




Are We Ready to Dance at Home?: A Review and Reflection of Available Technologies

Paula Alexandra Silva 

DigiMedia Research Centre – Universidade de Aveiro, Aveiro, Portugal
palexa@gmail.com

Abstract. It is well acknowledged that engaging in physical exercise is important to live a longer healthier life. In this context, dance is an especially interesting activity that may hold much potential in an ageing society. Dance combines the essence for successful ageing in a panoply of benefits that range from the physical to the cognitive and psychosocial. To be able to engage in dancing activities from home can then be a valuable add on to people’s health, wellbeing and quality of life; this paves the way for technology-mediated dance activities at home. This paper reviews the research in this area, to develop an understanding of currently available technologies and to provide researchers and practitioners alike with an overview of how the technologies reviewed can address the specific characteristics of dance.

Keywords: Older adults · Physical activity · Dance · Entertainment · Active Ageing · Fitness · Games · Technology

1 Introduction

Between the year 2000 and the year of 2016, the global average life expectancy saw its largest increase since 1960, of 5.5 years, with people born in 2016 being estimated to live until they are ~72 years old [1]. As our society ages and continues to conquer longevity, a growing concern is how to sustain more active, happier, and healthier lives.

Pushed by the challenges of demographic change, European and International governments and organizations have developed strategic plans to adequately address demographic change, namely through policies and partnerships for Healthy and Active Ageing [2–8]. An important mark among those actions is the World Health Organization’s policy framework on Active Ageing developed in 2002 [2]. Currently, and more precisely, between 2015–2030, the focus of WHO’s work on ageing is Healthy Ageing [4, 8]. Those actions emphasize, for example, the importance of sustaining health and well-being, of promoting participation and an active contribution to society, and of remaining physically, socially, and mentally active across the life course.

Another important idea that has been gaining momentum in the context of ageing successfully is the one of ageing in place, also referred to as ageing at home [8, 9]. Ageing in place expresses and gives voice to older people’s preference to remain home, as they grow older. “New technologies provide opportunities to achieve ageing in place, to enhance the quality of older people’s environments and to increase life

fulfillment and quality of life” [10]. The rising interest and acknowledgment of the importance of ageing at home underlines the need for research in the home context.

The research presented in this paper concerns the use of technology as a facilitator of ageing in place with a view to promoting a healthy and active lifestyle at home. In particular, this paper discusses the relevance, potential, and adequacy of existing technologies in supporting dance – here defined as “a physical, cognitive, and psychosocial activity, either done alone or in a group, which encompasses a sequence of movements usually performed to the sound of music or some sort of rhythm” [11] – at home.

Two research questions guide this research: i. What types of technology have been used to support the context of technology-mediated dance targeted at older adults? and ii. To what extent do those types of technology address the specific characteristics of dance? In addressing these questions, this paper engages in a review of research reporting on the use of technology-mediated dance interventions targeted at older adults. A purposive sampling selection of articles is applied to the studies retrieved from an extensive literature search, to then elicit the different types of technology in use and to develop a preliminary discussion around those technologies and to what extent they address the characteristics of dance. This review contributes to developing an overview and gaining a better understanding of the area.

2 Physical Activity, Health and Well-Being

2.1 Benefits of Engaging in Physical Activity

Physical activity is a key lifestyle factor contributing to living a longer healthy life [12]. Showing a panoply of benefits, physical exercise decreases risk of falling, reduces physical disability, improves sleep, and enhances mood and well being [13]. With physical activity prompting positive results that range from reducing pain to fostering functional mobility [14], to remain physically active offers an effective way to counterbalance the risk factors and functional decline associated with age [12].

Aware of the advantages of physical activity, the World Health Organization (WHO) has created a set of physical activity guidelines [15] that member states of the Europe Union (EU) are advised to implement [16]. In short, these guidelines recommend that older adults engage in: i. 150 min of moderate-intensity *aerobic physical activity* per week, or in at least 75 min of vigorous-intensity aerobic physical activity; ii. *muscle-strengthening activities*, involving major muscle groups, two or more days a week, and iii. *balance training activities* three or more days per week.

In addition to the evidence demonstrating that physical activity is effective in preventing or delaying chronic diseases [17], evidence also shows positive compelling results in addressing specific neurodegenerative conditions, such as Parkinson’s disease (PD), where physical activity not only lowers the risk of developing PD, but also improves the symptoms associated with it [18].

2.2 Previous Uses of Technology in Promoting Physical Activity

With a growing body of literature showing that to stay physically active is a precursor of good health and well-being, leading to successful ageing [19], it is important to both motivate older adults to exercise and to create opportunities for them to exercise. A possibility of doing so is to leverage on the potential of technology to make solutions available to older adults at the convenience of their home.

Several research projects have focused on developing solutions that promote the uptake of physical exercise (for a review see [20]). Regardless of the different approaches followed, a popular strategy used by those projects, resorts to exergames and serious games to motivate older adults to take up physical activity [20].

There is also a wealth of research reporting on the use of commercial game consoles (e.g.: [21, 22]) and of custom made solutions (e.g.: [23–26]) for exercise purposes among older adults.

While a number of studies shows positive results in physical function, cognition and quality of life, socialization and motivation to exercise [13], research on exergames still shows conflicting results in terms of health benefits [27], namely in psychosocial well-being [28, 29] with some interventions holding only short-term effects [30]; this underlines the need for further research in the area.

2.3 Dance as a Unique Form of Physical Activity

While intuitively one may think of dance mostly as a form of physical exercise, possibly also as a social activity, dance is a much more complete activity, that equally involves cognitive elements – triggered, for example, while one tries to memorize or recall a sequence of steps – and psychological elements – such as those that convey a sense of satisfaction with life.

Looking at dance from a diversity of perspectives, research has investigated the health benefits of dancing and found positive health effects in older adults across domains, being those physical (e.g. [31]), cognitive (e.g. [32, 33]), or psychosocial (e.g. [34]). A systematic review on the effectiveness of dance interventions in improving health among older adults has concluded that, irrespective of the style, dance improves older adults' functional fitness, in terms of muscular strength, endurance, and balance [31]. The health benefits of dance also extend to neuro-cognitive function [33] and dual-task performance [32]. Moreover, from a psychosocial viewpoint, studies have shown decrease in pain levels [14], improvements in psychological well-being related to general health and the decrease of bodily pain [34] as well as in social activity and community involvement [35]. Furthermore, dance has shown the highest levels of efficacy in terms of gait and quality of life with regards to specific neurodegenerative conditions, such as PD [18], both in the form of Argentine tango [36] and Irish step dancing [37], with some boldly stating that dance may hold the potential to demedicalize PD [38].

When compared to other types of exercise, dance shows increased physical and cognitive benefits, namely in terms of balance and brain structure, delaying cognitive deterioration [12] as well as brain plasticity [39]. Furthermore, a recent systematic review and meta-analysis on the effectiveness of dance interventions in comparison

with other types of interventions on physical health outcomes shows that structured dance of at least four weeks' duration can significantly improve physical health outcomes [40]. Research results like these, make dance a promising candidate in countering the age-related decline in physical and mental abilities [12], considered by Dhimi et al. [41] as *the* framework for rehabilitation, where dance is not only effective, but also enjoyable.

2.4 Motivation to Exercise Among Older Adults

Regardless of the benefits that engaging in physical activity entails, older adults are not regular exercisers [42]. This problem of adherence is one of the pitfalls of interventions with exergames, which use has shown to decrease over time [27]. This is not unique to technology-mediated interventions, as 50% of the older adults tend to drop involvement in regular exercise programs within the first six months into the program [13], with the decrease in motivation to exercise starting 16 weeks into it [13, 43].

Although willing to exercise, older adults fear injury and would rather exercise in a cost-effective way and at their convenience in the safety of their homes [44]. Considering the home scenario as a hypothetical alternative, previous studies [40] have found that a home-based program was as effective in increasing health benefits and exercise participation as the face-to-face interventions. These results indicate that home-based programs are not only desirable but also feasible and effective, which is encouraging if a home-based scenario is to be considered.

Socializing or the possibility for increased social interaction is seen as a motivating factor to exercise [44, 45]. While older adults may find typical forms of exercise monotonous and boring [22], dance is seen as an enjoyable activity among older adults [34, 37] that makes them feel happy [34]. Psychological benefits have been observed in previous studies involving dance, where improvements could be attributed to the social network and friendship developed while dancing [34].

In addition, having fun is one of the reasons older adults adhere to physical activity programs [43, 45]. The idea of fun is intrinsic to games, which then may mean that games hold the potential of making exercise more fun and, in this way, of increasing adherence [22]. Previous researchers have argued that physical and occupational therapy activities delivered through games, or 'therapytainment' systems (i.e.: systems that simultaneously engage older adults in learning, working, and play [46]), do transform physical therapy from a chore into a fun activity, while older adults are still doing hard work [46].

In the specific case of dance, the appealing recreational nature of interactive dance exercise may further help promote adherence to physical activity [42]. In line with this, other forms of technology-mediated dance have reportedly received a very positive and emotional response in the context of dance for PD [47].

The aspects discussed in this section put technology-mediated dance interventions in an advantageous position to promote physical activity among older adults at home. Dance is an attractive form of exercise, that has shown to hold positive physical, cognitive, and psychosocial health benefits among older adults [48]. Furthermore, the possibility of offering it in a home scenario is likely to further strengthen its potential, not only because these type of interventions have shown feasibility and effectiveness

[49], but also because engaging in exercise programs at home increases chances of adherence to physical activity in the long term [50].

3 Research Methodology

The goal of this study is to develop a greater understanding of what characterizes the technologies available in the context of technology-mediated dance for older adults. With that goal in mind, two research questions guided this research: i. What types of technology have been used to support the context of technology-mediated dance targeted at older adults? and ii. To what extent do those types of technology address the specific characteristics of dance?

In addressing the research questions above, this study engaged in an exhaustive literature search across a number of databases (PubMed, ACM Digital Library, Academic Search Complete, IEEE, Scopus, and Web of Science Core Collection) to locate research on technology-mediated dance targeted at older adults (for the full details on the search string please refer to Appendix A). All study designs and all types of dance were considered, for research published between the year 2000 and 2018.

During a second phase, studies were selected based on a purposive sampling technique (also known as judgment, selective, or subjective sampling), a method inspired in anthropology research, that involves a deliberate choice, in which the researcher decides what needs to be known and sets out to find it [51]. With the aim of getting a good overview of the spectrum of technology-mediated solutions for dance targeted at older adults, an heterogeneous sampling [52] was used with the purpose of eliciting as many unique solutions as possible, both in terms of designs and technology components.

Once the papers that fitted within the topic of this research were retrieved, they were further analyzed regarding the properties and features of the solutions.

4 Technology to Support Dance at Home

Following an extensive and comprehensive searching phase, the records retrieved were reviewed to identify eligible studies. Relevant studies reported on the use of technology-mediated dance systems designed and/or assessed with older adults. As previously mentioned, this research considered dance as “a physical, cognitive, and psychosocial activity, either done alone or in a group, which encompasses a sequence of movements usually performed to the sound of music or some sort of rhythm” [11].

In order to correctly interpret the results presented in this section, it is important to note that not all eligible studies were necessarily included in the review. This was the case, because this research aimed at identifying solutions, which were different enough from one another. So, if there were a number of different manuscripts, all reporting on the use of identical versions of the a given system, for example, StepMania and a dance mat with panels (e.g.: [53, 54]), only one, maximum a couple of studies, were explicitly

mentioned in the analysis, in representation of the remaining identical ones. Conversely, if there were a system, which contained similar components but at least one that would make the overall solution different enough, a different instance would be considered. An example of this would be the use of the above system – StepMania and a dance mat with panels –, but in which ropes to which participants could hold on too while using the system were added (see for example [55]).

The following two sections briefly describe and analyze the included studies. Findings are organized by the underlying purposes of the study in which systems were involved and by type of solution.

4.1 Studies' Purposes

The studies included in this review investigated technology-mediated dance interventions with a number of purposes. Looking at specific health conditions or frequent issues among older adults, fall risk and fall prevention have been repeatedly a target of investigation [23, 53, 56]. Other conditions which have been a focus of research include multiple sclerosis [54], Parkinson's [57, 58], and Huntington's disease [59].

A number of studies included in this review have focused on assessing foundational aspects of these systems, such as feasibility [55, 60]; feasibility and safety [61]; feasibility, acceptance, and usability [62]; and adherence, perceptions of the game, and safety [59]. Studies were also performed with the goal of tweaking the systems [63] and of understanding older adults' perceived advantages and disadvantages of such approaches [42]. With encouraging results on these dimensions, studies set out also to evaluate the systems' effectiveness in improving specific dimensions of health and wellbeing in older adults.

Into what concerns physical health outcomes, studies again assessed a number of different aspects, including spatiotemporal gait measures [59]; balance [57, 64]; exercise capacity [65]; balance and gait [58]; and stepping performance [61].

Aware of the multidimensional nature of dance, studies further evaluated walking dual task performance [55, 66] and balance, stepping, cognition and functional performance [54]. Turning more into the assessment of cognitive outcomes, studies investigated, for example, cognitive performance [66] and cognitive control and attention [67].

Although less frequent, studies also looked into psychosocial health outcomes. Among this type of studies, there are articles focusing on the development of social connections [68], quality of life [59, 65], and the effect of interventions on activities of daily living and depressive disorder [57]. Finally, there are studies specifically investigating motivation [69] and the effects of interventions on other specific health outcomes such as blood lipid and blood pressure [70, 71].

With more or less significant results obtained, the range of studies above shows the perceived potential that technology-mediated dance interventions entail. It also shows that this area has been gathering the attention of several researchers in a number of different domains.

4.2 Main Types of Technology-Mediated Dance Systems

To report on the different types of solutions found, this research developed a classification, which captures the main types of technology-mediated dance systems in a structured way. Figure 1 shows a classification divided into four groups, organized according to the ways in which technology is used and the level of adaptation of the system to cater for older adults' characteristics.

While the first two groups are mostly illustrative containing only a couple of examples each, the second two groups are more complete. This is the case not only because records fitting into the first two groups are very scarce, but also because the second two groups refer to solutions which have been adapted and specifically tailored to be inclusive of the needs of older adults and thus are, considering the scope of this study, the most interesting and relevant.

The top group '*Dance therapies delivered through technology*' includes conventional dance therapies, which are delivered exactly as they would be delivered in a normal face-to-face scenario, yet they are mediated by technology. Two examples were found that fitted this category: in one case, the therapy is delivered by a regular therapist via Skype [60]; in the other, the dance exercise is displayed from a video disk that the participants follow, while a facilitator supervises them *in locu* (see for example, [65, 70]). In this category, technology plays a merely instrumental role – that of a means of communication –, which purpose is simply to transcend geographic constraints.

The second group '*Commercial dance games*' contains references to mainstream commercial games, which have been used and assessed in interventions with older adults. Two types of examples were found, two instances using Dance Dance Revolution [59, 67] and another using K-Pop Dance Festival for the Wii game console [57].

The following group '*Adapted commercial dance games*' consists of adapted versions of commercial dance games. Aware of the issues imposed by commercial games, designed for mainstream users, likely to include jumps and fast-paced music [64, 72], commercial games were modified to accommodate older adults needs and characteristics. This is the group for which the largest number of instances were retrieved, with the majority of the research making use of StepMania, an open source version of Dance Dance Revolution (DDR) (for specific studies, see, for example, [22, 69, 73] but also [11]). Similarly to the original DDR, to play this game participants would follow the instructions on a screen while at the same stepping on a dance mat with panels. Variations of this system followed the initial attempts developed on MatLab [63], and included, for example, a version that included a set of ropes to which the participants could hold on to while performing the moves [55]. Another variation of DDR used an accelerometer, a gyroscope, and a mobile phone [74]. Another adaptation was found of Dancetown, in a version that played songs from the 50's and presented simplified graphics and dance step sequences that progressed slower in difficulty [42].

Finally, the last group, '*Custom made solutions*', includes solutions that have been specifically designed to cater for older adults and their specific needs. Examples in this category are extremely diverse, resorting to a smartphone-based game [23, 56] to a robot [58], or the Google Glass [38, 47].

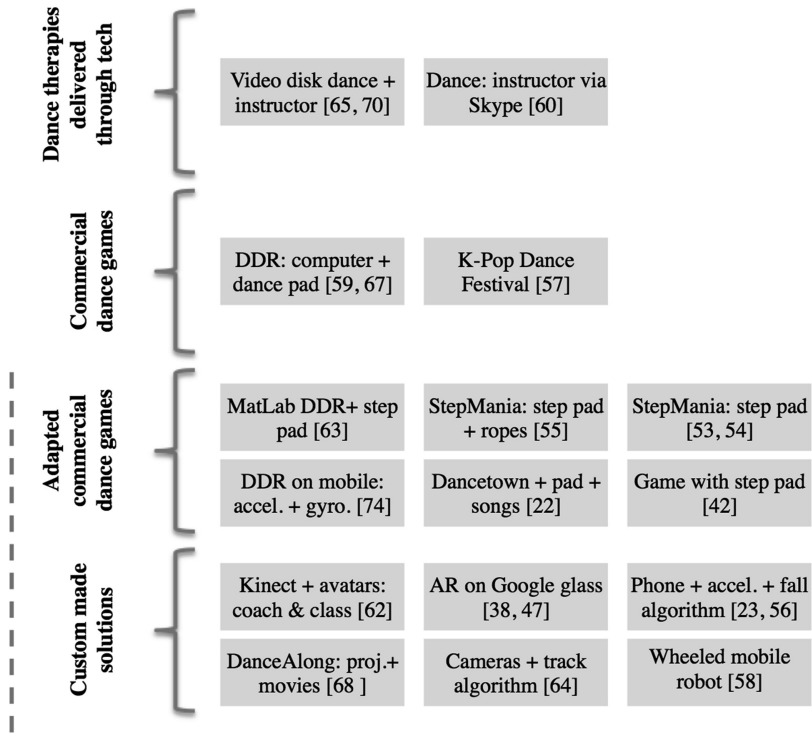


Fig. 1. Classification of studies according to type of technology-mediated dance system.

The example using the smartphone leverages on the potential of its embedded sensors and of a fall algorithm, to offer the user an experience that consists of mimicking the movements of a virtual coach [23, 56]. A similar approach uses a dance video game coupled with a low cost camera tracking [64]. Another example uses ‘Movioke’, allowing players to dance along with scenes from popular movies [68]. In this example, in addition to the song selection in the DanceAlong interface, the system uses three projectors, two showing the steps and another displaying the video of the movie. The Google Glass is used for rehabilitation with people with PD and is a sort of augmented reality class, where the specific dance therapy moves are displayed in the goggles and the person executes the movements accordingly [38, 47]. Another solution leverages on Kinect to create a virtual reality group dance class, where the dance participants see their avatars and those of the coach and other participants on the television screen and hear each other via headsets [62]. The last example uses a wheeled robot for partner dancing [58].

The specific strengths and drawbacks of each category are discussed in the next section.

5 Discussion and Future Work

Several purposes have been at the center of the studies presented in this review that show the interest and potential of the area. Still, as previous systematic reviews conclude [11, 75], the effectiveness of such interventions has not yet been definitely demonstrated. This is the case, namely, for cognitive–motor effects [75] and for psychosocial factors [11], where both systematic reviews report on the weak evidence, low-quality, and high risk for bias of studies. If it is true that conflicting and poor evidence have also been reported in similar areas [76], this also indicates the need for further research in the area.

Regardless of the possible learning demand in terms of basic technical and movement skills, interactive video dance exercise, does appear to be an appealing form of exercise for older adults [42] and several randomized controlled trials show positive indications of the effects of technology-mediated dance systems [53, 54, 61, 66].

When considering the categories in which this paper structured currently existing solutions (Fig. 1), a number of advantages and disadvantages can be identified, as displayed in Fig. 2. The first category is interesting from the perspective that it offers validated therapies. For example, one of the studies uses Healthy Steps, which is “a dance therapy program that is based on movements that are used in allopathic, medically based therapies, such as physical and occupational therapy programs” [60]. Approaches like these once shared through the Internet or placed on a player can reach a large number of people, however, they rely heavily on the presence of an instructor, who, for example, when participating remotely may not even have a complete view of the person on the other side, which may be a significant pitfall.

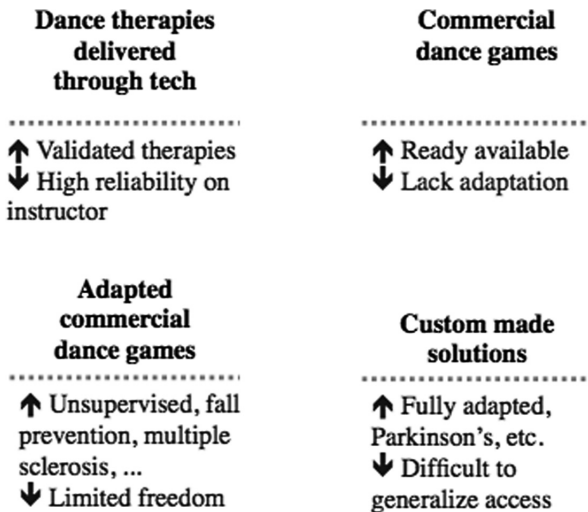


Fig. 2. Main advantages and pitfalls of each type of technology-mediated dance system.

Regarding the second category, if it is true that commercial games are of widespread access, they are generally not suitable for older adults, given their fast-paced music, frequent jumping, and overload of information on the screen [64, 72]. Still, these games have been assessed in improving the conditions of specific diseases, such as Huntington's [59].

As mentioned before, the third group '*Adapted commercial dance games*' is the one for which we found the most instances, with most of the studies resorting to StepMania and a dance pad with panels to step on. In spite of this approach showing positive results, namely in addressing specific health conditions (see for e.g. [54, 66]), the fact that the game requires players to step on specific panels and focuses very much on precision may remove the fun, and freedom of movement and expression that usually characterize the nature of dance.

The most diversity is found in the last category of systems, which includes technology-mediated dance systems that have been adapted or specifically designed to suit older adult's characteristics. The solutions found in this group cater for the necessary freedom of movement that a holistic dance experience entails. While some solutions focus on providing users with an experience that includes other dance class participants [62], or an actual dance partner [58], other approaches favor wearable, yet non-intrusive or limiting technologies [23, 56]. There are also solutions that leverage on the potential of depth cameras to offer a seamless technological solution [64, 68]. One of the seminal works in this area [68], additionally builds upon the reminiscence potential of old movies to offer a more rewarding user experience. This last category includes promising, compelling, and more recent technologies where researchers are experimenting with a robot [58] and augmented reality glasses [38, 47], much like a science fiction movie would anticipate. To some extent uncharted territory, these solutions therefore hold undiscovered potential in enabling an experience that is more natural and closer to what a dance experience would involve. However, these technologies are not easily accessible nor in their final commercial phase. They also have not been conveniently validated that they can be made available for health prescription.

It is therefore necessary to continue investigating, on the one hand, what constitutes a system that is both designed to be inclusive of the older adult population and to allow for a complete positive dance experience, and, on the other hand, the effectiveness of such systems.

To design for the rich context of dance and movement, constitutes a significant technological challenge. Fast-paced music, negative feedback, among others are problematic and may be intimidating [64, 72]. Having to use a dance pad may be limitative in terms of movement as well as dangerous [72], so other approaches have tried, using, for example, a mobile version integrating an accelerometer and gyroscope [74] or the Kinect [45]. There are also other sensors entering the market, such as Real sense (<https://realsense.intel.com/>), that may hold the necessary features that a complete dance experience requires, namely freedom of movement and partnered or group dancing, but also music, a sequence of steps, etc.

Dance is a positive health activity that nurtures body and mind. The research reported in this paper compiled and structured existent solutions for dance and older adults to then develop an understanding of the characteristics of those solutions and gauge to what extent they fitted and addressed the properties of a dance context.

Despite a thorough search of the existing literature, it is possible that other relevant studies may have been left out. Moreover, for a complete understanding of the existing types of systems that can be used to support dance, a more exhaustive study would be needed describing all solutions and deconstructing them into their different components. This offers a relevant opportunity for further research, as it is important to assess, for example, how to appropriately design for freedom of movement, customization of therapy, provisions health feedback, and group or partnered dancing.

6 Conclusions and Limitations

Regardless of the hypothetical potential of technology-mediated dance, to our knowledge, no studies have yet reviewed the types of technologies, which have been used in this context, nor have given careful consideration to how those technologies attend to the specific characteristics of dance and the experience it affords. This research aimed at shedding light into this area and to develop an awareness of the strengths and limitations of existing technologies in addressing the specific characteristics of dance.

An extensive search of databases was done that served as the basis for selecting relevant research. Based on a set of eligible papers, this research elicited distinct groups of technology to contribute with a classification that systematizes and organizes the technologies reported in the studies reviewed according to its main features and characteristics. This addresses RQ1: What types of technology have been used to support the context of technology-mediated dance targeted at older adults? where this research found that there are four main types of solutions: i. Dance therapies delivered through technology, ii. Commercial dance games, iii. Adapted commercial dance games, and iv. Custom made solutions.

Additionally, and in addressing RQ2: To what extent do those types of technology address the specific characteristics of dance?, this research sparks a discussion on the extent to which the types of solutions found address the specific characteristics of dance and enable a positive and complete dance experience at home. While the first two types of solutions present considerable limitations, the last two types hold significant potential, especially the last type, which includes technologies that have been specifically designed to cater for dancing and older adults. Still, findings point to the need of future research in the area.

Other research could additionally inform the relevance, potential, and adequacy of existing technologies in supporting dance that have not been considered in this study. These are, for example, studies on the general area of exergames for older adults that could help understand what works and what does not, as well as research involving other populations, that while less conservative, can point into alternative technological directions that could lend more freedom and completeness to the dance experience.

Health promotion actions and alternatives that can be offered to older adults in the home context have the potential to extend seniors' years of active and healthy living, while promoting their independence and continued engagement with society at large. Alternatives with the potential to improve physical, cognitive and psychosocial health may be particularly relevant for those living with temporary disability or in regional or

remote areas, yet technology-mediated dance offers great value, holding the prospect of a joyful active future to us all.

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Appendix A

The following filters were applied in PubMed: Publication date from 2000; Humans; English; middle aged + aged: 45+ years; Middle aged: 45–64 years; aged: 65+ years; 80 and over: 80+ years.

Two search strategies were used in PubMed. The first used Mesh Terms “dance therapy” “dancing” combined with the terms “technology,” “software,” “apps,” “playware,” “edutainment,” “exergaming,” “robot,” “game,” or “haptics” as search terms in all fields.

A keyword search was also run, using a combination of keywords: “technology,” “software” “apps” “playware” “edutainment,” “exergaming,” “AI games”, “robot,” “game,” “haptics,” all of which were combined with “dance,” “dancing,” “dance therapy” and also with the terms “older,” “elderly,” “frail elderly” “older-adults,” “Old-Old,” “geriatric” and “senior.”

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