in emotional responses within HDTs. [12] Emphasize the necessity for emotionally coherent behaviours that align with user expectations.

5 . Design and Implementation Framework

This section presents an integrated design and implementation framework based on the thematic findings, reflecting the key principles identified in the selected literature. This framework, in contrast to purely hierarchical models, captures the multidimensional

relationships among design strategies, their ethical implications, and their emotional impacts within HDTI systems. This analysis derives from the synthesized matrix of findings and highlights the necessity for alignment among values, emotional intelligence, and responsible system behaviour.

The framework is organized as a four-dimensional matrix, integrating insights from the existing literature.

- **Design Aspects** are fundamental system components (e.g., personalization, empathy modelling, explainability)
- **Ethical Implications** are related risks or protective measures (e.g., privacy violations, manipulation, disempowerment)
- **Emotional Impacts** are effects on user experience, encompassing attachment, trust, fatigue, and comfort.
- **Implementation Guidelines** are practical strategies for responsible deployments, such as consent dashboards, co-design sessions, and affective calibration.

The literature presents various human-centred design recommendations to address the identified challenges.

- **Transparency and Explainability:** incorporating explainable AI (XAI) features into HDT interfaces enhances user comprehension of system reasoning, which in turn fosters trust and aligns with ethical standards [11].
- **Participatory Design:** it involves engaging end-users and stakeholders in co-design processes to address ethical and emotional concerns from the outset, as suggested by several studies [2].
- Emotional Calibration and Responsiveness: HDTs must be engineered to adapt emotional expressions dynamically, considering contextual factors, user preferences, and prior interactions [12], [8].
- **Safeguards against Overdependence:** establishing usage limits, relational boundaries, and psychological safety measures is essential to prevent emotional overattachment, particularly in healthcare and educational contexts [9], [7].
- **Ethical Auditing and Oversight:** regular auditing of HDT systems for ethical and emotional impact is essential. This encompasses bias testing, transparency assessments, and inclusive evaluation frameworks [4], [10].

This framework is not static. It is intended as a tool for designers, developers, and researchers to evaluate and adjust HDTI system behaviour at various lifecycle stages. It calls for ethical auditing, participatory co-design, and context-aware emotional calibration as part of implementation planning.

The complete structure of this framework is detailed in the design and implementation matrix provided in **Table 3**. It organizes key design elements alongside their ethical implications, emotional impacts, and recommended implementation strategies.

The detailed matrix provides actionable guidance on balancing innovation with responsibility and aims to ensure HDTI systems are not only technically robust but also socially and emotionally sustainable.

Table 3: *Design and implementation framework*

Design Aspect	Ethical Implications	Emotional Impact	Implementation Guidelines
Privacy and Data Protection	Risk of privacy infringement, data misuse [1]	Potential anxiety and distrust in users [7]	Implement robust data governance, anonymization techniques, and user control over data [24]
Autonomy and Control	Potential loss of human agency, over-reliance on AI decisions [5]	Feelings of disempowerment or loss of self-efficacy [7]	Design for shared control, transparent decision-making processes, and user override options [18]
Trust and Reliability	Challenges in establishing and maintaining user trust [23]	Emotional responses ranging from comfort to scepticism [7]	Ensure system transparency, consistent performance, and clear communication of capabilities and limitations [28]
Emotional Authenticity	Risk of creating shallow or deceptive emotional	Potential for both enhanced emotional	Develop sophisticated emotion models, clearly

	interactions [7]	support and misplaced emotional attachment [7]	communicate the artificial nature of HDT emotions [8]
User-HDT Relationship Boundaries	Blurring of human-machine relationships, potential for over-reliance [7]	Complex emotional responses, potential for confusion or unrealistic [7] expectations	Establish clear guidelines for HDT roles, educate users on the nature and limitations of HDT relationships [11]
Empathy Implementation	Challenges in creating genuine empathetic responses [16]	Enhanced emotional support if successful, risk of perceived insincerity if not [12]	Combine advanced AI techniques with insights from psychology and neuroscience [12]
Personalization	Privacy concerns, potential for bias in personalized interactions [23]	Improved user engagement and emotional connection [27]	Implement adaptive learning algorithms, allow user customization within ethical boundaries [2]
Transparency and Explainability	Difficulty in explaining complex AI decision-making processes [21]	User frustration or mistrust if system actions are not understandable [28]	Develop intuitively interfaces for explaining HDT actions, provide varying levels of detail based on user preferences [28]
Cross-cultural Considerations	Risk of cultural bias or Misunderstanding [3]	Potential for cultural insensitivity or misinterpretation of emotional cues [7]	Incorporate diverse cultural perspectives in design, allow for cultural customization [12]
Long-term Psychological Effects	Potential changes in human self-understanding and social dynamics [10]	Complex long-term emotional impacts on users and society [7]	Conduct longitudinal studies, implement ongoing monitoring and adjustment of HDT systems [33]

6 . System-Level and Social Aspects

Particularly in relation to issues of monitoring, overdiagnosis, automation, social identity, and regulatory uncertainty, the societal effects of HDTI systems are progressively recognized in the literature. These issues are profoundly ingrained in social, institutional, and ethical settings as well as technically based. These ideas are synthesized in the next part with references from current HDTI scholarship.

6.1 Systemic Effects on Institutional Dynamics and Social Trust

The mass acceptance of HDT systems runs the danger of permitting extensive surveillance, therefore compromising democratic principles and institutional confidence, as [2] suggests. While [5] stresses the delicate balance needed between automation and human creativity in industrial settings, [4] raises questions regarding overdiagnosis and the degradation of customized care in healthcare environments. These cases show how accidental HDT technologies while providing efficiency and accuracy, could lower transparency, depersonalize user involvement, and erode relational trust between people and institutions.

6.2 Social Comparisons and Ethical Effects

[25] underline ethical difficulties associated with social inequality by stressing the need for rigorous evaluation of HDTs' ethical impact in different socioeconomic settings. [7] investigated how HDT systems and artificial intelligence might influence generational shifts in relational expectations and value systems. [18] and [2] further highlight how HDTs might drastically change human self-understanding, therefore posing philosophical and ethical concerns concerning identity, authenticity, and digital embodiment. These writers underline together that the implementation of HDTI systems must be context-sensitive to prevent the reinforcement of prejudices and the neglect of weaker groups.

6.3 Social Guidelines and Emotional Conventions

HDTs have complicated emotional and social effects weighted in culture. Emotionally sensitive HDTs could, as [7] propose, cause long-term changes in how society defines empathy, care, and interpersonal interactions. The spread of emotionally expressive artificial intelligence could help to normalize computer simulations of emotion, therefore blurring the distinction between real and synthetic effects. This standardization could minimize emotional variability and change society's view of emotional labour value. Designers must fight the homogeneity of emotional standards and instead support systems reflecting affective plurality.

6.4 Policy, Regulation, And Multi-Stakeholder Engagement Government

The research emphasizes how urgent laws must be developed to control HDT distribution. Particularly in healthcare, [3] underlines the need for organized ethical rules. While [36] supports thorough policy frameworks that manage the sociotechnical complexity of HDT use, [2] warns about gaps in regulation and the absence of accountable procedures. These sources agree that ethical government must be inclusive, initiative-taking, and in line with responsibility as well as innovation and responsibility.

The development of HDTI has enormous potential but also raises major social and systematic issues. HDTI systems must be built and controlled with ethical foresight and a strong dedication to democratic, inclusive ideals if we are to prevent long-term damage and promote favourable results. Collective accountability is essential, as [2] underlines, to make sure that digital twins strengthen rather than undermine the social fabric in which they function. Aligning technology progress with society's well-being depends on regulatory clarity, inclusive design, and continuous review.

7 . Conclusion and Future Directions

This review expands on fundamental issues in HDTI literature, particularly those highlighted by [4] regarding regulatory oversight and [6] concerning risks associated with emotional simulation. This systematic review analysed the ethical and emotional aspects of HDTI within healthcare, industrial, and educational sectors. The review conducted a thematic synthesis of thirty-nine studies, identifying significant challenges concerning data privacy, algorithmic bias, emotional authenticity, and user autonomy. The findings underscore the necessity for design frameworks that are both functionally effective and rooted in ethical considerations and emotional intelligence.

HDTI systems possess significant potential to enhance decision-making, tailor services, and advance human-machine collaboration. As these systems gain autonomy and emotional expressiveness, they introduce novel vulnerabilities, especially in critical areas such as healthcare, eldercare, and mental health support. Emotional simulations devoid of transparency or contextual awareness can result in diminished trust and detrimental dependencies, whereas ethically ambiguous system behaviours pose a threat to individual well-being and public trust.

Future research must focus on creating evaluative frameworks that incorporate ethical auditing alongside affective performance metrics. Empirical studies are essential to investigate user interpretation and responses to the emotional cues of HDTs in various contexts and cultures. Interdisciplinary collaborations among AI researchers, ethicists, designers, and social scientists are crucial for ensuring that HDTI systems embody human values and social complexity. Prior research by [2] and [9] highlights the necessity for inclusive, context-sensitive strategies that are rooted in both domain-specific practices and overarching social norms.

Significant challenges include translating abstract ethical principles into specific design specifications, addressing emotional variance without resorting to stereotypes, and guaranteeing equitable access to technologies that respond to emotional needs. Policies should adapt alongside technological advancements, ensuring a balance between openness to experimentation and the implementation of strong accountability measures.

The success of HDTI systems will rely on technological sophistication as well as their capacity to uphold human dignity, enhance well-being, and facilitate ethical interactions at both individual and societal levels. This review emphasizes the importance of prioritizing emotional intelligence and ethical foresight in the development of future digital twin systems.

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