# Game design and player experience evaluation in games for cochlear implant rehabilitation: A literature review*

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**Abstract**

A cochlear implant (CI) is an electronic device designed to assist individuals who are deaf or hard-of-hearing. It captures sound through a microphone and transmits it to electrodes, which directly stimulate the auditory nerve, bypassing the damaged areas of the ear. Although considered a very successful intervention, there is large variability in the outcomes of cochlear implantation. Patient- reported issues include difficulties hearing speech in noisy environments, disappointment in sound quality and difficulties appreciating music. A period of aural rehabilitation usually follows implantation, where patients see audiologists and speech language pathologists. There is evidence supporting the use of auditory training, actively practicing listening tasks, mainly focused on speech, at a clinic or at home. One such task, often suggested by audiologists and speech language pathologists is computer-based auditory training. There are a number of game-like computer programs and apps that are recommended to patients, most of which similarly focus on speech. In recent years there has been some research on serious games specifically aimed at CI-rehabilitation. This paper presents a literature review of studies using games for auditory training in CI-rehabilitation. The aim of this paper is to investigate how the reviewed studies relate to established game design knowledge, including how they evaluate player experience. The results reveal a gap, indicating that game design as a concept is rarely reported on, and the evaluation of player experience is seldom based on established instruments. While this study focuses on a specific and cohesive research community, it highlights the need for improved standards in the utilization and reporting of game design in such studies. We propose a set of guidelines for reporting on medical studies involving games.

**Keywords**

game design, player experience, rehabilitation, cochlear implant



## 1. Introduction

A cochlear implant (CI) is a small electronic device that is implanted in the cochlea of the ear. An external microphone, placed near the ear, picks up sound and sends it to electrodes that stimulate the cochlea to send signals directly to the hearing nerve, thus bypassing damaged parts of the ear and restoring a sense of hearing to people who are deaf or hard-of- hearing [1].

CI is widely considered a successful intervention, with the majority of patients being satisfied with their implants [2]. However, there is large variability in the outcome of CI, an ongoing research problem in the CI- research community [3]. Common problems for patients include difficulty with listening in noisy environments and pitch and timbre discrimination [4] [5].

After implantation, a period of rehabilitation usually follows to maximize the benefit of the CI for patients [6]. A recent survey indicated that a majority of CI practitioners in the U.S. recommend auditory training (AT) as part of rehabilitation [7]. AT can be described as purposefully listening to sounds with intent to improve perceptual sound discrimination [8]. One type of AT that is commonly prescribed is computer-based AT [7], which means computer programs or apps that lets patients perform AT on their own [9]. Benefits of using these types of tools, compared to in-clinic

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training, includes that they are cost-effective, easily accessible, can be used at home and can be customized to users' needs [9]. The aim of the majority of these tools, is speech understanding, speech production training and listening-in-noise training [8].

Serious games are games that have some type of learning goal, rather than being pure entertainment, and have been used for purposes such as vocational training, education, health and rehabilitation [10]. In order for the learning outcomes to be effective, player enjoyment and engagement are important aspects to consider [11].

This paper presents a literature review of previous studies, that have designed and evaluated digital games for AT, aimed at CI-rehabilitation. Of particular interest to this study, is to assess how the reviewed articles relate to game design as well as evaluation of enjoyment. To the best of our knowledge, no such review has been published to date.

This review is part of larger research project where one part is to design and evaluate a digital game for CI-rehabilitation. The field of CI-research is extensive and rehabilitation is an important part that receives a lot of attention. For context, a recent search on *Google Scholar for "cochlear implant" rehabilitation*, yielded 37,400 results. However, serious games are not widely used for CI-rehabilitation, but are emerging. The motivation for conducting this review is to gain insight into how games are designed, used and evaluated in the CI- research community. Findings from this review may also be of interest to other fields of research where serious games could be useful but are not yet established.

## 2. Background

Training activities in AT are often based on a hierarchy of listening skills, stemming from the order in which children learn to process sounds [12] [13]. The steps are:

1. sound detection – ability to be aware of sounds
2. sound discrimination – ability to differentiate between sounds
3. sound identification – ability to recognize sounds
4. sound comprehension – ability to understand meaning of sounds

In the current review, these categories of listening skills provide a theoretical basis for analyzing training tasks in the reviewed games.

Effectiveness of self-administered rehabilitation training, such as computer-based AT, is affected by patients' motivation and dedication [14]. The ability of games to engage players and motivate them to keep playing, has been utilized successfully in serious games for learning and rehabilitation [10], [15], [16]. In a systematic review on success factors for serious games, Ravyse et al. [11] concluded that learning aspects are secondary, and that players' main motivation for playing serious games is to have fun. Ravyse et al. (p. 411) further posit that "Serious games producers must not impede this hunger for fun, but rather use it to stealthily engage the player with the required learning material". Clark et al. [15] conducted a systematic review and meta-analysis on learning and digital games. They conclude that research needs to shift focus from asking if games can support learning to "cognitive-consequences and value-added studies exploring how theoretically driven design decisions influence situated learning outcomes for the broad diversity of learners within and beyond our classrooms" [15, p.116].

### 2.1. Game design

Game design is about creating an interactive experience for one or several players. The game design process involves determining the goal and objective of the game, the rules for pursuing the goal and the actions available to the player.

Game design as an academic field dates back to the beginning of the millennium when the first academic conference on game studies, DiGRA (Digital Games Research Association), was initiated.

Since then, numerous industry handbooks as well as academic literature on game design practices have been published. Some of the most influential works include *Andrew Rollings and Ernest Adams on game design* [17], *Game design workshop: a playcentric approach to creating innovative games* by Fullerton and Swain [18], *The Art of Game Design: A book of lenses* by Schell [19], *Theory of Fun for Game Design* by Koster [20], *Patterns in Game Design*, by Björk and Holopainen [21], *Rules of Play: Game Design Fundamentals* by Salen and Zimmerman [22] and the *MDA framework* proposed by Hunicke et al. [23]. Another influential publication is Järvinen's thesis *Games without frontiers: Theories and Methods for Game Studies and Design* [24].

Several of the publications named above could possibly have been used to conduct the game analysis in the current review although many of them have strong focus on guiding the design of games (e.g. [18], [23]), rather than analyzing them. In this paper, we based the game analysis on the work of Järvinen, which offers clear definitions of game elements and a comprehensive library of game mechanics suitable for this review. Additionally, Järvinen's method for identifying goals and game mechanics provided a practical framework for our analysis.

## 2.2. Game elements

Game elements, according to Järvinen, are the building blocks that make up a game. He identifies nine classes of game elements, divided into three categories, that interact to create the game system. In Table 1, the three categories and their related game elements are listed.

**Table 1**
Järvinen's three categories of game elements and their related elements

| Systemic elements | Compound elements | Behavioral elements |
|---|---|---|
| Components | Rule set | Players |
| Environment | Game mechanics | Context |
| | Theme | |
| | Interface | |
| | Information | |

*Systemic elements* are the formal parts of the game system. *Components* are objects, that players or the system can control or possess, for example, avatars, vehicles, weapons, points or money. *Environment* is the space where the game takes place, like the board in a board game or the virtual, two- or three-dimensional game world in a digital game.

In *behavioral elements*, *players* are those who play the game and *context* is where, when and how the game is played.

*Compound elements* facilitate and govern the interaction between the systemic and behavioral elements. Or in simpler terms, between the game system and the player.

*Information* is data that is stored by the system, such as the value of a score component or information the player needs to progress in the game, for instance, clues or time limits.

*Interface* is the means by which the player can interact with the game, such as, a touch screen, gamepad, keyboard or mouse.

*Theme* is a game's subject matter and can include things like setting, narrative, psychological motivations etc. Theme can be embodied into other game elements, for instance, if a game has a wild west theme, it will likely be reflected in the environment.

*Rule set* is the collection of different rules in the game system that affords and constrains what players can and cannot do in the game. Rules can, for instance, regulate boundaries of the game environment, define how scores are awarded and regulate what game mechanics are available to the player at a specific point in time. There are different types of rules and one important type to the current review, is g*oal rules*. According to Järvinen, explicit goals are what separate games from

non-games and are used to motivate players' actions. In games, goals provide challenges, or as Järvinen [24, p. 130] puts it "In effect, when we talk about the challenges in a given game, we are talking about its goals".

*Rewards* and *difficulty level* are two features that are relevant to the current review, and that are connected to rule set. Difficulty level in a game is governed by the rule set in the form of goals, and the player's ability to use game mechanics to achieve those goals. Rewards are handed out by the game system if goals are achieved according to the rule set.

*Game mechanics* are central to what a game is about and can define the gaming experience. According to Järvinen [24], they are means for the player to pursue and achieve goals. They are what the player is doing in the game. In Järvinen's *library of game mechanics* [24], they are described by verbs, such as, choosing, moving, shooting, jumping, etc.

In the current review, we are concerned with two elements in particular: rule set and game mechanics. Analyzing these two game elements and how they relate, provide insight into what the player is supposed to do in the game and what actions players need to take to progress and succeed in the game.

### 2.3. Enjoyment in games

Compared to non-game software that has utility as its main purpose, the main purpose of games is to be enjoyable [24], [25]. This makes evaluation more complicated compared to strictly utilitarian software [10]. Usability, accessibility and similar concepts are important factors to all software applications (operated by humans), including games [26]. Poor usability may no doubt impact the enjoyment of games, but simply because a game has high usability, does not mean it is enjoyable [26].

Over the past decades there have been numerous efforts to explain fun or enjoyment in games. In the current article we will use the term *enjoyment* when addressing the experience of fun, entertainment or similar terms. One often-used theory to understand enjoyment in games is *flow*, defined by psychologist Csikszentmihalyi as a "…state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it" [27, p. 4]. The concept of flow has in turn led to new efforts to explain, measure and design for enjoyment [28], [29]. *Immersion* [30], [31] is another concept that has been used frequently as way of measuring players' engagement, where enjoyment is a factor. Jennet et al. [31, p. 643] states that "immersion is concerned with the specific, psychological experience of engaging with a computer game".

To evaluate and measure enjoyment and other player experience factors in games, many instruments have been developed and used by researchers and practitioners alike. Some examples of often used instruments include the *Immersive Experience Questionnaire* (IEQ) [31], *Player Experience of Need Satisfaction* (PENS) [32] and *Game Experience Questionnaire* (GEQ) [33]. In addition, originally not an instrument for measuring player experience, the *GameFlow* model by Sweetser and Wyeth [25] has been modified and used in many studies for those purposes [29].
Rewards, such as, points, badges, stars and achievements can have an impact on player enjoyment [34]. A game's level of difficulty can also impact enjoyment. If the game is too easy it can cause boredom, and if it is too difficult it can cause frustration [35].

## 3. Research questions and method

Games have been used for rehabilitation for a long time. The motivational aspects of games are seen as a powerful tool. There is however a challenge in that there are clear gaps between research areas [36] and that results from game design research is not always applied in the health area. The field of CI is a focused research community, with conferences and journals dedicated to enhancing the quality of life for patients. This makes it an interesting case for analyzing the extent to which game design research has influenced medical research.

The aim of this study is hence to assess how published studies relate to game design methods, how they evaluate enjoyment and what game elements are present in the games. To examine these topics, three research questions (RQ) are formulated:

- RQ 1: What game elements are present in AT-games, presented in the reviewed studies?
- RQ 2: What game design methods are used for developing AT-games, in the reviewed studies?
- RQ 3: What methods for evaluation of player experience are used in the reviewed studies?

The questions are addressed through a literature review. A systematic search and selection process, guided by the PRISMA statement [37], was employed to identify eligible articles. Due to the diverse nature of the reviewed articles, the review is not systematic. Therefore, the PRISMA statement was only consulted in the search and selection stages. In Table 2, searched databases, search string, exclusion and inclusion criteria are presented. In *Scopus*, searches were limited to title, abstract and keywords. For the other databases all fields were searched. No additional filters were applied. The search string was adapted to suit the specific syntax of each database. All searches were performed in October of 2024.

A total of (n=207) records were identified from searches. *ACM Digital library* (n=129). *IEEE Explore* (n=4), *PubMed* (n=21), *Scopus* (n=27), *Web of Science* (n=26). After removing duplicates (n=24) a manual scan of abstracts was conducted by one researcher and (n=156) records were removed due to exclusion criteria (see Figure 1). Out of the (n=27) records remaining, (n=12) articles met the inclusion criteria and were included in the review. Efforts were made to identify additional articles by searching for newer articles from authors and by reviewing the references in the selected articles. No additional articles were identified through these steps.

The review was conducted by one reviewer utilizing thematic analysis. For RQ 1, the reviewer analyzed the games in the reviewed articles and assigned goals and game mechanics guided by the methods used by Järvinen [24]. For RQ2 and RQ3, content coding and thematic analysis was made using the *Dedoose* software.

**Table 2**
Specifications for database searches and article eligibility

| | |
|---|---|
| Databases: | *ACM Digital library, IEEE Explore, PubMed, Scopus, Web of Science* |
| Search string: | game* AND cochlea* AND (rehab* OR "auditory training") |
| Exclusion criteria: | Article is not about games<br>Article is not about CI<br>Article is not in English<br>Article is not published in journal or conference |
| Inclusion criteria: | Article presents design and evaluation of a game<br>The purpose of presented game is CI-rehabilitation or auditory training |

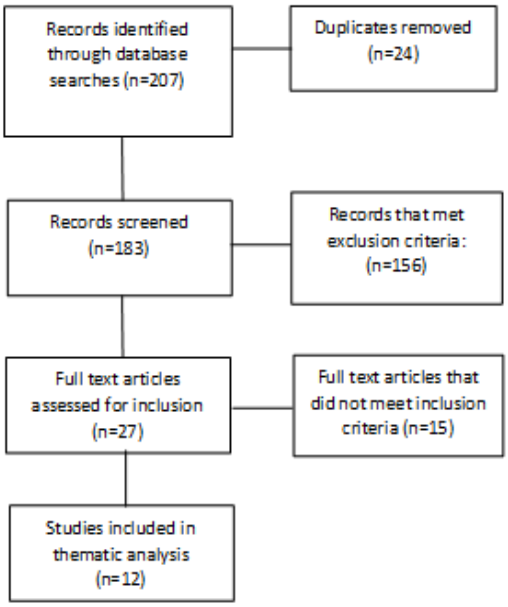


**Figure 1:** Search and selection process

## 4. Results

In Table 3 the reviewed articles are listed with paper ID's and references.

**Table 3**
All reviewed articles with references and ID's

| Paper ID | Title | Ref. |
|---|---|---|
| S1 | World of sounds (Seslerin Dunyası): A mobile auditory training game for children with cochlear implants | [38] |
| S2 | Development and Beta Testing of Serious Game-Based Auditory Training Application to Enhance Perceptual Learning of Speech in Cochlear Implant Recipients | [39] |
| S3 | Development of an auditory rehabilitation tool for children with cochlear implants through a mobile-based VR and AR serious game | [40] |
| S4 | Speech and Language Support System for Children with Hearing Impairment | [41] |
| S5 | Video Games to Support Language Therapies in Children with Hearing Disabilities | [42] |
| S6 | Talking to Teo: Video game supported speech therapy | [43] |
| S7 | Effect of Serious Gaming on Speech-in-Noise Intelligibility in Adult Cochlear Implantees: A Randomized Controlled Study | [44] |
| S8 | N.O.T.E.: Note Over The Edge | [45] |

| | | |
|---|---|---|
| S9 | Listen again: virtual reality based training for children with hearing impairments | [46] |
| S10 | Development of the Musi-CI Training, A Musical Listening Training for Cochlear Implant Users: A Participatory Action Research Approach | [47] |
| S11 | Involving Children and Teenagers With Bilateral Cochlear Implants in the Design of the BEARS (Both EARS) Virtual Reality Training Suite Improves Personalization | [48] |
| S12 | MOGAT: mobile games with auditory training for children with cochlear implants | [49] |

### 4.1. Game elements

In Table 4, a mapping of the main goals and their connected game mechanics are presented. Most of the goals are connected to listening tasks and correspond to the *hierarchy of listening skills* [12], presented in section 2. When not applicable, a descriptive keyword of the goal was assigned by the reviewer. When possible, Järvinen's *library of game mechanics* was used to map the game mechanics [24]. According to Järvinen, this library is not exhaustive, so when no matching mechanic was found, the reviewer labeled the mechanic by analyzing the action and assigning the verb that best describes the action.

Goals or challenges in the reviewed articles mainly concern the training tasks of listening, rather than the player's ability to control the game or complete challenges not directly connected to the training tasks. In most of the reviewed games, the gameplay is based around one action connected to the listening exercise. For instance, the player listens for a specific sound and presses a button as soon as they hear it (S1, S2, S3). The main goal in this instance is *sound-detection* and the game mechanic is *reacting*. The main challenge comes from hearing the sound rather than performing the game task of pressing a button as quickly as possible. Another example is when the player sees a number of images and selects the one corresponding to the sound being played (S1, S4). Here the main goal is *sound-identification* and the game mechanic is *choosing*. The challenge in this case comes from identifying the sound, rather than from interacting with the game. This type of gameplay of listening first, then interacting, is the most common type of gameplay in the articles, but there are exceptions.

Two studies (S2, S8) utilized the Endless/Infinite-runner genre as the foundation for their game designs. This genre was selected due to several advantages: minimal required interactions, the ability to procedurally generate levels (S8), that it is easy to learn and its widespread popularity across many demographics (S2). In these cases, timing and the game mechanics *maneuvering* and *jumping* are factors that provide added challenge, apart from the listening task.

In S11, the player is tasked with localizing a sound in virtual reality, i.e. finding the sound in the game world by listening to which direction it comes from. When the sound source is localized the player shoots at the sound source. This affords the player the game mechanics *exploring* and *aiming & shooting*. *Playing music* on a virtual instrument, speaking or singing (*verbalization*) to repeat a word or sequence were part of the gameplay in S4, S6, S10 and S12, which utilizes the game mechanics *expressing* and *sequencing*. In S4, the main goal was listening to instructions or *sound-comprehension,* to then perform the described actions. In terms of game mechanics, *following-instruction* is how to best describe it with the information that was provided in the article.

**Table 4**
Mapping of main goals and their connected game mechanics. * = Reviewer's own labels

| ID's | Main goal | Game mechanic |
|---|---|---|
| S1, S2 | sound-detection | reacting* |
| S2, S3, S7, S10, S12 | sound-discrimination | choosing |
| S3 | sound-detection, sound-discrimination | maneuvering, jumping |
| S8 | sound-discrimination | maneuvering |
| S1, S4 | sound-identification | choosing |
| S4 | sound-comprehension | following-instruction* |
| S3, S7 | sound-comprehension | choosing |
| S11 | sound-localization* | exploring*, aiming & shooting |
| S10 | playing music* | expressing, sequencing |
| S4, S6, S12 | verbalization* (speak or sing) | expressing |

Progressive difficulty levels are used in a number of the games to keep the level of challenge appropriate for the player (S1, S2, S7, S9). This technique is proposed to keep the player engaged for long periods of time. In S7, difficulty is applied adaptively based on the player's performance. Difficulty levels in most of the games are connected to the training tasks rather than the game mechanics. In S7 for instance, a game aimed at training speech-in-noise intelligibility, difficulty was adjusted by changing the ratio between the sound to be identified and the background noise. A similar technique of adding background noise to increase difficulty was used in S2.

Rewards are used in certain studies to give players encouraging feedback on their performance and incentive to keep playing. *Achievements* in the form of tokens, stars or collectibles are used to reward players when they complete a challenge or perform a task well (S2, S6, S9). *Game scores* are presented to players when they complete a task in S8, and in S12 the scores are saved to *leader boards*, where players can compare themselves to others. In S2, the player can receive *power-ups*, new or better abilities, meant to increase engagement.

Additional game features that are used to increase player engagement includes *avatars*, used in S5 and S6, and an overarching *narrative* in S6.

## 4.2. Game design methods

Mostly, the design methods that are described in the articles are not specific to games, but rather methods used in software development in general. These include participatory design or participatory action research and iterative development. The term "game design" was seldom

mentioned, which is noteworthy, and references to the application of established methods from game design research and practice were similarly limited. One exception is S6, where the authors consulted Oxland [50] and Schell [19] for designing the game.

Participatory design means involving all stakeholders, such as patients, parents, therapists, technicians, teachers and developers, in the design process, to ensure that the game is enjoyable and suitable to the target audience (S2, S9, S10, S11, S12). A few studies highlight the importance of employing interdisciplinary teams in development (S5, S10, S12).

Participatory action research was employed in (S2, S10, S11). In S2, the author discusses tailoring design for the target population and states (p. 264) "To accomplish the goals of this design, the five steps of the participatory action research were used; these include observation, reflection, action, evaluation, and modification…". Similarly, in S10 (p. 3), the authors reason that "By developing the Musi-CI training with CI users, it more accurately reflects their needs, wishes, skills, and individual musical experiences…".

Four articles specified that they employed an iterative approach to development and testing (S1, S10, S11, S12). In S11, for instance, the authors describe how early prototype testing of their virtual reality game, led to changes regarding difficulty and rewards. Furthermore, they implemented an option for using iPad based on feedback about the virtual reality headsets not being favorable by certain testers. Although not explicitly stated, iterative development was evident in several additional articles (S2, S4, S5, S6, S8). S2, for example, describes iterative testing of two game prototypes and states (p. 265) "Following each session, players' feedback and reflection on their gameplay experience was collected to make further modifications to the games based on the users' perspective".

### 4.3. Evaluation

The focus of this part of the review is to investigate how games for CI-rehabilitation evaluates player experience. Evaluation of the games' usability, usefulness or benefits towards the training tasks are outside the scope of this paper. After analyzing all articles according to RQ3, five articles were found to have done preliminary testing rather than conducting final evaluations of their games (S4, S5, S8, S10, S11). Therefore, those articles were excluded from this part of the review and this section only presents results from the remaining seven articles.

Enjoyment was evaluated in some way in all of the reviewed articles. Motivation (S1, S2, S12), engagement (S6) and attractiveness and uniqueness (S2) were also evaluated in certain studies.

The preferred method of data collection was questionnaires (S1, S2, S3, S6, S9, S12), but interviews (S2, S6, S7) and observations (S6) were also used in certain studies. Data logging was used in several studies (S1, S7, S9, S12), to record players' performance and usage which provided data on usability factors.

Apart from S1 and S6, no articles specified using established instruments for evaluating player experience. Enjoyment was measured by asking questions, such as, "did you enjoy the game?", "was the game fun to play?" and similar. In S1, existing usability instruments were consulted to prepare questionnaires [51], [52], [53]. S6 based their measurements of enjoyment and engagement on the works of Mekler et al. [54] and Hartson and Pyla [55]. S6 also used a modified version of the *Usefulness, Satisfaction, and Ease of Use questionnaire* and methods for summative evaluation for assessing user experience, both drawn from [55]. Moreover, S6 stands out as the only article that provides a definition for enjoyment in games. They conclude "We have gained evidence on how a serious game in therapy can be entertaining, stimulating enjoyment and engagement and consequently favoring long-term game flow" (S6, p. 4).

### 4.4. Additional findings

An additional finding, that is not within the scope of any RQ, is worth mentioning. In eight out of the twelve reviewed articles, the concept of *therapist control* was identified. *Therapist* in this context is defined as the professional – such as an audiologist, speech-language-pathologist, music

therapist, teacher or similar – in charge of the training the game is designed for. We define *therapist control* as when the game affords the therapist the ability to supervise or record the patient's performance, or to modify the game to suit the patient's needs. In eight articles the ability for a therapist to record and monitor the performance of the patient was suggested or implemented (S1, S3, S4, S5, S6, S8, S10, S12). In three of those articles the therapist could use that data to prescribe or recommend further training exercises based on individual performance (S1, S6, S12). Two other articles included a way for a therapist to impact the game directly by adjusting difficulty settings for the player (S3, S4). Yet another two articles took it even further and let the therapist manipulate the game design by generating individualized mini-games (S5, S8). This approach raises questions about whether the therapist's expertise in game design impacts the effectiveness of the games.

## 5. Discussion

The most explicitly stated reasons for using digital games, among the reviewed articles, was that games can be engaging and help with patient motivation (S2, S5, S6, S7, S8, S10, S11), and that they are fun and enjoyable (S2, S5, S8, S12). Considering that those are the rationales for using games in this context, it is noteworthy that so few articles reference game design methods or established instruments to measure player experience.

It is important to note that that this review does not consider whether the reviewed games were successful in achieving their respective training goals, nor does it consider whether players found the games enjoyable or not. As previously mentioned, most of the studies measured enjoyment by asking questions, such as, "did you enjoy the game?", "was the game fun to play?" and similar. Regardless of the outcome, by relying on such questions without rigorously investigating *what* is enjoyable about a game and *why* the player wants to keep playing, designers run the risk of not achieving long-term engagement, crucial to rehabilitation training [14]. Positive feedback from players when presenting a new game may be attributed to the novelty effect [11]. To promote long-term engagement, replay value and variation should be considered.

### 5.1. Games for rehabilitation

There are a few characteristics of using games for CI-rehabilitation that warrants attention. Firstly, the involvement of a therapist has implications for the player experience. As reported in section 4.4, several of the reviewed articles proposed or implemented ways for a therapist to monitor or even manipulate the game for their patients. Compared to "normal" gaming situations, where people play for their own enjoyment, having someone monitoring and assessing your performance in the game, could affect the level of enjoyment the game brings. Similarly, whether the game is played on the patients' own terms or if it is forced on them as a mandatory exercise, can also affect patients' motivation to play. This would be an interesting avenue for future investigation.

Secondly, compared to non-game CI-rehabilitation or playing games for pure enjoyment, games for CI-rehabilitation have two parallel skill-sets to consider – listening skills and skill at playing the game. This dual progression scale is a complex issue, that likely is relevant to more areas of game-based rehabilitation. When playing a game aimed at CI-rehabilitation, patients' listening skills will hopefully improve, and their skill at playing the game will most likely improve by just playing. Progression is an important part of keeping a game motivating over time. If the progression of the game is strongly linked to players' listening skills, rather than to their skill at playing the game, designers run the risk of losing the patients' interest if they do not increase their listening skills in perfect time with the game's overall progression.

In the reviewed games, the main goals and challenges were strongly connected to the training tasks, and difficulty levels and progression were based on the patients' listening skills. This stands in contrast to the recommendations by Ravyse et al. [11], mentioned in section 2, to stealthily present learning materials to players.

These concepts also resonate with a previous study we conducted, where serious games were used for stroke-rehabilitation [56]. Patients played mini-games with a custom-made controller, designed to stimulate movement that was useful to their rehabilitation. We found, based on patients' playtime and comments, that the games that were based around existing game concepts were more popular than games based around movement exercises.We ask the question if games for rehabilitation really should mimic traditional rehabilitation exercises? Or if it is more useful to design games that are enjoyable regardless of rehabilitation, and find smart ways to implement training as an additional layer. A well-designed game has the potential to captivate players and make them keep coming back. Games may best serve as a light and fun, complementary tool for quantitative training, rather than mimicking in-clinic qualitative training. For many applications it may be sufficient that the game provides *some form* of useful training for the patient and that the player keeps playing mainly because of the enjoyable experience.

Designing an engaging and enjoyable game is no trivial task. We recommend that professional game designers, or academics with expertise in game design and development are included in the interdisciplinary teams when games like in the reviewed studies are developed, to ensure quality.

## 5.2. Reporting on games in medical research

The studies examined in this review are published in journals and conferences that span several different areas with different main focuses. Approximately half of the studies are published in forums that have a clear medical focus while the other half is in forums with a focus on virtual reality and games. This division is not surprising since game research is conducted in many fields where the degree of overlap varies greatly. Through a network analysis of game research, Martin [36] identifies a clear division between the communities *Education/Culture* and *Medical*. Within the former, separate subgroups are identified as *player experience and game form*, *culture*, *education* and *serious applications*. Within Medical, the subgroup *rehabilitation* is found. Studies in game-based rehabilitation need to relate to this fragmentation that exists in game research. There is a structural distance between the areas that cannot be easily bridged. It is not enough to simply declare an interdisciplinary approach, which Deterding [57] clearly highlights in his reflection on the area of game studies. The realities of academia mean that researchers are often forced to orient themselves towards specific disciplinary traditions. There are, not least in medical research, structural obstacles to including results and methods that are not relevant to the tradition of this discipline. Page or word limits can make it impossible to include rich descriptions of parts that lie beyond the main focus of the discipline. It is not realistic that medically oriented studies of game-based rehabilitation will include complete descriptions of game design and development processes. However, it is possible to develop better guidelines and principles for how fundamental insights from game design and game user research should be acknowledged and reported even in medically focused publications.

In medical research, there are currently standards for how different types of studies should be reported. The *EQUATOR* Network [58], has a library of reporting guidelines for different types of medical studies. Currently, there is only one standard, *GAMING*, that concerns game-based intervention [59]. This standard focuses on the distinction between serious games and gamification and is based on studies published in the *Journal of Medical Internet Research* and ten sister publications. In other words, the study has a narrow focus on a single community, which previous studies [36], [57] clearly show does not provide a comprehensive picture of the gaming field. The description of GAMING reveals a reductionist view of games and that the challenge is mainly about providing a reliable description of the type of game or game element being studied. This approach is very rarely found among game designers and in game development. We see a need for expanded reporting guidelines for studies of game-based interventions in medical research. If a study expresses intentions towards harnessing the motivational potential of games, then fundamental principles of games and game development cannot be ignored. These are some examples of such principles:

The motivational aspects of games mainly come from the experience they provide. Different games provide different types of experiences and it is misleading to reduce them to "fun" or "entertainment" [60].

Games are interactive and must normally be played to be experienced and understood. Players' experiences can differ depending on the way they play the game [23].

Different players have different preferences and tastes for what type of game experience they appreciate. This has, for example, given rise to a number of different frameworks for player types (e.g. [61]).

Digital games have some unique characteristics but they share fundamental characteristics with analog games [22].

Game design and development is a complex iterative process that typically involves several different specialist skills that all have an effect on the quality of the game. Prototypes are developed and tested to achieve the desired player experience [62].

Expertise in a game development craft (e.g. 3D modeling, animation, sound design, game writing, and programming) takes a long time to develop [62]. This should be acknowledged in the same way as in other creative and professional businesses. It is for example apparent that the quality of a violin concerto will suffer if the soloist has only one year of violin playing experience. In the same way, if the art assets used in a game is created by a person with very little training or experience of making game art, this will most likely influence the game experience compared to when professional artists produce the assets.

Assumptions should not be made that gaming interest or gaming habits can be easily derived from factors such as age, gender or other common denominators (e.g. hearing loss). For example, there are large variations between children in how used they are to navigating in 3D [63] and even among the elderly there are different gaming preferences [64]. It is hard, if not impossible, to create a game that all members of a certain group (e.g. patients with a certain injury) will enjoy playing.

The experience of a game changes over time and there is a difference between studying the initial experience of players compared to the extended experience that develops over time [26].

Games do not continue to provide an interesting experience forever, it is to be expected that players eventually lose interest in a game [20].

Game developers put a lot of focus on maintaining the interest of players [65]. This means, for example, that they monitor gameplay and provide players with new content and updates. Many games have organic properties that are influenced by player behavior.

The social dimension of gaming cannot be ignored and can be of great importance in achieving long-term engagement in a game [66].

### 5.3. Proposition for reporting guidelines

Based on the principles in the previous section, guidelines for reporting medical studies involving games could be developed. In Table 5, examples of elements to be included in such guidelines, in addition to the aspects included in GAMING [59], are presented.

**Table 5**
Proposed guidelines for reporting medical studies involving games

| Proposed guidelines |
| --- |
| A clear statement of platform; genre; and type of experience the game aims at; expected play time for which the game was designed. |
| References to well-known games that the studied game is inspired by or has similarities to. Very few games have completely novel characteristics and |

positioning the game in relation to available games facilitates clarity.

Intended target group in terms of gaming habits, gaming interest and focus.

A description of the development process (time; budget; number of game developers involved and their expertise; approach taken).

Context and conditions for gaming sessions (e.g. voluntary or as part of an activity).

Participants' playing time and how it is distributed over time.

Instrument(s) used to study experience and on which occasions they were applied (repeated measurements etc.). These instruments should be well-documented and preferably standardized to enable comparisons between studies. They should be informed by the work conducted in the game user research community.

A link to persistent documentation of the game studied. Ideally, this should include a digital version of the game itself and its source components. At a minimum, a detailed description of it should be made available where game mechanics are described using documented methods (e.g. [24], [67]) and where the components (images, animation, sound) can be studied. A film recording of a game session should be made available, as it can provide a quick and clear picture of the game situation.

These proposed guidelines are probably most relevant for studies of serious games, but can also be adapted for gamification studies. For publications in the medical community, these principles could be followed without a significant expansion in word count of the report. For other game communities, there may be greater freedom, but the basic principles are the same. For example, the access to the game is an important principle that should be followed in line with the directives for open scientific data. Of the articles reviewed in this study, only one (S6) included a link to the game being studied. Unfortunately, the link no longer works, which underlines the need for persistent storage.

The suggestions made here are only examples of insight from game studies and game production that are largely missing in the medical community's presentation of game-based interventions. A more extensive effort is needed to bring together representation from game studies, game user research and medical communities in order to produce a more definitive reporting guideline for the EQUATOR network.

### 5.4. Limitations & future work

The review reported on in this paper was conducted by one reviewer. It would have been preferable if there were multiple reviewers, reducing the risk of bias.

In future work we will design and evaluate a game for CI-rehabilitation, based on existing game concepts with listening training as a secondary focus and enjoyment as the primary focus. We will also continue to develop the proposed guidelines for reporting on medical studies involving games.

## 6. Conclusions

The aim of this paper has been to investigate how games for AT in CI-rehabilitation relate to established game design knowledge, including how they evaluate player experience. The results indicate that established game design methods and instruments for evaluating player experience are under-utilized. It is conceivable that existing game design methods and evaluation instruments were utilized to a greater extent than reported in the reviewed studies. If this is the case, we advocate for more rigorous reporting on these topics to promote the exchange of game design knowledge and theories, bridging the gap [36] between research communities.

As a step in this direction, we proposed a set of guidelines for reporting on medical studies involving games.

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