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Future Challenges and Perspectives of Digital Dance Interventions for Depression in Older Adults

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Abstract

Depression is a common disorder among the elderly, significantly affecting their quality of life. Traditional dance interventions, although beneficial, have limitations in convenience, personalization, and retention. With the advent of digital technology, digital dance interventions have emerged as a potential solution to these limitations. This paper involves an extensive review of literature on digital dance interventions. Research databases were searched for studies that focus on the use of digital dance in treating depression among older adults. The review also includes analyses of the advancements in digital dance technology, its application in therapeutic settings, and the evaluation of its efficacy. The paper identifies three main challenges in the current digital dance intervention research: real-time dynamic assessment, multimodal dance generation, and improving compliance. Despite these challenges, digital dance interventions show promise in addressing the limitations of traditional dance therapy. The research suggests that the integration of human-computer interaction and personalized approaches in digital dance interventions could significantly improve outcomes in elderly patients with depression. Digital dance interventions represent a novel and promising approach to treating depression in older adults. Future research should focus on overcoming the identified challenges and enhancing the effectiveness of these interventions.

Keywords: *Digital Dance Dntervention, Depression, Older Adults, Real-time Dynamic Assessment, Multimodal Dance Generation, Improving Compliance*

1. INTRODUCTION

According to the World Health Organization's Population Prospects of 2017, the global elderly population is projected to continue growing. By 2050, it is estimated that the population will reach 2 billion, accounting for 22% of the total population [1, 2]. Depression is a crucial factor that affects both the physical and mental health of older people in their long-term daily life. Jorm et al emphasized that depression is a risk factor for cognitive decline and a major source of distress in older people [3]. And it was estimated that older adults with depressive symptoms make up approximately 8-16% of the older adult population [4], making it difficult to ignore the impact that depression has on the older adult population. Additionally, older adults

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with depression also exhibit worse depression symptoms compared to younger adults with depression. It has been proved that the presence of some risk factors for depression, e.g., the presence of chronic illness and progressive sensory impairment, may become particularly prominent in old age [5]. Compared with the younger adults with depression, the older patints are more likely to have sleep have sleep problems [6]. With the worldwide aging population, this will pose tremendous burdens on patients, families, and society. Therefore, exploring non-pharmacologic interventions for the treatment of depression in older adults is urgently necessary.

Non-pharmacological interventions are effective in treating and alleviating neuropsychiatric symptoms These interventions are recommended to be prioritized because of the better beneficial effects on cognition, emotion, social interaction, physical and mental health, compared to initiating pharmacological treatment along [7, 8]. Dance, a non-pharmacological therapeutic intervention, is a multi-modal movement modality that combines physical, cognitive, and social activities [9], and has gained increasing attention and recognition over the past decade [10-13]. The positive therapeutic effects of dance have been observed to alleviate depressive symptoms in older adults [14] and improve physical performance and mood levels in older adults [15]. Older women who danced or participated in five dance movement therapy sessions per week were reported with reduced stress, increased social engagement, and personal well-being [16]. Several previous studies have found neurological improvements from dance as detected by medical technology [17-20]. For instance, dance has been found to benefit the physical, cognitive, and emotional health of older adults [9, 21], by enhancing neuroplasticity and activating a wide range of cortical, subcortical, and cerebellar regions [17-19]. Ho et al. showed significant reductions in depression, loneliness, negative affect, and improvements in daily functioning and daily cortisol slopes following a dance movement intervention for people with dementia[20].

However, there are also limitations in traditional dance interventions, even though previous research has demonstrated the effectiveness of traditional dance interventions in alleviating depression in older adults. First, it is not accessible; during the COVID-19 pandemic, people's travel and collective community activities were restricted, requiring a pause in group activities such as dancing, and social contact and participation restrictions severely affected older adults and traditional offline dance interventions could not be initiated as a result [22-25]. Second, traditional dance interventions lack individualized intervention content; most studies of traditional dance interventions usually consist of one dance style for the intervention and the content applied to the dance intervention is usually selected by a professional dance intervention instructor with a fixed dance content [26-30], which often suffers from homogeneity of dance style and content, making it difficult to provide individualized intervention treatments based on the patient's specific situation. Finally, traditional dance interventions have shown some patient attrition in terms of patient attendance and retention [30], and similarly showed deficits in terms of intervention completion [27].

In response to the limitations of traditional dance interventions in terms of convenience, personalization, and retention, digital dance shows better promise for application. A recent study of an online exercise program for people with Parkinson's also appreciated the high frequency of participation regarding the convenience, variety, and engagement offered by digital resources [31]. Additionally, the digital dance interventions also has real-time dynamic assessment and multimodal dance generation and higher adherence rate, therefore, it is promising to address the aforementioned limitations of traditional dance interventions (Figure 1).

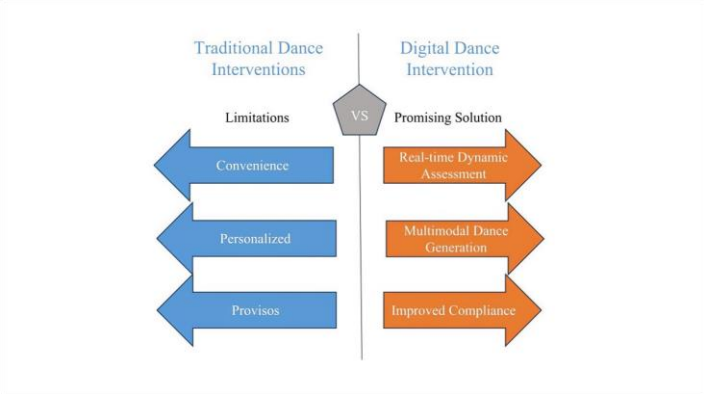

Figure 1. Limitations of Traditional Dance vs. Advantages of Digital Dance

Although some experimental studies have been conducted to prove the effectiveness of digital dance interventions, there is a lack of in-depth discussion on the future direction of digital dance interventions and the shortcomings of current research. Therefore, in order to fill this gap, this paper hopes to summarize and organize the current academic research in this area, supplement the shortcomings of the current research, and provide a referenceable direction for subsequent research. This paper firstly demonstrates the impact on the physical and mental health of elderly people with depression and the undeniable improvement of depression symptoms by traditional dance interventions. By discussing the limitations of traditional dance interventions in terms of convenience, personalization, and retention, the paper introduces the topic of digital dance interventions. The paper then traces the history of digital dance, outlining the past history of digital dance. Further, the paper describes future-oriented forms of digital dance interventions, including online dance interventions, mixed reality dance interventions, and socially assisted robotic dance interventions. Finally, in response to the limitations of traditional dance interventions in terms of convenience, personalization, and retention, this paper compiles relevant research on digital dance in terms of real-time dynamic assessment, multimodal dance generation, and improving compliance, and presents the challenges and perspectives for the future development of digital dance interventions for older adults with depression. It is hoped that this paper can provide a research direction that can be drawn upon for subsequent digital dance intervention research, especially for the intervention treatment of the elderly depressed patient population. The visual management of the full text references is shown in Figure 2.

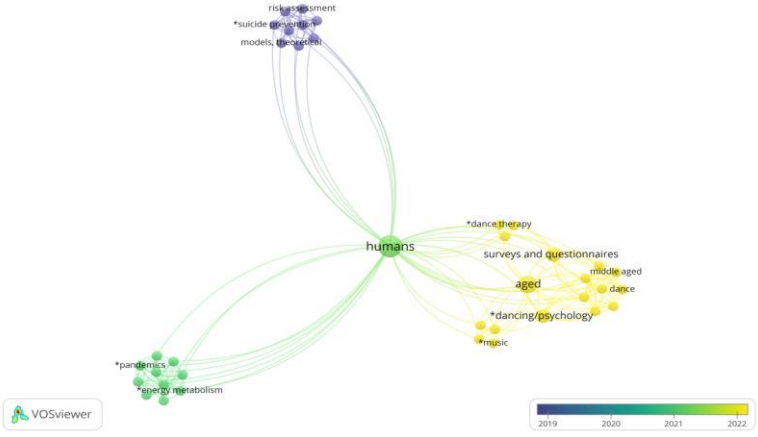

Figure 2. Visual management chart for full-text references

The remainder of the paper is organized as follows. Chapter 2 describes the historical progression of digital dance as it has developed in recent years. Chapter 3 describes several future-oriented forms of dance interventions that have recently emerged and may be utilized in digital dance interventions in the future, including online dance interventions, mixed reality dance interventions, and socially assisted robotic dance interventions. Chapter 4 This paper presents the challenges and perspectives of future digital dance interventions for older adults with depression in terms of real-time dynamic assessment, multimodal dance generation, and improved adherence to intervention treatment.

2. HISTORY OF DIGITAL DANCE

According to the World Health Organization's Population Prospects of 2017, the global elderly population is projected to continue growing.and improved adherence to intervention treatment.In recent years, digital dance has evolved, and research on digital dance has also changed. In this paper, we searched "web of science", "Google Scholar", and "journal citation reports" with "digital dance" as the theme or key word, and browsed relevant studies from 1998 to the present to understand the trajectory of the development of digital dance research. The historical timeline of the development of digital dance is shown in Figure 3.

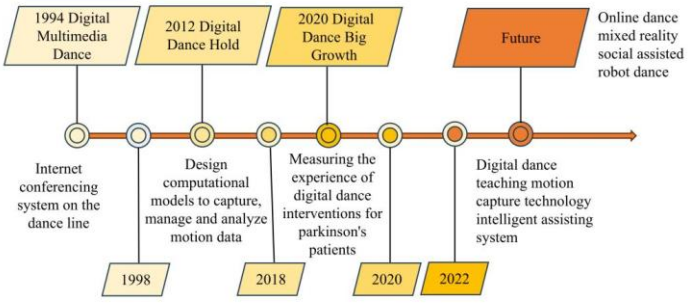

Figure 3. Historical Timeline of the Development of Digital Dance

The digital use of multimedia and remote dissemination over the Internet were the early forms of digital dance. The Macintosh computer was developed in 1984 by Apple in the United States [32], and since then multimedia-driven digital technology has been born. In 1998, a digital dance-related study utilized a videoconferencing system over the Internet that connected performers and audiences at remote sites in real-time for dance performances via computer networks [33], which was a breakthrough for dance to be remotely active and digitized online. Research on digital dance and the use of multimedia has been conducted over the past 20 years or so. Doug Risner et al. innovated the use of computer-mediated resources for teaching and learning by using video editing, graphic design, and web development software for an undergraduate dance technology course [34]. Another study brought digital animation and actors together on stage through the use of multimedia technology [35]. In the early stages of digital dance development, research on digital dance centered around multimedia use and Internet dissemination.

Beginning in 2012, studies related to the preservation and conservation of digital dance cultural heritage have been conducted [36-39], and until 2019, a significant portion of research on digital dance revolves around digitally generated technological innovations.In 2012, a study referred to the preservation of classical Indian dance in digital technology [36] and showed that it had begun to enable dance to be digitally and physically preserved by means of imagery and emoticons, with the help of digitally generated, bodiless physical expression preserved. Since then, research on digital dance has attempted to digitize dance through

algorithms. The digital preservation of dance was a breakthrough in digital dance research during this period. Sarah Whatley proposed a conceptual framework for creating and analyzing dance learning content, creating designed computational models through which movement data was defined captured, managed, and analyzed, systematically creating a movement library [38].Aristidou et al. on the other hand constructed databases and used digital to work on the organization of folk dances, and the study introduces an algorithmic framework on contextual analysis, organization and comparison of dance styles. The context-based movement organization approach, which exploits stylistic relationships between geometry and movement to automatically group similar dance performances, can be used to form digital dance ethnographies and reveal potential similarities between neighborhood dances [39]. Meanwhile, the digital use of multimedia in dance teaching and learning has been explored by more scholars [40, 41], but these studies have not made much of a breakthrough at the scientific and technological level. During this time, digital dance has taken cultural preservation as the theme of research, and is committed to collecting and organizing dances through digital technology, and algorithms regarding the preservation and organization of digital dances have been proposed.

Starting from 2020, due to the development of science and technology, more research on human-computer interaction related to dance, such as artificial intelligence, has been proposed, which has led to an unprecedented development of digital dance and injected new vitality into the research of digital dance. At the same time, the sudden outbreak of the new coronary pneumonia has provided the conditions for the wider use of digital dance because of the inconvenience of face-to-face communication as well as the limitations of related policies. Some scholars have explored the teaching of digital dance through new technological means [42-44].Yong Zhao and Fan Rao provided technical support for dance teaching by using motion capture technology [42, 43]; In order to improve training efficiency, LinJuan Zhang et al. combined digital feature recognition technology to correct and analyze Chinese dance training movements, and constructed an intelligent assisted training system [44]. In addition, research on digital dance in medical intervention has also made some progress. Several studies on the use of digital dance interventions in the treatment of Parkinson's patients have been presented [24, 45, 46]. Hulbert et al. examined the feasibility of using 3D motion analysis in conjunction with a dance intervention for people with Parkinson's and whether it was possible to measure how people with Parkinson's "feel (experience)" while dancing [45]. This is one of the earlier studies of the use of digital dance in medical interventions, and the first to utilize 3D motion analysis measures and digital dance "experience" measures, a breakthrough in digital dance interventions.

3. FUTURE-ORIENTED FORMS OF DIGITAL DANCE INTERVENTIONS

This paper summarizes three forms of interventions for digital dance that may be developed for use in the future based on recent research related to technology in digital dance, including online dance interventions, mixed reality dance interventions, and socially assisted robotic dance interventions. The research related to future-oriented forms of digital dance interventions is shown in Table 1.

Table 1. Research related to digital dance for the future-oriented

	Researches	Countries	Years	Facing crowd	Formality	Results
Online Dance Intervention	[22]	England	2021	Parkinson's patient	Online Family Interventio	Physical and non-physical (e.g., mood, confidence)

					n augmented reality intervention	improvements
	[47]	USA	2020	Parkinson's patient		May be able to safely increase physical activity
	[24]	England	2022	Elderly and Parkinson's patients	Online Family Intervention	Helps maintain connection and well-being, beneficial for seniors and people with Parkinson's disease
	[25]	USA	2023	Healthy adults	Social media interventions (online)	Increased positivity and self-esteem, decreased negative and depressive symptoms, improved social and community connectedness
	[52]	Ireland	2022	Patients with pulmonary fibrosis	Online Intervention	Increased health status and improved mental health status
	[60]	China	2023	Residents of Shanghai, China	Online Family HIIT Intervention	There is a preventive effect on depression, and the preventive relationship with depression is moderated by factors perceived by individual residents
Mixed Reality Dance Intervention						
	[48]	Japan	2022	Students of Tohoku University, Japan	Mixed Reality Social Dance Learning	Dance motor learning is further improved when all three modalities (visual, tactile and auditory) are present
	[49]	German	2020	University student	Mixed Reality Motion Guidance	Provide guidance for the design of motion guidance systems
Socially Assisted Robotic Dance Intervention						
	[50]	USA	2021	Children with autism on the spectrum	Robot Dance Freeze Game Intervention	The use of robots has more attention and commitment, showing strengths and potentials

[51]	USA	2008	Children with autism spectrum disorders	Socially assisted robotic interventions	Robot behavior has a social impact on children

3.1.Online Dance Intervention

As COVID-19 spread globally in the early 2020s and group activities such as dance were suspended, providers of community dance programs quickly turned to digital media-driven online service platforms, with a plethora of video recordings, live streaming, and interactive videoconferencing platforms appearing in a variety of formats, including interactive and streaming live classes, prerecorded videos, and dvds [22]. The inconvenience of traveling and policy restrictions have brought more attention to online platforms and have led more people to utilize online dance interventions. Studies on adherence to online dance interventions have received attention from some researchers. While conventional wisdom suggests that online dance intervention formats may be difficult for older adults to embrace, relevant research suggests that home-based dance programs have higher levels of engagement and show a range of potential [24]. Results from an online dance intervention trial conducted in Ireland demonstrated that virtual dance interventions are acceptable, enjoyable and feasible, and have improved physical health [52].

In addition to positive outcomes in terms of adherence such as acceptance and engagement, online dance interventions have shown better intervention outcomes in terms of cognition and improvements in depressed mood and negative affect. Rugh et al. reported in a study that dance therapy delivered through a mediated platform would be effective in addressing mental health challenges [53] , and has shown improvements and benefits to functional, cognitive, and affective domains, as well as fatigue levels and sleep [54-59]. Online dance interventions have been associated with improvements in positive states and can reduce negative and depressive symptoms by increasing positivity and self-esteem [25]. Results from an online dance intervention conducted in China during COVID-19 via social media Jitterbug live streaming showed that the more frequently Chinese residents participated in online HIIT dance, the less likely they were to suffer from depression during blockades, and that there was a preventative link between online HIIT dance participation and suffering from depression [60].

Online dance interventions, while lacking social interaction and direct instruction from the teacher, could still remain active in the future as an adjunct and complement to face-to-face interventions in dance intervention formats. In an online dance intervention study, the largest percentage of respondents expressed a preference for continuing both face-to-face and online digital interventions, rather than engaging in just one modality [22]. Most expressed interest in receiving supplemental video-based dance intervention resources to optimize the benefits of their dance practice [22]. After the conclusion of COVID-19, online dance interventions can still continue to be useful and valuable as an important form of dance intervention.

3.2.Mixed Reality Dance Intervention

Mixed Reality can be a form of intervention therapy in digital dance interventions, which will be expected to be utilized in digital dance intervention therapy for depression in older adults.The application areas of MR (Mixed Reality) include physical therapy, rehabilitative restoration, and maintenance tasks [61-64], and in the future will show a trend towards healthcare or clinical interventions such as digital dance interventions. Mixed reality (MR) is a technology that combines computer-generated "virtual worlds" with "real worlds" to build real-time interactive applications in three-dimensional space [65]. MR is differentiated from VR and AR. The distinction and comparison with VR and AR is shown in Figure 4.One of the main advantages of MR environments is their ability to change the point of view and display instructions in 3D space [49]. Methods in the literature have demonstrated the potential benefits of using MR for motion instruction.

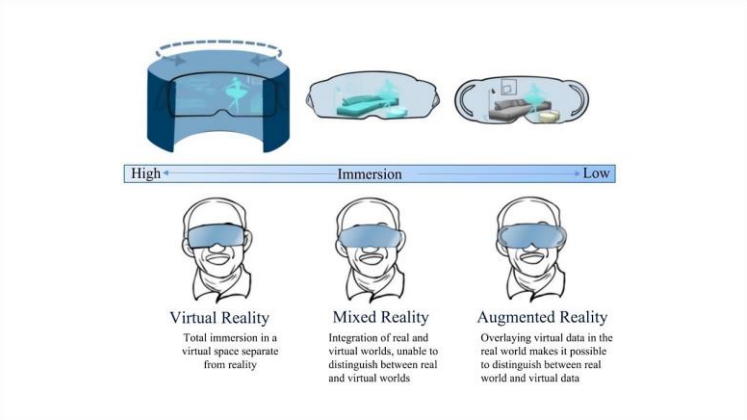

Figure 4. VR, MR, AR Comparison Distinction Chart

Yu et al. compared the situation in MR systems in first-person view, third-person view, and mirror-person view [49]. The study developed a prototype system for MR motion guidance, which reduced clutter in the user's view by segmenting long sequences into shorter chunks of motion and visualized the motion paths using an array of 3D views, and detected them in terms of task motion errors, completion time, and supervisor feedback. The experimental results indicated that the first-person view outperformed the mirror-person view and the third-person view in terms of speed and accuracy in terms of position and timing, especially for movements in front of the user, however, for movements in the periphery of the user, a view that provides an overview like the third-person view may be suitable for more rapid timing [49]. This study proposes a set of interaction design between visual selection and movement characteristics to select more optimized MR viewpoints by the type of movement, which can help to conduct MR dance interventions more scientifically, and to adjust and change the viewpoint selection of MR dance interventions when facing different types of dances or different acceptance levels of people.

A potential mechanism by which dance can promote improvement in depressive symptoms in older adults is that it promotes organic movement and guides older adults to convey negative emotions through learning dance movements [66], and dance interventions generated by mixed reality technology can do the same. Other studies of MR technology in dance training and learning have also provided relevant insights into the use of MR in digital dance interventions. A recent study on the use of MR in dance explored the Mixed-Reality Human-Machine Interface for Communicative Dance Movement Learning MRHMI (Mixed-Reality Human-Machine Interface) [48]. It provides visual feedback first through a computer-generated virtual teacher and a head-up display device, and secondly motor guidance to the learner in terms of haptic feedback through a vibrotactile wearable device. It was found that the combination of haptic, visual and auditory three-dimensional modes of feedback produced the lowest error in terms of position, speed and synchronization.MR dance interventions can enhance the accuracy of digital dance interventions through a three-dimensional feedback support system, and in the future the effectiveness, synchronization and accuracy of the system can be experimented in the older adult population and in populations with different motor fundamentals to bring digital dance interventions for depression in the elderly with Better results.

3.3.Socially Assisted Robotic Dance Intervention

Socially Assisted Robotics (SAR) aims to address key areas and issues in caregiving through aspects of automated supervision as well as companionship in one-on-one interactions with individuals. Socially assisted robots (SAR) are geared toward populations such as stroke survivors, older adults, and individuals with dementia, as well as children with autism spectrum disorders (asd) [67]. Socially assistive robots help the appropriate populations primarily by increasing the intervener's participation in social interactions and offer many potential advantages for clinical interactions. For example, they can allow therapists to better observe interveners interacting with the robot or engage in other aspects of intervention help [50]. In addition, robots often carry a variety of sensors and recording devices that can be used for quantitative analysis of

activities together [50]. It is also possible that, in the future, socially assistive robots will be able to be used in situations where the intervener has diverse needs or for longer periods of sustained intervention.

Regarding socially assistive robots (SARs), there have been a number of scholars who have conducted research and development related to this. For example, Wada et al. designed Paro, a pet-type therapeutic robot (Wada et al., 2006). Paro resembles a small harp seal, and it has been designed to have the ability to interact with simple sounds and motions like a pet, and it responds to being hugged and stroked. Experimental results suggest that Paro may be effective in reducing stress in nursing home residents. In addition, when placed in the common areas of the nursing home, it increased the social activities of the nursing home residents. This suggests that the SAR system may not only be used for its direct therapeutic applications, but may be utilized more broadly as a catalyst for social interaction, which coincides with the research of [67]. Increased social interaction can help reduce loneliness among older adults. Increasing older adults' connection to society can thus reduce depression and improve depressive symptoms.

Socially assisted robots (SARs) may provide positive stimulation and influence for older adults with depression, and although there are currently no studies for older adults with depression, there are existing studies geared toward children with autism that can inform socially assisted robotic dance interventions for older adults with depression. Barnes et al. conducted a study of a socially assisted robot (SAR) dance intervention for children with autism[50]. This exploratory study investigated the responses of children with autism to a socially assisted robot through a dance freeze experiment that included multiple elements of music therapy, dance therapy, and drama therapy. Based on respondents' comments, a social robot can take on different positive roles for a child with autism. The robot can provide a motivational activity; it can also give the child an outlet for special interests [50]. At the same time, robots as mentors, companions, and assistants in assisted dance interventions most likely have great potential to improve the quality of life of older adults. Research has shown that older users, patients with physical impairments, patients in rehabilitation facilities, and patients with cognitive impairments, can be supported with tutoring, physical therapy, self-care, and emotional expression [67].

4. PERSPECTIVES ON DIGITAL DANCE INTERVENTIONS

Although digital dance interventions have demonstrated certain strengths, there are still challenges in current research, and in the following section, we will summarize the challenges of digital dance interventions in terms of real-time dynamic assessment, multimodal dance generation, and improving compliance, as well as provide an outlook on future research in digital dance interventions. The mind map for this chapter is shown in Figure 5.

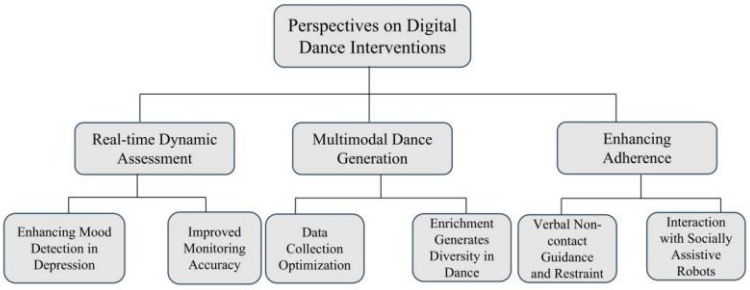

Figure 5. Prospective Thinking Maps for Digital Dance Interventions

4.1.Real-time dynamic assessment

The monitoring and management of depressive symptoms in older adults is essential during dance

interventions, and the concept of Ambulatory Assessment (AA) has been proposed because traditional depression scale tests are static tools that make it difficult to monitor patient-specific conditions in real time. Ambulatory Assessment refers to the use of computer-assisted methods of self-reporting, behavioral recording, or physiological measurements while the participant is engaged in normal, everyday behaviors [69], which is used in a variety of methods that include assessment of everyday life experiences [70], including ecological momentary assessment (EMA) of survey responses on smartphones, passive recordings from smartphones (e.g., keyboard typing behaviors, movements made with accelerometers, GPS location information), and other wearable devices used to measure physiological processes (e.g., electrocardiograms , ventilators, and sleep activity recorders) [70]. Compared to traditional assessments especially in terms of deformability [71], AA allows for an assessment of what is currently occurring, helping to avoid asking participants to report an "average" over a long period of time (e.g., mood over the past month). This area of development provides an important rationale for risk studies of related phenomena such as affective disorders, and holds great promise for investigating the mechanistic processes underlying affective disorders and improving personalized clinical care.

First, a number of related studies have raised the challenge of monitoring in the context of depression. The difficulty in monitoring out depression symptoms in real time using wearable devices was raised in a study on depression; assessing subjective mood symptoms using devices is difficult, and wearable devices mainly detect physiological data and have limitations in assessing subjective symptoms [72]. Some previous studies have described a dearth of dynamic assessments for psychology and state monitoring. In recent years, however, rapid advances in the affordability of digital technology have begun to allow for intensive monitoring of psychological processes in everyday life [73]. Furthermore, a recent study using the Apple Watch suggests that every watch has the potential for high-frequency cognitive and mood assessment using wearable devices [74]. This opens up the possibility of real-time monitoring and dynamic assessment of depression, and is expected to further enhance the ability to monitor mood in real-time dynamic assessment of depression in future studies.

Additionally, there are some studies that have raised challenges and hopes for dynamic assessment in improving accuracy. A study by [71] on dynamic assessment for life risk prediction indicated that future work in dynamic assessment of risk (AA) should continue to increase the focus on the accuracy, sensitivity, and specificity of assay predictions in order to determine the potential clinical utility of dynamic assessment for risk prediction. This study also suggests that by continually updating and improving predictive models over time, models may be able to continually improve their accuracy in predicting risk [71]. Another study of wearables in the field of depression raised unreliability and inaccuracy as great challenges in real-time monitoring [72]. There is a wide range of wearable devices on the market for fitness and health, but they are not simple to use for those who wish to monitor clinical symptoms [72]. Although several studies have been conducted to validate the accuracy of wrist behavioral compared to polysomnography (PSG) [75, 76], accelerometers at the wrist are not effective in detecting sleep patterns that do not involve limb movements, and therefore other instruments, such as pressure sensor tablets or chest-worn sensors are needed to obtain a higher level of accuracy [77, 78]. This suggests a viable direction for future improvements in the accuracy of depressive symptom monitoring.

The monitoring and management of depression and the accuracy of mood measures in existing studies have shown the possibility of practicing real-time dynamic assessment, and the effectiveness of depression monitoring and the accuracy of monitoring are expected to be further improved in future studies of real-time dynamic assessment.

4.2.Multimodal Dance Generation

The development and creation of intervention content is a key component in dance interventions for older adults, and it is essential that dance intervention content is developed and choreographed to suit the specific circumstances of different older adults. While multimodal dance generation provides more personalized intervention content for digital dance interventions, helping creators to speed up their workflow, provide inspiration and increase the possibility of innovation in older adult-oriented digital dance interventions [79]. A great potential is shown in expanding content creation in the field of dance interventions. Multimodality

refers to information in multiple modalities, which is data composed of two or more modalities, including forms such as text, images, audio, and video. Multimodal dance generation is a challenging generative task that has been shown to provide technical support in the area of computer-assisted choreography [80, 81]. Multimodal interactions occur in different aspects of human information processing and can facilitate perceptual and cognitive processing when different stimuli are presented in a temporally or spatially coincident manner [82]. Thus, multimodal user interfaces that provide consistent combinations of signals from different sensory modalities may have particularly beneficial effects on user behavior and performance in those perceptually or cognitively demanding situations [82]. In multimodal dance generation, judgments about a person's intentions can be made by intelligent devices fusing multidimensional information and feeding it back to the person through multiple sensory modalities, aiding in more optimal dance generation and more accurate interventions. The multimodal generation of dance can provide the intervener with richer content of dance intervention, and can be more personalized to respond to the needs of each intervener according to the intervener's specific situation. This paragraph will describe recent advances in multimodal dance generation research in terms of data collection and dance generation.

First, there are studies that attempt to break through some of the limitations that exist in the process of constructing multimodal dance movement data collection. Previous studies have acquired 3D skeletal information [83-85] by utilizing a motion capture (MoCap) system and recruiting a professional artist, which is often costly and time-consuming [86]. Using an automatic pose estimation framework that relies heavily on the accuracy of the latent pose estimation framework will inevitably require an additional post-processing stage [87-90]. However, in a recent study researchers attempted to solve this problem [86], which proposed an autoregressive dilated causal convolutional neural network with highway gating functions (an autoregressive dilated causal CNN with highway gating functions) with a deep multimodal architecture via stacked dilated convolutional operations to capture the long-term spatio-temporal context of dance sequences. It enhances the ability to capture dance movement data, which provides a feasible direction for data collection optimization.

Furthermore, in terms of the process of multimodal dance generation, recent studies have optimized the diversity and richness of the generated dances. Clip splicing of dance motion segments is the classical operational scheme for dance motion generation, which generates new motion sequences by reorganizing the motion segments of a dataset [91-94]. The fragment splicing method transforms the motion generation problem into a fragment selection problem, which can generate higher quality motion sequences, but the method is difficult to create new motions and the generated dances lack motion diversity [95]. A recent study utilized a frame-by-frame generation method [95] and, in order to reduce the number of input frames for motion sequences, used multilevel upsampling to extend the motion sequences and added a discriminator to improve the quality of predicted motions in order to produce longer unfrozen motion sequences. It is capable of generating long music-related 3D dance sequences by using fewer motion sequences as inputs, generating motion sequences that are rich in dance diversity. Optimizing the generation method is something that future research can keep working on.

Multimodal dance generation has important implications for the personalized creation of content for digital dance interventions, and its recent research in data collection and dance generation demonstrates the possibility of overcoming the limitations of dance content. More research is needed in the future to refine all aspects of multimodal dance generation and to improve the diversity of multimodal generated dances so that future digital dances provide more personalized interventions.

4.3.Improving compliance

In traditional dance interventions, previous studies have shown deficits in attendance, retention, and completion [27, 30]. However, digital dance, as a newer form of intervention, may be better able to increase patient interest and make patients more willing to accept dance interventions, thereby increasing adherence to dance interventions. Digital interventions have the clear potential to increase access to dance and other activities [24]. Research has found that augmented reality-based interventions, such as MTG (Moving Through Glass), which motivates participants to be physically active, may increase the feasibility of and adherence to dance for people with Parkinson's disease [47]. The Irish Lung Fibrosis Association (ILFA)

offers online exercise and yoga classes in Ireland for people with pulmonary fibrosis and has found that due to the influenza pandemic, patients prefer to use the online system [52]. Studies such as [31] have also shown that virtual digital exercise interventions are more popular with Parkinson's patients. The studies mentioned above suggest that digital dance has a clear advantage in promoting increased adherence to dance interventions. The future of digital interventions may be to improve treatment adherence through verbal non-contact instructional encouragement and individualized design, and to establish and enhance effective healthcare practices through constraint-induced treatments [50, 96]. In future studies of digital dance interventions, retention and adherence enhancement could be directions that could be studied and experimented with.

Socially assisted robots (SARs) may be able to enhance compliance with digital dance in the future, and existing research on children with autism can inform future compliance enhancement with digital dance interventions for older adults with depression. In a study of a socially assistive robot for children with autism, the idea of having the child teach the robot to demonstrate knowledge provided opportunities for new scenarios to be designed and motivations to use the robot [50]. Social stories can be the basis for interaction, and the reciprocal teaching of specific functional skills may elicit greater interest and engagement. While this work focused on having the child mimic the robot, future work may reverse this dynamic and have the robot mimic the child as suggested by the physical therapist to improve body awareness. It suggests that more research is needed to find effective combinations and interaction scenarios to pique the child's interest and facilitate interaction with participants. Perhaps by interacting with socially assisted robots could be a way to improve compliance with future digital dance interventions.

Some of the studies endorsed the high adherence to digital dance and made recommendations related to the future enhancement of digital dance adherence through non-contact constraints and personalized engagement of socially assisted robots may provide a viable direction for future enhancement of adherence to digital dance interventions.

5. CONCLUSION

Digital dance interventions have shown promise in the field of dance interventions, producing better intervention outcomes for older adults with depression than traditional dance interventions. Previous research has shown that digital dance interventions have produced better results not only for depression in older adults, but also for other conditions (e.g., Parkinson's, pulmonary fibrosis). Although at present, there are still some challenges with digital dance interventions, some of the studies have proposed directions to address them and are expected to be further addressed and improved in future studies. This paper reviews and analyzes the research results of digital dance interventions in real-time dynamic assessment, generation of multimodal dances, and enhancement of adherence. And based on this, it analyzes the problems in each research aspect. Considering the advantages and shortcomings of digital dance interventions comprehensively, it is pointed out that the future research direction about digital dance is borrowed, and the improvement of digital dance interventions is the main research direction in the future. In the future, it is hoped that more scholars can participate in the research of digital dance intervention and promote the improvement of digital dance intervention, so that digital dance intervention can be better utilized in clinical intervention treatment in the future.

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