Emotional Intervention for Patients with Chronic Kidney Disease using Avatars in Virtual Healthcare: A Survey

Abstract

This survey paper explores the innovative use of avatars in virtual healthcare to provide emotional support and anxiety management for patients with chronic kidney disease (CKD). By integrating digital avatars and AI technologies, virtual healthcare environments can simulate human-like interactions, offering personalized and empathetic support to address the psychological and emotional needs of CKD patients. Key advancements include real-time emotion recognition and expression mapping, which enhance the authenticity and effectiveness of avatar interactions. These technologies are crucial for managing anxiety, improving patient engagement, and ultimately contributing to better health outcomes. The survey highlights the role of avatar realism and emotional expression in creating immersive and supportive environments, as well as the potential of avatar-based systems to deliver scalable training opportunities, such as synthetic patients in medical training. Despite significant progress, challenges remain, including computational demands, accuracy in modeling, and the need for ethical frameworks to ensure privacy and data security. Addressing these challenges is essential for maximizing the potential of avatar technologies in virtual healthcare. Overall, this survey underscores the transformative impact of avatar-based emotional interventions on chronic illness management, providing a comprehensive framework for integrating emotional support into healthcare systems and enhancing patient care.

1 Introduction

1.1 Concept of Emotional Intervention Using Avatars

The integration of avatars in healthcare for emotional intervention represents a significant advancement in chronic illness management. Avatars, as digital proxies, facilitate human-like interactions, providing personalized emotional support by adapting to users' emotional states. This capability enhances user engagement and reduces anxiety, creating a more immersive experience compared to traditional video communications [1].

Beyond mere presence, avatars must actively engage in emotional support, addressing user issues through empathetic interaction, which is essential for effective emotional intervention [2]. Additionally, avatars enhance self-awareness in virtual training environments, serving as tools for introspection and learning [3].

Recent advancements in avatar technology emphasize contextual relevance, ensuring avatars align with user actions to foster trust and rapport within virtual healthcare systems [4]. The integration of affective skills in AI conversational agents further enhances user experience, demonstrating the importance of these skills in avatar-based interventions [5].

The interplay between avatars and emotional experiences is critical, with studies indicating that avatars can facilitate deeper emotional connections through online empathy measurement via EEG

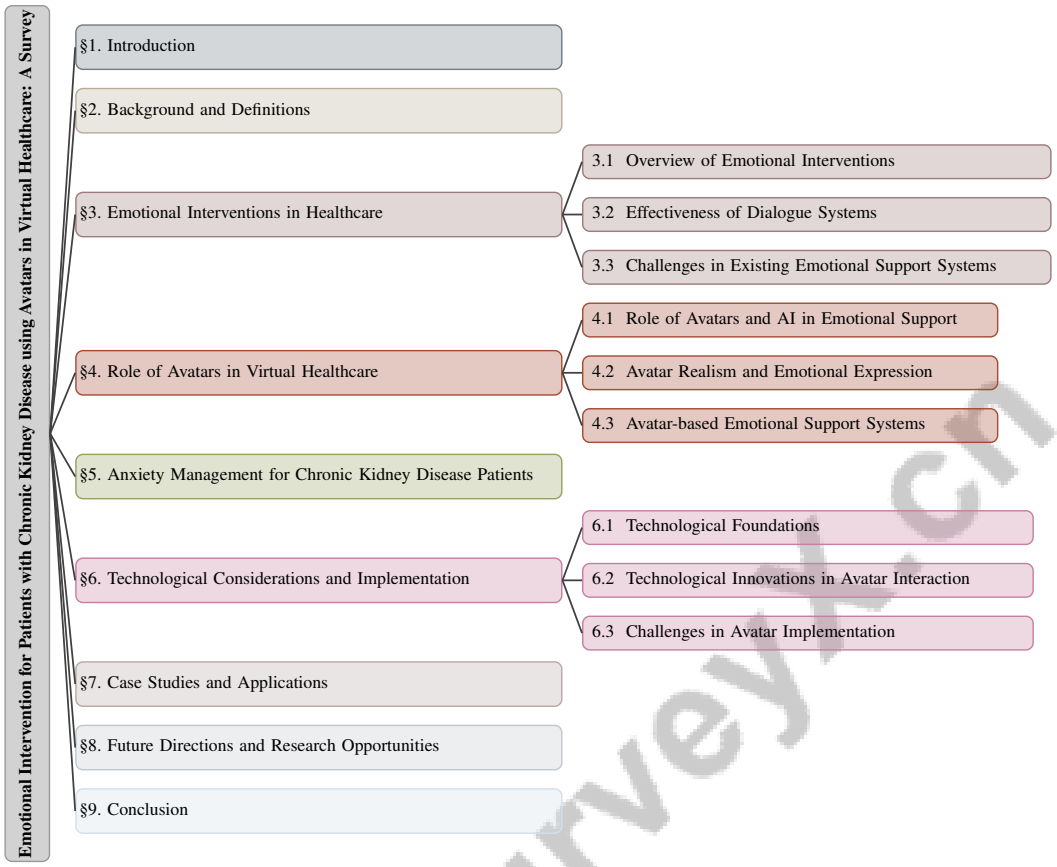

Figure 1: chapter structure

signals during virtual reality interactions [6]. Furthermore, research on avatar representation and identity management in social virtual reality contexts aims to close existing gaps, enhancing the therapeutic potential of avatars [7].

By leveraging AI avatars that simulate human interactions and adapt to emotional cues, virtual healthcare systems can provide effective support for chronic illness management. Utilizing machine learning and natural language processing, these systems create engaging conversational agents that improve diagnostic accuracy and offer personalized health advice. Customization of avatars to resemble users has been shown to enhance emotional connection and motivation, leading to improved health outcomes [8, 9]. This innovative approach not only bolsters patient engagement but also establishes a robust framework for emotional intervention, paving the way for advancements in digital healthcare solutions.

1.2 Significance of Anxiety Management and Emotional Support

Anxiety management and emotional support are vital in chronic illness management, particularly for conditions like chronic kidney disease. The incorporation of emotional support systems is essential, as positive affect correlates with higher body ownership, crucial for patient engagement and adherence to treatment regimens [10]. Avatars and virtual characters in healthcare settings can evoke positive emotional responses and enhance motivation, making them effective tools for addressing patients' emotional needs [11].

Neglecting emotional needs in remote patient monitoring (RPM) technologies can lead to inequities in healthcare delivery, highlighting the necessity of integrating emotional support mechanisms to ensure equitable care [12]. The COVID-19 pandemic underscored the importance of effective long-distance collaboration tools, further emphasizing the role of virtual healthcare interventions in supporting emotional well-being [13].

Systematic integration of technologies for anxiety management and emotional support is crucial in clinical settings to enhance patient experiences and improve clinical outcomes [14]. Avatars have been linked to increased self-confidence, improved engagement, and reduced social anxiety during video interactions, transforming patient-provider dynamics [1]. Affective conversational agents are increasingly recognized as essential in applications involving human interaction and emotional support, reinforcing the relevance of these technologies in healthcare [5].

Incorporating emotional support and anxiety management strategies into healthcare systems is necessary for holistic chronic illness management. By prioritizing the emotional dimensions of patient care, providers can foster a supportive environment that addresses diverse emotional needs. Current healthcare technologies, particularly RPM, often overlook these aspects, leading to feelings of neglect among patients. Implementing strategies that empower and care for patients can enhance engagement and overall well-being. Advancements in AI and training tools, such as emotional support conversation systems and synthetic patient simulations, further equip healthcare professionals to foster empathetic interactions, ultimately improving care quality [12, 15, 16, 17, 9].

1.3 Structure of the Survey

This survey is systematically organized to provide a comprehensive examination of emotional interventions utilizing avatars in virtual healthcare, specifically for patients with chronic kidney disease. It begins with an introduction outlining the concept and significance of these interventions, leading to a detailed exploration of the topic. A background section defines key terms and concepts, offering clarity for subsequent discussions.

The core of the survey is divided into several sections, each addressing critical aspects of the topic. A review of emotional interventions in healthcare focuses on strategies for managing anxiety and providing emotional support in chronic illness management. This is complemented by a section on the role of avatars in virtual healthcare, examining their capabilities in delivering personalized emotional support and the importance of avatar realism and emotional expression.

Further, the survey discusses anxiety management specific to chronic kidney disease patients, exploring the unique challenges they face and the potential of virtual healthcare interventions. The technological considerations section highlights foundational technologies and innovations in avatar interaction, as well as challenges in implementing these systems.

The survey includes various case studies and applications showcasing successful avatar-based emotional interventions, notably the innovative use of synthetic patients in medical training to enhance learning experiences through real-life scenario simulations. Insights from the ANA Avatar XPRIZE semifinals illustrate avatars' potential in advancing emotional engagement and interaction across diverse environments, contributing to the evolving field of virtual co-presence [10, 18]. The paper concludes with a discussion on future directions and research opportunities, identifying gaps in current research and proposing innovative approaches for future studies.

This structured approach facilitates an in-depth examination of digital healthcare solutions, particularly concerning RPM and generative AI applications. By addressing often-overlooked emotional needs of diverse patient groups and establishing comprehensive evaluation metrics for conversational models, the research offers critical insights into promoting health equity and enhancing patient engagement. These findings guide future research directions and inform practical applications aimed at improving patient care and outcomes in a rapidly evolving digital healthcare landscape [12, 19].The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Emotional Intervention and Chronic Illness Management

Emotional intervention is pivotal in chronic illness management, involving the real-time recognition and mapping of emotions within virtual environments to enhance patient engagement and motivation [20, 5]. Affective computing and machine learning algorithms significantly improve communication and patient outcomes, highlighting the need for personalized emotional support [14]. In virtual healthcare, avatars and virtual mental health assistants facilitate emotional interventions by engaging patients' psychophysiological states, enhancing personalization through simulations of body own-

ership [21]. Gamification strategies further boost user engagement and motivation, crucial for the success of these interventions [22]. Immersive virtual environments, such as virtual nature settings, enhance emotional recovery during work breaks, offering therapeutic benefits in environments devoid of natural elements [23]. However, challenges persist in ensuring dialogue models effectively utilize persona information for personalized support, as current systems often struggle with mixed-initiative interactions [2].

Emotional interventions provide a comprehensive framework for integrating emotional support into healthcare systems, addressing diverse patient needs. Recent studies emphasize incorporating emotional support strategies into healthcare technologies, such as remote patient monitoring, to alleviate emotional tensions, including feelings of being heard versus exploited and empowered versus anxious. By leveraging structured emotional support frameworks and understanding emotional dynamics, healthcare systems can enhance patient care and promote health equity [12, 16]. Implementing digital technologies and innovative strategies can significantly improve patients' emotional and psychological well-being, ultimately enhancing clinical outcomes and quality of life.

2.2 Chronic Kidney Disease

Chronic Kidney Disease (CKD) is a progressive condition characterized by gradual kidney function loss, potentially leading to end-stage renal disease if untreated. The kidneys are vital for filtering waste, regulating blood pressure, and maintaining homeostasis. Dysfunction can result in fluid imbalances, hypertension, and toxic substance accumulation, adversely affecting overall health [12, 11, 9, 24]. CKD patients often experience complications such as hypertension, anemia, bone disease, and increased cardiovascular risk, diminishing their quality of life. Managing CKD requires a comprehensive approach, including medical, dietary, and lifestyle interventions to slow disease progression and alleviate symptoms. The integration of advanced technologies, particularly machine learning models, into clinical practice presents challenges related to data privacy, the need for extensive datasets, and model interpretability [14]. Addressing these challenges is vital to fully leverage technological innovations for improved patient outcomes.

The emotional and psychological impact of CKD is significant, with patients frequently facing anxiety and depression, necessitating effective emotional support mechanisms. Virtual healthcare interventions, especially those utilizing customizable avatar-based systems, offer promising strategies for delivering personalized emotional support to CKD patients. Research indicates that user identification with virtual avatars—shaped by visual similarity and design—enhances emotional engagement and motivation during therapeutic interactions. Studies show that users creating avatars resembling themselves experience heightened emotional responses and enriched therapeutic experiences. Additionally, avatar characteristics such as facial expressions and body posture can subtly influence users' affective states, optimizing the therapeutic benefits of virtual environments. This tailored avatar design approach can improve emotional well-being and support for CKD patients, enhancing engagement and adherence to treatment regimens, ultimately leading to better health outcomes [10, 8].

2.3 Avatars and Virtual Healthcare

Avatars are integral to virtual healthcare, serving as digital proxies that facilitate interactions between patients and healthcare providers. These virtual entities simulate human-like interactions, essential for providing emotional support and enhancing patient engagement. Bioresponsive avatars, as seen in the Empathic Metaverse, reflect users' emotional and cognitive states, enriching emotional dynamics in virtual healthcare settings [25]. A critical feature of avatars is their ability to convey emotional authenticity. The EVOKE method exemplifies this by enabling real-time emotion recognition and mapping to 3D avatars, enhancing emotional communication [20]. Such capabilities are vital for avatars to effectively fulfill their roles in healthcare, where empathy and accurate emotional representation are paramount.

Customization and identification of virtual agents are vital in therapeutic contexts, allowing avatars to meet individual patients' specific needs and enhancing therapeutic outcomes [8]. Additionally, avatars in virtual healthcare are designed to support real-time audio-visual interactions, as demonstrated by systems like AVIN-Chat, which utilize 3D avatars to express emotions and respond to user input, enhancing the personalization and interactivity of healthcare services [26]. The implementation

of avatars extends to telepresence robots and augmented reality (AR) and virtual reality (VR) avatars, particularly for individuals with disabilities in social settings, facilitating inclusive healthcare environments through accessible interaction platforms [27]. Ongoing research into avatar creation emphasizes the importance of activity context, influencing self-representation strategies and avatar idealization [28].

Moreover, avatar manipulations, such as facial expressions, posture, and movement speed, are categorized to understand their impact on user experience and emotional engagement [10]. Evaluating user experiences in Social VR systems, particularly regarding emotional connection and communication, is critical for assessing avatar effectiveness in healthcare settings [29]. Surveys on social virtual reality applications, such as Facebook Spaces, VR Chat, and AltspaceVR, illuminate avatar dynamics in immersive social environments, pivotal for enhancing patient interaction in virtual healthcare [7].

Avatars are integral to delivering virtual healthcare, providing personalized, emotionally authentic, and accessible interactions. These advanced digital entities significantly improve patient engagement through tailored interactions and support, enhancing healthcare interventions by offering personalized health advice, facilitating early disease detection, and addressing the emotional needs of diverse patient populations, thereby fostering the development of sophisticated and inclusive virtual healthcare solutions [19, 15, 9, 12].

3 Emotional Interventions in Healthcare

The integration of emotional interventions in healthcare is increasingly recognized for its importance in addressing patients' emotional and psychological well-being. This section explores the foundational principles and applications of emotional interventions, crucial for understanding dialogue systems' effectiveness and the challenges in current emotional support mechanisms. As illustrated in Figure 2, the hierarchical structure of emotional interventions in healthcare categorizes key aspects into technological integration, the effectiveness of dialogue systems, and the challenges faced by existing emotional support systems. This figure highlights the integration of advanced technologies, the role of frameworks and strategies, and the challenges of realism and engagement, as well as contextual and cognitive challenges in emotional support systems. By examining these dimensions, we can better appreciate the complexities involved in implementing effective emotional interventions in healthcare settings.

3.1 Overview of Emotional Interventions

Emotional interventions target the psychological and emotional needs of patients, especially those with chronic illnesses. These interventions have evolved to incorporate advanced technologies like avatars and AI-driven systems, providing personalized and contextually relevant support. Avatars in virtual healthcare settings can enhance self-esteem and collaboration satisfaction during video-mediated interactions [1]. Manipulating avatars' visual similarity to users can foster self-awareness and understanding of emotional states [3].

Large Language Models (LLMs) in emotional support systems address traditional models' limitations, delivering diverse, contextually appropriate responses [30]. These systems are vital for timely emotional support in online health communities, particularly post-Covid-19 [2]. Immersive virtual environments blending physical and digital experiences significantly enhance audience engagement, showcasing potential in emotional interventions [31]. Techniques preserving interaction context and user intent offer advantages over simpler models, ensuring effective emotional communication [4].

Affective conversational agents are central to organizing emotional intervention strategies, providing a framework for understanding and improving healthcare interventions [5]. The process of avatar creation and identity exploration through avatar representation yields insights into users' roles in emotional interventions [7]. Employing EEG captures nuanced emotional responses, enhancing empathy understanding, crucial for effective emotional support [6].

Technological advancements underpin emotional interventions, enhancing patient engagement and emotional well-being. These strategies improve the healthcare experience through frameworks like the Emotional Support Conversation (ESC) task and the Muffin model, which focus on empathetic responses and mitigating unhelpful interactions. Techniques such as persona extraction ensure

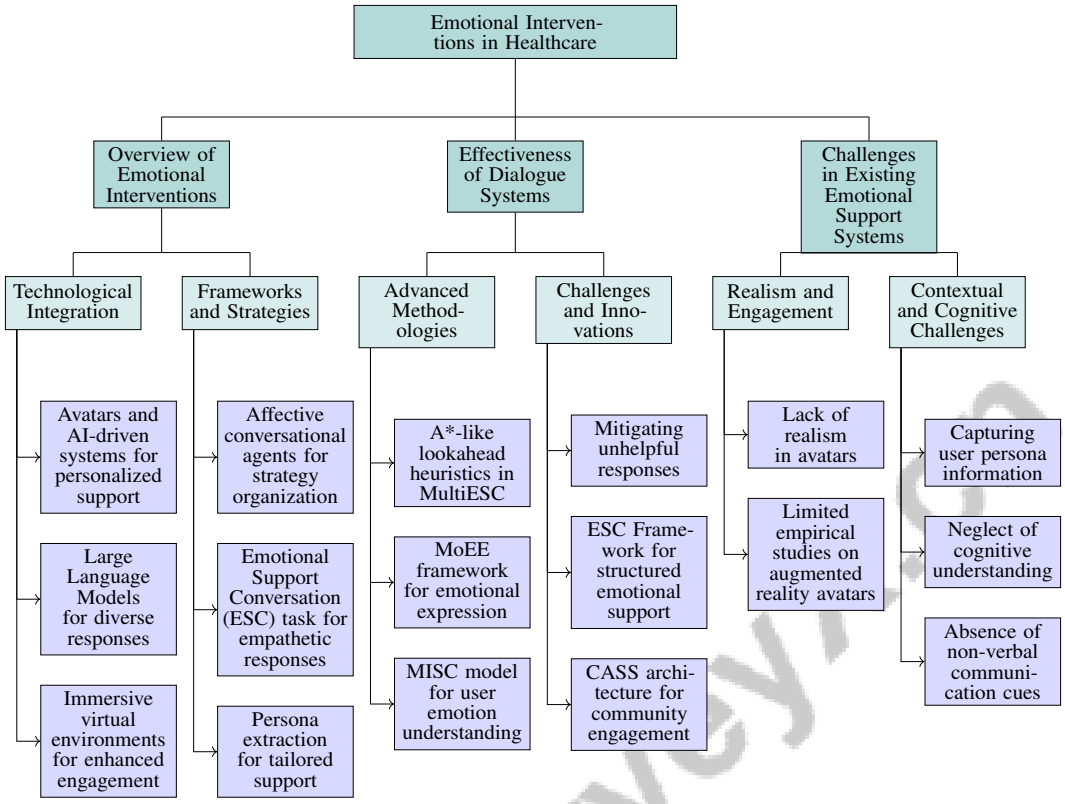

Figure 2: This figure illustrates the hierarchical structure of emotional interventions in healthcare, categorizing key aspects into technological integration, effectiveness of dialogue systems, and challenges in existing emotional support systems. It highlights the integration of advanced technologies, the role of frameworks and strategies, and the challenges of realism and engagement, as well as contextual and cognitive challenges in emotional support systems.

tailored support relevant to the user's emotional state, contributing to a more personalized healthcare experience [32, 16, 33].

3.2 Effectiveness of Dialogue Systems

Benchmark	Size	Domain	Task Format	Metric
MoEE[34]	150,000	Emotion Recognition	Emotion Control	FID, LPIPS
ESC[16]	31,410	Mental Health	Conversation	PPL, BLEU-2
SAAVR[35]	5,200	Animation	Pose Estimation	MPJPE, MPJRE
FMEHCC[19]	100,000	Healthcare	User Interaction Simulation	Accuracy, Trustworthiness
PosEmoDial[36]	3,000,000	Emotional Dialogs	Multi-turn Dialog Generation	PEG-Score, E-Score
iPPG-Syn[37]	450	Physiological Measurement	Vital Sign Measurement	MAE, RMSE
SocialVR[29]	30	Social Interaction	Shared Media Consumption	Quality of Interaction, Social Meaning
P.910[38]	237	Telecommunication	Quality Assessment	Emotion accuracy, Trust

Table 1: This table presents a comprehensive overview of representative benchmarks utilized in dialogue systems, highlighting their size, domain, task format, and evaluation metrics. The benchmarks span various applications, including emotion recognition, mental health, and virtual reality, providing a foundation for assessing the effectiveness of dialogue systems in emotional interventions.

Dialogue systems' effectiveness in emotional interventions is crucial for enhancing patient engagement and providing personalized support in virtual healthcare environments. These systems utilize advanced AI and machine learning technologies to simulate empathetic interactions, addressing patients' emotional needs with chronic illnesses. For example, A*-like lookahead heuristics in MultiESC improve emotional support quality by anticipating long-term outcomes [39].

The MoEE framework outperforms baseline models in generating emotional expressions and realism, emphasizing specialized emotion experts' role in enhancing dialogue systems [34]. The MISC model, employing a mixed strategy approach and commonsense knowledge, provides a nuanced understanding of user emotions [40].

Challenges persist in ensuring dialogue systems generate helpful responses. Unhelpful responses can exacerbate users' emotional states, necessitating robust mechanisms to mitigate such outcomes [33]. The ESC Framework categorizes emotional support into distinct stages, enhancing intervention delivery [16].

Retrieving and integrating contextual demonstrations are vital for generating empathetic responses, as identified in existing ESC systems' limitations [17]. Innovations like the strategy-enhanced role-playing framework in SweetieChat simulate real-world emotional support conversations, enriching interaction dynamics [30].

The CASS architecture exemplifies neural network-based chatbots' use to respond to emotional support-seeking posts, facilitating community engagement and timely support [41]. The KEMI model enhances mixed-initiative interactions by leveraging external knowledge, improving response generation and overall effectiveness [2].

To provide a visual representation of these concepts, Figure 3 illustrates the hierarchical classification of dialogue systems' effectiveness in emotional interventions, challenges, and innovative approaches. This figure categorizes key methodologies and frameworks that enhance emotional support, address challenges, and introduce innovative solutions in dialogue systems. Additionally, Table 1 provides a detailed overview of the benchmarks used to evaluate dialogue systems, offering insights into their application domains, task formats, and evaluation metrics.

Dialogue systems' effectiveness in emotional interventions is significantly enhanced by methodologies like the ESC Framework, utilizing a structured dataset (ESConv) and emphasizing support strategies, alongside advanced technologies promoting proactive engagement in conversations, ultimately improving meaningful emotional support provision [2, 16].

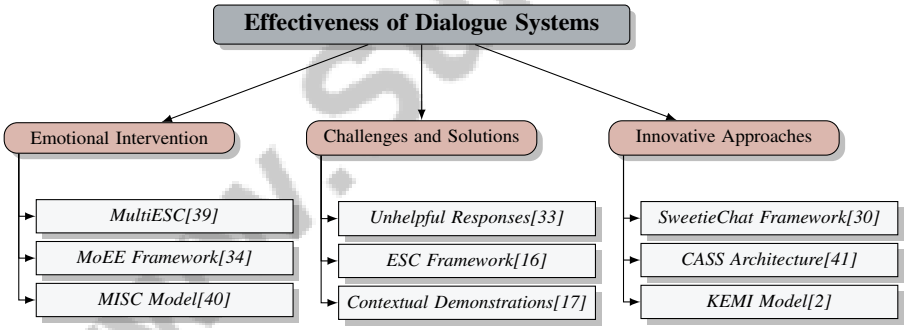

Figure 3: This figure illustrates the hierarchical classification of dialogue systems' effectiveness in emotional interventions, challenges, and innovative approaches. It categorizes key methodologies and frameworks that enhance emotional support, address challenges, and introduce innovative solutions in dialogue systems.

3.3 Challenges in Existing Emotional Support Systems

Current emotional support systems face challenges that hinder their effectiveness in delivering comprehensive emotional care. A primary issue is avatars' lack of realism, stemming from the absence of subtle physiological animations, creating a perception of artificiality and reducing user engagement [24]. This perception is further exacerbated by existing methods' inability to alleviate 'Zoom anxiety' and limited empirical studies on augmented reality avatars in collaborative settings [1].

Another significant challenge is capturing user persona information in dialogues. User utterances often contain noise, and persona expressions may span multiple utterances, complicating consistent vital persona information capture [32]. Traditional generative models' limitations in producing

contextually appropriate responses, particularly in open-ended dialogues, highlight the neglect of cognitive understanding in the emotional dialogue process [17].

Emotional dimensions of patient experiences are frequently overlooked in current studies, focusing more on cognitive and technical aspects [12]. This oversight is evident in ESC systems, where balancing empathy and elicitation while maintaining coherence in dialogue presents significant challenges [42]. Additionally, the absence of non-verbal communication cues in existing systems limits emotional nuances transmission, often necessitating specialized expertise for virtual environment management [13].

The black box nature of AI models introduces further challenges, leading to unsafe and incoherent responses, as well as a lack of user-level explainability and trust in these systems [43]. Existing benchmarks fail to capture emotional support conversations' complexity, lacking diverse support skills and multi-turn interaction capabilities [16]. Moreover, these models' integration into healthcare workflows is hampered by the absence of standardized model validation protocols [14].

To enhance emotional support systems' performance, it is crucial to address challenges of generating contextually relevant and empathetic responses, mitigating unhelpful interactions, and accurately inferring user personas, significantly influencing emotional support conversations' quality [32, 33, 21, 16, 17]. By improving avatar realism, capturing comprehensive user personas, and ensuring contextual appropriateness and safety in AI responses, emotional support systems can better meet patients' complex emotional needs.

4 Role of Avatars in Virtual Healthcare

4.1 Role of Avatars and AI in Emotional Support

Avatars and AI technologies are pivotal in providing personalized emotional support within virtual healthcare settings, leveraging advanced computational techniques to simulate empathetic human interactions. Systems like KEMI enhance responsiveness by integrating real-world knowledge, surpassing traditional empathetic response models [2]. The Real-Time VR Facial Animation Pipeline (RT-VR-FAP) exemplifies innovations that enhance avatar expressiveness by adapting to operators' facial expressions, facilitating immersive interactions [44]. Moreover, neural network-based approaches optimize avatar placement for contextual relevance in interactions [4].

In social VR, avatars enhance engagement and personalization, enabling profound social interactions and identity exploration, crucial for supportive experiences [7]. Frameworks that assess empathy as a personality trait and affective state emphasize the importance of real-time data in evaluating emotional engagement [6]. Real-time motion capture technology further enriches feedback, creating dynamic therapeutic environments [31].

AI-driven conversational agents, through personalized avatars, enhance patient engagement and emotional well-being, significantly influenced by avatar design and customization [10, 45]. Immersive environments and diverse avatar appearances improve user engagement and understanding, contributing to better mental health outcomes [8, 11, 9]. By harnessing these methodologies, healthcare providers can deliver more effective, empathetic care, enhancing patient outcomes.

4.2 Avatar Realism and Emotional Expression

Realism and emotional expression in avatars are crucial for enhancing user engagement and effective emotional support in virtual healthcare. Realistic avatars facilitate co-presence and self-identification, vital for immersive environments, yet many implementations still use generic avatars lacking necessary nuances [46]. The ExAvatar model and AvatarReX method are examples of advancements in avatar realism, combining parametric mesh models and structured radiance fields to enhance expressiveness and rendering efficiency [47, 48]. The RT-VR-FAP method further improves real-time facial expression mapping [44].

Techniques like MIA and MCA refine emotional expressiveness by extracting identity-invariant features and enabling accurate expression transfer [49, 50]. Recent advancements in photorealistic avatars are essential for authentic, emotionally resonant interactions, as indicated by metrics such as PSNR, SSIM, and FID [38].

Enhancing realism and emotional expression in avatars is pivotal for authentic interactions. Technologies like READ Avatars and InstructAvatar improve emotional accuracy and expression control, respectively. The quality of photorealistic avatars significantly affects user trust and comfort, underscoring these attributes' importance in designing effective communication systems [38, 51, 52]. By utilizing advanced technologies, avatars can significantly boost patient engagement and emotional well-being, enhancing virtual healthcare solutions' efficacy.

4.3 Avatar-based Emotional Support Systems

Avatar-based emotional support systems are integral to delivering personalized care in virtual healthcare settings. These systems employ advanced technologies to create avatars that emulate human interactions, facilitating emotional expression and connection. The EMOCA method, for instance, reconstructs 3D face shapes from single images, allowing avatars to express nuanced emotional states, fostering empathetic interactions [53].

Advanced animation techniques like AvatarCLIP demonstrate avatars' potential by creating high-quality 3D avatars and animations from natural language descriptions, showcasing strong zero-shot generation capabilities for diverse emotional scenarios [54]. Synthetic avatars also enhance healthcare interventions by developing comprehensive datasets for model training, such as for pain recognition.

In virtual care, avatar-based methods enhance presence and interaction, leading to more immersive emotional support systems [18]. The DH-FaceEmoVid-150 dataset, with extensive video content of various emotions, aids in training systems to recognize and respond to emotional cues [34]. The development of expressive avatars, such as ExAvatar, which combines surface meshes with 3D Gaussian representations, improves emotional expressiveness and realism [47].

AI-generated avatars simulating patient interactions offer practical tools for medical education, demonstrating avatar-based systems' versatility in delivering emotional support and training [15]. Cutler et al.'s benchmark enhances previous assessments by providing a comprehensive subjective testing framework encompassing multiple dimensions of avatar quality [38].

Avatar-based emotional support systems represent a significant advancement in virtual healthcare, offering personalized, realistic, and interactive platforms for emotional support. By integrating technologies such as remote patient monitoring, generative AI, and multimodal simulations, healthcare providers can enhance patient engagement and emotional well-being. These innovations address diverse emotional and cognitive needs, facilitating personalized interactions through AI-driven chatbots and realistic training simulations, ultimately improving care quality and effectiveness while reducing burdens on healthcare professionals [12, 15, 19, 9].

5 Anxiety Management for Chronic Kidney Disease Patients

5.1 Challenges in Anxiety Management

Managing anxiety in chronic kidney disease (CKD) patients presents specific challenges that extend beyond conventional healthcare practices. A critical obstacle is the integration of affective computing into AI agents, essential for personalized emotional support yet technically demanding [5]. Delays in responding to emotional support requests increase patient stress, highlighting the need for timely assistance [41]. Current social VR platforms limit avatar customization, hindering the provision of diverse options necessary for effective emotional support [7]. This limitation is particularly relevant for CKD patients, whose preferences may not align with generic avatars.

AI systems often fail to address CKD patients' complex emotional needs, struggling to tailor responses contextually. This shortcoming underscores the necessity for advanced dialogue systems that deliver empathetic responses with interpretability and contextual awareness, as seen in frameworks like ESCoT and models such as Muffin [32, 33, 2, 16, 55]. The lack of adaptability limits trust-building and effective support, crucial for successful anxiety management. Moreover, the absence of diverse conversational strategies in emotional support dialogues restricts the ability to cater to patients' unique needs.

To overcome these challenges, developing empathetic systems that incorporate advanced technologies and a deep understanding of CKD patients' emotional and psychological needs is essential. Implementing frameworks like the Emotional Support Conversation (ESC) task can enhance contextually

relevant and empathetic response generation. Techniques such as Dynamic Demonstration Retrieval and Cognitive-Aspect Situation Understanding (D2RCU) can significantly improve interaction quality, providing more effective emotional support for patients [16, 17]. Addressing these obstacles can improve anxiety management and enhance the overall well-being of individuals with chronic kidney disease.

5.2 Role of Virtual Healthcare Interventions

Virtual healthcare interventions play a vital role in addressing anxiety challenges faced by CKD patients, offering personalized, empathetic, and contextually relevant support. These interventions leverage advanced technologies, such as avatars and AI-driven dialogue systems, to create immersive environments that enhance emotional engagement and reduce anxiety. Dialogue systems capable of generating empathetic responses without requiring upfront user persona disclosures are particularly beneficial in sensitive emotional support contexts [32], allowing patients to receive necessary support without feeling vulnerable and enhancing their comfort with virtual healthcare systems.

The integration of AI and affective computing into virtual healthcare platforms enables real-time emotion recognition and response generation, crucial for effective anxiety management. By adapting to patients' emotional states, these systems provide timely interventions that alleviate stress and promote emotional well-being. Avatars in virtual healthcare environments enhance patient engagement by acting as relatable digital proxies that emulate human-like interactions. Advances in AI and computer graphics improve avatar interaction quality, fostering a greater sense of presence and connection. Incorporating personalized traits into avatars enhances their relatability, making interactions feel more human-like and supportive, which is essential for effective communication and emotional connection in healthcare settings [56, 7, 18, 8, 9].

Virtual healthcare interventions also allow for support customization to meet CKD patients' specific needs and preferences. This customization is crucial for addressing the diverse emotional and psychological challenges faced by these patients, as generic solutions often overlook their unique emotional needs. Tailoring interventions to these requirements is essential for fostering health equity and enhancing patient engagement in their treatment journey [12, 9, 23]. By delivering personalized and empathetic support, virtual healthcare interventions can significantly improve anxiety management, thereby enhancing the overall quality of life for individuals with chronic kidney disease.

6 Technological Considerations and Implementation

6.1 Technological Foundations

Avatar-based interventions in virtual healthcare are underpinned by technologies that create realistic, expressive, and interactive digital entities. The Synthetic Data Generation Pipeline (SDGP) is crucial, synthesizing realistic facial expressions of pain by capturing 3D facial movements and mapping them onto diverse avatars, enhancing medical training through interactive scenarios [15]. The CASS system automates retrieval, classification, response generation, and publication of posts, ensuring timely emotional support [41]. Innovations like low-cost motion-capture technology enable real-time interaction, improving the immediacy of support [31]. The KEMI system integrates relevant knowledge into conversations, allowing avatars to offer more informative support [2]. User-preferred placement data optimizes avatar positioning, enhancing interaction quality [4]. The development of affective AI agents capable of simulating emotions is critical for creating engaging avatars [5]. Cutler et al. provide a benchmark for evaluating photorealistic avatar performance across ten dimensions, facilitating effective evaluation in telecommunication scenarios [38]. Collectively, these advancements ensure avatar-based interventions deliver realistic, expressive, and personalized support, enhancing virtual healthcare solutions. Research indicates that animated avatars, particularly those with user-defined characteristics, significantly boost motivation and emotional engagement. Avatars with human-like features and positive expressions can influence emotions and foster a sense of ownership, enhancing the therapeutic experience. The integration of multiple output modalities, such as audio and text, alongside animations, creates a more immersive environment, enriching psychological support in virtual settings [10, 11, 8].

6.2 Technological Innovations in Avatar Interaction

Recent advancements in avatar interaction technology have enhanced virtual healthcare systems' ability to provide personalized emotional support. Fine-tuning models on the ESConv dataset has improved emotional support delivery compared to baseline models, highlighting the value of specialized datasets [16]. Sophisticated dialogue systems now utilize affective computing and natural language processing for empathetic conversations, crucial in mental health contexts. Frameworks like PESS and PAL demonstrate the effectiveness of inferred persona information in generating supportive interactions, improving communication outcomes [32, 56, 21]. These systems adapt to users' emotional states in real time, fostering engaging interactions. Advanced animation techniques, including real-time facial expression mapping and motion capture, enhance avatars' realism and expressiveness. Research shows that avatars' expressions and postures can influence users' emotional states. InstructAvatar enhances control over emotional expression and motion through natural language interfaces, resulting in more lifelike interactions [10, 52]. Ongoing innovations in avatar interaction technologies are crucial for enhancing virtual healthcare systems, leveraging AI and computer graphics to improve patient interactions, diagnostics, and health advice delivery [7, 18, 9].

6.3 Challenges in Avatar Implementation

Method Name	Technical Limitations	Realism and Accuracy	Evaluation Criteria
EVOKE[20]	Computational Requirements	-	Subjective Quality
ARX[48]	Real-time Rendering	Visual Artifacts	Subjective Quality
EA[47]	Computational Demand	Dynamic Clothing	Subjective Quality
MIA[49]	Pre-trained Texture Decoders	Photo-realistic Avatars	Average Euclidean Errors
RT-VR-FAP[44]	High-quality Source	Dynamic Clothing, Photorealistic	Subjective Quality, Differences
MCA[50]	Real-time Rendering	Dynamic Clothing	Subjective Quality
D2RCU[17]	Computational Demand	Dynamic Clothing	Subjective Quality
IVPS[31]	Computational Demand	Dynamic Clothing	Audience Feedback
PRVA[4]	Computational Demand	Dynamic Clothing	Inadequate Benchmarks

Table 2: This table summarizes the technical limitations, realism and accuracy challenges, and evaluation criteria of various methods employed in the implementation of avatar systems in virtual healthcare. It highlights the computational demands, rendering issues, and subjective quality assessments that impact the effectiveness and scalability of these methods.

Implementing avatar systems in virtual healthcare presents challenges that may hinder their effectiveness. Table 2 provides a comprehensive overview of the challenges and evaluation criteria associated with different methods used in avatar system implementation within virtual healthcare settings. The computational demand of existing models limits scalability and accessibility, although the EVOKE method has reduced model parameters without sacrificing performance [20]. Dense-view camera setups for rendering dynamic avatars at real-time framerates pose usability limitations [48]. Modeling unobserved body parts and handling dynamic clothing affect avatar realism [47]. Pre-trained texture decoders, not universally available, constrain photorealistic animations [49]. The RT-VR-FAP method relies on high-quality source images, leading to inaccuracies if expressions are poorly captured [44]. The complexity and cost of generating visually similar avatars pose additional hurdles. Limited training samples for person-specific agents result in rigid expression transfers [50]. Noise in the retrieval process using excessive demonstration pairs can dilute response effectiveness, as seen in the D2RCU method [17]. Synchronization and interaction accuracy between mocaptors and physical actors add complexity, as highlighted in interconnected virtual space theater [31]. Current retargeting methods may struggle to capture complex intentions or contextual nuances [4]. Existing benchmarks often focus on objective metrics that inadequately capture subjective experience quality, creating a gap in evaluating avatar performance [38]. The lack of consideration for individual differences in empathy complicates the generalizability of studies [6]. Addressing these challenges is essential for enhancing avatar system implementation and effectiveness in virtual healthcare, ensuring personalized and effective emotional support.

7 Case Studies and Applications

7.1 Synthetic Patients for Medical Training

The utilization of synthetic patients in avatar-based medical training represents a significant advancement in healthcare education, offering innovative methods for enhancing clinical skills and learner

engagement. High-fidelity avatars with realistic lip-syncing and expressive capabilities are essential for authentic patient interactions, as evidenced by recent studies [57]. These avatars enable the creation of virtual agents that mimic human behaviors and emotions, providing invaluable tools for researchers and developers.

Synthetic patients simulate diverse clinical scenarios, allowing medical trainees to hone diagnostic and communication skills within a controlled setting. This approach enhances the realism of training exercises and broadens clinical competencies through varied patient interactions. AI-driven dialogue systems and affective computing improve synthetic patients' ability to deliver contextually relevant and empathetic responses, crucial for effective medical training. This enables trainees to engage in realistic simulations of sensitive conversations with diverse patient avatars, building confidence in addressing difficult topics, such as end-of-life discussions, and deepening their understanding of emotional support dynamics, ultimately enhancing patient-centered communication skills [15, 2, 9, 55].

Furthermore, synthetic patients overcome the limitations of traditional medical training by providing scalable and repeatable training opportunities, free from constraints related to physical resources or patient availability. This scalability is particularly beneficial in medical education, where access to diverse patient populations may be limited. By leveraging advanced multimodal generative AI, educational institutions can offer standardized, immersive training experiences that prepare medical professionals to handle complex clinical scenarios, especially in sensitive areas like patient-centered communication and end-of-life discussions. This approach not only improves training realism but also fosters greater confidence and competence among trainees in real-world healthcare settings [58, 15, 9].

The integration of synthetic patients in avatar-based medical training signifies a transformative advancement in healthcare education. Utilizing multimodal generative AI to create interactive simulations of challenging patient-provider conversations addresses the critical need for effective communication skills among medical professionals. Training programs benefit from high-fidelity simulations that allow trainees to engage with diverse patient avatars, enhancing their ability to navigate sensitive topics and improve patient-centered care. This innovative method not only elevates training quality and effectiveness but also significantly contributes to better patient care outcomes through improved communication skills and increased confidence among healthcare providers. Future developments aim to further enrich these interactions by incorporating real patient histories and AI-generated feedback, ensuring ongoing improvement in training efficacy [15, 8, 9, 59].

7.2 ANA Avatar XPRIZE Semifinals

The ANA Avatar XPRIZE semifinals provided a platform for evaluating the effectiveness of avatar-based emotional interventions in practical scenarios. Rochow et al.'s method was rigorously tested, demonstrating its ability to facilitate seamless interactions between operators and human recipients through an advanced avatar system, achieving a remarkable score of 99 out of 100 points. This underscores its potential for delivering emotionally resonant and contextually appropriate responses in virtual healthcare environments [44].

This success highlights significant advancements in avatar realism and emotional expressiveness, critical for enhancing user engagement and interaction quality. The attention-based virtual reality facial animation technique employed in this method was pivotal to the team's success at the ANA Avatar XPRIZE Finals, further validating its application in avatar-based emotional interventions [60]. These achievements illustrate the transformative potential of avatar technologies in virtual healthcare, offering personalized and effective emotional support and paving the way for future innovations in digital healthcare solutions.

8 Future Directions and Research Opportunities

8.1 Innovative Approaches and Future Directions

The advancement of avatar-based emotional interventions in virtual healthcare presents numerous research opportunities. A primary focus is on developing dynamic avatars with increased sample sizes to enhance self-awareness and patient engagement, while exploring additional dimensions of avatar similarity [3]. Improving dataset construction and aligning user preferences with chatbot interactions,

particularly through speech integration, can augment the naturalness and efficacy of these exchanges [30].

Incorporating real patient data into synthetic patient simulations and creating automated feedback mechanisms for learners can significantly enhance the realism and educational value of these tools [15]. Expanding systems like CASS to address informational support-seeking queries and proposing innovative emotional intervention strategies are crucial for advancing virtual healthcare solutions [41].

Research should prioritize diverse participant demographics and integrate multiple representation modalities to assess the impact of avatar design on user experiences, thereby improving inclusivity and intervention effectiveness [1]. Enhancing knowledge retrieval methods and developing robust evaluation metrics for mixed-initiative interactions can improve dialogue systems' responsiveness and adaptability [2].

Further exploration is needed in expanding training datasets, utilizing higher-level features for better context understanding, and improving avatar animation to accurately reflect user movements [4]. Investigating automated recognition of user preferences and the influence of cultural differences on affective AI agents are additional research areas [5].

Enhancing benchmarks to encompass more diverse avatars, additional quality dimensions, and real-time interaction assessments will be vital for evaluating and improving avatar-based systems [38]. Customizing avatars and exploring their impact on social interactions and identity management in social VR environments can provide valuable insights into the social dynamics of virtual healthcare [7].

Integrating EEG with interactive technologies to enhance empathy measurement offers a novel approach to understanding emotional engagement in virtual environments [6]. Addressing these areas can significantly improve the quality and impact of digital healthcare solutions, offering more personalized, realistic, and effective support in virtual healthcare settings.

8.2 Future Directions in Avatar Research

The future of avatar research in virtual healthcare offers abundant opportunities for enhancing patient care and emotional support. One promising avenue involves exploring sophisticated avatar customization options that allow patients to create avatars resembling themselves or embodying aspirational identities, fostering ownership and emotional connection [7].

Advancements in real-time emotion recognition and expression mapping are crucial for future research. By integrating precise affective computing technologies, avatars can better interpret and respond to users' emotional states, delivering timely and contextually relevant support, which is essential for providing personalized care, particularly for patients with chronic illnesses [5].

Developing avatars for augmented reality (AR) and virtual reality (VR) environments opens new possibilities for immersive healthcare experiences. These environments can simulate real-world interactions, offering patients a safe space to practice social skills and manage anxiety, necessitating investigation into their impact on emotional well-being and treatment adherence [1].

Integrating artificial intelligence (AI) with avatars to enhance dialogue systems is another promising area. Advanced machine learning algorithms can enable avatars to engage in nuanced and empathetic conversations, improving interaction quality and emotional support, crucial for addressing complex emotional needs [2].

Future research should also address the ethical implications of avatar use in healthcare, focusing on privacy, data security, and potential bias in AI-driven systems. Establishing robust ethical frameworks and guidelines will be crucial for ensuring responsible development and deployment of avatar technologies, safeguarding patient trust and promoting equitable access [14].

Exploring these research avenues can significantly advance avatar technology, leading to more effective, personalized, and ethically sound solutions for emotional interventions in virtual healthcare. Studies indicate that user identification with virtual avatars—enhanced through customization and thoughtful design—can significantly influence user behavior and emotional responses during therapeutic interactions. Research shows that when users create avatars resembling themselves, it fosters a stronger sense of connection, enhancing motivation and emotional engagement in therapeutic

activities. Furthermore, integrating diverse virtual character designs, from cartoonish to human-like avatars, can amplify user motivation and comprehension in well-being practices, ultimately enriching the overall experience in virtual healthcare environments [11, 8].

9 Conclusion

Exploring emotional interventions through avatars in virtual healthcare for chronic kidney disease (CKD) patients highlights the transformative role of digital avatars in chronic illness management. By integrating avatars with AI, the survey demonstrates the potential for personalized and empathetic emotional support, addressing the psychological needs of CKD patients effectively. This approach leverages advanced dialogue systems and affective computing to enable avatars to provide human-like interactions, offering timely and contextually appropriate support, which is crucial for managing anxiety and enhancing patient engagement, thus contributing to improved health outcomes.

The survey also underscores the importance of avatar realism and emotional expression in fostering immersive and supportive healthcare environments. Technological advancements, such as real-time emotion recognition and expression mapping, enhance the authenticity of avatar interactions, resulting in a more personalized healthcare experience. Additionally, avatar-based emotional support systems show promise in providing scalable and repeatable training opportunities, exemplified by the use of synthetic patients in medical training.

While significant progress has been made, challenges remain in deploying avatar systems, including computational demands, modeling accuracy, and the need for robust ethical frameworks to protect privacy and data security. Overcoming these challenges is essential to fully realize the potential of avatar technologies in virtual healthcare.

This survey highlights the profound impact of avatar-based emotional interventions on chronic illness management, offering a comprehensive framework for integrating emotional support into healthcare systems. By leveraging these technologies, healthcare providers can enhance patient engagement, improve clinical outcomes, and deliver more holistic and effective care for individuals with chronic illnesses.

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