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Technologies to Support Adaptable Game Design: A Systematic Mapping Study

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Abstract Designing games accessible and inclusive to a broader audience requires considering social, technical, and cultural aspects that recognize the diversity of the target audience. One strategy to foster inclusion is through adaptability, allowing games to be adapted based on the needs of their users. In this context, a Systematic Mapping Study was conducted to identify and document existing studies focusing on the adaptation of digital games. Aiming at creating a structured and wide panorama of the scientific literature, this paper draws on the 5W2H Framework to answer the following research questions: (1) What game characteristics are being adapted? (2) Why is it being adapted? (3) For whom is it being adapted? (4) When does the adaptation occur? (5) Who is carrying out the adaptation? (6) What technologies are present? (7) Where are the technologies used? (8) How were the technologies evaluated? (9) What was evaluated? (10) Who evaluated? and (11) What theories and methodologies support the study? Beyond presenting the current state-of-the-art in digital game adaptation, the mapping study highlights a prevailing trend in research on adaptive systems. Notably, Patients and Health Professionals emerge as the primary target audience, although many studies did not specify their target audience. The results also indicate that the evaluation of technologies commonly employs Proof of Concept, Experiment, and Case Studies, with Patients and Students frequently considered as the target audience, albeit as secondary participants in the adaptation and evaluation processes. Finally, the findings reveal that most papers lack explicit grounding in a theoretical or methodological foundation, suggesting the need for further investigation.

Keywords: Adaptation, Inclusion, Accessibility, Digital Games, Personalization, Tailoring.

1 Introduction

Adaptability is a concept that refers to the capacity of a system to be configured, customized, or extended to meet the needs of its users [Oppermann, 1994]. Adaptation features have become more frequent in games, with both indie and mainstream game companies implementing these features to make games accessible to a wider audience. One widely acclaimed example was *Celeste*'s assist mode, which includes options for the player to adjust speed, become invincible, and other features that remove barriers in the game. It was a significant decision made by the independent developer Maddy Makes Games, since the game is known for its notorious difficulty in being relevant to the story [Shin, 2024].

Regarding games developed by mainstream companies, Naughty Dog put effort into developing the *Last of Us Part II* game. The company recruited consultants of varying disability backgrounds who are experts in gaming accessibility [Bayliss, 2020]. The result was a game with more than 60 adaptation features, including vision, hearing, and motor accessibility presets.

In hardware, the Xbox adaptive controller was a significant initiative, created in partnership with a range of accessibility organizations and released in 2018. The controller was designed primarily to meet the needs of players with limited mobility, working with a range of external devices such as switches, buttons, mounts and joysticks to create a unique controller experience [Microsoft, 2024].

In the academy, there is much research on making games more inclusive. Some research focus on general aspects of design [Miesenberger *et al*., 2008; Grammenos *et al*., 2009] while others focus on specific domains, such as therapeutic [Hocine and Gouaïch, 2011; Rodrigues *et al*., 2021] and educational games [Chang *et al*., 2015; Correa *et al*., 2018]. There is also focused research for specific audiences, such as visually impaired children [Archambault and Olivier, 2005], older adults [Foukarakis *et al*., 2011; Pisan *et al*., 2013], or stroke survivors [Gouaïch *et al*., 2012; Jacobs *et al*., 2013].

The aforementioned examples from both academy and industry use adaptability resources to make games playable for a wider audience, allowing to adapt game features such as visual preferences, difficulty level, and input devices to remove or reduce barriers and make games suitable for a broader audience. Beyond accessibility, adaptation possibilities can improve players' user experience, engagement, or motivation, even for players that do not have physical or cognitive disabilities.

However, designing games that can be adapted to attend the needs of a diverse audience, in its greatest possible sense, is challenging as there are sociotechnical issues to be considered during game design. Cultural and social values may be affected by the game interface and interaction elements, storyline, characters, and purposes, including adaptation possibilities. Prejudice and gender issues, for example, are objects of debate as female role models in games are uncommon and often heavily sexualized [Skowronski *et al*., 2021], and games often perpetuate racial stereotypes [Burgess *et al*., 2011]. These problems may emerge due to poor or biased design decisions or players' behaviors when exploring adaptation possibilities, which are a reminder that adaptation resources must be conceived ethically and consciously. Each adaptation choice can influence the perception of cultural norms, gender roles, racial representation, and more within the gaming landscape.

Looking at more technical issues, low-income users may own devices with limited software or hardware, which would require attention to the internet speed, the RAM, storage capacity, and processor specs demanded by a game. The awarded games developed by Naughty Dog and Santa Monica require a Playstation 4 to be played, which, by the time of this writing, costs \$300 in the US and R\$2300 in Brazil [Walmart, 2024; Mercado Livre, 2024], which can be an impeding factor for many users.

Sociotechnical aspects directly impact the requirements of a game and should be considered to build truly accessible games from an inclusive or socially-aware perspective. Such a perspective must recognize that social, cultural, and economic issues also cause barriers to the access and use of games, possibly excluding people, perpetuating bias, and triggering undesired social impacts. This is a challenging topic and demands a broader understanding of how adaptation can be used to make games more inclusive. Although there is research in the literature on constructing games more accessible [Miesenberger *et al*., 2008; Grammenos *et al*., 2009] and adaptable games [Garcia and de Almeida Neris, 2022], to the best of our knowledge there is no previous study mapping and organizing the variety of existing solutions dealing with the subject. Because adaptation for a broader audience is not only a matter of technical quality for games but also a matter of social responsibility, a panorama of the literature may help to understand the topic and to identify possibilities for further investigation.

In this paper, we present the results of a Systematic Mapping Study (SMS) of the literature on Games and Computing investigating digital game adaptation. To provide a broad overview of the area, our mapping investigated the following questions: (1) What is being adapted in games? (2) Why is it being adapted? (3) For whom is it being adapted? (4) When does the adaptation occur? (5) Who is carrying out the adaptation? (6) What technologies are present? (7) Where are the technologies used? (8) How were the technologies evaluated? (9) What was evaluated? (10) Who evaluated? and (11) What theories and methodologies support the study.

This paper is a revised and extended version of the paper "A systematic mapping study on digital game adaptation dimensions" [Carvalho *et al*., 2022]. While the original paper covers five (5) research questions, this extended paper covers a broader range of aspects with eleven (11) research questions and presents deeper discussions, especially regarding the identified panorama and the possibilities for future research.

In the following sections, we present the results of the Systematic Mapping Study, detailing its planning, conducting, and reporting. The text is organized as follows: Section 2 introduces the background of this research. Section 3 presents the Materials and Methods used in this research. Section 4 summarizes the data extracted from the 111 selected studies and presents the answers to the research questions. Section 5 discusses the practical implications of the findings. Finally, Section 6 presents the conclusion of this study.

2 Background

According to Oppermann [1994], there are two different approaches when it comes to adaptation in computing systems: adaptable systems and adaptive systems. A system is adaptable when it provides users with tools that allow to change the system's characteristics. This type of individualization gives the user control over the adaptation: it is up to the user to start the adaptation and use it. On the other hand, a system is adaptive if it can automatically change its characteristics according to users' behaviour or preferences. Changes in the presentation of the interface or the system's behavior depend on the way the user interacts with the system: the system initiates and makes the appropriate changes to users, their tasks, and specific demands [Oppermann, 1994].

These two concepts are helpful to characterize technical aspects of adaptation by differentiating systems regarding *who* has the responsibility and power to adapt (i.e., the user or the system), and also regarding *when* (e.g., runtime, design time, game settings) and *how* adaptation occurs (i.e., manually or automatically). However, additional aspects and dimensions must be brought into the scene to account for a sociotechnical perspective for adaptation. For instance, what to adapt in a game, for what purpose, for which audiences, in which context, etc., enrich the possibilities for designing how adaptation features should work.

The literature has explored some of these dimensions, adopting different approaches. For example, Monterrat *et al*. [2017] discuss gaming features (What?) that can be adapted in learning environments (Where?) and propose an approach that aims to predict to which game mechanics a user is responsive and to adapt the gaming features of the system according to this information. Shum *et al*. [2023] discuss the learner (For Whom?) as one of the key dimensions in designing adaptation in serious games, and propose an adaptation mechanism that measures learner proficiency and uses player and learner models to manipulate game tasks and optimize adaptation. Denisova and Cairns [2015], in turn, investigate the effect of challenge adaptation (What?) on player performance and experience (For what?) in digital games, discussing the importance of adapting game mechanics to the player's skill levels and preferences.

Although relevant works have explored adaptation dimensions, studies usually investigate how to adapt a technical system's features or behavior to meet the needs of predefined user profiles and requirements. We have found no work explicitly devoted to investigating adaptation from a sociotechnical perspective, aiming at reducing barriers and making systems more inclusive to a broader audience. Such a perspective stresses the possibilities and purposes of adaptation as it forces us to look wider and deeper at both social and technical aspects of human interaction with a system in a situated context. Indeed, when presenting a research agenda for adaptation as a means to tailor gamification, Klock *et al.* [2020] recognize that future research should focus on wider bases: from user profile characteristics (e.g., age, gender, personality traits) to task attributes, contexts of use, socioeconomic issues, emotional states, cultural context, etc.

Focusing on digital games, we argue that if we are to adopt a sociotechnical perspective to adaptation, we must first look broadly at how the scientific literature has approached the subject. Therefore, we designed a systematic mapping of the literature study to provide a panorama of digital game adaptation. To guarantee we have recognized different adaptation dimensions and provided a broad and structured characterization for the technologies mapped in our study, we adopted the 5W2H Framework's dimensions [Klock *et al.*, 2016]. This framework draws on well-known dimensions and concepts and has been successfully employed to structure research in different contexts, such as designing a catalog of gamification elements [Fedechen *et al.*, 2022]; creating and presenting a set of thematized badges for teaching Human-Computer Interaction [Pereira *et al.*, 2021]; and to consider motivation in a gamified system [Guebarra Conejo *et al.*, 2019]. Because, to the best of our knowledge, there is no widely accepted framework, structure, or scheme to support a sociotechnical perspective for adaptation, we adopted the 5W2H framework to structure our research questions as it presents flexible dimensions that cover both technical (what? how? when? where) and social aspects (who? why? how much?) of adaptation.

2.1 The 5W2H Framework

The 5W2H Framework (Figure 1) presents seven dimensions to assist in designing, developing, and evaluating user-centered gamification: Who? What? Why? When? Where? How? and How Much? [Klock *et al.*, 2016]. Because gamification refers to the use of design elements characteristic for games [Deterding *et al.*, 2011] and Klock *et al.* [2016] proposed their framework to be flexible, digital games is a compatible domain of investigation where we can apply the 5W2H. In the following, we present an overview of each dimension instantiated for our systematic mapping study.

The *Who?* dimension aims to identify the studies' target audiences and their characteristics. In our mapping, this dimension was used to characterize the different stakeholders involved in the adaptation process, either as agents or end-users of the adaptation technologies. The stakeholder characteristics extracted from the selected papers were information such as gender, age, and occupation. For example, an educational game may involve designers, teachers, and high school students (ages 14-18) as stakeholders. The teachers may be responsible for adapting the game, but the students may be the end-users of the game.

The *What?* dimension aims to identify what characteristics are being adapted in the games found in the literature. For example, an educational game to teach math lessons may have

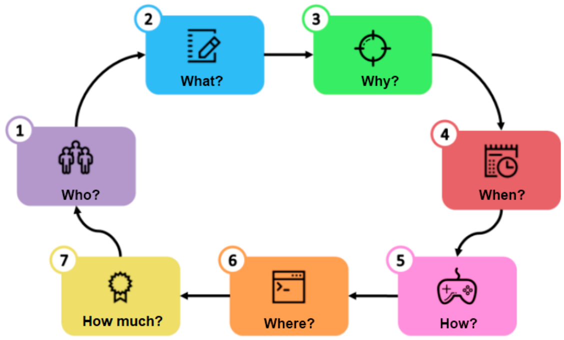

Figure 1. Framework 5W2H dimensions. Translated from [Klock *et al.*, 2016].

questions with difficulty adapted to the student's profile. Besides difficulty, the game may provide options to personalize the player's visual, audio, and input preferences.

The *Why?* dimension seeks to understand the benefits of the adaptation characteristics to the target audience. In the previous example, an educational game may be adapted to help a student's learning process. Thus, an advanced student would respond to more challenging questions, and a novice student would answer easier questions.

The *When?* aims to identify the moments in which the adaptation occurs. For example, an educational game could provide a settings menu where the student could select the game's difficulty, or the game could adapt the difficulty automatically during gameplay according to the number of correct and wrong answers.

The *Where?* aims to identify in which context the technologies are used. The previous examples are situated in the Educational Domain, but the games could also be used in Health scenarios or for Entertainment.

The *How?* aims to identify the method for adaptation. In our mapping, this dimension was used to identify the technologies supporting the adaptation process. Following the educational game example, a study may propose a Model to collect user data and generate profiles matching their learning style.

The *How much?* is related to evaluating the technologies used for adaptation. In our mapping, this dimension was used to identify how the technologies were evaluated, what was evaluated, and who evaluated them. Following the example, the study's authors may develop a game prototype as a Proof-of-Concept to evaluate the Feasibility of the proposed Model.

2.2 Related Work

We found three studies reporting a literature search relating adaptation and games during our review. Lopes and Bidarra [2011] surveyed the purposes, methods, and targets proposed to support adaptive game technology from academia and industry. The authors found that procedural content generation and semantic modelling can be combined to create customized content and online adjustments to game worlds, scenarios, and quests.

Bakkes *et al.* [2012] provided an overview of the literature on personalized gaming, focusing on player modelling and eight components of a personalized game: (1) space adaptation; (2) mission adaptation; (3) character adaptation; (4)

game mechanics adaptation; (5) narrative adaptation; (6) music adaptation; (7) player matching, and (8) difficulty scaling. The authors also discussed the relationship between personalized gaming and procedural content generation.

Snodgrass *et al.* [2019] performed a systematic review of game design frameworks and personalization approaches. Then, they developed and presented a framework called PEAS, an acronym made from the following high-level personalization aspects of a game: **P**layer, **E**nvironment, **A**gents, **S**ystem. The authors also present three guiding questions (Why, How, What) to help users decide how to personalize a game system with the PEAS framework.

The reviews performed in [Lopes and Bidarra, 2011; Bakkes *et al.*, 2012] did not provide a systematic protocol for the review process. In [Snodgrass *et al.*, 2019], the authors followed some systematic steps, but they focused their literature review on a list of proceedings conferences rather than searching in digital libraries and restricted their time scope to studies available from 2001 until 2018. Also, none of the studies covered all the 5W2H's seven adaptation dimensions (Who? What? Why? When? Where? How? How much?), nor did they adopt an equivalent scheme.

Thus, this study provides a contribution to the literature since we took the following steps to maximize the rigor and reproducibility of our process: (1) grounded our research questions in adaptation dimensions inspired by the 5W2H framework; (2) included a detailed protocol used to conduct the review; (3) provided access to the list of included and excluded papers per database and selection criteria, the data extracted from the selected papers, and the mapping protocol.

3 Materials and Methods

This Systematic Mapping Study aimed to provide a rigorous and repeatable process for identifying and documenting scientific studies investigating the adaptation of digital games for the users' needs. Our primary goal in performing this study was to investigate how adaptation is being used, from a broader perspective, especially to reduce barriers to make games more inclusive. The mapping was mainly based on the guidelines defined by Kitchenham and Charters [2007]; Petersen *et al.* [2008, 2015]. After identifying a set of relevant papers, we extracted the data needed to answer our Research Questions and used the thematic analysis method to analyse data and answer our research questions. Thematic analysis is a method of analyzing qualitative data. The idea is to examine the data to identify common themes, topics, patterns that come up frequently [Braun and Clarke, 2006].

According to Kitchenham and Charters [2007], a Systematic Mapping Study is composed of three main phases: 1. Planning, 2. Conducting, and 3. Reporting, each one involving several steps. In the *Planning phase*, we defined the mapping protocol, covering the objectives, research questions, digital sources, search string, selection criteria, and data extraction form. In the *Conducting phase*, we imported the studies from the digital sources chosen, performed the study selection based on the inclusion and exclusion criteria, extracted the data from the selected papers according to the previously defined selection criteria, and performed the data analysis using thematic analysis protocol. Finally, the *Reporting phase* is the writing of the mapping report from which the main results are presented here.

Four researchers participated in these phases, being identified throughout the text as R1, R2, R3 and R4. R1, a Ph.D. student, is the first author of the study and conducted all the steps of the study. R2 is a master's student, and R3 is a Ph.D. professor, both participated in the pilot test, study selection, and revision of the study. R4 is a Ph.D. advisor who participated actively in the protocol creation, pilot test, study selection, and reviewed all the other steps. All the steps are detailed in the next subsections. This research was conducted following ACM Code of Ethics and Professional Conduct [ACM, 2024].

3.1 Research Questions

The high-level research question of this study is: How scientific literature is approaching technologies to support adaptation for a broader audience in digital games?

Based on the main research question, we draw on the 5W2H Framework and defined a set of eleven sub-questions and their motivations, summarized in Table 1. Each question covers a different facet of how the scientific literature has approached adaptation, helping to draw a broad view of adaptation and to structure our mapping results. Having such a comprehensive view is necessary to start looking at adaptation as a means to design games that are more accessible and inclusive for the broadest audience possible.

3.2 Sources selection and search criteria

We formulated our search string based on the PICOC methodology [Petticrew and Roberts, 2006]. According to Kitchenham and Charters [2007], the Population may be an application area, which was defined as "Game". The Intervention may be the procedure used to address a specific issue, in which were included adaptation synonymous (e.g., personalization, customization, configuration, tailoring). Then, a test was performed to verify whether the search string returned a set of four control papers [Mavromoustakos-Blom *et al.*, 2018; Grammatikopoulou *et al.*, 2017; Ivan *et al.*, 2017; Afyouni *et al.*, 2019] that we knew were relevant to our mapping. The test was successful, and the search string defined for the protocol was the following:

"(Game) AND (Adaptable OR Adaptive OR Personalizable OR Configurable OR Customizable OR Tailorable OR Adapted OR Personalized OR Configured OR Customized OR Tailored)"

The search bases used were the ACM Digital Library and the IEEE Xplore Digital Library, both known for their tradition in the academic community and for being the main bases for computing papers. We adapted the search string to the syntax of each base, and only the abstract of the papers were considered to match the string. After running the protocol, a total of 4385 unique papers were found (1897 from ACM and 2488 from IEEE). This process occurred on August 25th (2021) and included all papers available until that day.

Table 1. Research Questions and motivations

Research Question	Motivation
RQ1. Who is the studies' target audience? What are their characteristics?	This question aims to characterize the target of the study. (e.g., students, children with disabilities, teachers, and so on) to understand whether there is a trend in some audiences and whether some audiences are not being investigated. The characteristics extracted are age, gender, and occupation.
RQ2. Who adapts the game? Are there other stakeholders involved?	This question aims to characterize the adaptation process to know if the end users adapt the game or other stakeholder is the responsible to do it (e.g., professor, healthcare expert) or whether the game adapts itself (adaptive process).
RQ3. What is adapted in the game?	This question aims to identify the adaptation characteristics of the game (e.g., colors, game difficulty, game scenarios, and so on).
RQ4. Why is it being adapted? What are the benefits of the adaptations?	This question aims to identify how the adaptation characteristics are helpful to the target audience.
RQ5. When does the adaptation occur?	The answer to this question is important to identify the different moments in which the adaptation may occur (e.g., in a settings menu, during gameplay).
RQ6. What technologies are present in the study?	This question aims to identify the type of technology (e.g., model, guideline, methodology, method, artefact, tool, framework, and so on).
RQ7. Where are the technologies used?	This question aims to identify the context of the technology (e.g., therapeutic, educational, and so on).
RQ8. How were the technologies evaluated?	This question aims to identify the type of evaluation conducted (e.g., interview, test, observational study, and so on).
RQ9. What was evaluated?	This question aims to identify which criterias were evaluated (e.g., usability, accessibility, acceptance, and so on).
RQ10. Who evaluated the technologies?	This question aims to identify the stakeholders evaluating the technology (e.g., experts, users, and so on).
RQ11. What is the theoretical or methodological background supporting the study?	This question aims to identify the literature supporting the study (e.g., Participatory Design, Organisational Semiotics, and so on). It is essential to understand what theories and methodologies support the decision-making process of the study.

3.3 Inclusion and exclusion criteria

Selection criteria are used to identify studies that provide direct evidence about the research questions, besides reducing the likelihood of bias [Kitchenham and Charters, 2007]. For inclusion, we considered papers that focused on technologies to support the adaptation of digital games. For exclusion, the most applied criteria were: (1) studies that did not provide enough information in the corpus to answer the research questions, and (2) studies that did not focus on technologies to support the adaptation of digital games for their users. We also excluded duplicated papers (same paper in different databases) and duplicated studies (same study, but different paper extension, in which case the most complete version was included). The summarized inclusion criteria (IC) and exclusion criteria (EC) are presented in Table 2.

Regarding the language of papers, besides English, we also considered Portuguese papers in the analysis since we did not want to exclude the Brazilian scientific community, which has important contributions in both Human-Computer Interaction and Games fields.

3.4 Data Extraction

After defining the search criteria and the selection process, we defined a data extraction form to guide the extraction process. According to Kitchenham and Charters [2007], the data extraction form should include all the fields and data needed to answer the research questions, besides additional information such as title, authors, and publication details. The data fields of the form are presented as follows[1] .

[1]Available in the "Availability of data and materials" Section as part of the Research Protocol.

- **Paper Information**: Source (ACM, IEEE); Year; Source Type (Conference, Journal); Authors list; Paper Title;
- **Technology Type**. The type of technology, as presented in the paper. In case it is "Other", the researcher must specify the type. (Architecture, Artefact, Framework, Guideline, Methodology, Method, Model, Tool, Other);
- **Name of the Technology**. The name of the technology present in the paper;
- **Application of the Technology**. The context in which the technology is used;
- **Target Audience**. The target of the study;
- **Evaluation Technique**. The evaluation technique(s) conducted in the study (Pilot Study, Questionnaire, Proof of Concept, Interview, Case Study, Experiment, Usability Test, System Usability Scale, Not Informed);
- **Evaluation Criteria**. The criteria evaluated in the study (Acceptance, Accessibility, Performance, Usability, User Experience, Feasibility, Other);
- **Evaluation Participants**. Who participated in the evaluation;
- **Theoretical Background**. The literature supporting the study;
- **Adaptation Agent**. The stakeholder(s) responsible for adapting the technology;
- **Adaptation Characteristics**. The list of characteristics that can be adapted in the game;
- **Adaptation Time**. The moment in which the adaptation occurs.
- **Adaptation Benefits**. The benefits of the adaptation, how it helps the target audience;
- **Additional Notes**. In this field, the researcher can fill

in relevant information not included in the data items.

Table 2. Inclusion and Exclusion criteria

Inclusion criteria
IC1: The paper should focus on technologies to support adaptation of digital games
Exclusion criteria
EC1: Keynotes, Tutorials and any study not reviewed by peers
EC2: Duplicated Papers
EC3: Duplicate studies
EC4: Secondary Studies
EC5: Studies in which the full text is not in English or Portuguese
EC6: Studies that are not available for download using institutional credentials
EC7: Studies that were not related to research questions
EC8: Studies not focused on technologies to support adaptation of digital games for their users

In some data fields, it was necessary to define classification schemes to guide our extraction. Table 3 presents the schemes adopted for Technology Type, Evaluation Technique and Evaluation Criteria.

A pilot test was performed with 4 control papers [Mavromoustakos-Blom *et al.*, 2018; Grammatikopoulou *et al.*, 2017; Ivan *et al.*, 2017; Afyouni *et al.*, 2019] to check whether the data extraction form provided enough information to extract the data needed to answer the research questions. In the test, R1, R2, R3, and R4 performed the data extraction process independently, and any inconsistency or lack of information was provided as feedback. As a result, we improved the review protocol with a more detailed description of the form's data fields.

3.5 Overview of Findings

After retrieving the papers from the digital libraries, an iterative process was applied to include and exclude studies according to the selection criteria. In the first phase, the duplicated papers were removed. In the second phase, papers were included or excluded based on the analysis of title, abstract, and keywords. In the last step, a full-text screening was performed, and the papers that did not provide enough information to answer the research questions were excluded with EC7. A summarization of the process is illustrated in Figure 2.

From the initial 4385 unique studies, 111 were selected for obeying the selection criteria, which represents 2.53% of the retrieved papers. The full list of selected papers, including ID, Authors Name, and Paper Title, is present in the Appendix, Table 9.

R1 first read the introduction and conclusion of the papers, to familiarize himself with the content. Then, R1 highlighted possible contributions of the papers while performing the full-text reading. These contributions were snippets of the

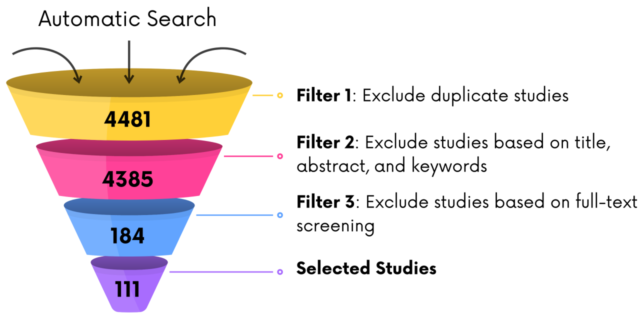

Figure 2. Studies selection process.

text that represent adaptation dimensions and helped answer the research questions of the study. The snippets were then condensed into codes that were documented in an online tool that helps documenting systematic reviews [Parsifal, 2024].

3.6 Codification

Table 4 illustrates an example of transforming snippets of text into codes that represent data items such as the Target Audience. Codes received names meaningful to the parts of the text to which they refer. This process was refined as new information patterns were discovered.

3.7 Categories' creation

We adopted an inductive approach for generating the themes, which means the data determines the themes, and a semantic approach, which means analyzing the explicit content of the data, rather than making assumptions underlying the data [Caulfield, 2024].

After extracting all the codes from the selected papers and organizing them in a spreadsheet, R1 searched for patterns that could be merged into broader themes. First, R1 analyzed the codes row by row and then used a spreadsheet function to automatize the counting process. For example, to count how many instances of the code "Psychologists" were found, we used the function:

=CONT.SE(A2:A114;"*psychologist*").

In Figure 3 there is an example of creating a category named "Health Professionals", which includes the subcategories "Psychologists", "Therapists", and "Physical Therapists". The number inside the parentheses indicates the number of papers related to the respective category. These categories were created by R1 and reviewed by R2, R3 and R4 to make sure they made sense and had a compatible granularity.

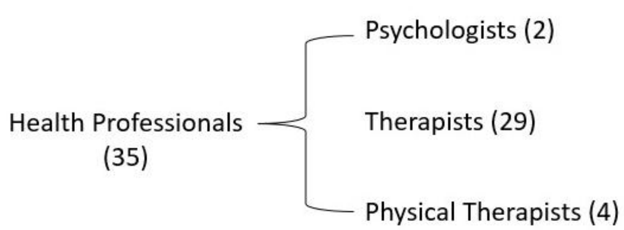

Figure 3. Example of categorization process.

Figure 4 illustrates a category hierarchy. Patients, Health Professionals, Students, Non-specified user, and Educational

Table 3. Classification Schemes

Technology Type	**Description**
Architecture	The design decisions related to the overall structure and behavior of a system [Carnegie Mellon University, 2024].
Artefact	A product of human workmanship, equivalent as a tool in HCI terminology. It can also be the outcome of a process activity (Adapted from [Interaction Design Foundation, 2024a]).
Framework	A supporting structure around which something can be built. This structure comprises tools, techniques, methods, strategies, guidelines, practices, and systems used to design and implement software (Adapted from [Garcia and de Almeida Neris, 2022]).
Guideline	Information intended to advise people on how something should be done or what something should be [Cambridge Dictionary, 2024a].
Method	A set of rules or ways things should be carried out [Ogunyemi *et al*., 2018].
Methodology	A set of methods used in a particular area of study or activity [Cambridge Dictionary, 2024b].
Model	Connotation of real world using semantics and notations, representing something on a smaller scale, hypothetical description of a process, e.g. UML, simulation, maturity models [Ogunyemi *et al*., 2018].
Other	
Evaluation Technique	**Description**
Pilot Study	A small-scale test of the methods and procedures to be used on a larger scale [Samet *et al*., 2009].
Questionnaire	A questionnaire is a research instrument that consists of a set of questions (or other types of prompts) for the purpose of gathering information from respondents through survey or statistical study.
Proof of concept	A Proof of concept is a realization of a certain method or idea in order to demonstrate its feasibility, or a demonstration in principle with the aim of verifying that some concept or theory has practical potential. A proof of concept is usually small and may or may not be complete.
Interview	The interview is one of the most used data collection and requirements-gathering techniques. It is a conversation guided by a script of questions or topics in which an interviewer seeks to obtain information from an interviewee (Adapted from [Barbosa and Silva, 2010]).
Case Study	A case study is a detailed examination of one or more specific situations. Four key aspects of this design can be used to describe case studies: (1) in-depth investigation of a small number of cases; (2) examination in context; (3) multiple data sources; (4) emphasis on qualitative data and analysis [Lazar *et al*., 2017].
Experiment	An experiment is a procedure designed to test a hypothesis as part of the scientific method. [ThoughtCo., 2024]
Usability Test	Usability testing is the practice of testing how easy a design is to use with a group of representative users. It usually involves observing users as they attempt to complete tasks and can be done for different types of designs. It is often conducted repeatedly, from early development until a product's release [Interaction Design Foundation, 2024b].
Not Informed	
Evaluation Criteria	**Description**
Acceptance	The degree to which a person believes that using a particular system would enhance their job performance and would be free from effort (Adapted from [Davis, 1989]).
Accessibility	The possibility for a product (or service) to be used by the largest possible number of people, regardless of their technical or physical abilities (Adapted from [IGI Global, 2024]).
Performance	Algorithm Efficiency regarding computational resources required such as space, time, and memory (Adapted from [Cormen *et al*., 2009; Kleinberg and Tardos, 2005]).
Usability	The capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions [ISO, 2011].
User Experience	A person's perceptions and responses that result from the use or anticipated use of a product, system or service [ISO, 2019].
Feasibility	An assessment of whether a proposed system or project is practical, viable, and achievable within the constraints of available resources, including financial, technical, and human resources, and time (Adapted from [Bocij *et al*., 2016]).
Other	

Table 4. Example of the codification process, where P: paper Id; S: snippets of text.

		Snippet	**Code**	**Data Item**
P1	**S1**	The development is targeted towards children and young adolescents aged 10-14 years	children, young adolescents	Target Audience
	S2	[...]game mechanics can be manually adapted to the user's physical and emotional condition in real-time	in-game adaptation	Adaptation Time
	S3	[...]the trainer can adjust the physiological and psychological levels of difficulty	difficulty level	Adaptation Characteristics
P2	**S4**	[...]supporting the therapists' supervision allowing them to customize the games	therapists	Adaptation Responsible
	S5	[..]therapists can add patients to their patients list and start creating exercises	type of exercise	Adaptation Characteristics

Experts are different types of a macro-category "User".

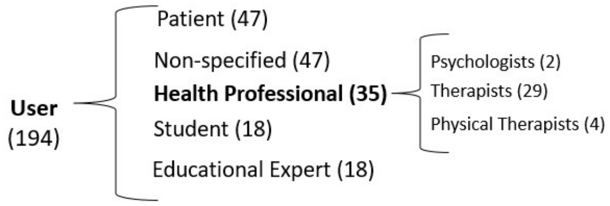

Figure 4. Example of category hierarchy.

3.8 Threats to Validity

There are a number of threats that may impact the quality of a study. Petersen *et al*. [2015] lists the following: descriptive validity, theoretical validity, interpretive validity, and repeatability. Each of these threats and the measures taken to mitigate them are detailed below.

According to Petersen *et al*. [2015], *descriptive validity* is achieved when observations are described accurately and objectively. To reduce threats, a data extraction form was used to support the extraction of data. The form contains: the data items to be extracted from the papers; an explanation about the meaning of the data items; the research questions related to these items.

Theoretical validity is determined by our ability of being able to capture what we intend to capture [Petersen *et al*., 2015]. A possible threat is having only one person conducting the study selection, which can cause the loss of important studies. In this study, the three filters applied (Figure 2) were performed by R1, and R2, R3, and R4 each reviewed 1/3 of the papers that passed Filter 2 independently while R1 was conducting Filter 3.

Then, if a paper was rejected by R1, but was accepted by R2, R3, or R4, that paper would be reevaluated by R1 with more attention to check if the paper had information to answer the research questions of the study. Another threat can happen in the data extraction and classification process. To minimize this threat, R1 conducted the classification process, but the categories created were reviewed by R2, R3, and R4. There was also a pilot test to check if the data extraction form was adequate.

Interpretive validity is achieved when the conclusions drawn are reasonable given the data, and hence maps to conclusion validity [Petersen *et al*., 2015]. A major threat in interpreting the data is researcher bias, which was minimized by having three co-authors reviewing the study.

The *repeatability* requires a detailed report of the research process which is presented in this document and followed existing guidelines [Petersen *et al*., 2008, 2015; Kitchenham and Charters, 2007]. In this research, we adopted steps to maximize the Repeatability, such as: well defined inclusion and exclusion criteria; list of papers excluded in each iteration and the criteria used for exclusion; and the data extraction form.

Even with the aforementioned measures, our study has some limitations. Since our goal was to map the literature on adaptation in digital games to provide an overview of the area, we did not consider evaluating the adaptation's effectiveness in the scope of our review.

Another limitation concerns the databases used. Even though the ACM and IEEE databases returned 4481 papers to filter and analyze, which we considered a reasonable amount, we left important databases out of our protocol, such as Springer, Scielo, Scopus, and SOL, and the Brazilian Computer Society's library which indexes the SBGames[2] proceedings. We recognize this is a limitation of our study, and we made our research protocol available[3] so it can be extended to include other databases.

We also recognize that four papers is a low number for control when testing our search string. However, by the time of our study, these papers were the most relevant and used in a pilot extraction where we analyzed the protocol and the extraction form. Still, we recognize that more papers could be used at this stage.

Finally, we recognize our review timespan as a limitation of our study as it covered papers published until August 2021. Since then, new research on the topic may have been produced and could add to the panorama. However, we do not consider this limitation as a threat to the validity of our study as we had an expressive amount of papers selected after applying the filters and, as suggested by the literature [Mendes *et al*., 2020], we have no reasons to suspect that the topic had evolved substantially in these two years to change findings, conclusions, or credibility of our mapping.

4 Results

Figure 5 summarizes the results for each research question, presenting the main categories created for each data item extracted. The number in parentheses indicates the number of papers related to the respective category. The quantitative data and the subcategories for each category are detailed in Section 5.

The most explored Target Audience (RQ1) in the papers were Patients (47), Non-specified Users (47), Health Professionals (35), and Game Designers (29). Other categories that appeared were Educational Experts (18) and Students (18).

The Health Professionals found in the literature are therapists, physical therapists, and psychologists who use adaptation to support the needs of their patients. Similarly, Educational Experts use adaptation to support the needs of their students. The category Non-specified Users refers to any potential user who may want to play a game. Game Designers are a separate category because they are not the users of games, but rather people with technical expertise engaged in the game design process.

Regarding "Who" adapts the games (RQ2), the System's category is prevalent (72), while Health Professionals, Educational Experts, and Non-specified Users are different types of Users performing the adaptation. Game Designers, on the other hand, appeared 17 times in the literature, not performing the adaptation directly but as audiences for technologies to support the implementation of adaptation features.

[2] Brazilian conference dedicated to games and digital entertainment
[3] See the "Availability of data and materials" Section

Figure 5. Overview of Research Questions.

In Adaptation Characteristics (RQ3), four categories were identified: Difficulty Level (70), Game Elements (52), Game Features (11) and Exercise Type (25). The Difficulty Level may be a physical or cognitive effort required by a challenge in the game. The Exercise Type is a category related to movements or muscles that can be personalized in the game. Games with this characteristic are called "Exergames", due to the physical exercises intrinsic to them [Muñoz *et al.*, 2019].

The Game Elements category encompasses the personalization of Non-Player Characters (NPCs), Themes, Images, Dialogue, Quests, Timers, Sounds, and Avatars in a game. The Game Features category includes options to personalize visual preferences (shadow, brightness, font size, colors), audio preferences (mute, volume, audio description), and input/control devices (remappable controllers, assistive technologies).

An interesting result was a technique called Dynamic Difficulty Adjustment (DDA) that was used in 15 papers (ID11, ID17, ID32, ID33, ID39, ID49, ID85, ID87, ID88, ID91, ID94, ID105, ID108, ID109, ID111) to implement adaptive behavior. DDA is a way of providing a suitable challenge to players with varying skills [Frommel *et al.*, 2018], usually accomplished by changing the strategies and behavior of the adaptive AI opponent or environment [Demediuk *et al.*, 2016].

The results also showed Procedural Content Generation (PCG) techniques being used for adaptation in 7 papers (ID19, ID38, ID65, ID87, ID88, ID108, ID111). According to Khoshkangini *et al.* [2017], PCG strategies are widely used in digital games to increase the player experience and sustain players' interest by adapting the game to the characteristics of each individual.

The most frequent categories in Adaptation Benefits (RQ4) were Engagement (27), Rehabilitation (23), User Experience (20), and Motivation (17). These categories were derived from a search in the papers for keywords associated with the terms "improve", "increase", or "benefits". Rehabilitation and Learning are categories associated with Therapeutic and Educational Games, respectively. Engagement, Motivation, and User Experience appeared in different contexts as the adaptation goal was to maintain the player focused on the game's objectives. Regarding accessibility, even though we consider that any approach that helps remove barriers promotes accessibility, only 8 papers (ID6, ID21, ID24, ID27, ID34, ID37, ID44, ID78) mentioned accessibility as a contribution of their works.

In Adaptation Moment (RQ5), five categories were identified. Design Time is a category to incorporate the papers in which adaptation happens during the development process. Settings is a category in which the adaptation is provided by a configuration menu. Installation is a category for when the adaptation occurs during the setup of a game. On-the-play refers to the adaptation happening during the game execution, automatically. Content Update refers to the cases in which adaptation happens after a session or round of play, based on the knowledge acquired by the system.

In Technology Type (RQ6), the most frequent categories were Artefact (74), Architecture (34), and Framework (23). The abundance of Artefacts is because many papers propose technologies such as Frameworks and Methods but implement Game Prototypes as Proof-Of-Concept. In those cases, we classified the Game Prototypes as "Artefacts" according to our classification scheme. The only result that appeared as "Other" was an Ontology in [Said *et al.*, 2019].

In Application of the Technology (RQ7), we identified three categories: Health (50), Education (27), and Domain-Independent (35). We classified as "Health" all papers in which the technology was intended to improve the health quality of users. Regarding "Education", we classified all applications intended to improve students' educational process. Papers with technologies not related to any specific domain were classified as "Domain-Independent".

Regarding how the technologies were evaluated (RQ8), the most frequent results were Proof of Concept (46), Experiment (45), Case Study (43), and Questionnaire (34). Proof of Concept and Experiment are directly linked to the two most frequent results in what was evaluated (RQ9), which were Feasibility (46) and Performance (41), respectively. In 23 papers, no evaluation was reported (ID1, ID3, ID4, ID6, ID7, ID13, ID14, ID35, ID37, ID46, ID51, ID63, ID68, ID71, ID73-ID77, ID82, ID97, ID100, ID107).

In Evaluation Participants (RQ10), the main result was no stakeholders taking part in the evaluation process (40). In addition, in 35 papers the evaluation participants are generic and, therefore, classified as "Other users". Patients (16), Students (14), Health Professionals (7), Educational Experts (3), and Game Designers (2) also appeared as results. Last, in 6 papers, their authors evaluated the technologies.

In Theoretical Background (RQ11), most papers (83) are not explicitly grounded in a theoretical or methodological basis. The most cited theory was Flow (12), developed by [Csikszentmihalyi, 1991], and other theories appeared in 2 or 1 paper each, such as Universal Design (ID24, ID78) and Learning Styles (ID76).

4.1 Answering the Research Questions

In the following, we answer each one of the research questions, from RQ1 to RQ11.

RQ1 - Who is the target audience of this study? What are their characteristics?

Figure 6 shows the categories created and their subcategories whenever applicable. The Patients category was the one with the most subcategories (8), revealing a wide range of needs and characteristics investigated by the papers adapting games for health purposes. Stroke patients, for example, often have permanent neurological and functional damages and may need to perform repetitive exercises as part of their rehabilitation process. Through adaptation, games provide an environment in which the training intensity, difficulty, duration and frequency can be manipulated and enhanced [Gouaïch *et al.*, 2012] to offer a personalized treatment.

The Health Professionals category is closely related to the Patients, contemplating professionals that use the games as tools to support their patients. They may perform the adaptation directly or leave it to the system to adapt in real-time.

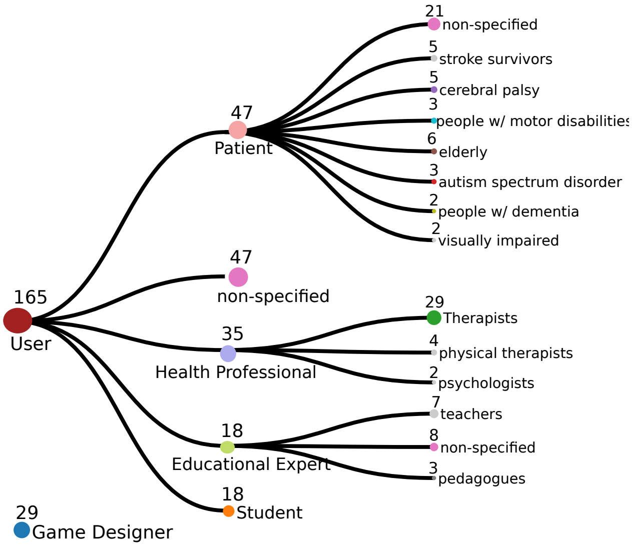

Figure 6. Target Audience.

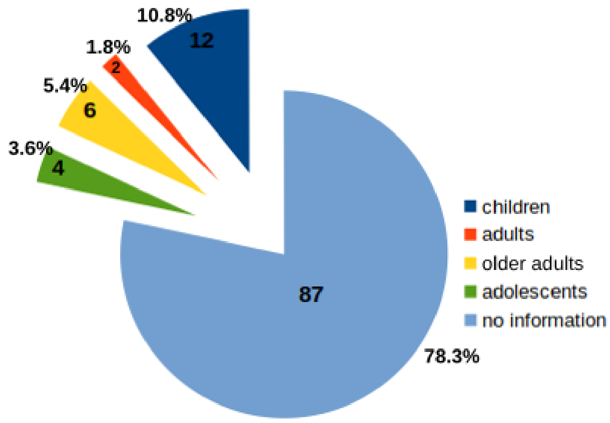

Figure 7. Target Audience Age.

According to Tresser *et al*. [2019], in many virtual environments, the therapist has to manually adjust the settings if necessary, which may limit the therapeutic intervention being conducted. For these scenarios, an adaptive system could be preferable.

The Educational Experts and the Students category are also closely related. Games can be used to support the learning process in many ways, such as: (1) enabling professionals to adapt the educational content; (2) performing the adaptation automatically according to data gathered in the game; and (3) providing user analytics to guide educational experts to understand the difficulties faced by their students.

Figure 7 presents information on the target audience's age, as extracted from the papers. Most of the papers (78.3%) did not specify the age range of their intended audience. Among those that did, the most frequent audiences were children (10.8%) and older adults (5.4%). The papers did not provide information on the target audience's gender. These findings suggest that the literature prioritized the occupation of the audience over age or gender, creating an opportunity for future research on adaptation technologies for specific age groups or genders. The papers that did specify the audience's age revealed that they were designed for a particular use, such as educational games for children or therapeutic games for older adults.

RQ2 - Who adapts the game? Are there other stakeholders involved?

Figure 8 illustrates the main actors performing the adaptation, with the System being the central result, indicating a trend of adaptive systems over adaptable ones. Some categories in the Target Audience (RQ1) have few occurrences, notably Patients and Students. In the selected papers, these categories are usually the game end-users, and the adaptation is performed by either the System or other stakeholders (Health Professionals and Educational Experts).

In 27 papers there were more than one agent involved in the adaptation process, and in 19 papers the System was one of them. The full list is presented in Table 5.

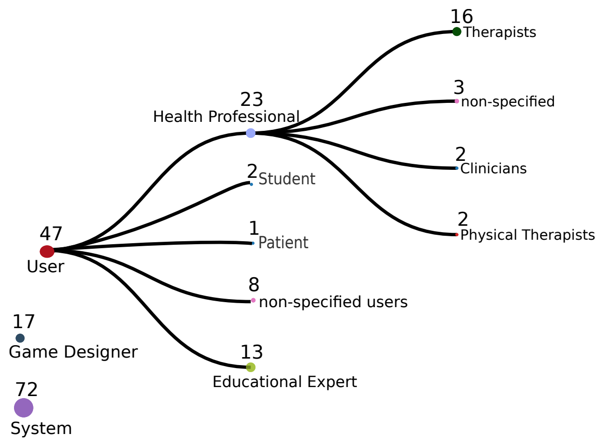

Figure 8. Adaptation Agent.

Table 5. List of Papers containing more than one Adaptation Agent

Adaptation Agent	Papers ID
System, Educational Expert	[3, 21, 83, 100]
System, Health Professional	[4, 45, 48, 75, 80] [82, 94, 108, 109]
System, Game Designer	[15, 65, 88]
System, Non-specified users	[13, 81]
System, Game Designer, Educational Expert	[101]
Health Professional, Educational Expert	[14]
Health Professional, Patient	[97]
Game Designer, Educational Expert	[46, 61, 89, 95]
Educational Expert, Non-specified users	[64]
Educational Expert, Non-specified users, Student	[57]

RQ3: What game characteristics are being adapted?

Figure 9 shows the elements categorized into four categories that emerged from the data. The Difficulty Level (70) was the most frequent one, being a characteristic dependent on the context. In Educational Games, the Difficulty Level was associated with the cognitive effort demanded to complete the required challenges. In Therapeutic Games, it could be defined as the amount of physical effort necessary to perform the challenges.

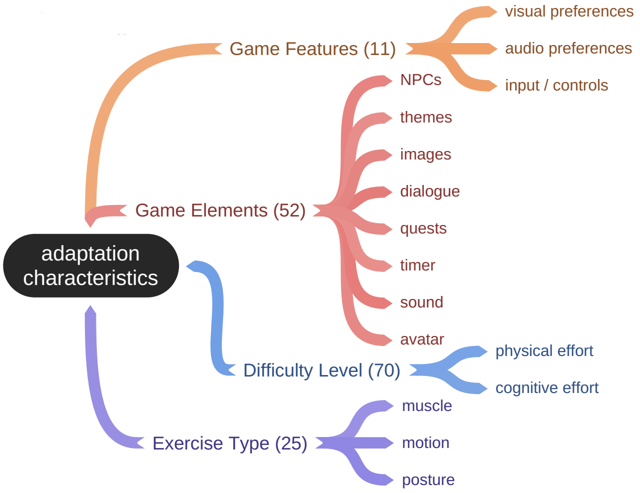

Figure 9. Adaptation Characteristics.

The Game Elements (52) is the characteristic with the most elements associated. These elements can be used individually or combined to promote various benefits such as Accessibility, Engagement, and User Experience. The Game Features (11) elements can also be applied separately or combined but focus more on Accessibility benefits.

Table 6 illustrates the selected papers ID correlated to the Adaptation Characteristics and Target Audience. We can see that the Difficulty Level and Game Elements are broad categories, appearing in all the different audiences. On the other hand, the Exercise Type is more focused on the Patients and Health Professionals categories, which are the main stakeholders in therapeutic games.

RQ4. Why is it being adapted? What are the benefits of those adaptations?

Figure 10 shows the derived categories from the key terms found in the papers, with numbers representing the number of papers in which each category was identified. These categories are associated with many characteristics found in RQ3. The Difficulty Level, for example, can be adapted in Educational Games to increase students' satisfaction or performance, improving their learning experiences by providing personalized challenges. In Therapeutic Games, the Difficulty Level can be altered to increase or decrease the challenges to avoid players' feelings of boredom or frustration. In nine papers (ID12, ID26, ID38, ID68, ID79, ID85, ID87, ID101, ID105), we found that the motivation to change the game's difficulty was to provide a "flow state": mental state in which people are so immersed in a task that they lose the sense of time [Csikszentmihalyi, 1991].

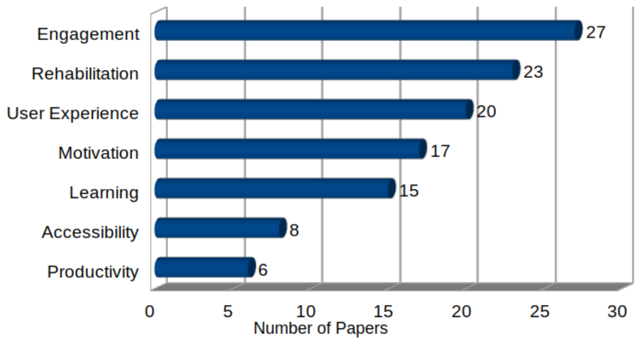

Figure 10. Adaptation Benefits.

Regarding Motivation and Engagement, they are crucial factors in various contexts, such as therapeutic games, educational games, and others. According to Mader *et al.* [2016], a significant problem in the health area is the patient's lack of adherence to therapy. Maintaining the patient's attention is difficult when performing "boring", repetitive or tedious exercises. In these situations, the tendency is for them to exercise less frequently or even give up treatment. Then, the playfulness of games shows potential to motivate patients to continue exercising.

Even though Accessibility was mentioned directly in 8 papers only (ID6, ID21, ID24, ID27, ID34, ID37, ID44, ID78), we understand that by adapting the Difficulty, Game Elements, and Exercises (RQ3) of games to increase Motivation, Engagement, and User Experience, these studies are also contributing to removing barriers and making games usable for a broader audience. Although a more profound analysis would be necessary to confirm this understanding, these results reveal dimensions that can be explored in further studies to go beyond accessibility and promote inclusiveness through adaptation.

Lastly, Productivity was found in 6 papers (ID52, ID53, ID56, ID57, ID92, ID101) in which the adaptation improved the users' workflow in tasks such as decision-making, application development, and content creation.

RQ5. When does the adaptation occur?

Figure 11 illustrates the categories representing the Adaptation Moment. The two most frequent results were On-the-Play (43) and Content Update (32), both associated with adaptive behavior, corroborating the System as the major Adaptation Agent (RQ2). We found different algorithms (ID2, ID69, ID79, ID86, ID104, ID111) and mechanisms (ID26, ID32, ID36, ID76, ID85) to implement the adaptive behavior in real-time or after play sessions. According to Said *et al.* [2019], the diversity of players and their different needs requires using player models to tailor the game experience. Player modeling is defined as "the study of computational models of players in games, including the detection, modeling, prediction and expression of human player characteristics which are manifested through cognitive, affective and behavioral patterns" [Yannakakis *et al.*, 2013].

On the other hand, the Settings (22) category is associated with adaptable behavior, with Health Professionals (10)

Table 6. Papers ID classified according to Target Audience and Adaptation Characteristics

	Target Audience					
Adaptation Characteristics	Patients	Non-specified users	Health Professionals	Educational Experts	Students	Game Designers
Difficulty Level	[4, 5, 11, 12, 13, 14, 20, 21, 24, 28, 43, 45, 50, 54, 58, 74, 80, 81, 82, 83, 84, 89, 94, 96, 97, 99, 104, 105, 106, 107, 108, 109]	[3, 9, 15, 17, 19, 26, 29, 30, 31, 32, 33, 38, 39, 42, 49, 52, 68, 69, 70, 72, 75, 76, 77, 79, 81, 85, 87, 91, 96, 101, 102, 103, 111]	[4, 5, 11, 12, 20, 21, 28, 45, 50, 54, 58, 75, 80, 81, 82, 84, 94, 97, 99, 105, 106, 107, 108, 109]	[3, 7, 14, 61, 76, 83, 89, 101]	[7, 25, 36, 56, 61, 71, 76, 92]	[3, 13, 14, 15, 19, 20, 24, 49, 61, 71, 76, 83, 87, 89, 101]
Exercise Type	[11, 12, 13, 27, 28, 34, 35, 50, 54, 58, 59, 80, 82, 84, 90, 94, 97, 106, 107, 108, 110]	[55, 64, 75, 93]	[11, 12, 28, 35, 50, 54, 58, 59, 75, 80, 82, 84, 90, 94, 97, 106, 107, 108, 110]	[27, 64]	-	[13]
Game Elements	[4, 14, 16, 21, 23, 28, 37, 41, 45, 48, 50, 54, 60, 78, 81, 83, 84, 90, 96, 97, 99]	[3, 9, 15, 22, 29, 40, 52, 53, 57, 65, 81, 86, 87, 88, 95, 96, 100, 101, 102]	[4, 16, 18, 21, 23, 28, 45, 48, 50, 53, 54, 81, 84, 90, 97, 99]	[3, 7, 14, 46, 53, 57, 61, 66, 73, 83, 95, 100, 101]	[7, 18, 46, 47, 56, 57, 61, 63, 66, 67, 73, 92, 98]	[2, 3, 10, 14, 15, 18, 37, 40, 46, 53, 61, 65, 83, 87, 88, 95, 98, 101]
Game Features	[6, 14, 24, 37, 44, 78, 108]	[1, 8, 9, 62]	[44, 108]	[1, 14]	[1]	[1, 6, 14, 24, 37, 62]

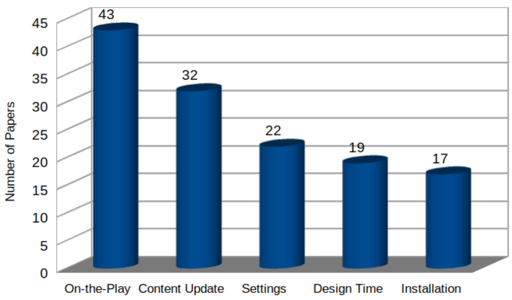

Figure 11. Adaptation Moment.

and Educational Experts (6) as the main Adaptation Agents (RQ2). They rely on their expert knowledge to adapt the games according to the different needs of their audiences (Patients and Students).

The Installation (17) category is divided between three approaches: (i) studies with only adaptive behavior (ID17, ID24, ID34, ID62, ID66, ID102); (ii) studies with only adaptable behavior (ID16, ID23, ID35, ID89, ID90, ID97); (iii) studies with both adaptive and adaptable behavior (ID21, ID75, ID94, ID100). The adaptation happens during the game setup. In [Yun *et al.*, 2010], the user has to answer some questions so the system can build a player profile to understand the difficulty level appropriate (RQ3).

At last, in Design Time (19), game developers or other stakeholders incorporate the adaptation features during the game design process. For example, in [Vidakis and Charitakis, 2018] the authors state: "*Expressly, educational experts are responsible for creating game preferences according to learning styles, learning theories and special needs that will be used to adapt game experience accordingly. As a result, game developers' work is getting familiar with this information and designing their games in a way that allows customizations at certain parameters and thus assist with the learning process profiling*".

RQ6. What technology is used in the study?

Figure 12 illustrates the technologies being used to support adaptation. It was necessary to adopt a classification scheme (Table 3) to define each of these categories since many papers describe their contributions using multiple names and are not always methodologically grounded. For example, authors constantly name their results as "Frameworks" without defining what they mean by the term, and without detailing the tools, strategies, and practices that comprise the structure of the Framework.

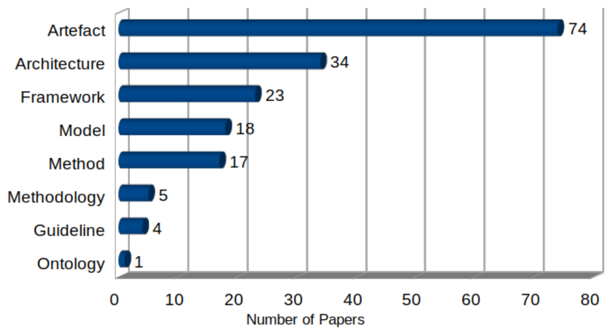

Figure 12. Technology Type.

Figure 13 presents a Sankey Diagram[4] illustrating the re-

[4]Sankey diagram is a flow diagram in which the width of the lines is shown proportionally to the flow quantity. It helps locate dominant contributions to an overall flow [Schmidt, 2008]

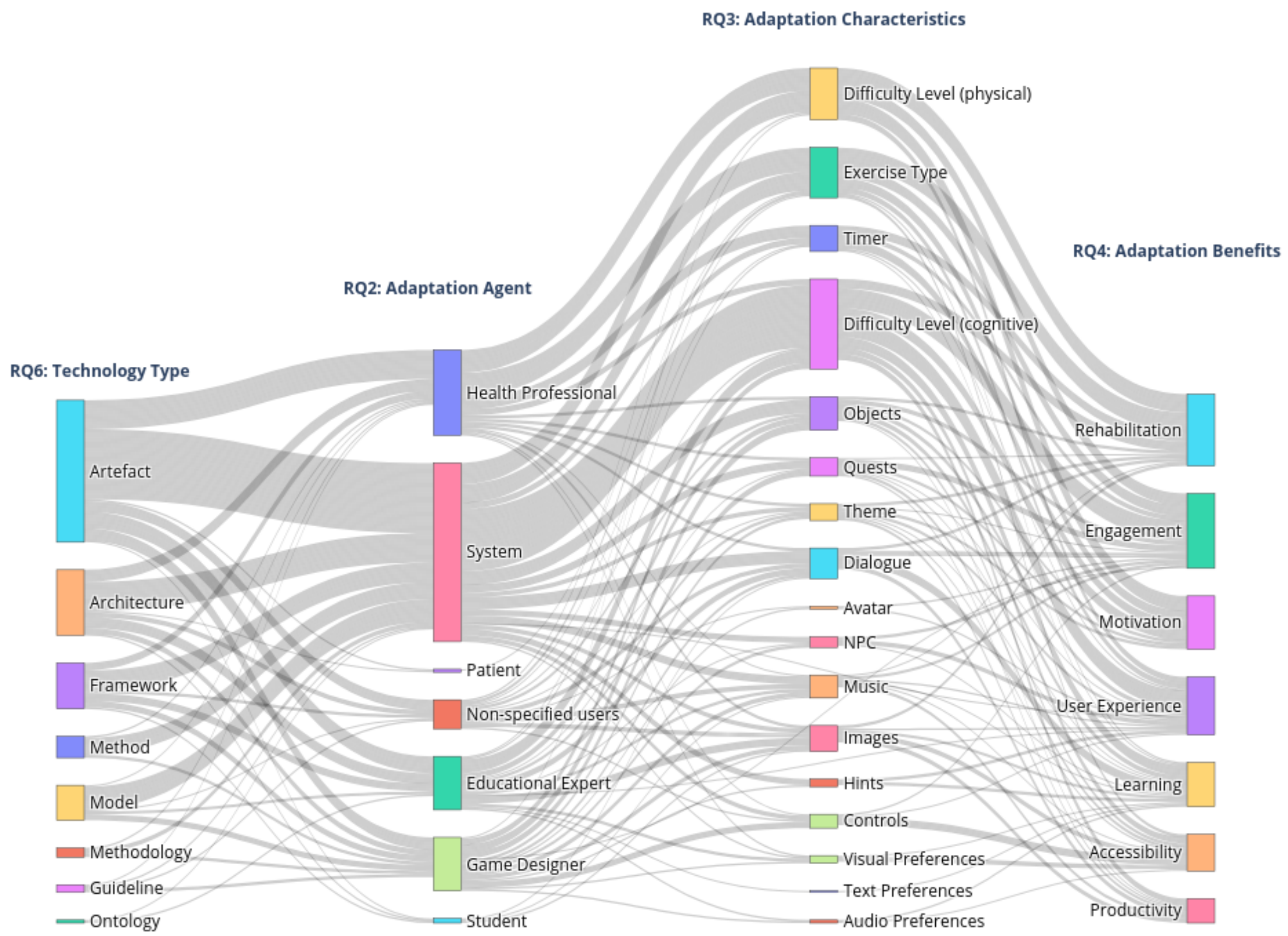

Figure 13. Sankey Diagram illustrating the relationship between RQ6, RQ2, RQ3, and RQ4

lationship between the Technology Type (RQ6), the Adaptation Agent (RQ2), the Adaptation Characteristics (RQ3), and the Adaptation Benefits (RQ4).

The Artefact and the Architecture, the most frequent technologies in the selected papers, have the System and the Health Professional as the most frequent Adaptation Agents. The distribution between other categories is more balanced, noting that the least frequent results have thinner lines, such as Guideline and Ontology in RQ6. Regarding RQ2, the System is more related to the Difficulty Level (cognitive) but is also related to most other Adaptation Characteristics. Health Professionals are more associated with Difficulty Level (physical) and Exercise Type categories, which have Rehabilitation as the main Adaptation Benefit (RQ4).

RQ7. Where is the technology used?

Table 7 shows the ID of each paper classified as Education, Health, or Domain-Independent. Only one paper (ID64) was classified in both “Health” and “Education” domains.

These findings indicate a lot of research conducted on using games for health purposes, which can be applied to various patient populations, as seen in RQ1. These patient groups include stroke survivors, individuals with cerebral

Table 7. The Papers ID in each of the classified domains

Technology Application		
Education	**Health**	**Domain Independent**
[1, 3, 7, 21, 25, 36, 42, 46, 47, 52, 53, 56, 61, 63, 64, 66, 67,71, 72, 73, 76,89, 92, 95, 98, 101, 103]	[4, 5, 11, 12, 14, 16, 18, 20, 23, 24, 26, 27, 28, 29, 30, 35, 41, 43, 45, 48, 50, 51, 54, 55, 58, 59, 60, 64, 69, 74, 75, 77, 80, 81, 82, 83, 84, 90, 93, 94, 96, 97, 99, 104, 105, 106, 107, 108, 109, 110]	[2, 6, 8, 9, 10, 13, 15, 17, 19, 22, 31, 32, 33, 34, 37, 38, 39, 40, 44, 49, 57, 62, 65, 68, 70, 78, 79, 85, 86, 87, 88, 91, 100, 102, 111]

palsy, those with motor disabilities, and individuals with autism spectrum disorder, among others. There is also a lot of research on games in the educational domain, which can be applied to various purposes, audiences, disciplines, etc. These are the two most common domains, which may be explored in isolation or combined (i.e., games with an educational purpose in the health context), not necessarily exploring adaptation (e.g., [Souza *et al.*, 2021] [Oliveira *et al.*, 2021] [Ferreira *et al.*, 2021]).

Much research has explored adaptation in different domains and for various purposes. Although this diversity is indicative of the broad applicability of adaptation in games, other domains (e.g., entertainment) were expected to appear with some prominence.

RQ8. How was the technology evaluated? RQ9. What was evaluated?

Figure 14 illustrates the techniques used to evaluate the technologies and Figure 15 the assessed criteria. While Proof of Concept and Experiment are directly linked to evaluating the Feasibility and Performance of the technologies, the other techniques, such as Case Study, Questionnaire, and Interview, are linked to multiple criteria, especially to User Experience, Usability, and Acceptance. On the other hand, in 23 papers no evaluation was performed.

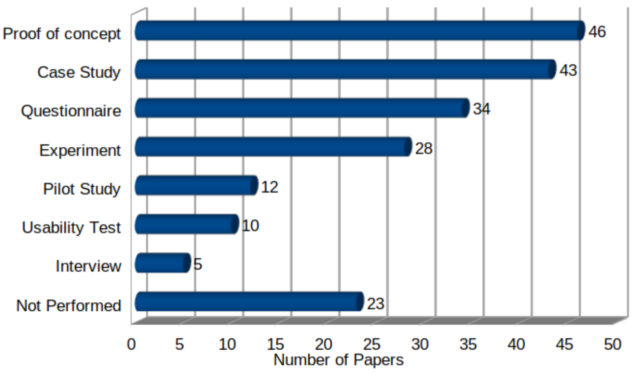

Figure 14. Evaluation Technique.

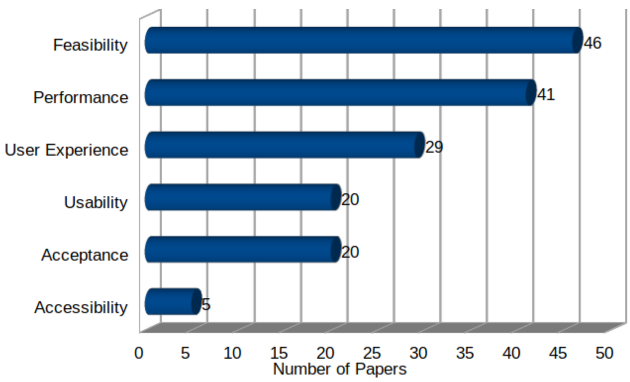

Figure 15. Evaluation Criteria.

These results indicate room for research using more evaluation techniques from the Human-Computer Interaction field. Usability Test only appeared in 10 papers (ID16, ID23, ID27, ID56, ID78, ID80, ID84, ID106, ID109, ID110) while Interviews were performed in only 5 papers (ID23, ID26, ID41, ID44, ID53). These are valuable techniques to collect data from the users and better understand their needs, goals, and expectations for a system or product.

RQ10. Who evaluated the technology?

Figure 16 illustrates the stakeholders participating in the evaluation process. There were 40 papers in which no stakeholder was involved in the evaluation, and Figure 14 shows that no evaluation was performed in 23 papers. In those papers, the research was usually in the initial stages, and the evaluation was planned for future work. In 17 papers, an evaluation was conducted without the participation of stakeholders. These evaluations were either in the form of a Proof of Concept (ID20, ID45, ID54, ID57, ID62, ID66, ID69, ID81, ID95), Experiment (ID79, ID102, ID111), or both (ID19, ID32, ID85, ID99, ID101).

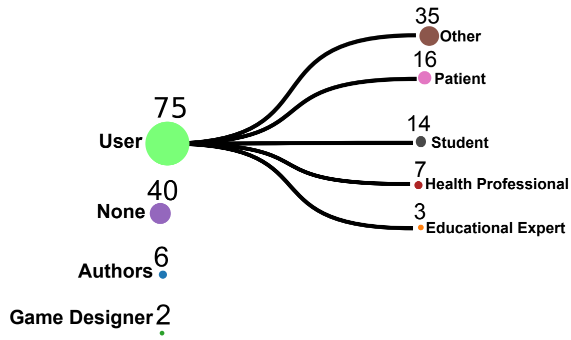

Figure 16. Evaluation Participants.

The most frequent Evaluation Participants were Other users (35), which are generic users not specified by the authors and do not fit into other specific categories. In fact, in 8 papers (ID11, ID41, ID58, ID84, ID90, ID94, ID109, ID110) the authors performed tests with generic users even though they were not their Target Audiences (RQ1). In those papers, the intended audiences were Health Professionals and Patients, but the authors chose to perform tests with general users primarily due to ethical reasons. According to the authors in [Gouaïch *et al.*, 2012], controlled and experimental tests with ordinary players are necessary before testing on patients and disturbing their classical rehabilitation program.

Figure 17 presents a Sankey Diagram showing the relationship between the Target Audience (RQ1), the Adaptation Agent (RQ2), and the Evaluation Participants (RQ10) of the studies. Patient, Non-specified users, and Student categories in RQ1 have little agency in the adaptation process (RQ2), and their adaptation is usually performed by Health Professionals, System, or Educational Expert stakeholders. Patient and Student also do not appear as much as Evaluation Participants, corroborating that there is no stakeholder in the evaluation or that participants are "Other" users in most cases.

RQ11. What is the theoretical background supporting the study?

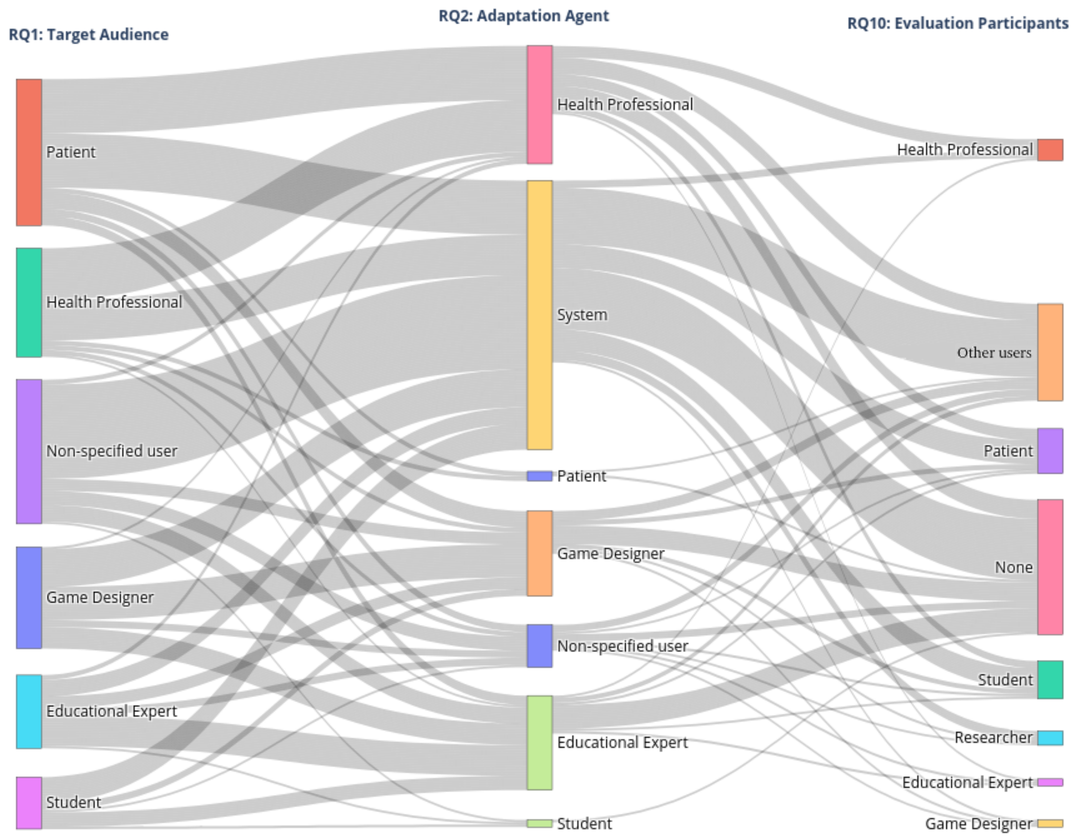

Figure 17. Sankey Diagram illustrating the relationship between RQ1, RQ2, and RQ10

Figure 18 illustrates the theories and methodologies that appeared in the selected studies. While most papers have a section dedicated to the Theoretical Background, authors tend not to present a theory but rather use this space to describe the Knowledge Areas or Techniques they employed or present their literature review. Some of the most frequent key terms found in these sections were “Serious Games”, “Dynamic Difficulty Adjustment”, “Exergames”, and “Artificial Intelligence”. As a result, we have found that most papers lack an explicit theoretical foundation.

Regarding the theories and methodologies that did appear in the papers, Universal Design (ID24, ID78), Participatory Design (ID28), and User-Centered Design (ID56) are from the Human-Computer Interaction field. Those from Psychology field are Behavioral Research (ID29), Learning Styles (ID76), Zone of Proximal Development (ID101), Goal-setting theory (ID51), Personality Theory (ID51, ID61), Reinforcement Theory (ID51, ID96), and Flow (ID12, ID26, ID38, ID44, ID67, ID68, ID79, ID85, ID87, ID88, ID101, ID105). Finally, there is Problem-Based Learning (ID63) in the Educational field.

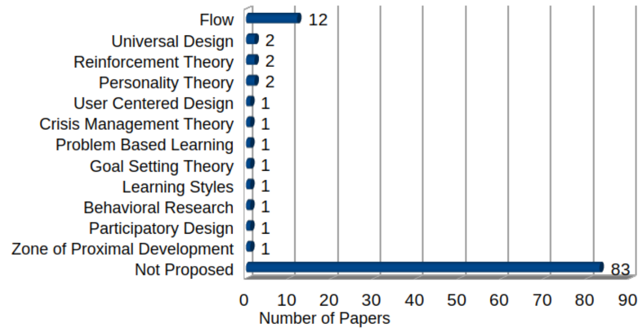

Figure 18. Theoretical Background.

5 Discussion

The seven dimensions of the 5W2H Framework are not always explicitly covered in the selected papers. Even when dimensions are identified, they are approached from a limited technical perspective, usually focusing on the technical aspects of adaptation rather than paying attention to the social world where adaptation makes sense, will work and impact. Even the literature reviews we found as Related Work [Lopes and Bidarra, 2011; Bakkes *et al.*, 2012; Snodgrass *et al.*, 2019] focus on technical aspects of adaptation, such as methods, frameworks, and approaches to personalizing game elements and components.

From the main results of our mapping, we can draw a panorama of the mapped literature investigating adaptation in digital games (focusing on the topic) and how the investigation is taking place (focusing on research practices). Focusing on the topic of adaptation, the results reveal Patients, Non-specified users, and Health Professionals as the primary audiences for whom the games are being adapted (RQ1); a trend in research on adaptive systems (RQ2); the Difficulty

Level, Game Elements, Game Features, and Exercise Type as the most explored characteristics to adapt in games (RQ3); the main benefits for adaptation are increasing or improving the Engagement, Rehabilitation, User Experience, and Motivation of the audiences (RQ4); the adaptation usually occur On-the-play or during Content Update (RQ5); Artefact, Architecture, and Framework are the leading technologies presented as contributions in the studies (RQ6); a considerable amount of research focusing on Health and Education domains (RQ7).

Focusing on research practices, our results reveal that most papers evaluate their technologies through Proof of Concept, Experiment, and Case Studies (RQ8); the main criteria evaluated in the studies are Feasibility, Performance, and User Experience (RQ9); most papers do not evaluate their technologies or conduct evaluation with users who are not the intended audiences (RQ10); and, finally, that most papers are not explicitly grounded on a theoretical foundation (RQ11).

The panorama presents adaptation as a topic far from being exhaustively explored, opening room for research on many dimensions. When analyzing "For Whom the games are adapted" (RQ1) and "Who adapts" (RQ2), there is space for exploring different players' profiles [Carneiro *et al.*, 2022] and advancing on technologies to support adaptation by the primary stakeholders of the games. For example, it is understandable that Health Professionals and Educational Experts have the expertise to adapt the games for their Patients and Students, but neglecting the latter in the process may result in games that are not useful, effective, enjoyable or desirable for the people who are intended to play them or get the ultimate benefit from adaptation. This is the typical situation where a supposed primary stakeholder (i.e., the player) is, in fact, secondary to the design process and product.

In HCI literature, Bannon [2011] has argued that many technologies designed to support older people living independently end up working as remote surveillance systems. Even when technologies run trials with the end users in their home environments, time limitation issues eventually hide the real needs of users. Bannon claims that it is urgent to listen carefully to all the relevant stakeholders to ensure their needs, expectations, and values are addressed. Pereira and Baranauskas [2015] also draws attention to the need for considering stakeholders' values and cultural issues throughout a design process.

Naturally, we cannot assume that designers can always identify all the stakeholders (interested parties) relevant to a design context. Nor are we considering that only listening to them is enough or that designers will always have the necessary resources (and power) to involve the parties in the design process. What we can stress from these results is the need not only to identify stakeholders but to understand them and recognize their importance and roles, putting the ones that will live the effects of adaptation as central stakeholders. Existing artefacts may support designers in this task, such as the Stakeholder Identification Diagram from Stamper [2001], which helps to identify different types of stakeholders and their "information forces", and the Value Identification Frame [Ferrari *et al.*, 2020], which helps to identify the central stakeholders and focus on them.

Regarding "What is being adapted in games" (RQ3), there was little research on technologies to support the customization of Game Features. This topic appeared in only 11 papers (ID1, ID6, ID8, ID9, ID14, ID24, ID37, ID44, ID62, ID78, ID108), and these features are essential to design games playable by a broader audience either by implementing elements that make the game fun or enjoyable [Tondorf and da Silva Hounsell, 2022] or by reducing barriers users may encounter to access and play. For instance, our mapping did not show adaptation to make the game more economically affordable, consume less energy, and require less processing power, memory, or bandwidth. An adaptation could be operationalized by allowing users to customize the game's graphics quality or to play offline.

As for "Why the games are being adapted" (RQ4), the benefits of adaptation were primarily focused on aspects that are influenced by the application domain, such as promoting players' engagement, rehabilitation, motivation, and learning. More comprehensive aspects, such as User Experience and Accessibility, received less attention. Accessibility was explicitly mentioned in 8 papers only (ID6, ID21, ID24, ID27, ID34, ID37, ID44, ID78), with the authors primarily taking a technical view of the term, focusing on the possible disabilities of the target audience. We see all the other aspects as somewhat related to user experience and accessibility, which, in turn, are related to each other. However, we identified that the literature commonly treats these concepts in isolation, which makes it challenging to consider adaptation more broadly. If we do not explicitly recognize that motivation, rehabilitation, and learning issues are related to the user experience, we may be overlooking other factors that affect this experience, such as privacy and security during gameplay. Similarly, if we do not explicitly recognize that accessibility issues affect the user experience, then we may be excluding potential users by ignoring barriers of different natures (cultural, economic, physical, etc.) that precede the experience and result in a "non-gaming experience" or prevent an effective play. In this line of reasoning, we advocate looking at adaptation as a way of making a game more inclusive, including making it more accessible to the broadest possible range of people. Therefore, there is room for research on accessibility from a broad perspective, considering cultural and technical aspects in an integrated manner.

Results for "When does the adaptation occur?" (RQ5) corroborated the prevalence of adaptive systems over adaptable ones. They indicated research opportunities for techniques that can be used to implement adaptive behavior, such as Procedural Content Generation and Player Modeling. It is also possible to explore techniques that combine manual and automatic adaptation. End-User Programming [Barricelli *et al.*, 2019], with its methods and techniques for empowering end users to modify and create digital artefacts, may be a field of inspiration.

In "What technologies are present?" (RQ6), there is much research producing Artefacts for adaptation and few papers proposing Methodologies, Guidelines, and Ontologies for adaptation, which can be gaps for the game community research. Methodologies can provide structured approaches to tackle inclusion challenges, and guidelines can provide recommendations on best practices for adapting games to attend the needs of a diverse audience. The Game Accessibility

Guidelines[5] and the Principles of Universal Design [Mace, 1997] are examples of instruments to support the design of more accessible and inclusive games.

Again, more than perceiving a preference for producing artefacts that give the system responsibility and power for adaptation, we need more focus on understanding how end-users can take advantage of and contribute to adaptation possibilities, which could lead to new technologies to support adaptation. For example, with the wave of generative AI, adaptation can be taken to a level of what de Oliveira Schultz Ascari *et al.* [2023] called personification: an approach that goes beyond adaptation and customization by making the computational system capable of dealing with a symbolic representation that personifies the users with their individualities in the most realistic form.

For "Where are the technologies used?" (RQ7), although a considerable amount of papers was found, they are either concentrated in a few specific domains (i.e., Health and Education) where they explore adaptation for particular purposes (e.g., rehabilitation, engagement, learning) or are domain-independent (or not specified) where they explore adaption of specific aspects (e.g., difficulty level, exercise types). Both specific and independent domain approaches demand further advancements as they feed each other: while independent domain research can offer rich contexts to investigate adaptation from the broader perspective we are claiming for in this paper, specific domain research can produce results and examples on how to go deeper when implementing and evaluating adaptation. Going broader or deeper must result from an informed decision, not a lack of knowledge. For example, investigating domains such as Social Awareness, Professional Activity, and Entertainment may help to understand how adaptation can improve the user experience by making games more sensitive to the (social, economic, and cultural) context in which they are being used and more inclusive for people and their differences.

The panorama also shows interesting insights into how research practices are taking place. When analyzing "How were the technologies evaluated?" (RQ8) and "What was evaluated?" (RQ9), we noticed that Player Experience and User-Centered evaluation techniques were missing from the selected papers. Player Experience has received growing attention from the literature by bringing UX concepts and methods to the realm of games [Borges *et al.*, 2020], which were not explicitly identified in our mapping. User-centered evaluation techniques, such as Cognitive Walkthrough, Heuristic Evaluation, and Focus Groups, also did not appear. Cognitive Walkthroughs involve examining the product or system from the users' perspective, which is especially useful in identifying problems related to users' mental models of the product or system. On the other hand, Heuristic Evaluations involve having experts reviewing a system against a set of established usability heuristics and help identify design problems that may not be immediately apparent to the user. Lastly, Focus Groups involve conducting a guided discussion with the users to understand their thoughts, opinions, and preferences. They can help identify user needs and preferences that may not have been uncovered through other evaluation techniques.

Regarding "Who evaluated the technologies?" (RQ10), by comparing the results with "For Whom the games are adapted" (RQ1) and "Who adapts" (RQ2), we found out that the evaluation process is not always conducted. Even when conducted, it often occurs with audiences different from the intended. Thus, there is room for research on technologies that not only empower the target audience in the adaptation process but also conduct evaluations with the same audience, ensuring that the adaptation features are appropriately evaluated and meet the needs of the intended users. Of course that evaluating with the target audience requires resources and conditions that are not always available. We subscribe to the understanding that employing evaluation techniques involving representatives from the target audience after conducting evaluations with experts is a matter of ethical responsibility [Ferrari *et al.*, 2020]. However, as the results for RQ8 and RQ9 suggest, evaluating with experts who are able to keep the user in mind is not the dominant practice in the topic. Therefore, these results seem to suggest that employing user-centered evaluation methods, either conducted by experts or with the target audience, is both a challenge and an opportunity for the field.

For "What theories and methodologies support the study?" (RQ11), there is a need for further research on technologies grounded on solid theoretical and methodological foundations. The fact that an explicit theoretical foundation has been identified in a few papers suggests a need to advance the rigor of both the research design and the publication of its results. Without an explicit theoretical and methodological background, rigor and reproducibility are affected, and results interpretation is compromised as the philosophical and epistemological positions of the authors are unknown.

The analysis of RQ1, RQ2, and RQ10 showed that the primary stakeholders of the games are frequently overlooked in the adaptation and evaluation process. Participatory Design is recommended to address this issue as a practical approach that involves collaborating with users throughout various phases of the design process, from ideation to validation. An example of Participatory Design techniques applied in the gaming context can be seen in the research of da Hora Rodrigues *et al.* [2023], in which the authors carried out semioparticipatory activities with health professionals, resulting in requirements for therapeutic games. The authors also developed a platform called RUFUS, which has an authoring web interface and enables the authorship of therapeutic digital games by health professionals.

Universal Design [Mace, 1997] offers seven principles developed to guide the design of any product, service, or environment, which could be applied to inform research on adaptation of games for the broadest possible audience. Equitable Use and Flexibility in Use are principles that can guide researchers to incorporate features such as personalized control schemes, adjustable difficulty options, high contrast color schemes, and adjustable text size. Simple and Intuitive Use and Perceptible Information are principles that can guide designers to ensure their game instructions are clear, concise, and perceptible. For example, designers should ensure that their settings menus are straightforward and contain options to activate subtitles, auditory feedback, and visual cues.

[5] https://gameaccessibilityguidelines.com/

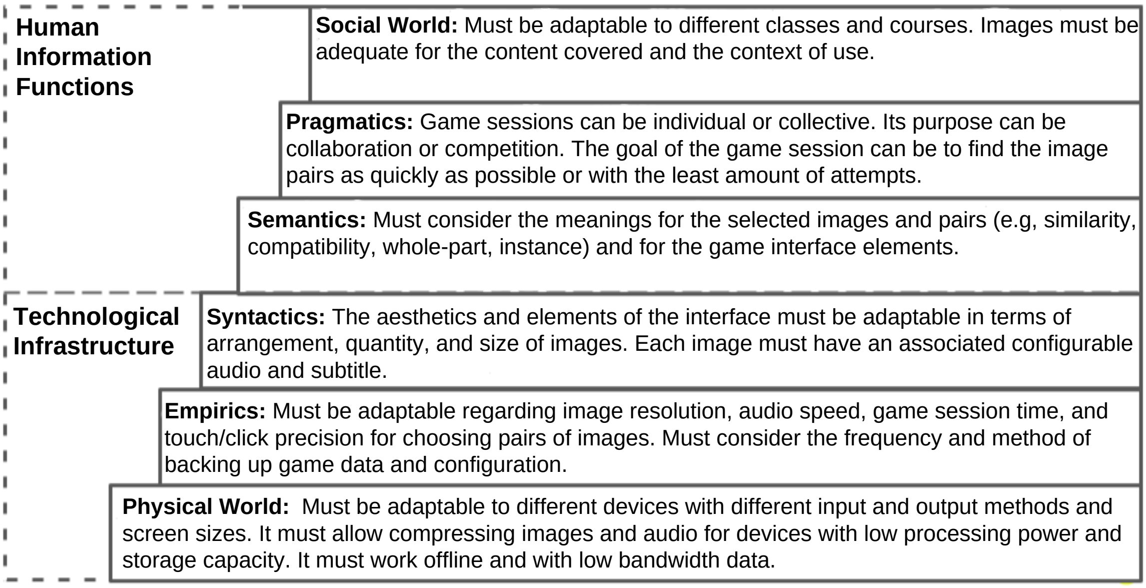

Figure 19. Example of Semiotic Ladder.

Organisational Semiotics [Stamper, 2001] is another foundation absent in the mapped literature, but that contains useful artefacts for researching adaptable game design, as presented in [de Miranda *et al.*, 2013]. Beyond the Stakeholder Identification Diagram, it offers the Valuation Framing, which helps to analyze the cultural impact of a system and that has been adapted for the game domain [da Silva Cardoso *et al.*, 2018], and the Semiotic Framework [Stamper, 2001], which is helpful to structure and organize requirements for a designed solution. Indeed, the Semiotic Framework is particularly relevant as it contains six layers (Social World, Pragmatics, Semantics, Syntactics, Empirics, Physical World) that deal with different levels of abstraction in a system or process, allowing to consider technical and human issues in an integrated manner. The Semiotic Framework may be used to understand how to design games adaptable to people with different backgrounds and needs, from the physical components (hardware) of a game to the social interaction it can promote, supporting the sociotechnical approach we are claiming for adaptation.

Figure 19 illustrates some aspects of each layer that could inform requirements for adaptation features. The top three layers are reminders of human functions while the bottom three are related to the technological infrastructure. For example, consider a simple digital game in the "Memory Game" style: the player's purpose is to discover all available pairs of images with as few attempts as possible. The Semiotic Framework makes it possible to understand this game as an artefact that will mediate people's communication and interaction in a social context. A technical infrastructure is necessary for the game to exist and operate: hardware with processing and storage capacity, software architecture, programming language, and graphical interface. For the game to be effectively used, it is necessary to understand human functions: the meanings and intentions of the designers need to be compatible with the users' intentions and make sense in the social context in which they will play.

Consider that the game above is intended to be used as a teaching material in public schools and, therefore, need to be accessible to the widest possible audience in different use contexts. The Semiotic Framework can help us identify adaptation possibilities: in the Social World, the game must be adaptable for use in different classes and courses, with images appropriate to the content covered and the context of use. For the Pragmatics layer, the dynamics of a game session can be both individual and collective (two or more people), and its purpose must allow both competition and collaboration; the goal of the game session can be either to find the image pairs as quickly as possible or with the least amount of errors, or both. In the Semantic layer, meanings for the selected images and pairs (e.g., similarity, compatibility, whole-part, instance) and for the game interface elements must be configurable. At the Syntactics layer, the aesthetics and elements of the interface must be adaptable in terms of arrangement, quantity, and size of images for each game session; each image must have associated configurable audio. In the Empirical layer, aspects related to image resolution, audio speed, game session time, and touch/click precision for choosing pairs of images are possible adaptation aspects; defining the frequency and method of backing up game data and configuration is another aspect. In the Physical World, adapting the game to different devices with different input and output methods varying screen sizes is a basic requirement; allowing to reduce/compress images and audio for devices with low processing power and storage capacity, and configuring the game to work both on and off-line requiring no internet connection are other examples of adaptation aspects that help to produce games usable for a greater extension of people.

Far from being exhaustive in terms of adaptation possibilities, the example above shows that the Semiotic Framework has the potential to support the identification of adaptation possibilities (What) that make sense to interested parties (Who and Why) and that can be operationalized (How) for use at different times (When), according to the demands

(How Much) of the context of use (Where). The feasibility of combining the layers of the Semiotic Framework with the dimensions of 5W2H also demands investigation as both have the potential to help think about and structure adaptation possibilities. These possibilities can be further refined if they are informed by solid foundations such as Universal Design [Mace, 1997] and Game Accessibility Recommendations [Game Accessibility Guidelines, 2023], and if design and evaluation practices involve domain experts and target audience representatives. Therefore, there is a broad range of challenges and research opportunities to advance our ability to understand, operationalize, and evaluate adaptation from a sociotechnical perspective that aims to make games more inclusive to the greatest possible diversity of people.

6 Conclusion

This Systematic Mapping Study provides an overview of research on adaptation of digital games aiming at making games more accessible and inclusive for different people in different usage contexts. Drawing on the dimensions of the 5W2H Framework, we elaborate the following research questions: (1) What is being adapted in games? (2) Why is it being adapted? (3) For whom is it being adapted? (4) When does the adaptation occur? (5) Who is carrying out the adaptation? (6) What technologies are present? (7) Where are the technologies used? (8) How were the technologies evaluated? (9) What was evaluated? (10) Who evaluated? and (11) What theories and methodologies support the study.

A total of 4385 unique studies were identified from searching the literature, of which 111 were selected after applying inclusion and exclusion criteria. The selected studies were read entirely, and data was extracted to answer the research questions proposed in the study. The data was analyzed using the thematic analysis method. At last, categories were created to illustrate the main themes that emerged and the relationship between the subjects.

The main results of this study were: (1) the identification of a trend in research on adaptive systems; (2) the use of Dynamic Difficulty Adjustment and Procedural Content Generation techniques to implement adaptive behaviour in games; (3) the Patients, Non-specified users, and Health Professionals categories as the main audiences of the studies; (4) the Difficulty Level, Game Elements, Game Features, and Exercise Type as the characteristics being adapted in the games; (5) the characteristics being adapted to increase or improve mostly the Engagement, Rehabilitation, and User Experience of the audiences; (6) the adaptation happening mostly On-the-Play or during Content Update; (7) the Artefact and Architecture as the main types of technologies present as contributions in the papers; (8) most papers evaluate their technologies through Proof of Concept, Experiment, and Case Studies; (9) Patients and Students are often primary stakeholders in the target audience but secondary in the adaptation and evaluation process; (10) most papers are not grounded on a theoretical foundation.

Given this panorama, there is plenty of room for research on technologies that support adaptation for making games more inclusive to the greater extension of people and their context of use. Regarding Target Audience (RQ1) and Adaptation Agents (RQ2), future research should support the games' primary stakeholders in the adaptation process since they can often be secondary to the design process and product. As for Adaptation Characteristics (RQ3), researchers should investigate more Game Features, vital to making games more enjoyable and promoting accessibility to players with disabilities or experiencing other barriers to access. One feature that could be adapted in this respect is game graphics quality, making games more economically accessible regarding energy consumption and processing power requirements. Regarding the Adaptation Benefits (RQ4), future research should explore adaptation for making games inclusive, going beyond accessibility. As for the Adaptation Moment (RQ5), researchers should investigate techniques that can be used to implement adaptive behavior, such as Procedural Content Generation and Player Modelling, as well as hybrid approaches that combine manual and automatic adaptation methods.

Regarding the technologies for adaptation (RQ6), there is space to advance in understanding how end-users can take advantage and contribute to adaptation possibilities and how new technologies can support them, such as the recent wave of generative AI. As for where the technologies are being used (RQ7), future research could explore specific domains such as Social Awareness, Professional Activity, and Entertainment, but also independent domains that can provide a broader perspective. As for how the technologies are being evaluated (RQ8) and what is being evaluated (RQ9), there is room for research using more User-centered and Player Experience evaluation techniques. Regarding the audiences evaluating the technologies (RQ10), further research should explore technologies not only conducting evaluations with the target audience, but also empowering them in the adaptation process.

Regarding the Theoretical Background (RQ11), there is a need for further research on technologies grounded on solid theoretical and methodological foundations. Several theories and methodologies, such as Participatory Design, Universal Design, and Organisational Semiotics, can provide valuable insights to researchers on how to involve their target audiences in all phases of the design process. Adopting these approaches may enable technologies that can be increasingly adapted to be more inclusive to people with diverse backgrounds and needs, thus contributing to more inclusive and tailored gaming experiences. In future work, we plan to extend this study to include more databases, such as Springer, Scielo, Scopus, Science Direct, and the SBC Open Lib, as they may include valuable papers on game adaptation.

Declarations

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Authors' Contributions

CC, MM, and RP contributed to the conception of this study, analysis, and writing. CC is the main contributor and writer of this manuscript. MM, RP, and LT participated in the validation of the study, review and final editing. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The list of papers selected in each phase of the Systematic Mapping Study, the data extracted from the papers, and the Mapping Protocol are available with open access in: https://osf.io/6xvpj/?view_only=577e0c8dde234368bacf3e10f5ee6283

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Appendix

Table 8. Overview of Research Questions and Answers

For Whom is it adapted? (RQ1)	Who adapts the game? (RQ2)	What is adapted? (RQ3)
Patients (47) Non-specified users (47) Health Professionals (35) Game Designers (29) Educational Experts (18) Students (18)	System (72) Health Professionals (23) Game Designers (17) Educational Experts (13) Non-specified users (8)	Difficulty Level (70) Game Elements (52) Exercise Type (25) Game Features (11)
Why is it adapted? (RQ4)	When is it adapted? (RQ5)	What technologies are present? (RQ6)
Engagement (27) Rehabilitation (23) User Experience (20) Motivation (17) Learning (15) Accessibility (8) Productivity (6)	On-the-play (43) Content Update (32) Settings (22) Design Time (19) Installation (17)	Artefact (74) Architecture (34) Framework (23) Model (18) Method (17) Methodology (5) Guideline (4) Ontology (1)
Where are the technologies used? (RQ7)	How were the technologies evaluated? (RQ8)	What was evaluated? (RQ9)
Health (50) Domain Independent (35) Education (27)	Proof of Concept (46) Experiment (45) Case Study (43) Questionnaire (34) Pilot Study (12) Usability Test (10) Interview (5) Not Performed (23)	Feasibility (46) Performance (41) User Experience (29) Usability (20) Acceptance (20) Accessibility (5) Not performed (23)
Who evaluated the technologies? (RQ10)	What theories and methodologies support the study? (RQ11)	
Other users (35) Patients (16) Students (14) Health Professionals (7) Authors (6) Educational Experts (3) Game Designers (2) Nobody (40)	Flow (12) Universal Design (2) Reinforcement Theory (2) Personality Theory (2) Others (8) Not informed (83)	

Table 9. List of Selected Papers with IDs and Authors

ID	Authors	Paper Title
1	Vidakis and Charitakis [2018]	Designing the Learning Process: The IOLAOS Platform
2	Loria and Marconi [2020]	Reading Between the Lines – Towards an Algorithm Exploiting In-Game Behaviors to Learn Preferences in Gameful Systems
3	Antonova *et al*. [2019]	Smart Services for Managing the Design of Personalized Educational Video Games
4	Tsiakas *et al*. [2016]	Interactive Learning and Adaptation for Robot Assisted Therapy for People with Dementia
5	Afyouni *et al*. [2019]	RehaBot: Gamified Virtual Assistants Towards Adaptive TeleRehabilitation
6	Archambault and Olivier [2005]	How to Make Games for Visually Impaired Children
7	Karoui *et al*. [2021]	Adaptive Pathways within the European Platform for Personalized Language Learning PEAPL
8	Villar *et al*. [2007]	The VoodooIO Gaming Kit: A Real-Time Adaptable Gaming Controller
9	Jones [2016]	Adaptive Play: A Prototype of a Responsive Children's Videogame for Greater Inclusivity
10	Snodgrass *et al*. [2019]	Like PEAS in PoDS: The Player, Environment, Agents, System Framework for the Personalization of Digital Systems
11	Gouaïch *et al*. [2012]	Digital-Pheromone Based Difficulty Adaptation in Post-Stroke Therapeutic Games
12	Jacobs *et al*. [2013]	CONTRAST: Gamification of Arm-Hand Training for Stroke Survivors
13	Mason *et al*. [2020]	Dash Lane An Adaptive Exergame for People Using Manual Wheelchairs

14	Loiacono *et al*. [2018]	Social MatchUP: A Memory-like Virtual Reality Game for the Enhancement of Social Skills in Children with Neurodevelopmental Disorders
15	Wauck and Fu [2017]	A Data-Driven, Multidimensional Approach to Hint Design in Video Games
16	Coyle *et al*. [2010]	PlayWrite: End-User Adaptable Games to Support Adolescent Mental Health
17	Yun *et al*. [2010]	PADS: Enhancing Gaming Experience Using Profile-Based Adaptive Difficulty System
18	Zhao *et al*. [2019]	Knowledge Assessment: Game for Assessment of Symptoms of Child Physical Abuse
19	Khoshkangini *et al*. [2017]	Machine Learning for Personalized Challenges in a Gamified Sustainable Mobility Scenario
20	Montoya *et al*. [2019]	Design of an Upper Limbs Rehabilitation Videogame with SEMG and Biocybernetic Adaptation
21	Buzzi *et al*. [2016]	Learning Games for the Cognitively Impaired People
22	Ahmad *et al*. [2016]	Effect of Different Adaptations by a Robot on Children's Long-Term Engagement: An Exploratory Study
23	Ferreira *et al*. [2019]	A Usability Study with Healthcare Professionals of a Customizable Framework for Reminiscence and Music Based Cognitive Activities for People with Dementia
24	Foukarakis *et al*. [2011]	An Adaptable Card Game for Older Users
25	Miljanovic and Bradbury [2020]	GidgetML An Adaptive Serious Game for Enhancing First Year Programming Labs
26	Martin-Niedecken *et al*. [2019]	ExerCube vs. Personal Trainer: Evaluating a Holistic, Immersive, and Adaptive Fitness Game Setup
27	Ascari *et al*. [2020]	Personalized Gestural Interaction Applied in a Gesture Interactive Game-Based Approach for People with Disabilities
28	Geurts *et al*. [2010]	Digital Games for Physical Therapy: Fulfilling the Need for Calibration and Adaptation
29	Berkovsky *et al*. [2012]	Physical Activity Motivating Games: Be Active and Get Your Own Reward
30	Niedecken et al. [2016]	Design and Evaluation of a Dynamically Adaptive Fitness Game Environment for Children and Young Adolescents
31	Wetzel *et al*. [2014]	Dynamically Adapting an AI Game Engine Based on Players' Eye Movements and Strategies
32	Philezwini et al. [2020]	A Reinforcement Learning-Based Classification Symbiont Agent for Dynamic Difficulty Balancing
33	Demediuk *et al*. [2016]	An Adaptive Training Framework for Increasing Player Proficiency in Games and Simulations
34	Vickers *et al*. [2013b]	Performing Locomotion Tasks in Immersive Computer Games with an Adapted Eye-Tracking Interface
35	Madeira *et al*. [2017]	Web Applications and Web Services Support Therapists in a Multi-Sensor Platform for Therapeutic Gaming
36	Leonardou and Rigou [2016]	An Adaptive Mobile Casual Game for Practicing Multiplication
37	Vickers *et al*. [2013a]	Accessible Gaming for People with Physical and Cognitive Disabilities: A Framework for Dynamic Adaptation
38	Bicho and Martinho [2018]	Multi-Dimensional Player Skill Progression Modelling for Procedural Content Generation
39	Moon and Seo [2020]	Dynamic Difficulty Adjustment via Fast User Adaptation
40	Ng *et al*. [2018]	Situated Game Level Editing in Augmented Reality
41	Xu *et al*. [2018]	Personalized Serious Games for Cognitive Intervention with Lifelog Visual Analytics
42	Bontchev and Vassileva [2016]	Assessing Engagement in an Emotionally-Adaptive Applied Game
43	Pisan *et al*. [2013]	Improving Lives: Using Microsoft Kinect to Predict the Loss of Balance for Elderly Users under Cognitive Load
44	Graf *et al*. [2019]	IGYM: An Interactive Floor Projection System for Inclusive Exergame Environments
45	Tresser [2017]	Personalization of Virtual Games for Children with Cerebral Palsy
46	Nogueira *et al*. [2013]	Utilizando Meta-Design Para Customização de Conteúdo Em Um Portal de Jogos Educativos
47	Conati and Zhao [2004]	Building and Evaluating an Intelligent Pedagogical Agent to Improve the Effectiveness of an Educational Game

48	Rossol *et al*. [2011]	A Framework for Adaptive Training and Games in Virtual Reality Rehabilitation Environments
49	Frommel *et al*. [2018]	Emotion-Based Dynamic Difficulty Adjustment Using Parameterized Difficulty and Self-Reports of Emotion
50	Vandermaesen *et al*. [2016]	Integrating Serious Games and Tangible Objects for Functional Handgrip Training: A User Study of Handly in Persons with Multiple Sclerosis.
51	Orji *et al*. [2017]	Towards Personality-Driven Persuasive Health Games and Gamified Systems
52	Blom et al. [2018]	Personalized Crisis Management Training on a Tablet
53	van Herk *et al*. [2009]	ESPranto SDK: An Adaptive Programming Environment for Tangible Applications
54	Daoud *et al*. [2015]	An Interactive Rehabilitation Framework for Assisting People with Cerebral Palsy
55	Yoo *et al*. [2017]	Towards a Long Term Model of Virtual Reality Exergame Exertion
56	Anyango and Suleman [2021]	Supporting CS1 Instructors: Design and Evaluation of a Game Generator
57	Mildner *et al*. [2014]	Creation of Custom-Made Serious Games with User-Generated Learning Content
58	Lioulemes *et al*. [2015]	Self-Managed Patient-Game Interaction Using the Barrett WAM Arm for Motion Analysis
59	Chang *et al*. [2015]	Designing Kinect2Scratch Games to Help Therapists Train Young Adults with Cerebral Palsy in Special Education School Settings
60	Mei *et al*. [2015]	"I Built It!" — Exploring the effects of customizable virtual humans on adolescents with ASD
61	Tlili *et al*. [2019]	Does Providing a Personalized Educational Game Based on Personality Matter? A Case Study
62	Pelegrino *et al*. [2014]	Creating and Designing Customized and Dynamic Game Interfaces Using Smartphones and Touchscreen
63	Tang and Shetty [2011]	Adaptive virtual reality game system for personalized problem-based learning
64	Grammatikopoulou *et al*. [2017]	An adaptive framework for the creation of bodymotion-based games
65	Lopes *et al*. [2018]	Authoring Adaptive Game World Generation
66	Arnold *et al*. [2013]	Adaptive Behavior with User Modeling and Storyboarding in Serious Games
67	Peirce *et al*. [2008]	Adaptive Educational Games: Providing Non-invasive Personalised Learning Experiences
68	Delgado-Mata and Ibánez [2011]	Adaptive Physics for Game-Balancing in Video-Games for Social Interaction
69	Silva and El Saddik [2011]	An adaptive game-based exercising framework
70	Nakamichi and Ito [2015]	Implementation and qualitative analysis of an adaptive computer Shogi program by producing seesaw game
71	Assiroj *et al*. [2018]	Adaptive Game Design using Case-based Reasoning Method for High Performance Computing Learning
72	Tahai *et al*. [2019]	Scalebridge: Design and Evaluation of Adaptive Difficulty Proportional Reasoning Game for Children
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