A Review of Prototyping and Evaluating Approaches for Intergenerational Social Exergames Targeting Older Adults

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ABSTRACT

As society ages, social exergames may play a significant role in promoting positive and effective intergenerational communication. This review presents a comprehensive overview of social exergames that facilitate social interaction among older adults, with a particular emphasis on intergenerational communication. The paper primarily concentrates on three key areas: (1) System design, mainly including the interactive devices used and the methodologies adopted for participatory design; (2) Evaluation methods, consisting of the particulars of the user groups engaged and the approaches used for data collection; (3) Considerations for future design research. A comprehensive literature search was conducted in the ACM Digital Library, covering articles published after 2010 using specific keywords, aiming to provide an overview of empirical studies on social exergames among older adults. According to the literature search and screening strategy, eight out of 355 articles were finally identified. Our findings demonstrate that social exergames for older adults can be categorized into two primary types: (1) task-based social exergames and (2) immersive social exergames. These games incorporate interactive devices to construct the gaming system; 37.5% of these studies focused on the interaction between different generations. Age and relationship factors in generational differences play a crucial role in game design. Besides mainstream qualitative analysis such as interviews and observations, the analysis of indicators such as physiological data gradually becomes the research trend of data collection to provide more comprehensive experiments and data support. This study provides an overview of system design and evaluation methods employed in social exergames for older adults, with implications for game designers and researchers.

KEYWORDS

social exergames, older adults, social interaction, intergenerational communication, aging society

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1 INTRODUCTION

The increasing elderly population presents many new challenges to society, including not only the huge demand for healthcare and aged care but also the general problems of social isolation and insufficient social support. Thus, measures must be taken to improve their physical and mental health and social well-being as a whole. Chinese population structure development trend indicates that the aging rate will reach 14% in 2022, making it a deeply aging society. By around 2030, the aging rate will reach 20%, making it a super-aging society [1]. Researchers, healthcare professionals, policymakers, and other members of society have clearly recognized the importance of maintaining mental health and social adjustment in older age groups([2], [3]). With the rapid advancement of internet technology, society is undergoing great changes and people's lifestyles and communication habits have also changed. People in different age groups have different communication styles, needs and behaviors, etc., which sometimes lead to mutual misunderstandings in their daily interactions. Simultaneously, the stereotypes that people of different ages have about each other tend to aggravate the generation gap and sense of alienation [4], which will eventually lead to huge differences and conflicts between generations, intensifying the contradictions within the family and even in the society [5]. Thus, it is crucial to expand intergenerational communication among older adults [5], which not only alleviates their loneliness but also helps them integrate into society and improve their mental health [6].

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Exergames are a combination of "sports" and "digital games" designed to overcome barriers to physical activity and make physical activities more attractive to a diverse range of age groups [7]. Researchers have found a correlation between exergames and improvements in both physical and mental health [8]. Additionally, exergames can provide real-time feedback on physical performance, encouraging the engagement of players in individual gameplay or multiplayer cooperative competition [9].

Several studies have demonstrated the advantages and feasibility of exergames in the context of intergenerational communication [10]. Intergenerational communication through exergames can facilitate different forms of social interaction between age groups ([11–13]). Researchers have demonstrated the efficacy of intergenerational play as a mediating tool that facilitates participant generation of new topics and fosters positive interactions ([14], [15]). In turn, this helps to ease intergenerational tensions and awkward relationships, ultimately helping to strengthen family ties ([14], [15]). Additionally, experiments have demonstrated that older adults have reduced social anxiety and increased social competence after playing exergames with adolescents [16]. Researchers believe that exergames increase endorphin secretion, which in turn improves mood and induces positive social influences ([17], [18]). Moreover, sports equipment used for exergames can improve the quality of life of frail elderly individuals by promoting exercise engagement ([19], [20] ,[21]). Emerging forms of games such as Virtual Reality (VR) can also promote the physical and mental health of older adults by increasing their social participation [22]. It has also been shown that exergames can alleviate participants' mental stress [23] and improve muscle balance, promoting the physical health of older adults [24].

Previously, we conducted reviews and empirical studies of social assistance systems, with a particular focus on how exergame systems support social interactions involving older and younger players. For instance, we investigated socially assistive systems from system design and evaluation and classified 11 HCI technologies that supported social interactions for older adults and people with disabilities [25]. We also conducted a review to summarize data-gathering methods for evaluating socially assistive systems for people with special needs [26]. Aside from systematic reviews, we also designed to enhance social interaction between Older and Younger Players and at-home balance training ([27], [28]), and then recruited 18 unfamiliar young-old pairs to participate in a user experiment to evaluate this social exergame [29]. Results demonstrated that older participants perceived significantly higher social interaction than younger participants.

In this paper, a systematic review is used to search for specific research types, and specific guidelines for search methods. The similar research methods have been proposed in ([25], [26]). We reviewed the impact of social exergames and intergenerational communication and examine them from two aspects. The first aspect concerns the approaches taken in-game prototyping, exploring techniques, and game mechanisms for developing game prototypes. The second aspect focuses on the execution of experimental evaluation and data-gathering methods to assess game effectiveness and performance and analyze their contribution and value. Finally, we discussed the opportunity to design social exergames for older age groups to promote intergenerational communication. The research framework was shown in Figure 1.

2 METHOD

2.1 Search Strategy

To gain a deeper understanding of the benefits of intergenerational communication research in exergames, and the implications of these studies for game design and evaluation methods, we conducted a literature review aimed at obtaining an overview of recent empirical studies in this area, performing a search in the ACM Digital Library. The formulation of keywords mainly comes from the foundation laid by [17]. Given differences in research fields and researcher preferences, exergames can be referred to in many different forms, so the keyword set needs to include a variety of names to ensure access to all papers on the topic. We used the same reasoning to search for papers related to intergenerational communication and older populations, looking for related terms representing the same concepts. The search syntax was as follows: ("exergame" OR "Wii" OR "Kinect" OR "active video game") AND ("social support" OR "social interaction" OR "social bonding" OR "intergenerational communication") AND ("aging" OR "aged" OR "elderly" OR "older" OR "senior"). Given the development of the game will be significantly influenced by advancements in recent technologies, we added a search restriction based on a specified time range, setting "articles published after 2010" as the criterion for inclusion. In addition, the content type of articles was limited to research-based articles. This research work began in May 2022 and 281 articles were identified according to the search strategy. In July 2023 we started a new search with the same search syntax to update the articles published in 2022, and 74 articles were identified after applying the same search syntax. That was 355 articles in total.

2.2 Article Selection

(1) Exclusion Criteria

Following excluding articles that were not exergames or social games, or social games designed for older adults, we removed all theoretical articles, conceptual articles, reviews or books, articles not written in English, articles that were less than four pages, a well as duplicate reports of the same study from different sources.

(2) Inclusion Criteria

The inclusion criteria used to winnow out papers were that the paper described a system design of social exergames for older adults or included an evaluation of social exergames for older adults, or covering both. We searched extensively for social interactions, and not just intergenerational ones.

(3) Screening Results

Applying the aforementioned exclusion and inclusion criteria, two independent researchers retained eight empirical studies from the 355 articles and conducted qualitative and quantitative analyses of these studies, as shown in Figure 2.

2.3 Data Extraction

Based on the research framework of the previous systematic reviews ([24], [25]), We found that the analysis from the perspective

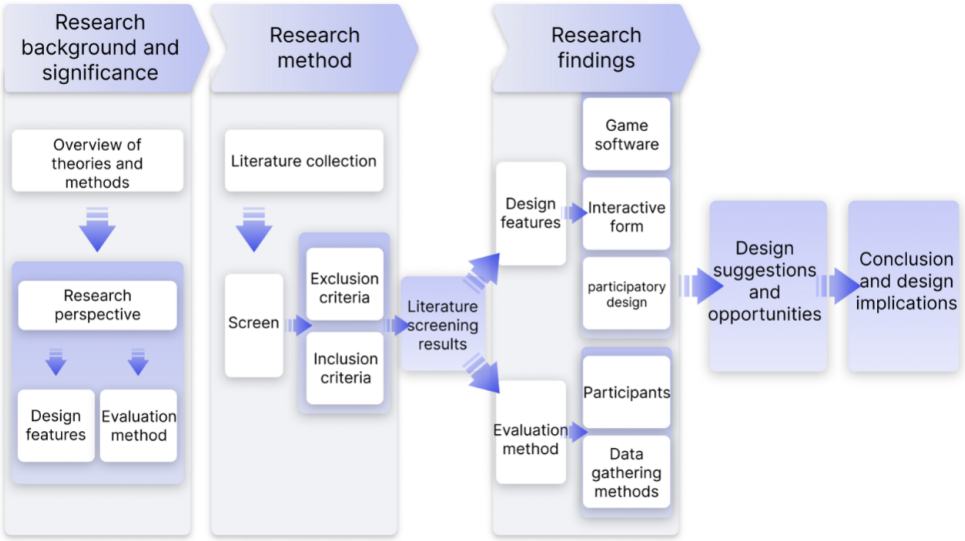

Figure 1: Overall research framework.

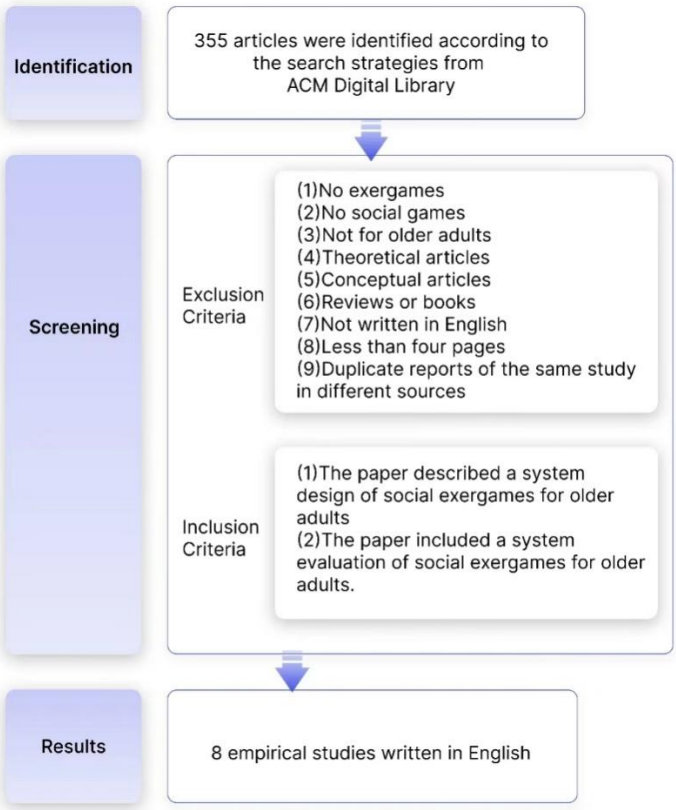

Figure 2: Flow chart of literature search and screening.

of system design can provide a comprehensive and clear understanding of the subject matter. In addition, the systematic review of the evaluation of existing research allows for a better understanding of the specific methods used in current practice and the applicability of each method, so that future researchers and developers can understand various evaluation methods and challenges to better support future research and evaluation. We analyzed the papers by the following two aspects: 1.System design was primarily centered around addressing the following three inquiries:(1) How was the game prototype developed?(2) What forms of interaction were utilized?(3) To what extent were participants engaged in the design process? 2.Evaluation methods included two key aspects:(1)What user populations were involved in these studies?(2)What data gathering methods were used?

Based on these research questions, we further divided the "system design" aspect into three distinct subsections: "game software design strategy ", "interactive devices" and "participatory design". With the comprehension of the design purposes, we developed an in-depth understanding of the elements, technique, rationale, and structure of game prototype design, so as to bolster the design practice of various concepts from "system design". Besides, we also segmented the perspective of the "evaluation method" into two separate subcategories of "participants" and "data gathering method". In this aspect, we discussed and concluded empirical research methodology and effective design verification, which can strongly support the design in this specific field of study.

3 FINDINGS

3.1 System Design

Different from traditional digital game forms (i.e., keyboard, mouse, joystick, gamepad), exergames allow players to control game prototypes through body movements. Therefore, exergame equipment typically consists of software, interactive hardware, various types of sensors, or motion recognition tracking devices, as well as some auxiliary support devices, such as displays [30]. In terms of system design, our analysis focuses on game software, game mechanics, interactive forms, technology, and the content of participatory design in the design process.

3.1.1 Game Software design strategy. Through systematic research, we summarize the existing case studies of social exergames design strategies as follows: *task-oriented games* (n=7) ([11], [19], [23], [24], [31–33]) , a game in which the player has to follow some tasks ,and *immersive experience games* (n=2) ([19], [22]), a game that is highly immersive for the player[34]. One study demonstrated a design approach that combined both forms [19]. See Table 1 for details. Since immersive games rely on virtual reality technology, which is relatively new, there are few existing studies related to this field. But due to the recent publication time of its articles, it is not difficult to see that it is a promising trend for future development.

Task-oriented games require players to complete the target tasks set by the game and appropriately engage in in-game challenges [35]. These games usually combine physical exercise in specific scenarios. For example, motion-sensing games like "Virtual Soccer," "Human Tetris," and "Mosquito Invasion" [31] involve completing game tasks through movements such as kicking, twisting,

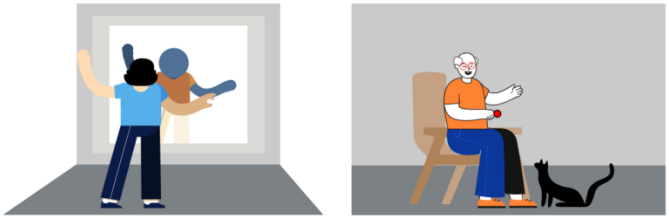

Figure 3: Exergames of "Human Tetris" [31] and "Hungry Cat"[24] (illustrations have been redrawn based on ([31] and,[24]).

Figure 4: Posture balance projection exergame, redrawn based on [32] and [33].

or raising one's arms. Additionally, physical activity can be stimulated through fun-guided methods in games such as "Walk in the City," "Hungry Cat," and "Balance" [24], which is shown in Figure 3. Some task-oriented games, such as the posture-balancing projection game designed by Mark Rice et al. [32] and the story-driven, motion-sensing plant-growing game "Xtreme Gardener" [33], set cooperative game tasks to better promote collaborative communication among multiple players. Players of both games interact directly with the projected images through graphic silhouettes and communicate and cooperate through verbal language to complete game tasks, as seen in Figure 4.

Immersive experience games typically build virtual world scenario prototypes for players, allowing them to experience physical activity and multiplayer social situations in a virtual environment. For example, in the avatar design workshop, participants played as virtual avatars and interact with other virtual avatars, stimulating the latent social abilities and interests of older adults [22]. Another game "the virtual walk", shown in Figure 5 [19], involves mini-game interactions in virtual scenes based on specific themes, creating a leisurely, communication-friendly gaming experience for older adults.

3.1.2 Game mechanisms. Social exergames are a unique category of games with game mechanisms designed to encourage social interaction and cooperation among players. In our study, we specifically focused on individuals in need of intergenerational communication, particularly older adults. We conducted an in-depth analysis of the game mechanisms of the existing cases.

(1) Game objectives and rules

In all the cases studied, the game goals of social exergames are more focused on collaboration, competition and teamwork. For example, players control their bodies together to complete sports levels ([24], [33–35]), or work together to complete team

Table 1: Game software classification

Game Type	Categories	References
Mission-based games	Sports Exercise	[11], [19], [24], [31]
	Promote cooperative communication in multiplayer games	[23], [32], [33]
Immersive experience-based games	Virtual social interactions	[19], [22]

Figure 5: Virtual walking game [19].

achievements [23], or by role-playing ([11], [19], [22]). This kind of rule design facilitate bonding between players, as players are required to work together to accomplish their goals. This is a difference from traditional single-player and competitive games.

(2) Team cooperation mechanism

Teamwork in game mechanisms often requires players to work closely together and share information and strategies to win the game. Such mechanism encourages communication, especially between players of different ages. For example, in [11], young people may play the role of captain or coach to guide older adults in their interaction strategies. In the study [23], the game customizes exclusive game stories and challenges for the eldlythrough the communication between caregivers and older adults.

(3) Social interaction function

Social exergames may provide social interaction features, such as chat systems [22] and virtual item gifting [23], [33]. Such features allow players to connect with each other and share their experiences, facilitating easier interaction for older adults.

(4) Interaction and feedback

Game interactivity and feedback mechanisms should offer players instant feedback and rewards, including winning effects triggered when players achieve certain goals ([24], [33], [34]), and level upgrades at the end of the game ([23], [35]), are also important for the appeal of social exergames. Players are able to feel that their actions affect the game's progress, resulting in satisfaction and increased social interaction.

(5) Health benefits

All of the cases in this research study emphasize that physical activity, cognitive stimulation, and social interaction can provide many health benefits that are important for health and quality of life in older adults, and more importantly, help to promote long-term social interaction and intergenerational communication.

Therefore, the main mechanisms of social exergames are found to be more focused on encouraging collaboration and friendship between players and developing their social skills, while engaging in full-body movement. This is different from therapeutic games which typically focus on physical rehabilitation and cognitive training.

3.1.3 Interactive Device. Existing exergames' interactive devices typically consist of display devices and motion input devices. Motion input devices can be further divided into motion sensors ([11], [19], [23], [24]) and motion capture cameras ([22], [31]–[33]) (including infrared depth cameras and image recognition cameras). Figure 6 summarizes the two main types of motion input devices mentioned in the selected papers.

Hardware devices often incorporate interaction modes that utilize sensors. For example, the Nintendo Wii game console is equipped with a Wii Remote controller, which allows players to interact with game characters on the display device by swinging and moving the remote control in their hand. For example, the Wii Bowling Game can be used for upper body exercise [1]. Additionally, the Wii Balance Board can be used as an input device, as in the "Silver Promenade" game [19], where the balance board acts as a sensor to detect players' walking movement, and players can walk in the virtual game by stepping on the board. Besides the built-in sensors that come with existing products, smartphones can also function as sensor devices by detecting changes in smartphone orientation during gameplay to analyze players' movements. For instance, in the exergame designed by Antonio Santos et al. [24], smartphones are placed in the pocket or held in the hand to capture the direction and quantity of players' lower and upper limbs. This function can also be realized by using business motion sensors, such as the Fitbit Alta HR activity tracking wristband [23].

Motion input devices are implemented through motion capture cameras, which typically include Kinect infrared depth cameras or network-integrated cameras. The infrared depth camera of Kinect can detect the shape of a player's body by projecting a full-size image, allowing the player to interact directly with the mirrored image in the form of graphic silhouettes. For example, in the balance posture game designed by Mark Rice et al. [32], players are required to adjust their silhouette appropriately into a separate body template for motion training. Integrated network cameras capture images in the game area through image recognition techniques to track the player's movements. As shown in Figure 7, the "Xtreme Gardener" game players' silhouette is projected through a projector and a projection screen, allowing the camera to capture images of full body movements [33].

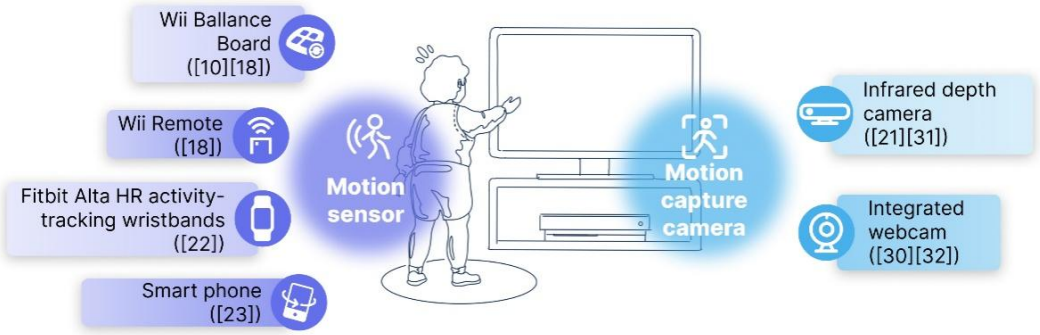

Figure 6: Two types of motion input devices are involved in the selected papers.

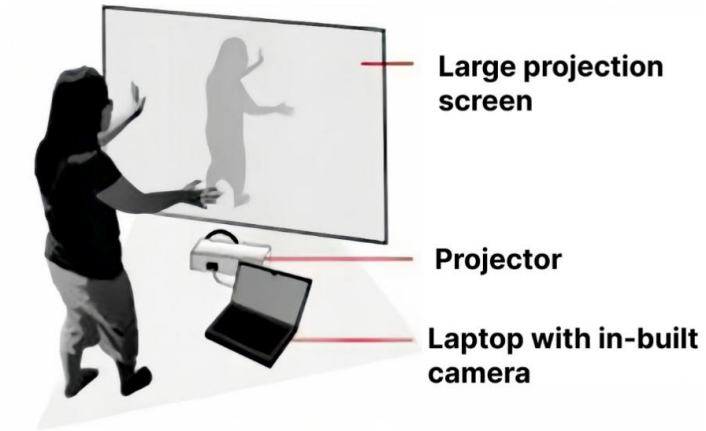

Figure 7: Motion input devices in the "Xtreme Gardener" game [33].

In addition, there is also one study [22] that have attempted to combine VR technology with social exergames, enabling older adults to control personal avatars in the virtual environment through natural gestures and communicate with each other. Anthropomorphic mapping of the player's movement into avatars' specific behaviors results in a more intuitive and engaging experience of speaking, moving, and interacting with others.

3.1.4 Participatory Design. The methods of participatory design approach are used in some game designs (n=3) ([19], [23], [31]) to enhance the usability and technical acceptability of the game. Here, participation design refers to the research method used in the prototype design phase [36], rather than the research method in the system evaluation process. The design process includes design investigation, design ideation, design verification, and the improvement of the prototypes. This design approach enables user participation in the design phase of developing new products and technologies [37]. Therefore, participatory design should include: fair forms of participation, a deep understanding of participants' practices, and attention to reflection in action [38]. Three studies used a participatory design approach, specifically incorporating observation, interviews, and questionnaires. During the design phase of the game "Xtreme Gardener" [19], researchers collected

and analyzed first-time participation data of older adults living in nursing homes through observation, questionnaires, and player performance data to evaluate the game's usability and players' performance. Mark Rice et al. used a 5-point Likert scale to measure users' physical engagement (PE), perceived ease of use (PEOU), perceived usefulness (PU), and social interaction (SI) in their research. This allows users to evaluate the usability and acceptability of game applications, including which aspects of the prototype still need further improvement. In addition, it is also possible to understand the application games that are more suitable for different age groups, as well as the advantages and disadvantages that game design can bring to users.

Furthermore, participatory design methods can also be applied in the design investigation phase. The game designers of "Go & Grow" [23] utilized a participatory design method, employing semi-structured interviews, to explore the preferences of the target users regarding the game. Additionally, this approach helped in defining the objective of the game, system interaction, and forms of social interaction in the game.

3.2 Evaluation Methods

The evaluation method is introduced around two aspects: user analysis and data collection methods, which are very important for experimental evaluation. Empirical research requires a thorough understanding of user characteristics and mastery of methods for collecting data.

3.2.1 Participants. We extracted and summarized the participants' demographic information of each study from four dimensions:

(1) Age range;
(2) Number of participants (i.e., the total number of participants, including the number of older and younger people);
(3) Relationship between participants (i.e., the relationship between older and younger people, such as strangers, family-based relationships, friends, etc.);
(4) Pre-testing (refers to collecting information on small samples of the subject population before the formal experiment, such as technical experience, physical and mental condition, etc.).

Age Range. Based on the age classification criteria for older adults [28], the age range of the older group differs across each study, as shown in Table 2. Many studies have focused primarily on older adults in the age ranges of 65-75 years (referred to as "young-old") and those aged 75 years and above (referred to as "old-old") ([19], [22–24], [31], [33]). Some studies have investigated the age ranges of middle-aged adults (60-65 years) ([31], [33]). Two studies do not set restrictions on the age of the older participants ([11], [32]).

Three studies ([11], [23], [33]) emphasized the interaction between different generations when designing social exergames. In these studies, the age range of the younger population was typically limited to the adolescent age group. For example, in the study [11], the age of the younger group ranged from 17 to 18 years, while in the study [33], the age range of the younger group was 15 to 20 years. However, there are also some exceptions. For instance, in the study [23], due to the investigation of intergenerational gaming between dementia patients and caregivers, there were fewer age restrictions placed on the caregivers. The age range of the caregivers varied from 22 to 70 years old.

Number of Participants. Three studies ([11], [23], [33]) recruited both younger and older populations as participants. The ratio of young and old adults is 1:1 so that the subjects could be paired up according to age in the experiment. For example, Theng et al. [11] recruited 28 participants (14 pairs), while Lin et al. [23] recruited 36 participants (18 pairs). In addition to this, there are also different ways of grouping. Rice et al. [33] recruited a total of 60 participants in the experiment and divided them into three groups: Young - Young group (Y-Y), Young - Old group (Y-O), and Old - Old group (O-O). Each group consisted of 20 participants divided into 10 pairs. In other studies ([19], [22], [31], [32]), only older age groups were recruited and the number of participants was controlled between 10 and 40. There was also the preliminary experiment that recruited only five older participants [24].

Relationships between Participants. In the eight studies, the participants in the experimental design can be divided into two categories according to their age: (1) the older-older group (n=5) ([19], [22], [24], [31], [32]), and (2) the older-younger group (n=3)([11], [23], [33]).

The relationship between participants was strangers in six studies ([11], [19], [24], [31]–[33]). Three of them recruited older adults who were independent dwellers ([11], [24], [32]). In addition, experimental users were recruited from nursing homes as permanent residents receiving full care, where their relationships with each other were characterized as either friends or strangers [19].

Pre-test for participants. Five studies conducted pre-test assessments on the participants. These studies generally tended to use a five-point Likert scale to gather information through a pre-test. Most of these pre-tests were utilized to acquire information on users' experience in using relevant technology (n=3) ([22], [24], [32]). Participants experience with computer technology and their expertise level in virtual reality (VR) technology, virtual worlds, and virtual avatars were gathered [22]. Participants' experience in utilizing mobile phones, internet usage, and engaging in digital games was also collected [32]. It is worth noting that studies also conducted differentiated pre-tests based on different experimental purposes and participants. The semantic differential scale by Hawkins ([11], [39]) and the intergroup anxiety scale designed by Stephan [40] were applied to collect users' attitudes and anxiety levels towards members of other age groups. Rice et al. ([11], [32]) used pre-tests to exclude participants with specific physiological or cognitive impairments, based on the health guidelines formulated by Greig et al. [41].

3.2.2 Data Gathering. Based on the study by Qiu et al. [26], we adopted seven types of data-gathering methods to evaluate social interaction systems. Similarly, in the field of social exergaming research, data-gathering methods can be classified into the following categories, as shown in Table 3.

Interview Data. Interview data was gathered from six out of eight studies. Furthermore, these 6 studies preferred semi-structured interviews and group interviews. Among them, four studies (i.e., [23],

Table 2: Age range of the older adult population.

Age range of the older adult group	References
Middle-aged (60-65 years old)	[31], [33]
Young-old (65-75 years old)	[19], [22]–[24], [31], [33]
Old-old (over 75 years old)	[19], [22]–[24]
No age limit for the elderly group	[11], [32]

Table 3: Types of data gathering methods.

Data collection methods	**References**
Interview data	[11], [22], [23], [31]–[33]
Questionnaire	[11], [19], [22], [23], [31], [33]
Observation Data	[11], [19], [22], [24], [31]–[33]
System log	[23]
User Task Performance	[19], [24], [31], [32]
Physiological data	[23], [24]

[31]–[33]) conducted semi-structured individual interviews, while three studies (i.e., [22], [31], [33]) conducted group interviews. Interviews in these studies (i.e., [22], [31], [33]) were mainly used to gather participants' feelings. For example, Rice et al. [33] conducted paired and semi-structured interviews to elicit participants' experiences and preferences concerning the prototype game, including interactive experiences during testing and the system's applicability to different age groups. For another example, interviews in [31] were conducted to acquire participants' detailed experiences and preferences, particularly regarding gameplay, interactivity, and team involvement. It is noteworthy that several studies had provided detailed descriptions of the interviews. In particular, one study conducted focus groups and offered detailed overviews of the questions used and the responses given by the participants[22]. Additionally, this study employed a stakeholder check method where the initial draft of the paper was shared with participants for their comments and feedback.

Questionnaires. A total of six studies collected data through questionnaires. Notably, two studies explicitly mentioned what standard questionnaires were used. One study [19] utilized a modified version of the Game Experience Questionnaire incorporated with a single item of ISO-Norm Questionnaire 9241/10, while the other study [8] employed the revised semantic differential scale based on Hawking's study, as well as the intergroup anxiety measure developed by Stephan.

Based on the stage of the research, questionnaires can be divided into pre-test and post-test questionnaires. Pre-test questionnaires tended to collect participants' demographic information ([22], [23], [33]), technology literacy ([22], [31], [33]), and game experience ([31], [33]). For example, Rice et al. [31] used a pre-test questionnaire to investigate participants' web browsing habits, mobile phone usage, video game playing, and engagement in physical activities. Post-test questionnaires, on the other hand, typically focused on collecting participants' experiences with the game prototype. For instance, the post-test questionnaire conducted by Pappa et al. [15] was applied to evaluate social interaction during gameplay which included cooperation (COOP), communication (COMM), and partner preferences (PARPREF), and the game's appropriateness and usability which included ease of use (EOU) and competence (COMP).

Observational Data. A total of seven studies collected observational data. Most of the observations in these studies focused on interactions between paired participants ([19], [32], [33]). Researchers in ([11], [19]) not only observed the use of controllers but also paid attention to communication between players. Furthermore, the general observation methods were video recording and researcher notes. Five studies ([11], [24], [30], [31], [32] ,[33]) mentioned the adoption of video recordings. For example, in the case of [24], researchers obtained data on gain points, pain points, and overall acceptance during participants' interactions with the system based on video records. Three studies ([11], [22], [32]) collected data by researcher notes. Meanwhile, these studies also preferred the open-coding approach in analyzing observational data. For example, studies in ([32], [33]) elaborated on the open-coding process, in which three types of codes (verbal, physical, and non-compliant) were tagged based on the level of cooperation exhibited in the dyadic interactions between young and old participants.

User Task Performance. User task performance was measured by four studies. These studies ([19], [24], [31], [32]) gathered user task performance through observations or the help of intelligent devices.

And they all set up physical activity tasks and conducted usability evaluations. Researchers in [24] collected movement assessment metrics and evaluated usability through two measurement indicators, namely the number of successful and erroneous attempts for each task. Interestingly, since these tests were, in fact, games per se, some studies took advantage of such game systems to record relevant data and participants' task performance automatically. For instance, one study [19] designed a scoring system that recorded game outcomes based on the number of times participants completed a task, and subsequently formed Player Performance Metrics to conduct comparisons between three different interactive ways (i.e., Wii remote, balance board, and hand gesture).

Physiological Data and System Logs. Some papers mentioned other methods. Two studies ([23], [24]) collected physiological data. In the study [23], Lin et al. monitored caregivers' daily physical activity via Fitbit Alta HR wristbands and developed a smartphone app to visualize the data. in the study [24], mobile phones were used to continuously collect physical movement data generated by the users during visits to designated locations. In addition, only one study collected system logs [23]. The system built in this study could record users' login times and the times of activities (e.g., story posting and replying) automatically.

4 DISCUSSION

In this section, we present several insights into the design and evaluation of intergenerational communication exergames for older adults based on the analysis of eight selected papers. We also propose new design opportunities based on the analysis. Specifically, we focus on discussing the following aspects: (1) interaction modalities, (2) game mechanisms under age differences, and (3) considerations of data gathering methods.

4.1 Insights on Interaction Modalities

In this review, the interaction devices employed in the research projects primarily include display devices and motion input devices. Notably, the utilization of motion sensors and motion capture cameras is frequently observed in the context of exergames. These studies share a common focus on prioritizing visual feedback as a design element to enhance the gaming experience and promote adherence to exercise among the older adult population. This observation also highlights the existing gap in exploring emerging interaction modalities within the realm of research. For example, VR technology was only adopted in one study [22], but it has been proven to play a crucial role in social applications for older adults. Most of the research has focused on how VR technology can be used to help with physical exercise and improve physical weakness [42]. The study [43] found that virtual social facilitation increased exercise effort among more competitive exercisers. Participants that used the VR system reported being less likely to suffer from depression [44].Some articles explored the application of VR technology in the social aspects of older adults. The study [22] investigated how can VR serve as a communication medium for older adults. McRae et al. [45] explored the use of social VR to support group reminiscence for older adults.

Moreover, the potential of multisensory interaction modalities can be further explored, such as enriching information feedback channels through auditory and emotional stimuli, thus enhancing the immersiveness and interactivity of the game. Existing studies have shown the important relationship between body balance control and multisensory. Cross-sensory information integration of the Vestibular system can generally better reduce the risk of falls [46], and audio-visual comprehensive training can enhance cognitive motor function [47] and improve concentration [48]. In addition, more immersive game design solutions are gradually gaining acceptance among older adults [49]. So multi-sensory interaction has great potential for development in fields such as sports rehabilitation training or online virtual socializing. For example, immersive interactive games can utilize the five senses, including sound, smell, and touch, to increase engagement in social topics and activity incentives. Story games provide a platform for both players to experience immersive role play, encouraging in-depth communication based on common subjects and reducing the awkwardness of icebreaking. These opportunities present valuable areas for research within the interactive games field. At the same time, improving the physical function of older adults to increase acceptance of virtual reality experiences is a pressing challenge for future developments.

4.2 Game Mechanisms under Age Differences

Within the selected papers, there is a limited number of design cases that specifically address cooperative game mechanics and task allocation in the context of users with varying ages. Only three studies emphasized the interaction between different generations when designing social exergames ([11], [23], [33]). Understanding the differences in interests and abilities between generations, as well as the social and activity preferences of the target audience, is crucial in engaging both younger and older individuals in games. It is important to identify the core factors that can promote or hinder the use of social exergames as a means of communication between people of different ages [50]. For example, certain groups possess varying abilities when it comes to comprehending the visual and perceptual elements of game media, and exhibit differences in their execution of actions and learning speed. Furthermore, playing games with different generational pairings, such as older adults with children, older adults with middle-aged individuals, and older adults with individuals from other generations, the game's settings like role-playing, reward and punishment system, and response speed may have more evident differences. Therefore, additional empirical studies are necessary in the future to assess the effects of age discrepancies in game design.

Research studies ([11], [12], [22], [31], [51]) have shown that age differences in players' technical experience can lead to disparities in gaming abilities between younger and older groups. Therefore, intergenerational game design should simultaneously satisfy usability for older players and interest for younger players. In addition, older adults face physical limitations and be affected by psychological factors such as anxiety, tension, and lack of confidence. Thus, researchers face challenges in the interaction technology, form, or interactive design of the game, and participatory design methods can be helpful in this regard.

4.3 Considerations for Data Collection Methods

In this review, we have compiled the data collection methods used in the studies. As we found in our analysis, most design studies, particularly those focusing on users' attitudes and motivations, predominantly employ qualitative analysis methods such as interviews and observations. At the same time, we identified a clear trend: an increasing number of studies emphasize accurate data metric collection. From the publication dates of the articles, we can observe that later studies ([23], [24]) have collected users' physiological data, including physical activity and exercise data obtained through Fitbit Alta HR wristbands or smartphone sensors. Collecting such data helps games provide better sensory feedback and body movement detection. Digital quantification allows for a more intuitive mapping of game usability or intervention effectiveness, which can better support innovation in combination with various fields such as exercise rehabilitation or medical health, providing more comprehensive experimental data for design researchers.

4.4 Limitations and Future Work

This review has several limitations. Firstly, this study' sample is small and the study only searched for empirical research written in English and was only limited to the ACM database, which may have overlooked valuable literature written in other languages or other databases. To improve the completeness and comprehensiveness of the research, future studies can expand the literature search and screen from more databases and an article that searched across multiple databases will be written. In addition, as social exergames involving intergenerational communication are a relatively new research area, there are currently few studies focusing on this direction. To ensure a comprehensive understanding of this research area, we chose to maintain a broad focus, encompassing all types of interactive games, intergenerational relationships, and age ranges for older adults. However, from a more subdivided perspective, there are different research of games designed for different user groups, and different interactive forms of the game. Further consideration of the classification or comparative analysis of different studies is needed. In our future research, we can conduct a more specific targeted analysis to provide more accurate theoretical support for different types of designs.

5 CONCLUSION

This article provides an overview of social exergames for intergenerational communication among older adults. In this review, we analyzed eight articles from two main aspects: system design and evaluation methods.

In terms of system design, games based on social and exercise aspects often take the form of task-based and immersive experiences, combined with interactive devices to construct the game system. The most common interactive devices consist of display devices and motion input devices, with the latter adopting emerging technologies such as motion sensors, motion capture recognition, or VR. These technologies demonstrate great potential for future development and are worth further investigation. Nearly half of the game designs employed participatory design methods, where the target users' involvement in "participatory design" can help design researchers improve and refine the game's interaction technology, format, and interactive design experience.

At the same time, new technologies are more accessible to young people, so we can explore the following ways to increase older people's acceptance of this new form of gaming:

(1) Offer user-friendly interface: when developing a game, it is vital to ensure that the user interface is simple and easy-to-navigate that includes options for large fonts and high contrast. This helps older adults understand and use the game more easily.
(2) Provide tutorials and training: online or offline courses can be offered to help older adults learn quickly.
(3) Encourage intergenerational interaction: families, communities or schools should work together and hold activities to foster older adults's acceptance of technology.
(4) Highlight the health benefits of social exergames: these benefits are essential for the health and well-being of the older adults.
(5) Personalize gaming experience: older adults should be able to choose the difficulty level and game mode that best suits their needs and ability levels..
(6) Provide feedback and rewards: Real-time feedback and rewards can encourage older adults to participate in the game. The use of a point system, achievements, and rewards can enhance their motivation.

Regarding evaluation methods, we extracted and summarized information on user groups from four dimensions. Most experiments were divided based on users' age and relationships, with three studies specifically focusing on interactions between different generations. Age and relationship factors in generational differences play a crucial role in game design. In terms of data collection, we employed seven types of methods for analysis and evaluation. In addition to mainstream qualitative analysis methods such as interviews and observations, the collection of physiological data indicators can provide more comprehensive experimental data support.

In summary, this study reveals the commonalities and characteristics of existing research on social exergames for intergenerational communication among older adults. It proposes design suggestions and new design opportunities for social exergames targeting this group and explores the possibilities of game content and interaction and experimental evaluation for designers and researchers. This study provides valuable insights into clear approaches and methods for future experiment design for social exergames.

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