Advance Access publication on 6 January 2021
doi: 10.1093/iwc/iwaa026

Systematic Review of Design Guidelines for Full-Body Interactive Games

Sruti Subramanian[1,*], Nina Skjæret-Maroni[2] and Yngve Dahl[1]

[1]*Department of Computer Science, Norwegian University of Science and Technology, NTNU Sem Sælandsvei 9Gloshaugen, NO-7491 Trondheim, Norway*
[2]*Department of Neuromedicine and Movement Science, Norwegian University of Science and Technology, NTNU Edvard Griegs gate 8, NO-7491 Trondheim, Norway*
**Corresponding author: sruti.subramanian@ntnu.no*

This paper provides a systematic review of research articles published between 2010 and mid-2018 that have offered design guidelines for full-body interactive games for recreational purposes and physical exercise. From an initial 3562 retrieved database references, 22 articles were found to meet our predefined criteria and were included in the final review. The review of 22 articles resulted in the extraction of 107 design guidelines, which were grouped in 12 different categories: *movement elicitation*, *mapping of movement*, *explicit movement guidance*, *player representation and game world*, *attention*, *feedback on player performance*, *player agency and customization*, *exertion*, *safety*, *universal design* and *social aspects*. While the current body of guidelines was found to cover multiple aspects pertaining to the design of full-body interactive games, the conducted review also revealed a number of overarching concerns regarding the present state. Specifically, these concerns relate to (i) the hedonic–utilitarian divide in movement-related design guidelines of relevant literature, (ii) the lack of common structure for specifying guidelines, (iii) the lack of systematic development of guidelines, (iv) the issues related to the validity of the existing guidelines and (v) the limited focus on tangible interfaces in the present state of the art. In conclusion, the current review paints a somewhat questionable picture of the present state of the corpus of design guidelines for full-body games, with relatively large differences in the quality of the guidelines proposed in the individual articles and a lack of reference to already existing guidelines. In the longer run, these quality issues risk watering out the original meaning of the term *design guideline* and reducing the potential value design guidelines can offer in development of full-body interactive games.

RESEARCH HIGHLIGHTS

- There is a wide variety of design guidelines for full-body games. Existing guidelines generally aim to support the design of full-body games either for entertainment or for rehabilitation/preventive training purposes.
- Most design guidelines for full-body games have been derived from the studies of screen-based games.
- The lack of a common structure for design guidelines for full-body games and the apparent non-systematic development of the existing guidelines make it particularly challenging to build a structured network of guidelines that can be easily extracted and navigated.
- The current literature review paints a somewhat questionable picture of the present state of the corpus of design guidelines for full-body games, with relatively large differences in quality and a lack of reference to already existing guidelines.

Keywords: full-body games; exergames; design guidelines; game design

Handling Editor: Ian Oakley

Received 19 June 2020; Revised 1 October 2020; Accepted 16 November 2020

1. INTRODUCTION

The past two decades have given rise to entirely new gaming concepts where players are encouraged to use their entire body when playing. As such, movement-based or *full-body* interactive games stand in sharp contrast to traditional device-controlled computer games, where the player's body largely remains idle during gameplay. This development was to a large extent propelled by commercial gaming consoles such as Microsoft Kinect®, Nintendo Wii® and Sony PlayStation®.

By utilizing the body as a medium for interaction and putting the body at the center of the user experience, full-body games open up new and rich interactive possibilities. The fun and playfulness many associate with games and gaming, combined with the health benefits of physical activity, are making full-body games applicable for potentially multiple purposes, ranging from leisure (Nijholt *et al.*, 2010) to more 'serious' objectives such as improved mental, social and physical health and well-being (Li *et al.*, 2018; Rosenberg *et al.*, 2019; Staiano and Calvert, 2011). However, full-body games present interaction, and game designers, with challenges where existing design knowledge falls short. For example, Höök (2018) proposes a shift in interaction design toward a more experiential, felt and esthetic stance that reincorporates body and movement into the design regime. Others, such as Bamparopoulos *et al.* (2016) and Plow *et al.* (2011), argue that realizing the potential health benefits of such games also requires extensive knowledge about the physical functioning of the body. The latter argument emphasizes that successful design of full-body applications often requires multi-disciplinary skills (Wiemeyer *et al.*, 2015).

The design and use of full-body games have gained increased attention in human–computer interaction (HCI) and other fields of computer science over the previous decade. Within HCI, this growing interest reflects in many ways the paradigm shift in the field toward embodied interaction (Dourish, 2001) and the increased focus on physical and bodily aspects of the interaction this shift has entailed (Konrad *et al.*, 2003; Mueller *et al.*, 2019; Svanæs, 2013). A potentially important indication of a maturing body of knowledge on the design of full-body games is the increasing number of published works offering design guidelines or recommendations for best design practice. According to Nowack (1997), a design guideline is '*a prescriptive recommendation for a context sensitive course of action to address a design issue*'. Fu *et al.* (2016) offer a similar definition also highlighting the basis on which the design guidelines are derived: [*A design guideline is a*] *context-dependent directive, based on extensive experience and/or empirical evidence, which provides design process direction to increase the chance of reaching a successful solution*.

Drawing on the above definitions, then, a design guideline, as understood in the context of this work, is an explicit, experience-based or empirically grounded advice on how a designer can or should go about to accommodate factors that have been identified as important for a design solution to meet certain domain-specific goals or standards. As such, design guidelines can be considered to form an intermediary interface between the designer and user interface design knowledge (Huhn, 2010). Nowack (1997) suggests that a design guideline should contain the following parts: a description of the issue or issues addressed or impacted, the links to design context, the action recommendations and a rationale. Within HCI, Shneiderman's (1997) recommendation to *offer informative feedback* is an example of a well-known guideline for the design of interactive user interfaces. Shneiderman (1997) elaborates his recommendation as follows: '*The user should know where they are at and what is going on at all times. For every action there should be appropriate, human-readable feedback within a reasonable amount of time. A good example of applying this would be to indicate to the user where they are at in the process when working through a multi-page questionnaire. A bad example we often see is when an error message shows an error-code instead of a human-readable and meaningful message*.' While easily accessible and comprehensible descriptions of what-to-do and how-to-do are key criteria of usable design guidelines (Cronholm, 2009), the format and elaborateness of design guidelines may vary considerably.

The primary value of design guidelines lies in their potential to provide empirically based directions for the design of future solutions by allowing practitioners to draw on the (sometimes hard-won) experience of others. As such, guidelines have played an important role in multiple design disciplines, including architecture and building design (Brittin *et al.*, 2015), product design (Telenko and Seepersad, 2010), software architecture design (Robbins *et al.*, 1998) and of course HCI. With respect to the lattermost, the guidelines offered by Nielsen (1993), Norman (2013) and Shneiderman (1997) are examples of well-established and highly acknowledged 'rules of thumb' in the design of graphical user interfaces (GUIs). These guidelines are part of the current HCI curriculum at most universities that offer an HCI program. Design guidelines continue to form one of the key contributions of HCI studies (Abascal and Nicolle, 2005; Benyon, 2013; Gong and Tarasewich, 2004;

Stephanidis *et al.*, 1998), including studies investigating the design and use of full-body games (Amershi *et al.*, 2019; Rossmy and Wiethoff, 2019).

With the growing body of design guidelines for movement-based games, it is becoming increasingly challenging to have an overview of the current design knowledge and what aspects of the design the existing guidelines cover. The overall aim of this study is to synthesize and provide a systematic review of the existing design guidelines for interactive games that require players to use their full body to achieve the game objectives. In this review, we refer to this type of interactive games as *full-body* games. Our study has involved three main steps.

- *Mapping of relevant studies*: first, we mapped existing studies that have produced design guidelines of relevance for full-body games. This involved identifying and comparing key characteristics of the studies from which the guidelines were derived.
- *Grouping and review of design guidelines*: second, we grouped the guidelines offered in the corpus of relevant studies according to what aspects of the design the guidelines covered. An extensive description of each category and its associated guidelines are provided in the review.
- *Identification and discussion of key concerns*: based on the mapped studies and the guidelines they proposed, the review identifies and discusses a set of key concerns regarding the status quo of the design guidelines for full-body games.

The article is structured as follows. In Section 2, we describe what we mean by *full-body interactive game* as the term is understood in the context of this work. Section 3 accounts for the applied method, that is, how we conducted the literature review. Section 4 describes and characterizes the articles. Section 5 accounts for the results of the mapping and review process. In Section 6, five key concerns emerging from our review are presented. Section 7 presents the methodological considerations before conclusions are drawn in Section 8.

2. DEFINING FULL-BODY GAMES

This review focuses on the design guidelines for *full-body interactive games* for recreational purposes and physical exercise. Before we continue, we first need to establish more precisely how the term is understood in this article. Addressing the latter part of the term first, we have adopted Salen and Zimmerman's (2004) definition of what a game is: *a game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.* Our focus is on *interactive* (full-body) games, meaning that we take into consideration only games in which players interact with their bodies through computer technology.

The term *full-body*, or *whole-body* (Koštomaj and Boh, 2009), is ambiguous and has been used to denote a number of interactive games that encourage and/or respond to a range of body motions in players, often involving combinations of multiple body parts (e.g. arms, hands, legs, feet and torso). In the current work, we use the term to refer specifically to body movements that are *weight-bearing*. A medical definition of weight-bearing body movement was provided by MacKelvie *et al.* (2002). To be weight-bearing, according to the authors, motions must be part of a structured, force-generating activity that provides loading to skeletal regions above that provided activities of daily living. We found this definition to be particularly helpful in deciding whether a movement-based or body-controlled game qualified as a full-body game. For example, a clapping game (Sheridan, 2010), which only encourages and responds to hand and finger movements of an otherwise immobile player, does not qualify as a full-body game, since such a game does not involve loading (of body weight) to skeletal regions. Similarly, serious games for hand rehabilitation (Elnaggar and Reichardt, 2016) and games played while being seated (Hernandez *et al.*, 2012) do not qualify for the same reason. Moreover, interactive games that only provide very rough responses to a player's physical movements, and where the game design remains largely ignorant to the specific body movements that go into resolving the game challenge (e.g. *Into* (Ahtinen *et al.*, 2010), *UbiFit garden* (Consolvo *et al.*, 2008), *myFitnessCompanion* (Leijdekkers and Gay, 2013) and commercially available mobile games such as *Pokemon Go*® and *Zombies, Run!*®), also fall outside our definition. While a player may employ weight-bearing body movements while playing such games, the designer-intended goal of such applications is more toward promoting general physical activity, or exertion, in players rather than eliciting certain body movements.

While all full-body games use sensor technology to infer aspects of players' body movements, we do not consider full-body games to be restricted to any particular type of sensor technology. As such, full-body games may employ sensor technologies ranging from simple step pads (as in the stepping game *Dance Dance Revolution*) to advanced 3D motion capturing cameras (e.g. Schönauer *et al.*, 2011). Likewise, we do not consider full-body games to be limited to any particular output medium. While many full-body games provide visual output to players via a display such as a TV screen, there are also examples of full-body games that do not make use of screen-based output. The vertigo game *Balance Ninja* (Byrne and Marshall, 2016) is an example of these.

3. METHODS

The volume of research on the design and use of full-body games is continuously growing. For the individual practitioner or researcher, this growth makes it increasingly challenging to remain updated or critically evaluate and synthesize the state of existing relevant knowledge. Within many scientific disciplines, literature reviews have become indispensable tools for anyone who wants to keep up with the research 'frontier' and for identifying areas where the existing evidence is insufficient. Due to the lacking scientific rigor of traditional narrative reviews, there has been a significant increase in computer science over the recent years, including HCI (Clark *et al.*, 2019; Doherty and Doherty, 2019; Hornbæk and Hertzum, 2017; Nunes *et al.*, 2015), in the number of published reviews that follow formal and structured methods, also known as *systematic literature reviews* (SLRs). The rigor associated with SLRs is reflected in their capability to produce explicitly formulated, reproducible and state-of-the-art summaries of research relevant to a particular research question, area or phenomenon of interest. In the context of full-body games, the SLR thus forms a key tool for providing an overview of the 'best practice' when it comes to design, as SLRs bring together and combine findings from multiple relevant studies.

3.1. Databases and search terms

The papers included in the review were collected on 2 July 2018 using five major databases: ACM, Scopus, Engineering Village, PubMed and Web of Science. As such, we collected data material from search engines indexing articles both within technically and medically oriented sciences. Our main rationale for including PubMed, a medical science database, was that initial queries revealed that relevant work has not been indexed by the other databases.

The query we used to collect data from the beforementioned databases was constructed iteratively, meaning that we used the results from initial queries, that is, specific terms used in the index articles and the studies they referenced, to expand our search string. Through the process, we learned that a relatively wide variety of terms are used in the literature to describe the applications that we understand as full-body games, for example, movement-based game, motion-controlled game, exertion game, serious game and different variations of the listed terms. Hence, we found it necessary to include a wide variety of synonyms for full-body game in our final search string. Similarly, we found a relatively wide range of synonyms used to describe guidelines in relevant literature, for example, considerations, suggestions and recommendations. These terms were often used in combination with design or development, for example, design considerations or guidelines for the development of movement-based games. Multiple keywords related to the three distinct categories, *game*, *activity* and *design knowledge*, were included in the search string. Since one of the key intentions with the review was to map as much as possible of the existing body of design guidelines for full-body games, we did not include any domain-specific terms in the search string. This has resulted in a broad range of design guidelines and different focal points of the corresponding studies included in the review. This issue is further discussed in later sections of the article. Table 1 shows the list of search terms that were used to construct the final query.

TABLE 1. Search terms.

Game	Activity	Design knowledge
Exergam*	design*	consideration*
Exertion gam*	develop*	recommend*
Multimodal gam*		guideline*
Exertion video gam*		suggestion*
serious gam*		strateg*
exercise gam*		lessons
movement-based gam*		
motion-control gam*		
motion-controlled gam*		
motion-based gam*		

Given the large variety in the nomenclatures used in relevant literature to describe the design guidelines for full-body games, we ended up with a relatively extensive search string. The full final query, including boolean operators (AND, OR) and truncations (denoted by an asterisk) can be found in Appendix 2.

The syntax of the query was adapted to the specific format of each database. Further, based on available search options, an advanced full-text search was performed in the ACM database, while an advanced title/keyword search was conducted in the PubMed database and a title/abstract/keyword search was conducted in the Scopus, the Engineering Village and the Web of Science databases. The decision to use a relatively extensive search string meant that we increased the possibility of finding articles relevant to the topic of the review within the corpus of articles returned by the query.

3.2. Selection process

To guide the selection of studies that were to be part of the review, we used a protocol that, in addition to the search string, contained specific inclusion and exclusion criteria (see Table 2 for a detailed description). The database search identified 3562 studies of potential interest. As part of an initial screening process (conducted by the first author), duplicate records, non-peer-reviewed studies, non-English articles, systematic reviews, books/dissertations and articles with less than 5000 words such as extended abstracts (1816 studies) were eliminated from the corpus. Next, the title, abstract and keywords of the remaining 1746 articles were carefully examined independently by all three authors to identify articles offering design guidelines or recommendations for full-body games as a key scientific contribution, which further eliminated 1704 studies. A consequence of using such an inclusion criterion is that any article providing relevant design guidance in its body text, but whose abstracts does not explicitly state design

TABLE 2. Inclusion/exclusion criteria.

Inclusion criteria	Exclusion criteria
Articles *explicitly* offering design recommendations or guidelines for *full-body games* as a key scientific contribution of the described study or studies	Non-English articles
	Systematic reviews
	Articles with less than 5000 words (i.e. short papers and extended abstracts)
	Overlap of identical guidelines described by the same authors in different articles (in such cases only the most extensive work was included)
	Books and dissertations
	Non-peer-reviewed articles

guidelines (or recommendations or similar synonyms; Table 1) to be a scientific output from the described study, has been excluded from our review. Hence, the inclusion or exclusion in the final review was strongly dependent on the phrasing of the abstract of an article and whether or not design guidelines appeared to form a key contribution of the described study. For example, the clause, ‘*Based on our studies, we present seven guidelines for the design of full-body interaction in games*’, which appears in the abstract of a study described by Gerling *et al.* (2012), clearly met our inclusion criteria. In comparison, Bianchi-Berthouze’s (2013) article, which proposes a model for player engagement in full-body games did not meet our criteria. The abstract of the article states ‘*Finally, I conclude by considering how the proposed model could lead to a more systematic and effective use of body movement for enhancing game experience*.’ While the statement suggests that the article conveys design knowledge of potential relevance for the development of full-body games, the abstract does not suggest that this is in the form of prescribed recommendations. In cases where the abstract of an article raised uncertainty whether design guidelines formed a scientific output, the body of the article was examined.

Trade-offs resulting from selection processes such as the above are unavoidable in SLRs. Hence, and as further discussed in the *Methodological Consideration* in Section 7, the current literature review should by no means be regarded as a *complete* summary of a relevant guidance for the design of full-body games produced in 2008–10 but as a review of central parts of that body.

Studies that provided only the design methodological guidelines (for example, how to include people with Parkinson’s disease in design activities; McNaney *et al.*, 2015) were not included in the review. Disagreement about the eligibility of a study was resolved by full-text screening conducted by all three authors and resolution in a subsequent consensus meeting. As part of the title and abstract screening, 1704 studies that did not comply with the inclusion criteria were excluded. The remaining 42 papers were then independently assessed in full text by three authors (the first author assessing all papers and the second and third authors assessing 21 different papers), yielding a total of 22 studies that were included in the review. In the final round of assessment, the study by Byrne and Marshall (2016) was excluded as the offered guidelines were not for the design of full-body games but for the design of digital vertigo games. Furthermore, the conference paper by Mueller and Isbister (2014a/b) was eliminated due to the overlap of identical guidelines with their journal paper (Isbister and Mueller, 2015), which was included in the review. Figure 1 illustrates the described selection process.

3.3. Analysis

The 22 articles included in the final review were read in full by the first and the second or third author. Data on aim, study design, participants, intervention and game and game technologies were extracted from the included studies. Details regarding game and game technology included game system and game objective, I/O technology and mapping of movements performed during gameplay and design-intended movements. Details relating to study design included data collection and duration (Table 5).

The design guidelines and the rationale proposed in the individual articles were iteratively coded for themes. The set of papers in the final review were read again by all the authors and as new papers were added, new codes were created, renamed, removed or rearranged, to match the categories suggested by all studies included up to that moment. In cases where we found different codes being used to describe the same feature, we selected the code providing the most precise description. Papers were read multiple times in order to ensure newer codes included all studies in the review. For example, the following design criteria provided by Gerling *et al.* (2010) was coded as two design guidelines with corresponding rationales in two different themes, *mapping of movement* and *feedback on player performance* (Tables 7 and 12): ‘*Due to the target audience’s lack of previous gaming experience, games should focus on simple interaction mechanisms and provide the player with constructive criticism to avoid frustration and foster an enjoyable player experience*.’ Comparative analysis was a driving principle in our analysis, forcing us to categorize the different studies and guidelines and thereby leading us to reflect on what the data were telling us. As the classification of the studies and guidelines became clearer, they were iteratively discussed among all the three authors of the paper. The analysis was only complete as the final version of this article was ready for submission, as the categorization was further refined during the writing process.

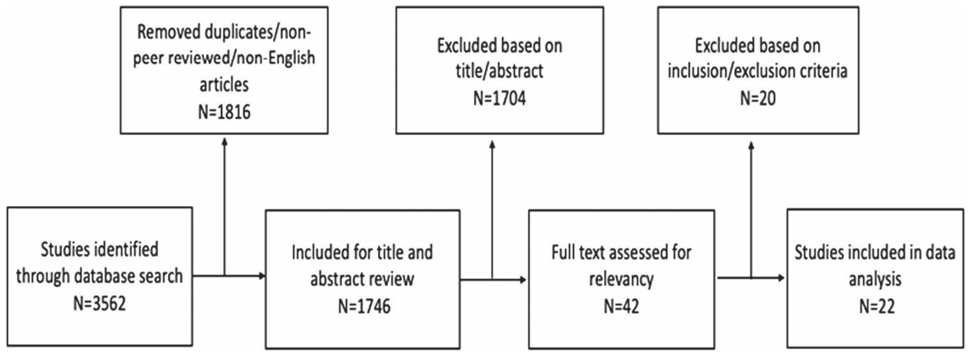

FIGURE 1. Flowchart over study selection through different phases of the review.

TABLE 3. Study design of the included papers.

Study design	No. of studies	Studies
User evaluation/ usability test	12	Thin and Poole (2010), Gerling *et al.* (2012), Skjæret *et al.* (2014), Zaczynski and Whitehead (2014), Harrington *et al.* (2015), Jensen *et al.* (2015), Wiemeyer *et al.* (2015), Jensen and Grønbæk (2016), Richards and Graham (2016), Pyae *et al.* (2016a,b, 2017)
Action research	2	Velazquez *et al.* (2013, 2017)
Semi-structured interview	1	Isbister and Mueller (2015)
Group discussion	2	Brox *et al.* (2017), Wiemeyer *et al.* (2015)
Comparative study	1	Altimira *et al.* (2014)
Randomized control trial	1	Uzor and Baillie (2014)
Empirical feasibility study	1	Fernandez-Cervantes *et al.* (2018)
User-centered design	2	Brox *et al.* (2017), Nawaz *et al.* (2014)
Qualitative field study	1	Barenbrock *et al.* (2014)
Focus group tests	1	Gerling *et al.* (2010)
Brainstorming workshop	1	Jensen *et al.* (2015)

4. CHARACTERIZING THE ARTICLES OF THE REVIEW

The final corpus of papers in the review comprised 22 studies (see Table 3 for an overview). The initial list of studies identified through the database search covered 22 years of research, with studies published since 1996. However, the earliest article included in the final review was published in 2010 (Gerling *et al.*, 2010).

The included studies were published in a number of different venues. In total, there were 13 conference papers, 8 journal papers and 1 book. The most common venues for the conference papers were ACM conferences, with eight papers, followed by IEEE conferences, with two papers. The remaining three conferences (ITAP, WIS, REHAB) and a book published by Springer provided one study each. The most common venue for the journal papers was *Gerontology*, with two studies. The remaining studies were published in *Human–Computer Interaction*, *Games for Health*, *Pervasive and Mobile Computing*, *Entertainment Computing*, *JMIR Serious Games* and *Journal of Usability Studies*. This also reflected in a broad range of study designs as illustrated in Table 3. Usability tests were opted by as many as 12 studies, while the other study designs were not used by more than 2 studies. The gaming interventions were carried out either in laboratory settings or at nursing homes with a duration of gaming lasting from a few minutes only (e.g. Jensen and Grønbæk, 2016) to intervention studies with several weeks of gaming (e.g. Uzor and Baillie, 2014) or in user-centered design projects with years of follow-up (e.g. Brox *et al.*, 2017; see Table 5 for details).

In the 22 included studies, the sample size ranged from 4 to 50, with a mean of 20 participants. In total, 14 of the included studies focused on older adults, of which the aim of 11 studies (Barenbrock *et al.*, 2014; Brox *et al.*, 2017; Fernandez-Cervantes *et al.*, 2018; Gerling *et al.*, 2010, 2012; Nawaz *et al.*, 2014; Pyae *et al.*, 2016a,b, 2017; Velazquez *et al.*, 2013, 2017) was to focus on understanding the exergaming experience among older adults and provide relevant guidelines for exergame design for the senior population. The other three studies (Harrington *et al.*, 2015;

TABLE 4. Overview of the games.

	Purpose		Sensor technology						Game(s)
	Entertainment	Rehabilitation/ prevention	Pressure mat	Inertial sensors	Wii	Kinect	Webcam	N/P	
Gerling *et al.* (2010)		•			•				Customized balance game
Thin and Poole (2010)	•		•		•				Commercial dance and sport games
Gerling *et al.* (2012)		•				•			Customized gesture-based game
Velazquez *et al.* (2013)	•							•	Commercial sport games
Altimira *et al.* (2014)	•				•				Commercial sport game
Barenbrock *et al.* (2014)	•				•	•			Commercial sport, dancing and virtual twister games
Nawaz *et al.* (2014)	•	•				•			Commercial sport, fitness and balance games
Skjæret *et al.* (2014)		•	•			•			Commercial stepping games
Uzor and Baillie (2014)		•		•					Customized fantasy fall rehabilitation games
Zaczynski and Whitehead (2014)	•				•				Commercial yoga game
Harrington *et al.* (2015)		•				•			Commercial puzzle and fitness games
Jensen *et al.* (2015)	•			•					Customized handball game
Jensen and Grønbæk (2016)	•			•					Customized handball game
Pyae *et al.* (2016a)		•					•		Customized skiing game
Pyae *et al.* (2016b)	•			•		•	•		Commercial sport games
Richards and Graham (2016)		•				•			Customized muscle strengthening game
Brox *et al.* (2017)		•				•			Customized fantasy game
Pyae *et al.* (2017)		•					•		Commercial skiing game
Velazquez *et al.* (2017)	•				•	•			Commercial sport games
Fernandez-Cervantes *et al.* (2018)		•				•			Customized gym game

N/P indicates not provided.

Skjaeret *et al.*, 2014; Uzor and Baillie, 2014) focused on the usability of Kinect-based games, the movement characteristics and the long-term use of exergames for older adults, respectively. Of the remaining eight studies, six (Altimira *et al.*, 2014; Jensen and Grønbæk, 2016; Jensen *et al.*, 2015; Richards and Graham, 2016; Thin and Poole 2010a/b; Zaczynski and Whitehead, 2014) focused on younger adults and the studies by and the studies by Isbister and Mueller (2015) and Wiemeyer *et al.* (2015) focused on providing age-neutral design guidelines for full-body games and recommendations for designing exergames for people with disabilities, respectively.

The intended exercise movements were not specifically mentioned in several of the studies. However, based on the games used in the studies, we were able to extract these details for most of the studies (see Table 5 for references). Of the 22 studies, 2 studies (Isbister and Mueller, 2015; Wiemeyer *et al.*, 2015) were based on semi-structured interviews and group discussions with game design experts, respectively. The remaining 20 studies provided design guidelines based on an evaluation of either one or more games. Of these 20 studies, 10 used commercially available games such as the Nintendo Wii games, *SilverFit* games and *Dance Dance Revolution*, while the remaining studies designed their own games according to the needs of their individual study. With the exception of three studies (Jensen and Grønbæk, 2016; Jensen *et al.*, 2015; Uzor and Baillie, 2014), the remaining studies made use of commercially available gaming technology such as the Microsoft Kinect, webcam or Nintendo Wii consoles. All the games used in the included studies were screen-based games that employed either a monitor or a TV screen. Table 4 provides an overview of the games used in the 20 studies that have explicitly evaluated full-body games. The table illustrates details such as the overall purpose of the game(s) (i.e. entertainment or

TABLE 5. Overview of the included studies.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample characteristics
Gerling *et al.* (2010)	To discuss chances and challenges of game design for an elderly audience	*SilverBalance* exertion game prototype with two balance tasks—Task 1: avoid falling obstacles; Task 2: avoid possible collisions	Screen, balance board, mapping of feet	Weight shift movements	Focus group test at a nursing home in Germany, observations; N/P	Older adults; N = 9; A: 77–91; M = 84
Thin and Poole (2010)	To investigate the level of physical exertion required to play three different dance-based exergames and assess the interaction between gameplay factors and exercise intensity on the level of enjoyment that players experience while playing the exergames	G1: *dancing stage*: to step on defined areas of the mat and shake hands to a choreographed sequence shown on the screen G2: *step aerobics*: to perform stepping movements to a choreographed sequence G3: *hula hoop*: requires players to rotate their hips in a coordinated manner as fast as possible to accumulate as many revolutions as possible in the time limit	Screen, pressure mat, Wii's hand-held motion sensitive controllers, balance board, mapping of feet	Arm and leg movements, stepping movements	User evaluation, ambulatory gas analysis system, questionnaires; N/P	University students; N = 11; M = 20 ± 2
Gerling *et al.* (2012)	To develop game design guidelines for full-body motion controls for older adults experiencing age-related changes and impairments	'*Gardening game*': to stand on one leg or walk in place (to grow plants). If players are seated, plants automatically grow. Lift or wave one arm (to grow flowers). Extend one or both arms to the side or wave both arms (to make the flower bloom). Move hand (to catch a bird).	Screen, Kinect, stick figure, mapping of arms and legs	Set of static and dynamic gestures	E1: user evaluation of gesture-based tutorial and E2: gesture-based game in a nursing home; questionnaires, sensor-based metrics, observations; N/P	Institutionalized older adults; E1: N = 15 (7 females, 8 males); A: 60–90; M = 73.72 ± 9.90 E2: N = 12 (5 females, 7 males); A: 60–91; M = 76.7 ± 10.6

Continued

TABLE 5. Continued.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample characteristics
Velazquez *et al.* (2013)	To develop insights for the design of full-body motion-control exergames for older adults experiencing age-related changes addressing problems raised by their motion capacity	Various movement-based games, N/P	Screen, N/P	Various movements (e.g. jog, walk, throw)	Action research study, literature reviews, interviews, experiencing (field notes, observations, diaries, photographing), inquiring (focus groups, informal face-to-face and questionnaires) and examining (attendance data, test scores and encoding video files); 6 months	Specialists in aging; N = 18 healthy older adults; E: N = 18; A: 63–82; M = 70
Altimira *et al.* (2014)	To measure player engagement after applying balancing adjustments to a digital table tennis game and the traditional table tennis game	Wii Tennis, table tennis, N/P	Screen, Wii hand-held controller, N/P	Tennis movements (swing, sideward movement)	Comparative study, questionnaires, interview; N/P	18+ that had previously played the traditional table tennis; N = 46 (9 females, 37 males); A: 19–43; M = 26.7 ± 4.9

Continued

TABLE 5. Continued.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample char-acteristics
Barenbrock *et al.* (2014)	To discuss our qualitative findings and formulate design lessons to consider when developing games for older adults	G1: *Mario Kart*: to win the race and shoot opponents. G2: *Table Tilt*: to navigate marbles into a hole. G3: *Wii Bowling*: to throw bowling balls to knock pins. G4: *Wii Tennis*: to hit the tennis balls. G5: *Groove On*: to synchronize their motions with the beat of the music. G6: *Ski Jump*: by leaning forward at the right time and keeping the balance, the player can control his/her avatar. G7: *Soccer Heading*: standing on the Wii balance board, the player has to change his/her balance to keep the ball from the goal. G8: *Dance Central*: to imitate dancing moves as demonstrated by a virtual avatar G9: *20,000 Leaks:* the player tries to close virtual 'holes' at different locations with hands, feet or other parts of the body	Screen, Kinect, Wii (Wiimote, nunchucks, balance board, steering wheel), N/P	N/P	Qualitative field study at home, questionnaires, interviews; 3 days	Healthy older adults; N = 4; A:71–86 (2 females, 2 males)

Continued

TABLE 5. Continued.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample characteristics
Nawaz *et al.* (2014)	To design and evaluate an exergame concept developed to fit the need and preferences of elderly users	G1: Skiing and tennis in Kinect sports: N/P G2: YourShape: Fitness Evolved: N/P G3: *Fruit Ninja*: players use their arms like a ninja to slice fruit that is thrown up into the air G4: *Out in Nature*: different obstacles in the nature trail: (i) jump from rock to rock to get over the river, (ii) walk over the log lying across the path, (iii) duck under the branch hanging over the path, (iv) get over the lake by rowing the boat, (v) balance on the log to get over the river, (vi) walk on the rocks lying on the path.	Screen, Kinect, simple avatar mapping	Challenge players' muscle strength and balance	User-centered design with elderly, focus group interviews; N/P	Older adults; W1: N = 7 W2: N = 5; M = 70.6 ± 7.9
Skjæret *et al.* (2014)	To investigates game elements and older players' movement characteristics during stepping exergames	G1: *Dance Dance Revolution*: hitting targets (arrows) and avoiding obstacles (bombs) G2: *the mole from SilverFit*: hitting targets (moles and mice) and avoiding obstacles (ladybug) G3: *LightRace in YourShape*: hitting targets	Screen; G1: step pad; no avatar, no mapping, G2: Kinect; simple avatar, mapping of feet, G3: Kinect; humanoid avatar, mapping of player's body	Stepping exercises	Laboratory-based user evaluation of three games; video observation; G1: 3 min, G2: 2 min, G3: 1 min	Older adults; N = 14 (9 females, 5 males); A: 65–85; M = 73 ± 5.7
Uzor and Baillie (2014)	To explore long-term use of exergames for fall rehabilitation in homes	G1: *Pigeon Express Game*: hit target (fruits falling out of the back of a moving van) G2: *River Gems Game*: hit target (colored gems that comes toward the game character) G3: *Panda Peak Game*: march on the spot in optimal speed (making a panda walk across a log) G4: *Horse Hurdles Game*: the objective of the game is to jump over as many hurdles as possible	Screen; inertial motion sensors; G1: pigeon; mapping of sit-to-stand movements G2: game character; mapping of side-stepping motions G3: panda; mapping of on-the-spot marching G4: Horse; mapping of bending and standing up movements	Strength and balance exercises	Randomized controlled trial, exercise diaries, functional walking, questionnaires, interviews; 12 weeks	Older community-dwelling adults older than 65 years who had at least one fall 12 months prior to taking part in the study; group 1: N = 8 (7 females, 1 male); M = 75 Group 2: N = 8 (6 females, 2 males); M = 76

Continued

TABLE 5. Continued.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample characteristics
Zaczynski and Whitehead (2014)	To examine several issues including adapting for occlusion and lack of visibility, learning and orientation, and providing feedback to develop a set of design recommendations	*Wii Fit Yoga*: to repeat yoga poses demonstrated by the virtual yoga instructor	Screen, Wii balance board, Avatar with mapping of player movements	Yoga poses	User evaluation, feedback, interviews; N/P	Young adults; E1: N = 20 (10 females, 10 males); M = 30 ± 7 E2: N = 20 (9 females,11 males); M = 29 ± 5
Harrington *et al.* (2015)	To evaluate the usability challenges of Kinect-based exergames for older adults	'Body and Brain Connection' and 'Your Shape Fitness Evolved', N/P	Screen, Kinect, complete avatar with mapping of full body movements	N/P	Usability test of two Kinect-based games, questionnaires, interviews; E: 1.5–3 hours	20 healthy older adults; N = 10 (5 females, 5 males) A: 60–69; M = 66.2 ± 1.40 and N = 10 (5 females, 5 males); A: 70–79; M = 74.6 ± 2.72
Isbister and Mueller (2015)	To collect design guidelines for movement-based games	N/A	N/A	N/A	Semi-structured interviews with movement-based game design experts in person/Skype; 1 hour	Movement-based game design experts; N = 14
Jensen *et al.* (2015)	To investigate how game elements can affect the training experience	*The bouncer*: the Bouncer is similar to traditional handball training, where the players would run toward goal and shoot to score. The bouncer forces the players to make decisions in air based on their perception.	Screen; 3×3 meter rebounder frame mounted with 8 sensors to detect the impact of balls with an estimated 10 cm accuracy; no avatar, no mapping	Handball related movements (running, jumping, throwing)	Brainstorming workshop with students; user study with three games; semi-structured interviews, audio/video recordings; 60–90min	Handball players and students; N = 10 (2 females and 8 males); A: 24–27; M = 25

Continued

TABLE 5. Continued.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample characteristics
Wiemeyer *et al.* (2015)	To develop recommendations for design, evaluation and application of exergames in therapy, serving as potential guidelines for researchers, developers, and therapists	N/A	N/A	N/A	Group discussion with experts in exergame design; N/P	Individuals with expertise in the field of exergames in prevention and therapy (i.e. the authors of the article), N = 7
Jensen and Grønbæk (2016)	To compare three approaches of balancing the game: a physical, an explicit digital, an implicit digital balancing approach	*The bouncer*: hitting virtual elements displayed on the physical rebounder	Screen; The 3×3 meter rebounder frame is mounted with 8 sensors to detect the impact of balls with an estimated 10 cm accuracy; no avatar, no mapping	Throwing	User study/evaluation, interviews, audio/video recordings; each game lasted 1 min and 40 seconds	Young adults; N = 24 (11 females, 13 males) divided in 12 pairs; A: 14–54; M = 27 ± 11.5
Pyae *et al.* (2016a)	To investigate Japanese elderly participants' feedback toward the usability of the Skiing Game, and to investigate their game experiences during and after the gameplay.	*Skiing game*: to move both hands forward and backward to ski, while moving the body left and right to avoid obstacles	Screen; webcam; N/P	Double pole skiing movements	Usability test; Questionnaires, Interviews; 45 min	Older adults from nursing homes; N = 24; A: 60–85
Pyae *et al.* (2016b)	To understand game design guidelines, the usability of Kinect, commercial and non-commercial games	G1: *puuhas* sport wall game, G2: *Xbox* climbing game, G3: *Playstation* tennis game; N/P	Screen; G1: webcam, G2: Kinect, G3: handheld sensors; N/P	Side swaying, sit to stand, light jump	Usability test of three games in an elderly service home in Finland; questionnaires, feedbacks; E1:45 min, E2: 1 hour	Healthy older adults residing/visiting service homes; E1: N = 8; A: 64–78 E2: N = 5; A: 60+
Richards and Graham (2016)	To investigate methods for enhancing agency in repetitive motion exergames while still meeting these rigid constraints	*Brains & Brawn–Strategy card game*: the player has a fixed number of turns to defeat their opponent by reducing all enemy characters' health to zero	Screen; Kinect; no avatar, no mapping of movements	Muscle strengthening exercises (bicep curl, shoulder press, squats)	Laboratory-based user study; questionnaires, semi-structured interviews; N/P	Students; N = 8 (2 females, 6 males); A 17–25; M = 21

Continued

TABLE 5. Continued.

Study	Aim	Game and game objective	I/O technology and mapping of movement	Design-intended movements	Study design, data collection and duration	Sample characteristics
Brox *et al.* (2017)	To record lessons learned in 3 years of experience with exergames for older adults	GameUp-project developed games; N/P	Screen; Kinect; N/P	Balance, flexibility, strength	User-centered design: interviews, semi-structured interviews, observations, group discussions; gathered every second week for 3 years	Older adults from a senior center; N = 16; A = 66–95; M = 80
Pyae *et al.* (2017)	To investigate the Finnish elderly people's user experiences in playing a digital game-based exercise called 'The Skiing Game'	*Skiing game*: to move both hands forward and backward to ski, while moving the body left and right to avoid obstacles	Screen; webcam; N/P	Double-pole skiing movements	Usability test in an elderly service home in Finland; questionnaires, interviews, observations; 2 days (45 min)	Older adults; N = 21; M = 76
Velazquez *et al.* (2017)	To understand how the exertion experience in commercial exergames can be personalized to the individual condition of each older adult	Various movement-based games (e.g. Kinect sports, bowling, tightrope, walking out); N/P	Screen; Wii, Kinect; N/P	Customized movements for users based on their health	Action research study; experiencing (field notes, observations, diaries, photographing), inquiring (focus groups, informal face-to-face, and questionnaires) and examining (attendance data, test scores and encoding video files); E1:32 weeks, E2: 24 weeks (total = 8 months)	Older adults; E1: N = 22 (12 females, 6 males); A: 63–82; M = 70 E2: N = 50 (37 females, 13 males); A: 58–92; M = 71
Fernandez-Cervantes *et al.* (2018)	To provide set of practical guidelines relevant to design of Kinect-based exergames for older adults	*VirtualGym*: follow instructions and mimic the movements of a virtual coach avatar (standing in front of the user's translucent shadow avatar). Corrections are provided graphically.	Screen; Kinect; shadow avatar (partly transparent silhouette) seen from rear	Set of six different exercises: (i) arms to the side, (ii) arms to the sky, (iii) side bends, (iv) overhead press, (v) waist rotation, (vi) standing on one foot	Empirical feasibility study; questionnaires, interviews; 2×20 min session (separated by 3 weeks)	Older adults (with no mobility issues) from community dwelling and assisted living facilities); N = 10; A: 68–91; M = 79 ± 6.8

N/A indicates not applicable; N/P, not provided; N, number of participants; E, experiment; A, age range; M, mean age; G, game.

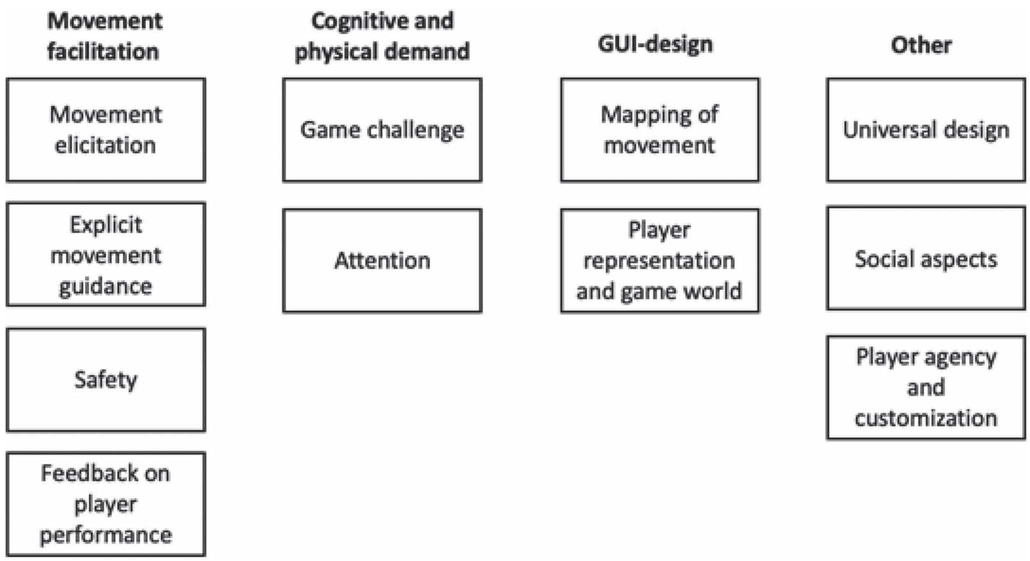

FIGURE 2. Categories of design guidelines grouped into four overarching classes.

rehabilitation/preventive training), the type of sensor technology used and the genre of the games corresponding to the individual studies. Table 5 further provides an elaborate overview of all the included studies.

5. DESIGN GUIDELINES

Based on the iterative coding process explained in Section 3.3, the design guidelines were classified into 12 categories: movement elicitation, mapping of movement, explicit movement guidance, player representation and game world, attention, game challenge, feedback on player performance, player agency and customization, exertion, safety, universal design and social aspect. Figure 2 shows the 12 categories divided into four overarching classes of design guidelines: movement facilitation, cognitive and physical demand, GUI design and other.

Tables 6–17 present an overview of the categorization, describing relevant guidelines (with a unique identifier for later reference), their rationales and the study context and the evaluated game (or games) from which the guidelines were derived. The phrasing of each design guideline is similar to the way the guidelines are presented in the original source, except for supplementary words (in brackets) added to present the guidelines in a clear and consistent manner.

This section presents the guidelines corresponding to the various categories in separate tables (6–17), followed by an explanation of the individual guidelines pertaining to each category.

5.1. Movement elicitation

Table 6 presents the guidelines corresponding to *movement elicitation*. This category includes guidelines describing movement characteristics that a full-body game, depending on its purpose, should promote, along with suggestions as to how desirable movement characteristics can be encouraged through the use of various game mechanics. Guidelines describing movements that should be avoided also fall under this category.

The guidelines in Table 6 highlight the importance of unrestricted or non-choreographed player movements. Specifically, Isbister and Mueller (2015) recommended that movement-based games should support freedom in the way players chooses to use their body when playing (DG 1.3), as self-expression might increase the fun of gaming. Further, providing rhythm can be beneficial in supporting player movements (DG 1.5), as many players find it easier to move to a beat. Isbister and Mueller (2015) also argued that, rather than forcing players to perform movements with great precision, a movement-based game should be designed to embrace ambiguity of movement (DG 1.4), as employing sensor technology to detect fine-grained movements is likely to frustrate players and inhibit their gaming experience.

Studies that focused on games for older adults also found that the players preferred motion-based interactions that felt natural and easy to perform (Pyae *et al.*, 2016a,b, 2017). When designing for older adults, providing simplicity and familiar action to elicit movements is recommended (DGs 1.1 and 1.2). Typically, the types of physical activities most popular among older adults are of lower intensity, such as walking, gardening, golf and other low-impact aerobic activities performed as part of their daily life activities in and around their home (Jørstad-Stein *et al.*, 2005). However, having games that consist of repetitive movements (DG 1.11) might be less interesting as this might become monotonous (Pyae *et al.*, 2017) and, hence, could demotivate further play.

TABLE 6. Guidelines for movement elicitation.

1. Movement elicitation				
Guideline		Rationale	Study context	Game(s)
1.1	[Provide] controller-free natural movements (Pyae *et al.*, 2016a,b)	Suitable for the elderly players because of its simplicity and ease-of-use	Usability test with healthy older adults in an elderly service home/health promotion center	Customized skiing game; commercial sport games
1.2	[Provide] familiar game actions (Pyae *et al.*, 2016b, 2017)	Participants enjoyed performing familiar game actions	Usability test with older adults in an elderly service home/health promotion center	Commercial sport games; customized skiing game
1.3	Support players in expressing themselves using their bodies (Isbister and Mueller, 2015)	Playing a movement-based game is a form of self-expression	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
1.4	Embrace ambiguity of movement, instead of fighting it (Isbister and Mueller, 2015)	Trying to force [movement] precision may only frustrate the player and make the limitations of the sensor obvious in a very un-fun way	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
1.5	Help players identify rhythm in their movements (Isbister and Mueller, 2015)	Movement is rhythmic and becomes easier with a beat	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
1.6	Elicit weight-shift (Skjæret *et al.*, 2014)	Displacing center of mass is important for balance as a fall prevention exercise	Laboratory-based user evaluation with older adults	Commercial stepping games
1.7	Provide temporal variation (Skjæret *et al.*, 2014)	Offering adaptive changes in speed is important for fall prevention	Laboratory-based user evaluation with older adults	Commercial stepping games
1.8	Promote step length variation (Skjæret *et al.*, 2014)	Offering variation in task is a fall prevention exercise	Laboratory-based user evaluation with older adults	Commercial stepping games
1.9	Elicit variation in movement directions (Skjæret *et al.*, 2014)	Stepping in different directions is a fall prevention exercise	Laboratory-based user evaluation with older adults	Commercial stepping games
1.10	[Provide] a model based on evidence-based therapy (Uzor and Baillie, 2014)	To promote ideal quality of movement for effective therapy	Randomized control trial with community dwelling older adults	Customized fantasy fall rehabilitation games
1.11	[Avoid] repetitive game action (Pyae *et al.*, 2017)	Repetitive game action is less interesting	Usability test with older adults in an elderly service home	Customized skiing game
1.12	[Beware of] unsuitable physical actions (Pyae *et al.*, 2016b)	Some physical actions are not suitable for the safety of elderly players	Usability test with healthy older adults in an elderly service home	Commercial sport games
1.13	[Beware of] unadvisable movements (Brox *et al.*, 2017)	Various health issues may make some movements unadvisable	Usability test with older adults in a senior center	Customized fantasy game
1.14	Avoid sudden or extensive movements (Gerling *et al.*, 2010)	To consider the age-related physical limitations in older adults	Focus group test with older adults in a nursing home	Customized balance game

Drawing on the above, design recommendations with regard to elicitation of movements appear uniform across all ages and should generally enhance natural movements and facilitate variation of movements through gameplay.

While some of the reviewed studies (Isbister and Mueller, 2015; Pyae *et al.*, 2016a,b, 2017) have focused on promoting general activity through movement-based games, other studies have considered full-body games used in the context of therapy or specific exercise for older adults. Uzor and Baillie (2014) considered full-body games used in the context of therapy and recommended that designers pay specific attention to ways of promoting movement that are effective in such regard. The authors provided a general guideline advising designers to model games based on evidence-based therapy (DG 1.10), eliciting desirable movement characteristics such as range and pace of motion through an appropriate reward (scoring) system.

Similarly, Skjæret *et al.* (2014) offered four movement-specific guidelines specially intended to support the design of full-body stepping games for balance training in older adults. The study highlighted how promotion of weight-shift in players is important for balance training (DG 1.6) and that full-body games used in this context therefore should constantly urge players to transfer body weight from one foot to the other; for instance, by employing stepping targets that players will intuitively attempt to press down rather than just touch or tap. Furthermore, Skjæret *et al.* (2014) recommended a temporal variation in stepping games by offering adaptive changes in game speed based on either the players' movement abilities or the accuracy of their performance (DG 1.7). The authors also suggested that a stepping game should be designed to vary in step length (DG 1.8) and movement direction (DG 1.9), which can be achieved by providing stepping targets at different distances from the player and in different locations in the playing area.

Comparing the guidelines advocating freedom of movement (Isbister and Mueller, 2015; Pyae *et al.*, 2016a,b) with guidelines for games aiming to serve specific health purposes (e.g. balance-training in older adults; Skjaeret *et al.*, 2014), one apparent distinction is the extent to which the latter tend to focus on promoting specific movement characteristics. This does not necessary mean that the health-oriented design guidelines require a strict choreography of player movements (thus conflicting with many of the guidelines proposed by Isbister and Mueller, 2015, and Pyae *et al.*, 2016a,b). Existing studies (Subramanian *et al.*, 2019) suggest that the same movement characteristic may be achieved also by opening up for various ways to accomplish movement-related tasks in full-body games.

When designing specifically in the context of older adults, there are also recommendations regarding game-related movements that should be discouraged in a game. Even though several people are living longer and healthier lives, the number of disabilities increases considerably with age, and above the age of 65 years, most people have more than one chronic condition that needs to be taken into consideration when designing games for this population (Wolff *et al.*, 2002). For instance, Pyae *et al.* (2016b) and Brox *et al.* (2017) advised game designers to be mindful of unsuitable movements that can be harmful for the older players (DGs 1.12 and 1.13) as they often may have physical and cognitive challenges that will affect their possibility to move during gameplay. Similar concerns about the potential negative effects that game-related movements can have on the players' health were raised by Gerling *et al.* (2010). They advised game designers to avoid provoking sudden or extensive movements that may be unsuitable for the users (DG 1.14).

5.2. Mapping of movement

Guidelines under the category *mapping of movement* offer advice on how the players' body movements should be represented within the game during gameplay. Table 7 presents the extracted guidelines corresponding to the mapping of movements. In most of the full-body games described in the reviewed studies, player movements are usually mimicked by means of a virtual representation of the player, that is, an *avatar* (Klevjer, 2006). The following guidelines address different concerns related to the mapping of player body movements.

Full-body interactive games allow movements to be mapped in a wide variety of ways. Isbister and Mueller (2015) suggested that game designers should take advantage of this opportunity and map movements imaginatively, including using ways that are not possible in real life (DG 2.1). Being creative in the mapping process is considered to provide players with fantasy-fueled opportunities. Likewise, Richards and Graham (2016) recommended decoupling physical movements from avatar movements, arguing that doing so opens space to various design possibilities (DG 2.2). However, decoupling movements might only be advisable while designing a fantasy game and not for a real-world sports experience. Jensen *et al.* (2015) emphasized that the challenge in designing training games is choosing an appropriate level of sensing as game input to facilitate interaction between players and the game (DG 2.7) while ensuring sports relevance and allowing for engaging interactions. They also underlined that designing training games where every movement is sensed and dictated by the system will affect the players' engagement negatively and perhaps curtail the players' opportunity to experiment with different strategies that are important in a sport setting.

In contrast, Gerling *et al.* (2012) state that when designing specifically for older adults, it is necessary to provide natural mappings and clear instructions that support gesture recall to empower players (DG 2.3). Games designed for older adults should also focus on simple interaction mechanisms to avoid frustration and to promote an enjoyable player experience (DG 2.4) (Gerling *et al.*, 2012) and be simple but effective enough

TABLE 7. Guidelines for mapping of movement.

2. Mapping of movement				
Guideline		Rationale	Study context	Game(s)
2.1	Map movements in imaginative ways (Isbister and Mueller, 2015)	To offer players fantasy-fueled opportunities that they do not otherwise have	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
2.2	Decouple physical movement from avatar movement (Richards and Graham, 2016)	Such mapping can be unsafe or inappropriate for many exercises.	Laboratory-based user study with university students	Customized muscle strengthening game
2.3	[Provide] easy gesture recall (natural mapping with clear instructions) (Gerling *et al.*, 2012)	Many older adults have no previous gaming experience and are dependent on assistance while playing.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
2.4	Focus on simple interaction mechanism (with respect to gameplay) (Gerling *et al.*, 2010)	Older adults often lack previous gaming experience	Focus group test with older adults in a nursing home	Customized balance game
2.5	[Promote] simple but effective gameplay (Pyae *et al.*, 2016a,b)	To improve users' ability in exercising	Usability test with healthy older adults in an elderly service home	Customized skiing game, commercial sport games
2.6	Classify gamers' motion capacities during gameplay (Velazquez *et al.*, 2017)	The classification was demonstrated to be useful at programming exertion time.	Exergaming interventions and focus groups with older adults in a hospital	Commercial sport games
2.7	Choose an appropriate level of sensing (Jensen *et al.*, 2015)	The challenge when designing training games is choosing the appropriate level of sensing for game input while ensuring sports relevance and allowing for engaging interactions.	Brainstorming workshop and user study with students at a sporting resort	Customized handball game

to improve the players' ability to do exercises (DG 2.5) (Pyae *et al.*, 2016a,b).

Furthermore, Velazquez *et al.* (2017) suggested classifying gamers' motion capacities during gameplay, as it was demonstrated to be useful at programming exertion (DG 2.6). Though it is already known that motion capacity must be assessed before starting any physical exercise, the authors established an elaborate classification method that includes not only an arcs assessment but also a simple test of strength and balance aimed at obtaining a more accurate profile of a gamer's motion capacity.

The differences in guidelines for how to represent players' body movements within the game during gameplay shows the importance of designing and adapting full-body games to the players at hand, being young adults gaming for specific sport exercise or institutionalized older adults. Decoupling movements (DG 2.2) and imaginatively mapping of movements (DG 2.1) may be motivating for younger adults or active and healthy older adults; however, for adults with reduced physical and/or cognitive capacity, natural mappings (DG 2.3) may be preferable to motivate and activate the players.

5.3. Explicit movement guidance

Table 8 presents various guidelines for *explicit movement guidance*. These guidelines are related to the use of explicit intended instructions informing players on *how* and/or *when* to move their bodies while playing full-body games. The guidelines consist mainly of how movement instructions should be provided during gameplay and include recommendations about what mode of delivery to use (e.g. visual or auditory).

Interestingly, both younger and older adults stated that movement guidance in full-body games should not be delivered by text on screen only. Zaczynski and Whitehead (2014) observed that the young adults participating in their study preferred verbal delivery about how and when to move their bodies during gameplay. The authors stated that descriptive verbal delivery had a significant impact on the players' understanding and pose accuracy, whereas the absence of verbal delivery was considered inadequate by the participants. Based on this rationale, the authors emphasized on providing multimodal demonstrations that include providing accurate verbal delivery as a supplement (DGs 3.3 and 3.4) to textual guidance, as the latter often led to confusion.

TABLE 8. Guidelines for explicit movement guidance.

3. Explicit movement guidance				
Guideline		Rationale	Study context	Game(s)
3.1	[Provide] in-game instructions (Pyae *et al.*, 2017)	Participants stated that in-game instructions made the game easy to understand and play.	Usability test with older adults in an elderly service home	Customized skiing game
3.2	Use animation instead of texts and figures (Uzor and Baillie, 2014)	Users got bored of reading text and animated movements were more effective than static images.	Randomized control trial with community dwelling older adults	Customized fantasy fall rehabilitation games
3.3	[Provide] multimodal demonstration (Zaczynski and Whitehead, 2014)	Descriptive verbal delivery had a significant impact on players' understanding and pose accuracy	User evaluation with healthy young adults	Commercial yoga game
3.4	Provide verbal delivery as supplementary (Zaczynski and Whitehead, 2014)	The use of direction (i.e. left and right) in descriptions often caused confusion	User evaluation with healthy young adults	Commercial yoga game

Similarly, both Pyae *et al.* (2017) and Uzor and Baillie (2014) found that providing clear in-game instructions are important in games designed for older adults (DGs 3.1 and 3.2). Uzor and Baillie (2014) modeled their study by replacing heavy text-based instructions with image-based instructions, as the users felt that they became bored reading texts. Being bored might, however, not be the only reason for replacing text. As visual impairment is common in older adults, and the prevalence increases with age (Congdon *et al.*, 2004), providing pictures might be a more beneficial way of proving instructions for this age group. Providing verbal delivery as a supplement might also be valuable for older adult (as suggested in Zaczynski and Whitehead, 2014), having in mind that approximately one-third of persons older than 65 years are affected by disabling hearing loss (WHO, 2012).

5.4. Player representation and game world

This section describes the guidelines concerning the design of the virtual game world, that is, the screen-based representation of the game setting, and how the players are represented within this world (i.e. what the player *is* within the game world). Table 9 presents guidelines corresponding to this category of *player representation and game world*.

In game design, it is rather challenging to translate physical elements into a digital representation within the game world and Jensen *et al.* (2015) stated that it is important to maintain relevance when doing so (DG 4.4). The authors stated that a literal translation, such as a simulated goalkeeper, poses several technical difficulties for the game to be perceived as a useful tool for training. Hence, the authors suggested choosing an abstract representation that provides designers with more freedom to utilize game mechanics and elements in the design. In contrast to Jensen *et al.* (2015), Fernandez-Cervantes *et al.* (2018) suggested designing more human-like avatars without much detail but with elements of an older appearance, when designing for older adults (DG 4.1). The authors recommended doing so based on findings of their empirical feasibility study, in which the older adults involved in the study did not appreciate fantasy or cartoon-like avatars but rather preferred more simply shaped humanoid avatars.

Providing visual demonstration and cues, however, seems to be important regardless of age. Zaczynski and Whitehead (2014) recommended that instructions should begin by establishing a clear orientation environment (DG 4.3). Based on a yoga game used in their study, the authors observed that several users missed an entire demonstration as they were too engaged in identifying which hand or foot to use. Hence, establishing a clear orientation environment, for example, by facing the virtual instructor away or toward the user, or providing visual cues such as a yoga mat would allow users to mentally clarify the relationship between their own body and the instructor, which is particularly important when performing complicated poses. Likewise, Pyae *et al.* (2016b) found that providing effective visual cues would enable elderly players to pay more attention to gameplay, which further enabled the players to easily understand and succeed with game tasks (DG 4.2) (Pyae *et al.*, 2017).

Furthermore, the study performed by Barenbrock *et al.* (2014) and Pyae *et al.* (2016a) revealed that participants mainly enjoyed games that offered them the opportunity to do sports or other real-world activities that they enjoyed doing in the past (DG 4.6). Similarly, Nawaz *et al.* (2014) also recommended providing a game story that is close to the real-life activities of older adults as the senior participants in their studies suggested real-life activities for the game design.

TABLE 9. Guidelines for player representation and game world.

4. Player representation and game world				
Guideline		Rationale	Study context	Game(s)
4.1	Avatars should be anthropomorphic, without much detail but with elements of an older appearance (Fernandez-Cervantes *et al.*, 2018).	The senior participants involved in the study preferred simple humanoids.	Empirical feasibility study with healthy older adults at home	Customized gym game
4.2	Provide effective visual cues (clear orientation environment) (Pyae *et al.*, 2016b, 2017)	Visual cues are important for elderly players to pay closer attention to their gameplay and easily understand how to succeed in-game tasks.	Usability test with healthy older adults in an elderly service home	Commercial sport games, customized skiing game
4.3	[Provide] clear orientation of the environment (Zaczynski and Whitehead, 2014)	Establishing a clear environment orientation to clarify the relationship between one's own body and the game is important with complicated poses	User evaluation with healthy young adults	Commercial yoga game
4.4	Maintain relevance when translating physical elements into digital representation (Jensen *et al.*, 2015)	Designing poses a great challenge of extracting relevant elements from a sport and choosing an appropriate type of representation without reducing the sport relevance.	Brainstorming workshop and user study with students at a sporting resort	Customized handball game
4.5	Utilize both physical and digital domains (Jensen and Grønbæk, 2016)	Design packages that suits different player pairs, as participants did not prefer one specific balance mechanism	User study with people aged 14–54 years at a sporting resort	Customized handball game
4.6	[Provide] reality-based game mechanics/ideas (Barenbrock *et al.*, 2014; Pyae *et al.*, 2016a; Nawaz *et al.*, 2014)	Participants preferred performing real-world activities that they had enjoyed in the past	Qualitative field study at home with healthy older adults; user centered design with older adults	Commercial sport, fitness, dancing, balance and virtual twister games; customized skiing game

Another challenging aspect is balancing mechanisms within the game, for which Jensen and Grønbæk (2016) recommended utilizing both the digital and physical domains by fusing balance mechanisms and providing players with choices, since the participants did not prefer a specific balancing mechanism (DG 4.5). The authors also recommended designers to design for different player pairs, such as brothers, father–daughter and others.

Adding a social factor to a game is often perceived as one of the advantages with gaming, and promoting a social interaction is an area in which full-body games can excel. As games are generally popular among all age groups, they can be used to encourage different generations to play together. Hence, DG.4.5 might be utilized across all ages and with different constellations.

5.5. Attention

The reviewed articles provided several guidelines that concern the players' attention and awareness during gameplay, as presented in Table 10. Many of the guidelines in the *attention* category address how designers can deal with cognitive issues that full-body games may give rise to.

When designing full-body games, Isbister and Mueller (2015) recommended not overloading players with too much feedback during gameplay (DG 5.1) as moving can create a high cognitive load, particularly when learning new movements. As Table 10 shows, most papers that deal with the players' attention and awareness during gameplay concern older adults.

Learning new movements requires a great deal of concentration and focus, which can compete with the attention needed

TABLE 10. Guidelines for attention.

5. Attention				
Guideline		Rationale	Study context	Game(s)
5.1	Consider movement's cognitive load (Isbister and Mueller, 2015)	Moving can demand a lot of mental attention, creating high 'cognitive load' especially when learning new movements	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
5.2	[Consider/provide] appropriate reaction time (Barenbrock *et al.*, 2014; Brox *et al.*, 2017)	The game speed needs to be appropriate so that players have enough time to react.	Qualitative field study at home with healthy older adults; usability test with older adults in a senior center	Commercial sport, dancing and virtual twister games; customized fantasy game
5.3	Provide visual independency (Skjæret *et al.*, 2014)	The focus of player during gameplay should be on the exergame activity or task and not on where to place the feet to make a correct step.	Laboratory-based user evaluations with older adults	Commercial stepping games
5.4	Simplicity is key (Fernandez-Cervantes *et al.*, 2018)	Elements that serve only entertainment purposes can be distracting	Empirical feasibility study with healthy older adults at home	Customized gym game
5.5	Games should be developed with attractive and user-friendly interfaces that are not complex and are easy to interpret (Harrington *et al.*, 2015)	Minimizing the amount of information presented on a single screen allows older adults to better perceive information	Laboratory-based usability test with healthy older adults	Commercial puzzle and fitness games
5.6	Important information must come after gameplay (Brox *et al.*, 2017)	Older adults have only one focus of attention	Usability test with older adults in a senior center	Commercial fantasy game
5.7	[Provide] simple and uncluttered user interface (Pyae *et al.*, 2016a,b, 2017; Nawaz *et al.*, 2014; Wiemeyer *et al.*, 2015)	Elderly people prefer simple and uncluttered user interfaces so that they can play the game without distractions.	Usability test with healthy older adults in an elderly service home/health promotion center; workshops with older adults in a senior center; group discussion with experts in exergame design for persons with disabilities	Commercial sport, fitness and balance games; customized skiing game
5.8	Focus attention on effective movements (Velazquez *et al.*, 2013)	Older adults need to reduce the intensity of motion to focus their attention on effective movements.	Action research study with specialists in aging and healthy older adults	Commercial sport games
5.9	The primary focus should be on movement quality without too much distraction (Nawaz *et al.*, 2014)	Senior participants wanted to know why to do the different tasks and what kind of training benefits the games could give them beyond entertainment.	Workshops with older adults in a senior center	Commercial sport, fitness and balance games
5.10	Provide more audio and visual feedback with less text (Pyae *et al.*, 2016b)	To ensure that elderly players pay attention	Usability test with healthy older adults in an elderly service home	Commercial sport games

to understand the provided feedback (Spelmezan *et al.*, 2009). Fernandez-Cervantes *et al.* (2018) found that elements that only serve the purpose of 'entertainment' can be distracting and hence state that simplicity is key (DG 5.4). Based on their own guidelines, the authors modified their game 'VirtualGym' from a fantasy setting into a simple, spacious and minimalist yoga studio that proved to be more efficient.

Harrington *et al.* (2015) stated that games should be developed with attractive and user-friendly interfaces that are not complex but rather easy to interpret (DG 5.5). The authors stated that minimizing the amount of information presented on a single screen will allow older adults to better perceive information, thereby making instructions easier to follow. In addition, Brox *et al.* (2017) realized that none of the older adults were aware of the information about the gameplay such as scores and time left while they were playing, irrespective of the size of the information, until the game stopped and hence recommended displaying important information after gameplay only (DG 5.6). Likewise, Nawaz *et al.* (2014), Pyae *et al.* (2016a,b, 2017) and Wiemeyer *et al.* (2015) stated that when designing games for physical rehabilitation, the game interface should be simple and uncluttered, as this was well received by the elderly players (DG 5.7). Pyae *et al.* (2016b) further recommended providing more audio and video feedback instead of text to ensure that the elderly players pay attention (DG 5.10).

Another important aspect to consider when designing for older adults is the decrease in reaction time. In the study by Barenbrock *et al.* (2014), participants identified games as hard to play when they were either too fast or did not allow enough time to react. Hence, the authors suggested providing appropriate time to react (DG 5.2). Similarly, Brox *et al.* (2017) stated that players need time to understand and process the information given to plan an appropriate movement reaction. Also, Velazquez *et al.* (2013) stated that older players require longer time to engage with games and be guided through game mechanics. They suggested that senior players instead should reduce the intensity of motion and focus their attention on effective movements (DG 5.8).

Nawaz *et al.* (2014) stated that the primary focus within gameplay should be on movement quality without too much distraction as senior participants wanted to know why they had to perform different tasks and the health benefits they would gain in addition to entertainment (DG 5.9). One thing to keep in mind then is the recommendation from Skjæret *et al.* (2014) that identified that it was necessary to help players maintain visual independency and focus their attention on the game activity or task rather than on how to control the game (DG 5.3). The authors stated that visual attention or the focus of the player during gameplay should be on the game activity, not on where to physically move. In addition, the authors stated that there should be no need for the players to focus on the ground, thereby implying that all relevant information should be provided on the screen.

Even though most of the guidelines concerning the players' attention and awareness during gameplay have been given in studies concerning older adults (DGs 5.2–5.10), providing simple and relevant feedback that ensures movement quality is important disregarding who the game is designed for (as suggested by Isbister and Mueller, 2015) (DG 5.1).

5.6. Game challenge

The category *game challenge* provides suggestions regarding the tasks or actions that are to be performed by the players in order to reach the goal of the game. In particular, the guidelines concern the difficulty of the game challenge and how to design for an appropriate level (Table 11).

Several studies recommended providing dynamic game difficulty when designing for full-body games. This involves automatically changing the difficulty parameters of a game in real time based on the players' abilities to avoid making players either bored or frustrated, which can be caused if a game is either too easy or too difficult (Oppermann and Slussareff, 2016). Jensen and Grønbæk (2016) stated that a game should assess the players' absolute skill level and utilize it to increase (or decrease) the challenge and suggested that designers create dynamic difficulty not only to balance between the players but also to balance the difficulty of the game for individual players (DG 6.7). They determined that in their game, when one player (or both players) was continuously hitting targets, the targets should begin to move or decrease in size in order to increase the challenge of the game. Contrarily, if a player (or both) was unable to hit any targets, they should grow in size. Thin and Poole (2010) also pointed to the importance of designing exergames with very low initially demand skills to maximize users' exertion and to realize and reward progress, thereby promoting an enjoyable exercise experience and in turn counterbalance any sense of exertional discomfort (DG 6.22). Similarly, Zaczynski and Whitehead (2014) stated that, particularly in training, the system's awareness of the users' capabilities is essential to ensure that poses are performed accurately without any injury (DG 6.12). The authors stated that the system must be aware of the user's ability and provide alternative actions that still address the benefit of the pose without overexerting or discouraging the user.

When designing for people with disabilities, Wiemeyer *et al.* (2015) stated that the pace of the game should match the respective speed of information processing (DG 6.5) and that the difficulty of the game must be adapted to the current state of the individual (e.g. size of target zones, distance of targets or resistance) (DG 6.6). They also recommended that automatic adaption by appropriate algorithms or manual adaptation by a therapist would be feasible for this target group.

In addition to the above, Barenbrock *et al.* (2014), Gerling *et al.* (2010, 2012) and Velazquez *et al.* (2013) also recommended having dynamic game difficulty for games designed specifically for older adults. Gerling *et al.* (2010) pointed out

TABLE 11. Guidelines for game challenge.

6. Game challenge				
Guideline		Rationale	Study context	Game(s)
6.1	Provide possibility of individually adjusting the level of difficulty (Gerling *et al.*, 2010)	To challenge the experience of a broad audience and equally account for individual needs	Focus group test with older adults in a nursing home	Customized balance game
6.2	[Provide] dynamic game difficulty (Gerling *et al.*, 2012)	Games need to adjust to large range in able to keep more active players engaged while avoiding overstraining others.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
6.3	Identify mobility capacity and adapt gameplay to it (Velazquez *et al.*, 2013)	Motion capacities need to be taken into account, as reduced mobility requires reduced intensity and adequate feedback.	Action research study with specialists in aging and healthy older adults	Commercial sport games
6.4	Games need to provide enough challenge, but at the same time, they should not be too difficult (Barenbrock *et al.*, 2014).	For players to be encouraged to play again	Qualitative field study at home with healthy older adults	Commercial sport, dancing and virtual twister games
6.5	Adapt the pace of the game to match the respective speed of information processing (Wiemeyer *et al.*, 2015)	Adapt to fit the condition of the target group	Group discussion with experts in exergame design for persons with disabilities	Not based on game evaluation with users
6.6	The difficulty of the tasks is adapted to the current state of the individual (Wiemeyer *et al.*, 2015)	Self-adaptation can overload the patient and lead to demotivation.	Group discussion with experts in exergame design for persons with disabilities	Not based on game evaluation with users
6.7	Assess and utilize players' absolute skills (Jensen and Grønbæk, 2016)	The game should provide new challenges at an appropriate pace and increase as the player progresses.	User study with people aged 14–54 years at a sporting resort	Customized handball game
6.8	Provide range of motion adaptability (Gerling *et al.*, 2012)	Institutionalized older adults often suffer from a reduced range of motion that limits their ability to engage in full-body interaction.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
6.9	[Avoid] unexpected physical challenges (Altimira *et al.*, 2014)	Introducing an unexpected physical challenge led players to experience decreased sense of control, frustration and disengagement.	Laboratory-based comparative study with adults aged 19–43 years	Commercial sport game
6.10	[Avoid] unacceptable competitive advantage (Altimira *et al.*, 2014)	More skilled players disengaged when playing with a score disadvantage.	Laboratory-based comparative study with adults aged 19–43 years	Commercial sport game
6.11	[Provide] adaptability (Barenbrock *et al.*, 2014)	Elderly persons have very different age-related issues.	Qualitative field study at home with healthy older adults	Commercial sport, dancing and virtual twister games
6.12	Understand and adapt for capability (Zaczynski and Whitehead, 2014)	To ensure that poses are performed accurately without injury	User evaluation with healthy young adults	Commercial yoga game

Continued

TABLE 11. Continued.

6. Game challenge				
Guideline		Rationale	Study context	Game(s)
6.13	Fuse balancing mechanisms (Jensen and Grønbæk, 2016)	The participants in the study did not prefer one specific mechanism	User study with people aged 14–54 years at a sporting resort	Customized handball game
6.14	Inform players about balancing (Jensen and Grønbæk, 2016)	Probing players about the presence of balancing mechanisms played an important part in their acceptance of them.	User study with people aged 14–54 years at a sporting resort	Customized handball game
6.15	Make balancing available for both players (Jensen and Grønbæk, 2016)	Players emphasized that knowing balancing could be applied for both players increased their acceptance of it and made them consider the game more fair.	User study with people aged 14–54 years at a sporting resort	Customized handball game
6.16	Reduce the negative effects of competitiveness (Velazquez *et al.*, 2017)	To recover the desire to play among gamers with low skill levels	Exergaming interventions and focus groups with older adults in a hospital	Commercial sport games
6.17	Provide a variety of games and different gameplay to make them more interesting (Pyae *et al.*, 2017)	Participants stated that they would like to play a variety of digital games.	Usability test with older adults in an elderly service home	Customized skiing game
6.18	Increase efficiency from first attempt at playing by privileging motion-tracking based on step-by-step decomposition of the game mechanics (Velazquez *et al.*, 2017)	To increase self-efficiency and to reduce the time needed to control the game	Exergaming interventions and focus groups with older adults in a hospital	Commercial sport games
6.19	Elderly users should be able to choose and add difficulty elements in the game for confidence and better progress (Nawaz *et al.*, 2014)	The participants expressed that they wanted a simple way to display progress and learning in their gameplay.	Workshops with older adults in a senior center	Commercial sport, fitness and balance games
6.20	Describe if the outcome of the game is a physical challenge, a cognitive challenge or both (Nawaz *et al.*, 2014)	Some older adults were concerned that including cognitive tasks takes the focus away from the physical tasks to cognitive tasks.	Workshops with older adults in a senior center	Commercial sport, fitness and balance games
6.21	The exergame concept must make it clear what kinds of movements are required at different difficulty levels (Nawaz *et al.*, 2014).	Senior participants wanted a clear description of what was required for different difficulty levels.	Workshops with older adults in a senior center	Commercial sport, fitness and balance games
6.22	Exergames should be designed with very low initial skill demands (Thin and Poole, 2010).	To maximize the user's level of exertion and to realize and reward progress	User study with students	Commercial dance and sport games

that games need to adjust to a large range in functional ability from one institutionalized older adult to another to allow for an appropriate level of activity and challenge to keep more active players engaged while avoiding overstraining others. They stated that when designing for older adults, players should be provided the possibility of individually adjusting the level of difficulty, game speed and sensitivity of the input device, so that games can be used by a wider range of audience and also support individual needs (DG 6.1). Similarly, Gerling *et al.* (2012) recommended offering difficulty adjustments between players and individually scaling challenges, as this will keep the active players more engaged while not overstraining others (DG 6.2). To achieve better adaptability in games, Gerling *et al.* (2012) further recommended creating interaction paradigms that adapt to individual differences in player range of motion, as these adults need to be calibrated according to individual player abilities (DG 6.8). In this regard, the authors suggested creating interaction paradigms that adapt to individual differences, as it is common for this user group to suffer from a reduced range of motion that limits their ability to engage in full body interaction. Also, Barenbrock *et al.* (2014) emphasized the need for a healthy balance between challenge and easy progress. As providing a clear and measurable account of the players' progress is important for all audiences, games need to provide enough challenge for players to be encouraged to play again, but at the same time, the challenge should not be too difficult (DG 6.4). The authors also stated that as older adults have different age-related issues, it would be advisable to make games and hardware adaptable for users (DG 6.11) and allow players to directly select and switch between different stages of a game. Another initiative for achieving dynamic game difficulty was given by Velazquez *et al.* (2013), where the authors suggested identifying mobile capacity and adapting gameplay to it and that measuring arcs of mobility provide good insight in this regard (DG 6.3). Velazquez *et al.* (2017) further proposed assisting older adults to increase their efficiency from the first time they play by privileging motion-tracking based on the step-by-step decomposition of the game mechanics in contrast with fast and uncontrolled movements, as this was shown to increase self-efficiency and reduce the time needed to control the game (DG 6.18).

Another aspect that was raised as important when designing for older adults was the game content. In the study by Pyae *et al.* (2017), several older participants suggested that games should provide a variety of mini games as different gameplay makes playing more interesting to perform (DG 6.17). Also, Nawaz *et al.* (2014) suggested that elderly participants should be able to choose and add difficulty elements in the game for confidence and better progress as the participants expressed that they wanted a simple method of displaying progress and learning in the gameplay (DG 6.19). The authors recommend describing if the outcome of the game is a physical challenge, a cognitive challenge or both as some older adults from their studies were concerned that including cognitive tasks may take the focus away from the physical tasks (DG 6.20). Nawaz *et al.* (2014) additionally suggest providing a clear description of what type of movements are required to be performed at different difficulty levels as they state that senior participants wanted to have a clear description of what was required at various levels of difficulty (DG 6.21).

Interestingly, balancing mechanisms in games were described in studies with young adults only. For instance, Jensen and Grønbæk (2016) suggested fusing the balance mechanism, utilizing both the physical and digital, as the participants in their study did not prefer a specific balancing mechanism (DG 6.13). Furthermore, the authors suggested informing the players about balancing, as informing players had a large impact on player acceptance in their study (DG 6.14). Next, the authors suggested making balancing available for both players, since doing so would make the game more easily accepted and fair in that case (DG 6.15). Similarly, considering multiplayer games, Velazquez *et al.* (2017) stated that negative effects from competitiveness must be avoided to recover the desire to play among gamers with low skills (DG 6.16). They suggested implementing cooperative gameplay to avoid negative effects due to poor performance, pondering scores using motion classification aimed at leveling performance and/or increasing social interaction by including observers in the playground area. To prevent disengagement among skilled players, Altimira *et al.* (2014) found that introducing an unexpected physical challenge (e.g. playing traditional table tennis with a non-dominant hand) can lead to frustration and player disengagement and therefore suggested avoiding unexpected physical challenges (DG 6.9). Second, the authors stated that an unacceptable competitive advantage should be avoided, as more skilled players disengaged when playing with a score disadvantage (DG 6.10). In this regard, the authors suggested that a lower score adjustment be applied in games that require a lower skill level to play to avoid overbalancing the game and thereby increasing the chance of disengagement owing to an unacceptable competitive advantage.

5.7. Feedback on player performance

Feedback on player performance refers to the evaluative and/or corrective response a full-body game provides the players about their movements during gameplay. Relevant guidelines, presented in Table 12, provide recommendations concerning both how and when feedback should be provided and which forms of feedback should be avoided.

Zaczynski and Whitehead (2014) stated that providing customized, contextual feedback offers a direct solution to inaccuracy rather than only demonstrating inaccuracy and allowing users to determine a solution. They suggested providing customized, contextual feedback to help resolve errors (DG 7.5). The authors stated that feedback including verbal and haptic, and a combination of these, were found to have an impact on pose performance, as they were highly

TABLE 12. Guidelines for feedback on player performance.

7. Feedback on player performance				
Guideline		Rationale	Study context	Game(s)
7.1	Provide constructive criticism (Gerling *et al.*, 2010)	To avoid frustration and to foster an enjoyable player experience	Focus group test with older adults in a nursing home	Customized balance game
7.2	Present rewarding feedback such as knowledge of results (Wiemeyer *et al.*, 2015)	To support intrinsic motivation	Group discussion with experts in exergame design for persons with disabilities	Not based on game evaluation with users
7.3	[Provide] continuous player support (Gerling *et al.*, 2012)	Extended tutorials are required to ensure that players are given time to learn the skills needed to play the game.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
7.4	Communicate progress (Uzor and Baillie, 2014)	Providing an exergame score gives participants a motivational boost	Randomized control trial with community dwelling older adults	Customized fantasy fall rehabilitation games
7.5	[Provide] custom contextual feedback (Zaczynski and Whitehead, 2014)	Customized, contextual feedback offers a direct solution to inaccuracy rather than just demonstrating inaccuracy and allowing the user to determine a solution	User evaluation with healthy young adults	Commercial yoga game
7.6	Provide helpful information and feedback at appropriate time (Harrington *et al.*, 2015)	Many participants were unsure of what action was supposed to take place at a particular time.	Laboratory-based usability test with healthy older adults	Commercial puzzle and fitness games
7.7	Feedback must be timely and contextual (Fernandez-Cervantes *et al.*, 2018)	Providing users with continuous feedback on their performance can be overwhelming and eventually ignored	Empirical feasibility study with healthy older adults at home	Customized gym game
7.8	Avoid feedback overloading (Isbister and Mueller, 2015)	Developing movement skill requires not only bodily but also cognitive attention, with attention being a limited resource.	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
7.9	Focus on the body and not the screen when designing player feedback (Isbister and Mueller, 2015)	In movement-based games, the body is a major focus of attention.	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
7.10	Celebrate movement articulation (Isbister and Mueller, 2015)	With movement-based games, it is about not only if and when but also how movement is performed. Sometimes the movement can be enjoyable on its own.	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users
7.11	Introduce points in training exercises without reducing sport relevance (Jensen *et al.*, 2015)	Game elements hold great potential to motivate players to exert themselves in training sessions, but it also raises the challenge of avoiding influencing sport relevance in a negative way.	Brainstorming workshop and user study with students at a sporting resort	Customized handball game
7.12	Negative feedback should be avoided (Wiemeyer *et al.*, 2015)	Not provided	Group discussion with experts in exergame design for persons with disabilities	Not based on game evaluation with users

Continued

TABLE 12. Continued.

7. Feedback on player performance				
Guideline		Rationale	Study context	Game(s)
7.13	Schematic and generic positive feedback should be avoided (Wiemeyer *et al.*, 2015)	Not provided	Group discussion with experts in exergame design for persons with disabilities	Not based on game evaluation with users
7.14	Progress in-game should be more simple and meaningful than using scores and points (Pyae *et al.*, 2016b)	Not provided	Usability test with healthy older adults in an elderly service home	Commercial sport games
7.15	Provide clear indication of expected results and the health benefits achieved by playing (Nawaz *et al.*, 2014)	Elderly participants wanted information regarding the specific effect and outcome of the exercises.	Workshops with older adults in a senior center	Commercial sport, fitness, and balance games
7.16	Provide simple and effective audio feedback (Pyae *et al.*, 2016a)	Excessive audio feedback could make the elderly distracted from the gameplay.	Usability test with older adults at a health promotion center	Customized skiing game
7.17	Provide multimodal feedback (Zaczynski and Whitehead, 2014)	Feedback is suitable if it is provided in a modality that compliments the orientation of the action being performed.	User evaluation with healthy young adults	Commercial yoga game
7.18	All important information must be communicated consistently and promptly (Fernandez-Cervantes *et al.*, 2018).	Since many older adults experience deteriorated peripheral vision, information around the edge of the screen or in many different places may be ignored.	Empirical feasibility study with healthy older adults at home	Customized gym game
7.19	Multiple alternative information-communication channels must be supported (Fernandez-Cervantes *et al.*, 2018)	Older adults may experience visual or auditory decline.	Empirical feasibility study with healthy older adults at home	Customized gym game

preferred to commercially available feedback systems such as avatar mirroring. The authors further stated that multimodal feedback should be provided in a modality that compliments the orientation of the action being performed by the player (DG 7.17), as players are likely to be mid-action when feedback is provided. Therefore, the authors recommend that the system should adapt accordingly, for instance, by providing haptic or verbal feedback if the users' eyes are averted. Wiemeyer *et al.* (2015) further stated that providing rewarding feedback such as knowledge of results would support intrinsic motivation (DG 7.2) and white out further ideas for practical implementation.

Isbister and Mueller (2015), however, prompted designers to think past screen-based feedback and to use audio and haptics to provide feedback. They recommended focusing on the body and not just on the screen when designing player feedback, as the body must be the main focus of attention. Further, they found that it was necessary to celebrate how well the players articulate movements, and the movement of joy, by providing feedback on the movement quality from moment to moment (DG 7.10). To practically implement these guidelines, Isbister and Mueller (2015) suggested highlighting the players' articulation without judgment, so that the players may reflect and learn from it by themselves. Furthermore, Isbister and Mueller (2015) suggested avoiding feedback overload, as developing movement skills requires not only bodily but also cognitive attention (DG 7.8). Therefore, players initially need to focus on learning a new movement, and while getting better at the movement, they can devote more cognitive attention toward more complex and nuanced forms of feedback. In this regard, the authors' ideas for practically implementing this guideline were to provide feedback on the movement itself, without much focus on the score, and to provide players with several forms of feedback with no requirement to engage with all of them.

To avoid frustration and to promote an enjoyable player experience among elderly players who lack previous gaming experience, Gerling *et al.* (2010) suggested providing constructive criticism (DG 7.1). However, they did not provide ideas for practical implementation. Fernandez-Cervantes *et al.*

(2018) and Harrington *et al.* (2015) identified the importance of timing when providing feedback for older adults. Harrington *et al.* (2015) stated that in their study, several older participants were unsure of when to perform a specific action and claimed that this could have been addressed by providing on-screen instructional gestures during each activity to serve as a form of reinforcement. Based on this rationale, the authors suggested providing useful information and feedback at appropriate times throughout a program, as it will be beneficial to older adults (DG 7.6). On a similar note, Fernandez-Cervantes *et al.* (2018) stated that feedback must be timely and contextual, as continuous feedback on performance can be overwhelming and eventually ignored (DG 7.7). They further suggested that multiple alternative information-communication channels must be supported for older adults such as both written and spoken instructions (DG 7.19). Similarly, Nawaz *et al.* (2014) suggest providing a clear indication of expected results and health benefits that can be achieved by playing as the elderly participants were interested to know more information regarding specific health effects and outcome of the exercises (DG 7.15).

Gerling *et al.* (2012) stated that integrating continuous tutorials and player prompting facilitates gesture learning and interaction (DG 7.3). The authors suggested doing so by integrating continuous tutorials and player prompting. They stated that extended tutorials are necessary to ensure that players have enough time to learn the skills needed to play the game. In addition, they stated that some older adults suffer from reduced attention span, and hence, to grasp their attention, games should visually and audibly prompt the user if no interaction is detected. The authors added that it should never be assumed that the players are capable of knowing when actions are required, and hence continuous prompting for correct input is necessary. On a similar note, Fernandez-Cervantes *et al.* (2018) stated that because many older adults experience deteriorated peripheral vision, information around the edge of the screen or in many different places may be ignored and therefore recommended that all important information should be communicated consistently and promptly (DG 7.18).

Similarly, with respect to communicating to the players, Uzor and Baillie (2014) identified in their study that giving players a motivational boost encouraged them to maintain the exercise program and that if exergames are tailored to rehabilitation exercises with progress modeled on exergame scores, then an improvement in score corresponds to improve physical functioning. Therefore, the authors suggested communicating progress to give participants a motivational boost (DG 7.4). The authors stated that this can be accomplished through scoring systems within the game. On the other hand, Pyae *et al.* (2016b) stated that progress in the game should be more simple and meaningful than scores, without offering any further explanation (DG 7.14). Pyae *et al.* (2016a) additionally suggests that simple and effective audio feedback must be provided as excessive audio feedback can distract older adults from their gameplay (DG 7.16).

With respect to designing specific sports-training games, Jensen *et al.* (2015) stated that introducing points in training exercises without reducing sport relevance can motivate players to exert themselves in training sessions without influencing the sport relevance in a negative way (DG 7.11). The study illustrated that introducing a competitive element caused players to perform detrimental movements, deviating from regular handball movements just to gain higher scores. The authors believed that one way of tackling this situation would be to frame the game as training and reward optimal performance, so that players remain in a training mindset and exert themselves as necessary without reducing movement specific to the sport.

Regarding the types of feedback that should be avoided, Wiemeyer *et al.* (2015) suggested that in full-body games, negative feedback should be avoided and that instead specific positive feedback should be provided (DG 7.12). Furthermore, the authors suggested that designers avoid schematic and generic positive feedback and instead provide realistic, specific and individually tailored feedback (DG 7.13). Though the authors provided specific feedback guidelines, they did not further provide any rationale for why or how the guidelines could be implemented.

5.8. Player agency and customization

Table 13 presents the guidelines related to *player agency and customization*, which provide an advice on how the players can be given control over certain game aspects for the purpose of tailoring to individual needs and desires.

Richards and Graham (2016) provided three guidelines with respect to *player agency and customization*. First, the authors recommended considering timing for the types of agency provided, as it is difficult for people to perform cognitive tasks while actively exercising (DG 8.3). The authors rationalized this by stating that granting players strategic agency would be inappropriate while they are actively exercising because they would have to divide their attention between strategizing and performing the exercise safely. Second, the authors stated that illusion of agency can be combined with real agency (DG 8.4). An illusion of agency may be provided to meet the exercise constraints, but they also warned designers that the guideline must be crafted carefully so that it does not diminish the game experience and that seeing through the illusion can change the way players interact with the game. Finally, Richards and Graham suggested exploiting agency to improve form and safety (DG 8.5). The authors stated that people have a real-world choice when it comes to exercise, namely gym settings, but many people choose to perform them poorly. The authors stated that a real-world agency can be exploited to have consequences in-game, with the dual benefit of increasing the players' perception of control and encourage correct form. However, games should go beyond simple extrinsic rewards, such as simply being awarded points for correctly performed movements. Furthermore, Jensen and Grønbæk (2016) stated

TABLE 13. Guidelines for player agency and customization.

8. Player agency and customization				
Guideline		Rationale	Study context	Game(s)
8.1	Enable choices where necessary (Uzor and Baillie, 2014)	There were aspects of the exergame that users felt could benefit from customized options such as music, collectable objects and background.	Randomized control trial with community dwelling older adults	Customized fantasy fall rehabilitation games
8.2	Provide players with choices (Jensen and Grønbæk, 2016)	Players themselves can choose whether they would like to balance the game and how skill level should influence gameplay.	User study with people aged 14–54 years at a sporting resort	Customized handball game
8.3	Consider timing for the type of agency provided (Richards and Graham, 2016)	Granting players strategic agency would be inappropriate while they are actively exercising because they would have to divide their attention between strategizing and performing the exercise safely.	Laboratory-based user study with university students	Customized muscle strengthening game
8.4	Illusion of agency can be combined with real agency (Richards and Graham, 2016)	Seeing through the illusion can change the way a player interacts with a game.	Laboratory-based user study with university students	Customized muscle strengthening game
8.5	Exploit agency to improve form and prevent injury (Richards and Graham, 2016)	Games should go beyond simple extrinsic rewards for correct movements.	Laboratory-based user study with university students	Customized muscle strengthening game
8.6	Provide game calibration and customization (Pyae *et al.*, 2017)	To meet the needs of elderly peoples' abilities in physical movements	Usability test with older adults in an elderly service home	Customized skiing game

that providing players with choices during gameplay (DG 8.2) enables them to decide if they want to balance a game at all and if so, which kind of balancing they prefer based on their skill level.

With regard to designing for older adults, Uzor and Baillie (2014) stated that there are certain aspects of exergames that need to be static, such as the core mechanic, as this must emulate the exercise that the game is modeled upon. However, the authors stated that there are other aspects of exergames that their participants felt could benefit from customized options, such as music, collectible objects and background elements. Hence, the authors stated that designers should enable choices where necessary while maintaining the core mechanics, since people have different tastes, and prevent users from losing interest in the game over time (DG 8.1). In this regard, Pyae *et al.* (2017) suggested providing game calibration and customization to meet the needs of elderly peoples' abilities in physical movements (DG 8.6).

5.9. Exertion

The following section describes the guidelines related to exertion or the use of energy in the players of full-body games. Table 14 presents the guidelines for *exertion*. The majority of guidelines in this category were derived from the studies performed with older adults (e.g. Barenbrock *et al.*, 2014; Gerling *et al.*, 2012; and Velazquez *et al.*, 2017). Hence, the recommendations offered are particularly relevant when designing for this user segment.

Based on user evaluations with institutionalized older adults, Gerling *et al.* (2012) emphasized the importance of providing fatigue management and preventing overexertion by appropriate game pacing (DG 9.1) as older adults often have reduced endurance level and are prone to movement-based injury and overexertion. Hence, the authors stated that games need to manage player fatigue through appropriate pacing, for example, by alternating physically intense and less-challenging game periods that allow the players to relax and recover. Similarly, Barenbrock *et al.* (2014) also highlighted that motion-based games should prevent overexertion and not overstrain the player physically or mentally (DG 9.2). The study identified that games that require a lot of concentration are particularly exhausting for older adults and can lead to overexertion. Velazquez *et al.* (2017) recommended controlling perceived exertion according to the gamers' motion capacity, as it was identified that correctly classifying the gamers' mobility helped

TABLE 14. Guidelines for exertion.

9. Exertion				
Guideline		Rationale	Study context	Game(s)
9.1	Provide exertion anagement by appropriate game pacing (Gerling *et al.*, 2012)	Due to the prevalence of sedentary lifestyles, institutionalized older adults often have a reduced stamina level and are much more prone to movement-based injury and overexertion.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
9.2	Prevent overexertion (Barenbrock *et al.*, 2014)	Games that require a lot of concentration are exhausting for older adults.	Qualitative field study at home with healthy older adults	Commercial sport, dancing and virtual twister games
9.3	Control the perceived exertion according to the gamers' motion capacities (Velazquez *et al.*, 2017)	Studies show that using the classification of the motion capacity facilitates establishing a time of exercise aimed at avoiding excessive strain or risky situations.	Exergaming interventions and focus groups with older adults in a hospital	Commercial sport games
9.4	[Utilize] motion benefit for perceiving exertion (Velazquez *et al.*, 2013)	Fitness benefit can be changed to motion benefit for older adults; older adults' perceived exertion does not necessarily require a high intensity exercise	Action research study with specialists in aging and healthy older adults	Commercial sport games
9.5	Implement fatigue as an intentional game challenge (Isbister and Mueller, 2015)	Movement results in fatigue that can be both positive and negative for the player and intend fatigue if used as a game challenge but avoid it if it is not part of the game.	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users

to gradually increase the perception of exertion and health benefits without any health risks (DG 9.3). Velazquez *et al.* (2013) stated that fitness benefit can be changed to motion benefit for older adults, as perceived exertion does not necessarily require a high intensity exercise (DG 9.4). The study recommended using casual exergames to evaluate, warm up and restrain older adults in more intense challenges. It is also stated that some signals of tiredness or loss of balance can be detected visually, for instance, limb shaking or outbreak to fall, which should not be ignored.

Isbister and Mueller (2015) provided generic guidelines for designing movement-based games and suggested using fatigue intentionally as a game challenge rather than incidental (DG 9.5). As movements often result in fatigue, it can either be a welcomed challenge for players if wanting to manage it (e.g. in an endurance sport) or negatively affect engagement if the game gets too hard to play. Isbister and Mueller (2015) further identified that fatigue can be minimized by creating short game cycles, having variation in movements or distracting players from fatigue through, for example, the use of music.

The guidelines provided with respect to exertion provide recommendations to design for safe gameplay experience by taking into consideration and controlling the exertion of the players (DGs 9.1–9.4), as well as how exertion can be used to manipulate the game challenge (DG 9.5).

5.10. Safety

Table 15 presents the guidelines sorted under the category *safety*. These guidelines describe measures that can be taken to ensure that an environment or a physical gaming area is suitable for physical activity to reduce the risk of physical injury during gameplay.

One of the potential benefits of full-body games is that they can be used as a mean to increase physical activity and exercise in a home environment. However, movement, especially in everyday indoor environments, has an inherent sense of risk associated with it such as the risk of hitting furniture or other people that can lead to injury. However, Isbister and Mueller (2015) stated that with risk comes a sense of thrill, which can contribute positively to the game experience, and movement-based games should exploit this risk (DG 10.4). It is, however, important to inform the players of the risk involved in a gaming activity and consider the environment while exploiting the

TABLE 15. Guidelines for safety.

10. Safety				
Guideline		Rationale	Study context	Game(s)
10.1	Prevent health risks and injuries (Barenbrock *et al.*, 2014)	While most healthy people can assess risks quite well, supervision is valuable for the target group.	Qualitative field study at home with healthy older adults	Commercial sport, dancing and virtual twister games
10.2	Promote safety during gameplay (Pyae *et al.*, 2017)	Many elderly participants expressed concern about falling during gameplay.	Usability test with older adults in an elderly service home	Customized skiing game
10.3	[Provide] a secured game interface (Wiemeyer *et al.*, 2015)	To adapt for persons with disabilities	Group discussion with experts in exergame design for persons with disabilities	Not based on game evaluation with users
10.4	Exploit physical risk sensibly (Isbister and Mueller, 2015)	Movement has an inherent sense of risk associated with it, and with risk also comes a sense of thrill, which can contribute positively to the game experience.	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users

potential physical risk. They also recommended letting the players' movements interfere with each other to facilitate body contact, always having the safety of the players in mind.

Similarly, playing with others or having a supervised gameplay was identified to be valuable for the senior user group. Based on the studies with healthy older adults, Barenbrock *et al.* (2014) advised designers to take measures to prevent health risk and injuries in players during gameplay, particularly when motion-based games are used unsupervised (DG 10.1). Barenbrock *et al.* (2014) further stated that sensor technology can be used to facilitate gaming (e.g. biometric measures, camera observation) and help trigger for instance an emergency call in the case of a fall. Pyae *et al.* (2017) stated that safety in gameplay is highly important as most of the participants expressed concerns about falling during gameplay (DG 10.2). In addition, Wiemeyer *et al.* (2015), who based their guidelines on a group discussion with experts working in the field of exergaming and rehabilitation, recommended securing the game interface, for example, by providing a handrail around a balance board (DG 10.3).

Even though risk might enhance movement in some populations, ensuring safety during gameplay is crucial if full-body games are to be used in a home setting, especially with older adults or people with an acquired disease. When using these games, one must anticipate potential risks with reference to the established best practice including risk assessment, health and safety and legal liability guidelines to ensure movement quality and quantity of activity.

5.11. Universal design

Table 16 presents various guidelines for *universal design*. These guidelines provide advice on how to design full-body games so that they can be accessed, understood and played by a number of user segments, including older adults and groups that have little or no experience with interactive technology.

Promoting an age-inclusive design was identified as a common base line among all the guidelines within this category as the guidelines were all extracted from the studies performed with older adults. Having age-inclusive designs were highly emphasized by Brox *et al.* (2017), Gerling *et al.* (2012) and Harrington *et al.* (2015). Both physical and cognitive declines are common for institutionalized older adults that can strongly influence game interaction. Therefore, Gerling *et al.* (2012) recommended having systems that account for this decline by offering simple game structures to accommodate cognitive changes and offering gestures that adapt to each player's individual impairments (DG 11.7). They also suggested promoting easy menus and simplified startup and shutdown routines to encourage independent gameplay among older adults (DG 11.5) as technical knowledge cannot be assumed among either institutionalized older adults or nursing staff. In Gerling *et al.* (2010), the authors recommended having interaction mechanisms that allow for navigation while sitting or standing, so that players can choose an adequate interaction scenario (DG 11.6). Additionally, they suggested that along with foot-based input, using the players' hands and arms may be appropriate to reduce access barriers for persons using wheelchairs.

With regard to colors and contrast, Brox *et al.* (2017) recommended that as eyesight deteriorates with age, more light is needed with a reduced variety of colors and that graphics should be bright with good contrast (DG 11.1). Further, the authors stated that large menu buttons should be provided, with enough distance between them (DG 11.2) and that small details are lost on people who do not see well and hence suggested

TABLE 16. Guidelines for universal design.

11. Universal design				
Guideline		Rationale	Study context	Game(s)
11.1	Design with good colors and contrast (Brox *et al.*, 2017)	Eyesight naturally deteriorates with age.	Usability test with older adults in a senior center	Commercial fantasy game
11.2	Provide large menu buttons with distance between each other (Brox *et al.*, 2017)	Eyesight naturally deteriorates with age.	Usability test with older adults in a senior center	Commercial fantasy game
11.3	Volume should be the same for all sounds (Brox *et al.*, 2017)	Sound was in some cases disturbing during the study.	Usability test with older adults in a senior center	Commercial fantasy game
11.4	Provide thick, clear font (Brox *et al.*, 2017)	Eyesight naturally deteriorates with age.	Usability test with older adults in a senior center	Commercial fantasy game
11.5	[Provide] simple setup routines (Gerling *et al.*, 2012)	Technical knowledge cannot be assumed for either institutionalized older adults or nursing staff.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
11.6	Allow for navigation while sitting or standing (Gerling *et al.*, 2010)	Players must be able to choose an adequate interaction scenario.	Focus group test with older adults in a nursing home	Customized balance game
11.7	[Promote] age-inclusive design (Gerling *et al.*, (2012)	Embrace age-related physical and cognitive impairments that are common for institutionalized older adults.	User evaluations with institutionalized older adults in a nursing home	Customized gesture-based game
11.8	Provide age-appropriate music for elderly users, and the music should fit the aim of the game or the movements performed (Nawaz *et al.*, 2014)	The elderly did not like the music and background noise in the three game systems.	Workshops with older adults in a senior center	Commercial sport, fitness, and balance games
11.9	Avoid small details (Brox *et al.*, 2017)	Small details are lost on people who do not see well.	Usability test with older adults in a senior center	Commercial fantasy game

TABLE 17. Guidelines for social aspects.

12. Social aspects				
Guideline		Rationale	Study context	Game(s)
12.1	Facilitate social fun (Isbister and Mueller, 2015)	Moving with others is fun.	Semi-structured interviews with movement-based game design experts	Not based on game evaluation with users

avoiding small details (DG 11.9). They further recommended using big, thick and clear text (DG 11.4); that less text is better; and that the placement of the text on the screen plays an important role.

Brox *et al.* (2017) also stated that sound was identified to be disturbing by older adults in some cases during their study, and hence the authors suggested providing uniform volume for all sounds in the game (DG 11.3). Similarly, Nawaz *et al.* (2014) recommended providing age-appropriate music for elderly users such that the music also fits the aim of the game and the movements performed (DG 11.8).

The above guidelines indicate the importance of diverse factors such as interface design, interaction mechanisms and communication in promoting an age-inclusive design.

5.12. Social aspects

Interestingly, Table 17 presents a single guideline corresponding to *social aspects*. The guideline is related to the social factor and offers a suggestion concerning the social environment in which the gameplay occurs.

Even though the social aspect of a game, e.g. the ability to play, interact and compete with others, is a major attraction for all gamers. Isbister and Mueller's (2015) is the only paper presenting a guideline with the social aspect in mind. They suggested facilitating social fun by making movement a social experience, as moving with others can be perceived as fun (DG 12.1). Hence, the authors suggested a multiplayer design that includes other players and audience by making the game easy to learn by observation and potentially turning bystanders into players.

However, in Section 5.6 'game challenge' balancing mechanisms in games have been recommended as a way to increase game challenge (DGs 6.9, 6.19, 6.13–6.15). These guidelines might also be a way to increase social aspects as balancing of games often deals with a multiplayer feature.

6. EMERGING CONCERNS

Having systematically categorized and reviewed existing guidelines for the design of full-body interactive games, we now turn our attention to what we see as overarching concerns given the state of the art:

- the hedonic–utilitarian divide in movement-related guidelines,
- the lack of a common structure for specifying design guidelines,
- the lack of systematic development of design guidelines,
- the validity,
- the limited focus on tangible user interfaces.

6.1. The hedonic–utilitarian divide in movement-related guidelines

During the past decade, a new form of interactive gaming that requires physical body movements to play computer games has emerged, often referred to as full-body games or exergames. One of the main advantages of full-body games is the potential to provide both fun and utility for the users to engage in physical activity. Therefore, full-body games can be used for hedonic reasons, such as entertainment or fun, or for utilitarian reasons, such as rehabilitation and exercise, or for both.

If we take a closer look at the categories in the current review that offer guidelines for how a full-body game can influence the way players use their bodies during gameplay (i.e. *movement elicitation*, *mapping of movement* and *explicit movement guidance*), we find that the relevant guidelines tend to address two different objectives: (i) how to utilize body movements to promote positive player experiences (Isbister and Mueller, 2015) and (ii) how to design with the intention of helping players achieve desirable health-specific effects from gameplay (Nawaz *et al.*, 2014; Skjæret *et al.*, 2014). These two objectives correspond to the *hedonic* and *utilitarian* aspects of the game design (Kari, 2017). Below, we elaborate the two groups of guidelines further and discuss concerns related to imbalances and contradictions that may exist between them.

Many of the guidelines listed under the category *movement elicitation* in Table 6 (i.e. DGs 1.1–1.5 and 1.11) give suggestions for hedonic gameplay and how one can design for positive player experiences in full-body games. In general, these guidelines appear to point toward the importance of encouraging movements that are perceived by the player as unrestrictive and 'natural' during gameplay, thereby encouraging explorative rather than strictly choreographed gameplay. For instance, Pyae *et al.* (2017) recommended that players should be able to interact with a game using movements that they are likely to already be familiar with through activities such as sports and daily life (DG 1.2). The suggestion to embrace the natural expression of movements and not to curtail individual self-expression in movements was also emphasized by Isbister and Mueller (2015) (DGs 1.3 and 1.4), who stated that embracing ambiguity of movement is necessary, as forcing precision may only frustrate the players. Interestingly, these two articles are based on entirely different study contexts. As Pyae *et al.* (2017) based their studies with healthy older adults, Isbister and Mueller (2015) are presenting findings from a long-term collaboration with design experts. This highlights the importance of enjoyment behind the usage intentions and the actual use of full-body games as an exercise tool, disregarding age and function of the intended users.

While most of the movement-related guidelines in the reviewed articles gave advice on how to design for enhanced player experiences *during* gameplay, the guidelines offered by Skjæret *et al.* (2014) and Uzor and Baillie (2014) provided (utilitarian) recommendations for how full-body games can be designed to elicit player movements associated with health-specific effects. Interestingly, these guidelines derive from work with older adults specifically. However, even though several studies have found positive health effects of full-body usage, few games have been designed exclusively for specific physical functions or movement characteristics with utilitarian reasons in mind. Gaining long-term exercise adherence is difficult for persons of all ages and adherence to exercise programs is generally low, with estimates suggesting that as many as 50% drop out in the first 3–6 months (Dishman, 1988). Enjoyment or interest in exercise benefits (White *et al.*, 2005), as well as intrinsic motivation and satisfaction of basic needs (Duncan *et al.*, 2010), is a predictor of adherence to exercise. Previous research also pointed out that hedonic enjoyment perceptions have a stronger effect on attitude toward using full-body games compared with utilitarian perceptions of physical fitness promotion (Kari and Makkonen, 2014; Lin *et al.*, 2012), which in turn might be the reason why most guidelines focus on this aspect.

Other movement-related design guidelines that concern the health effects of gameplay include more safety-oriented guidelines, such as DGs 1.12–1.14. These guidelines draw attention to how game-related movements, in some cases, may present a safety hazard for players (with specific reference to older adults) and hence should be avoided. As there is limited evidence to assess where the use of full-body games is a safe tool of activity for older adults, measures to ensure safety during gameplay should be of high priority when designing these games.

Given the two 'silos' that current design guidelines fall under, we see two main concerns. First, if we take the envisioned health benefits of full-body games into regard (e.g. Li *et al.*, 2018; Rosenberg *et al.*, 2019; Staiano and Calvert, 2011), the status quo suggests that there are currently few design guidelines that focus on health effects and that consequently can help realize these visions. Consequently, it can be argued that the existing body of design guidelines for full-body games suffers from a lack of specific clinical relevance for health and rehabilitation interventions.

Second, we see potential contradictions between the utilitarian and hedonic design guidelines, particularly when applied to the design of health interventions. While many of the guidelines addressing hedonic aspects of the game design can be considered relevant for ensuring user acceptance and, hence, contribute indirectly to fulfilling utilitarian (health) purposes, one should be aware of possible tensions. For example, by offering freedom of movement (DGs 1.1, 1.3 and 1.4) in a full-body game, with the intention of enhancing a player's immediate game experience, one also risks opening up for movements that are inefficient in terms of yielding desirable health effects—if the goal is to design for balance training, then movements that do not produce weight shift in players during gameplay might be undesirable (DG 1.6). Similarly, there may be contradictions between freedom of movement and safety-oriented guidelines (DGs 1.12–1.14). The exemplified contradictions may be seen as a consequence of guidelines having been derived from different contexts, for example, a physical rehabilitation context with older adults (Skjæret *et al.*, 2014) versus a recreational context with young adults (Jensen and Grønbæk, 2016). Based on the above, we recommend that designers and developers of full-body games be mindful about potential conflicts between guidelines serving hedonic and utilitarian purposes, as well as designing for different generations.

For HCI and design of full-body games, we consider the two concerns raised above to represent new and interesting research possibilities. The lack of guidelines for how to design for specific movement qualities that can yield positive health effects is one (interdisciplinary) area of opportunity in this regard. Another research opportunity lies in bridging the hedonic–utilitarian divide that characterizes the existing body of design guidelines, that is, designing both for positive long-lasting player experiences and desired health effects from the gameplay.

6.2. The lack of a common structure for specifying design guidelines

The conducted review revealed that the way design guidelines for full-body games are specified in the literature varies considerably. Some guidelines, such as those proposed by Isbister and Mueller (2015) (DGs 1.3–1.5, 2.1, 5.3, 7.8–7.10, 9.5 and 10.4), are presented in a structured format, with rich descriptions that specify elements such rationale, examples of use, strategies for designers, 'do's and don'ts', references and HCI relevance. The majority of reviewed guidelines, however, are presented in a more unstructured manner, often without the provision of a clear rationale, the examples of practical implementation or a description of how a specific guideline relates to others. We consider such 'thin' specifications to reduce the credibility of a guideline and also to have practical consequences due to the limited advice provided on how it can be implemented. As such, the lack of consensus in the relevant literature on how to specify design guidelines for full-body games risks watering out the main purpose of design guidelines, that is, to clearly communicate recommendations for good practices in design (Interaction Design Foundation, 2019).

The way inconsistent structures and other format issues can reduce the usability of design guidelines have been discussed in earlier HCI research (Cronholm, 2009; Huhn, 2010). Given the focus of the current study, we find it relevant to specifically call attention to the consequences inconsistent guideline structures can have with respect to the design of full-body games. Below, we highlight three relevant issues.

First, and as elaborated further in Section 6.3, we consider the lack of a common specification format a key barrier that prevents the *systematic* development of design guidelines for full-body games. This in turn may explain why several guidelines for full-body games appear to replicate guidelines that have existed for years.

Second, we consider the absence of a common structure to reduce the likelihood that central aspects pertaining to a specific guideline, for example, information about the context from it has been derived, are sufficiently communicated. With respect to design guidelines for full-body games, context information is particularly relevant as design knowledge derived from one context is not automatically transferable to another. For example, recommendations that advocate freedom of movement and that typically have been derived from studies involving recreational full-body games may have to be applied more cautiously in full-body games design for rehabilitation contexts. Naïve application of guidelines derived from other context may have undesirable effects.

Third, inconsistency in the structure of design guidelines for full-body games is also problematic in light of the complexity of factors that designers are likely to have to deal with. In the current review, we identified a large variety of issues pertaining to different aspects of the game and the game experience (cf. Tables 6–17). Compared with the more well-defined and usability-oriented sets of guidelines and principles proposed by Nielsen (1993), Norman (2013) and Shneiderman (1997), the design guidelines for full-body games form a relatively large and highly unstructured network of design insights. The inconsistency in the format of design guidelines arguably makes this network less accessible and more challenging to navigate.

While identifying an ideal format the specification of full-body game design guidelines is beyond the scope of this work, we consider the pattern-inspired format adopted by Isbister and Mueller (2015) to be more in line with earlier definitions of what design guidelines are and what they should contain (Fu *et al.*, 2016; Nowack, 1997). However, to benefit designers, we argue that it is important to understand the full-body game designers' needs and behavior in dealing with design guidelines. This argument is very much in line with the motivation underlying Huhn's (2010) observational study of designers' behaviors when developing online shopping sites. The study was conducted with the intention of informing the organization of relevant guidelines. To our knowledge, no similar studies addressing the organization of design guidelines for full-body games have been conducted.

6.3. The lack of systematic development of guidelines

As described earlier, full-body games are first and foremost characterized by the way the body is both a medium of interaction and also at the heart of the user or player experience. However, we found that the majority of the reviewed guidelines (i.e. categories 4–12) were neither concerned with movement as a design element nor strictly limited to movement-based applications (such as full-body games). For example, most guidelines listed under the category *universal design* (e.g. DGs 11.1, 11.2 and 11.8) are highly generic and hence potentially applicable to several other types of applications. Similarly, the larger portion of guidelines listed under the category *feedback on player performance* (e.g. DGs 7.1–7.8, 7.12–7.14, 7.16–7.19) can be considered relevant for motivating not only the players of full-body games but also the users of, for example, behavior change technologies. The same generalizability also applies to many of the guidelines grouped under the category *game challenge* (e.g. DGs 6.1, 6.2, 6.4–6.6, 6.10 and 6.11).

While a generic and varied set of design guidelines (addressing many aspects of design) may initially be considered to form a rich 'toolbox' for designers of full-body games, we were surprised to find that many of the guidelines related to the three categories mentioned above are to a large extent repeating the essence of guidelines published in an earlier work. For example, the guidelines listed under the categories *universal design, feedback on player performance* and *attention* are to a large extent covered by the seven principles of universal design and work by Honeywell (1992); Story (1998). We also found large overlaps between several guidelines reviewed as part of the current study. Examples of such overlaps can be found between DGs 9.1 *provide exertion management*, 9.2 *prevent overexertion* and 9.3 *control perceived exertion*, which essentially convey the same message. Similarly, DGs 10.1 *prevent health risks and injuries*, 10.2 *promote safety during gameplay* and 10.4 *exploit physical risk sensibly* convey similar meaning.

We see two main problems related to the relatively large number of 'replicated' guidelines in the reviewed studies. First, the observation arguably questions the novelty of some of the insights the corresponding studies contribute. This is *not* to say that reproducing research result on which the existing design guidelines are based is without value—as further discussed in the next subsection, the limited evidence that many design guidelines for full-body games appear to be based on is a considerable validity problem. From such a perspective, it can even be considered highly beneficial to see similar design lessons arise from comparable studies. In addition, we recognize that the application of design guidelines in various contexts may potentially create opportunities for new interpretations, which again may complement existing guidelines. When we question the research value of studies that close to replicate existing guidelines, we mean first and foremost the problem that the study that originally produced the guideline often is not discussed in the 'replicating' study.

Second, and perhaps more dire, the replication of guidelines strongly suggests that there is a lack of systematic development of design guidelines for full-body games. The absence of a common guideline format (see above) can in many ways be seen as a key barrier preventing such a development, as it makes it more challenging to identify, compare and relate guidelines found in the literature. This situation makes it particularly challenging to build a structured network of guidelines that can be easily extracted and navigated and seriously compromises the quality of the corpus of relevant design guidelines as a whole. However, while a common guideline format might help the situation, we consider it equally important that review processes of work that offer new design guidelines thoroughly scrutinize how proposed recommendations fit into the network of existing ones described in related work. For the design of full-body interactive games, this means that the quality of the evolving body of design guidelines is in part a responsibility of the associated design community.

6.4. Validity

The reviewed design guidelines were derived from studies that employed different research methods (Table 3) and that were highly diverse, for example, in terms of the number of conducted assessments, duration per assessment and number of participants (Table 5). The variations described above raise an interesting issue concerning what is required in the context of full-body games for a design recommendation to qualify as a guideline. As long as there is no formal definition of the quality requirements of a guideline for the design of human–computer interfaces in general, the validity of existing design guidelines for full-body games is likely to be highly ambiguous. Given these concerns, we consider the majority of the guidelines presented in the reviewed articles to form candidate guidelines rather than the proven best practices in design. As a consequence, the guidelines should be used with caution.

6.5. The limited focus on tangible user interfaces

Another noteworthy finding from the literature review is that the vast majority of identified guidelines were derived from studies of full-body games where large displays (e.g. TV screens and projected screens) played a central role in player–game interaction. The high representation of screen-based solutions raises issues concerning the practical use value of some of the produced guidelines. First, many of the guidelines, for example, those concerning the use of animations, avatars and text (DGs 2.2, 3.2, 4.1–4.3, 5.10, 11.4 and 11.9) will only be applicable in the design of games that actually make use of large displays as the primary output channel.

Second, and more importantly, the limited attention paid to non-screen-based full-body games indicates that there is a potential gap in the existing body of design guidelines. While design guidelines derived from screen-based full-body games (e.g. DGs 5.5–5.8) in many cases can also be applicable in the design of games that employ tangible user interfaces, new generalizable design knowledge might also be derived from studying non-screen-based games. Isbister and Mueller's (2015) recommendation to *focus on the body and not the screen when designing player feedback* (DG 7.9) is an example of a design guideline, which was derived in part from the studies involving the use of a non-screen-based game, *i-dentity* (Garner *et al.*, 2013, 2014). Other recommendations Isbister and Mueller (2015) offer, which partly build on insights from studying players interacting with non-screen-based games, are *support players in expressing themselves using their bodies* (DG 1.3) and *exploit physical risk sensibly* (DG 10.4). For both design guidelines, the game *JS joust* (Fabrik) is given as an example of implementation. In both *i-dentity* and *JS* joust, Sony Move controllers are used as I/O technology (Mueller and Isbister, 2014). Moreover, Isbister and Mueller's guideline *help players identify rhythm in their movements* (DG 1.5) appears to draw on lessons learned from the face-to-face interaction clapping game *Mary Mack 5000* (Abe). In the game, sound (rhythm) plays an important complementary role to screen-based (visual) output by helping two collaborative players synchronizing hand clapping (Mueller and Isbister, 2014). The examples provided above illustrate how studies of full-body games employing alternative or additional output media to large displays may offer novel design insights.

7. METHODOLOGICAL CONSIDERATIONS

In the current study, we have synthesized and provided a systematic review of the existing design guidelines for full-body games. As with all structured SLRs, the picture that is painted of the topic in focus is colored by the aspects pertaining to the applied method. Hence, we find it relevant to call into attention some methodological considerations that have influenced the status the current work gives of full-body games and relevant design guidelines.

First, inclusion of an article in the SLR was dependent on the abstract of that article specifying that design guidelines (or equivalent terms) for body-controlled games was a main scientific outcome. As mentioned earlier in the paper, this means that papers providing other forms of design knowledge or *guidance* have not been included. Hence, it is important to understand that the current review does not present a status of all available design knowledge relevant for full-body games but only reports on the body of research literature providing explicit recommendation for design of such applications. Using a relatively complex search string to gather relevant articles also meant that we retrieved a broad range of design guidelines that had been derived from studies with different focal points and designs targeting different user (player) groups. It is also worthwhile to note that while we focused on reviewing research articles explicitly offering design guidelines as the main outcome of the described study, we did not distinguish between the variety and quality in the formatting of the guidelines, i.e. the structure used in the individual papers to describe the guidelines.

Second, it is important to note that the categorization of identified guidelines (Tables 6–17) was based on our (the authors') interpretation of the guidelines. While we attempted to ensure consistency in our grouping through internal discussions and constant reassessments of the categories as they were expanded with new guidelines, the final result should not be regarded as a 'blueprint' or an attempt to standardize categorization of the design guidelines for full-body games. The categories are in other words a result of the authors' sense-making of the existing corpus of relevant recommendations.

Third, we recognize that our relatively broad coverage of design guidelines and the way we categorized them may to some extent also have affected the concerns we identified and discussed in Section 6. For example, the hedonic–utilitarian divide in movement-related guidelines (Section 6.1) can be seen as a result of this comprehensive coverage. The lack of systematic development of guidelines (Section 6.2), again, is to some degree an issue that emerged as a result of our interpretation and grouping of design guidelines, i.e. we became gradually aware of the issue through the grouping process. Thus, the emerging list of concerns is neither exhaustive nor complete but rather a consequential result of the aspects pointed out above.

8. CONCLUSIONS

In light of the increasing attention that the design and use of full-body interactive games have gained in HCI and game design research in recent years, we assessed the present state of design guidelines for such applications through a systematic review of existing literature. A total of 22 articles were included from an initial 3562 retrieved references. The review resulted in the extraction of 107 design guidelines, which were further sorted into 12 different categories and accounted for. The 12 categories were *movement elicitation*, *mapping of movement*, *explicit movement guidance*, *player representation and game world*, *attention*, *game challenge*, *feedback on player performance*, *player agency and customization*, *exertion*, *safety*, *universal design* and *social aspects*.

The broad range of categories suggests that the existing body of design guidelines for full-body interactive games cover many relevant design aspects. As such, the current work offers a comprehensive overview of both challenges related to design of full-body games and possible ways to cope with the same challenges. At the same time, the review revealed a number of overarching concerns regarding the present state of the same body. These concerns were related to (i) the hedonic–utilitarian divide in movement-related design guidelines relevant literature, (ii) the lack of common structure for specifying guidelines, (iii) the lack of systematic development of guidelines, (iv) the issues related to the validity of the existing guidelines and (v) the limited focus on tangible interfaces in the present state of the art.

In conclusion, the current review paints a somewhat questionable picture of the present state of the corpus of design guidelines for full-body games, with relatively large differences in the quality of the guidelines proposed in the individual articles and a lack of reference to already existing guidelines. In the longer run, these quality issues risk watering out the original meaning of the term *design guideline*. Rather than communicating the best practices in design—if we understand 'best practices' as simple-to-follow, exemplified, justified, structured, validated and well-explained recommendations—there is a danger that the concept of *design guideline* will be reduced to nothing more than a simple hypothesis about design, thereby losing its potential value in design of full-body interactive games. To counter such prospects, we encourage designers of full-body games, including both users and developers of design recommendations, to engage in the discourse on how we can ensure the usability and value of design guidelines.

Author Disclosure Statement

No competing financial interests exist.

Funding

This research was funded by NTNU Health, Norwegian University of Science and Technology.

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Appendix 1

Search string used in the ACM Digital Library focusing on CHI proceedings over the past decade: (Exergam* OR 'Exertion gam*' OR 'Multimodal gam*' OR 'Exertion video gam*' OR 'serious gam*' OR 'exercise gam*' OR 'movement-based gam*' OR 'motion-control gam*' OR 'motion-controlled gam*' OR 'motion-based gam*').

Appendix 2

The full query used to extract relevant studies for the review is as follows:

((Exergam* OR 'Exertion gam*' OR 'Multimodal gam*' OR 'Exertion video gam*' OR 'serious gam*' OR 'exercise gam*' OR 'movement-based gam*' OR 'motion-control gam*' OR 'motion-controlled gam*' OR 'motion-based gam*') AND (design* OR develop*) AND (consideration* OR recommend* OR guideline* OR suggestion* OR strateg* OR lessons))