

Empowering vulnerable target groups with serious games and gamification[☆]

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ABSTRACT

Serious games and gamification is a popular and growing field, commercially and for academic research. This paper aims to give an overview of a specific domain within the field of serious gaming and gamification; the field of serious games and gamification to empower vulnerable target groups. This overview contributes to a better understanding of this field, by identifying different vulnerable groups and empowerment methods with their own characteristics. From this overview a gap in the existing research can be identified: complex, more indirect, vulnerabilities are not covered in existing research. Moreover, opportunities lie in creating more standardized ways of describing games, enhancing the generalizability of the research. To introduce what distinguishes this specific sub field of serious games and gamification research from other fields, an overview which distinguishes games based on their objective. With the use of a structured literature review, this field is further studied. Next, the identified empowerment methods are studied in more detail, describing the technology, game mechanics and study results found in the literature research. The results of the found studies are often positive, but the generalizability of the results is often limited.

1. Introduction

Serious games and gamification, the use of games or game elements for serious rather than entertainment purposes, are gaining more and more attention in many fields and are used for various target groups. This increased interest cannot only be seen in the number of applications, but also in the growing research within this area. Academic research studies various aspects of serious games and gamification, often describing specific applications or case studies.

When talking about the types of applications that exist for serious games and gamification, it becomes clear that there are many different domains in which they are used. One way to cluster serious games and gamified applications into domains is based on the goal or application domain. To give an overview of the field of serious games and gamification, this paper starts with a theoretical background section that classifies serious games and gamified applications based on their objectives: the high-level goals of the application (e.g. economic, education or marketing). One of these objectives is of specific interest of this paper: the goal to empower vulnerable target groups with the use of serious games and gamification.

While vulnerability is a concept everybody knows and intuitively understands, it is often hard to explain what the concept actually means [1]. The dictionary provides different meanings, but when studying them closely it is possible to see some common factors. Vulnerable has negative associations. It stems from the Latin word *vulnus*, which means wound. However, a vulnerable person does not necessarily need to be wounded, he/she has some weak spot that could possibly be a wound when being hurt. So, a person that is denoted as vulnerable has some characteristic or is in a certain situation that could potentially influence the person in a negative way.

Yet it is still hard to pinpoint one definition for vulnerability, as it can be used in different contexts with different appropriate definitions. In order to understand the concept better, a taxonomy for vulnerability can be proposed, explaining three sources and two states of vulnerability [2]. The sources explain where the vulnerability is coming from: inherent, situational, or pathogenic. Inherent sources of vulnerabilities are intrinsic to the human condition; such as hunger or thirst. Situational sources on the other hand, are context specific vulnerabilities; such as vulnerabilities due to natural disasters. Pathogenic vulnerabilities are situational vulnerabilities that are caused by injurious social

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phenomena. For example: “people with cognitive disabilities, who are occurrently vulnerable due to their care needs, are thereby susceptible to pathogenic forms of vulnerability, such as to sexual abuse by their carers.” [2]. The states explain how pressing the vulnerability is: dispositional (potential) or occurrent (acute). Hoffmaster (2006) explains how vulnerability is in fact harming the autonomy of a vulnerable person. The characteristic or situation causing the vulnerability has taken control from a vulnerable person, the vulnerable person therefore loses its autonomy.

In this research, vulnerability is seen as a condition, that is coming from a personal characteristic (source), that potentially negatively influences the wellbeing or potential of the target group or person. What is affected by the vulnerability is called a vulnerability risk in this paper. To limit the scope of this research, we have chosen to limit this research to personal characteristics (inherent sources), rather than including context specific vulnerabilities (situational sources) as well. Moreover, this paper studies how vulnerable groups can be empowered by serious games or gamified applications. According to the Cambridge dictionary, empowerment is the process of gaining freedom and power to do what you want or to control what happens to you [3]. In the context of this paper, empowerment thus describes the process of mitigating the described loss of autonomy. A serious game or gamified application can be a tool to facilitate this process. Serious games and gamified applications are accessible ways to reach a broad target audience. It has different advantages, among which is the fact that it allows users to independently use it as often as they want. Whereas more traditional empowerment methods, like real-life trainings, might be costly and hard to organize or repeat; developing a serious game or gamified application is a onetime effort. Empowering vulnerable people can have many different benefits, often related to increasing the well-being of the person, but ultimately could also lead to economic benefits, as costs related to the vulnerability are reduced, or the economic opportunities of the person are increased.

This paper studies in more detail how vulnerable groups are empowered by serious games or gamified applications, using a systematic review. In the first part of the review, it is studied which vulnerable target groups are empowered through serious games and gamification. Secondly, the paper identified if there are specific patterns between the empowering method and game aspects such as the type of game, the used game elements or the evaluation method.

The next section discusses the theoretical background to explain the concepts serious gaming and gamification, and introduces a classification of serious games and gamified applications based on their objective. Moreover, this theoretical background explains in more detail what game mechanics, used in serious games and gamified applications, are and which mechanics exist. In Section 3, the method of the systematic review is explained. First, in Section 4, a review is performed to get insight in the vulnerable target groups and empowerment methods. Secondly, in Section 5, the different empowerment methods are reviewed on more technical details and study results. Finally, in Section 6, an overall conclusion can be found, giving a summarized overview of the domain of serious gaming and gamification to empower vulnerable target groups.

2. Theoretical background

2.1. Defining serious games and gamification

Different definitions of serious games exist; some examples are:

- Serious games “have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement” [4].
- “A game in which education (in its various forms) is the primary goal, rather than entertainment” [5].

- “Digital games created not with the primary purpose of pure entertainment, but with the intention of serious use as in training, education and health care” [6].

The first two definitions do not limit serious games to digital games, as the last definition does. Although it is less common, it is not impossible to have a non-digital serious game. Within this review, the focus will be on digital games. Furthermore, it is also not stated whether the games should be designed for their serious purpose, or that existing games could also be used. However, in all the definitions the emphasis is pointed away from entertainment, which is the primary goal of so-called off-the-shelf-games that are used as serious games. For this review those off-the-shelf-games are therefore excluded. Based on the above-mentioned definitions, the following definition that will be used throughout this paper is formulated: *Serious games are digital games, created specifically for an educational purpose and not solely intended for amusement.*

Gamification can be defined as “the use of game design elements in non-game contexts” [7]. Another, slightly different definition describes gamification as “the intentional use of game elements for a gameful experience of non-game tasks and contexts” [8], this definition is used in this review paper. Other variants of these definitions exist as well, some of which focus at using gamification for purposes such as marketing. This review does not focus on such purposes for gamification.

From these two definitions the difference between serious games and gamification becomes clear. Serious games are entire games, whereas gamification is a way to (re)design a non-game task, so it is only adding some elements instead of designing an entire game. Although this distinction might look very clear, it can sometimes be confusing. Within gamification, two different types of gamification can be distinguished: shallow and deep gamification [9]. In shallow gamification the core process is not really changed, but rather enhanced with gamification elements. For the shallow gamification, mainly programming and visual design skills are needed, as there is no need to redesign the main task. This type of applications is clearly different from serious games, as their focus is still very much on the task itself. An example of shallow gamification is adding points and a leaderboard to assignments of a course. For deep gamification on the other hand the core processes are changed for the gamification. In this case game design skills are needed to redesign the activity accompanied by game mechanics, and it can become more similar to a serious game.

2.2. Classification of serious games and gamified applications

This section proposes how serious games and gamified applications can be classified based on their objectives. One of these objectives is the focus of this review paper, namely empowering vulnerable target groups. This classification can be used to identify whether serious games or gamified applications fit the objective studied in this review.

Serious games and gamification are used for corporate or marketing objectives of commercial institutions. Well known examples of (simplified) gamification for marketing are loyalty programs, in which certain consumer behaviour is motivated by the game mechanics of the program. A customer for example earns points for buying products in a specific store, which eventually leads to rewards such as discounts [10]. Often the goals of these applications of serious games and gamification are of an economic nature (see for example the review of [11]): improving the customer relationship and/or increasing sales. Related to this is the rise of the use of serious games and gamification in tourism (see for example the review of [12]), where serious games and gamification can, for example, be used to increase the satisfaction of visitors with their visit, increasing the chance of them to return.

However, there are also other large domains that have adopted serious games and gamification, without an economical goal but with an educational objective. In the medical domain (see for example the review of [13] or [14]), many different applications exist, for example to

train specific situations with health professionals or students. Furthermore, there are many games that are used for rehabilitation purposes [15]. As these games have a specific medical purpose and grounding, we do not include them in the category of empowerment. Another example of such a large domain is education (see for example the review of [16] or [17]), where many different applications are used to motivate and engage students for various different courses or to learn various skills, either physical skills or social skills. In these domains the goal of the serious game or gamification application is not economical, instead it can aim to improve or stimulate education or motivation for learning. However, the target audience is very large and broad, it can be a class following a course, a group of nurses, doctors etcetera. Moreover, although all the target users have something in common (they are students of the same group or have the same job), their personal characteristics, such as previous gaming experience or initial motivation, can differ a lot. Furthermore, many applications have comparable (or the same) subjects, or the application designs for different subjects are comparable. For example, there are many serious games or gamified applications that address a subject such as math or learning a (programming) language. There are also many examples of serious games or gamified applications in the field of education that use game mechanics such as experience points and badges to indicate the students' progress, but for a wide variety of subjects/courses.

There are also applications that do not directly impact humans; for example, applications that try to change the behaviour of users to save energy, improving the climate (see for example the review of [18]). It can be said that these serious games or gamified applications have an environmental objective, as they want to change something in the environment through human behaviour.

Serious games and gamified applications can also be used for research objectives. Data for research purposes is sometimes collected with the use of serious games and gamification. For example the game 'Adventures with Lex', which is used to research the perception from children on the law [19]. However, it can also be used on a larger scale by gamifying the crowdsourcing of certain tasks for research purposes [20]. The main goal of these serious games or gamified applications is to collect data.

The current research focuses on another objective of serious games and gamification; namely to empower vulnerable target groups with serious games or gamification. The target group of such applications is defined by personal characteristic(s), such as age or health condition, rather than a situational characteristic such as a school class or job. Because the subjects of applications with this objective can be very different, this paper aims to study if and which common factors can be found, and explore the area of empowering serious games and gamified applications.

2.3. Game mechanics

In Section 2.1 the following definition of gamification was given: *"the intentional use of game elements for a gameful experience of non-game tasks and contexts"*. In this definition, game elements (or mechanics) are mentioned as discriminating factors between normal tasks and gamified tasks. Game mechanics are not exclusive for gamification, but are used in the broad field of game design. The Mechanics-Dynamics-Aesthetics (MDA) framework for game design [21] aims to guide all the different type of people that are involved in game design (including serious games and gamification) such as designers, developers, and researchers. The components of the framework are:

- Mechanics: the functioning of the components within the game;
- Dynamics: the interaction between the player and the mechanics;
- Aesthetics: the feeling the player gets from the game;

Although both serious games and gamification use these components in their game design, the way it is used differs. As serious games are

entire games, all the components of the MDA framework are useful for the game design process. For gamification however, the game mechanics are the main focus.

Within serious games and gamification, game mechanics are used as motivational affordances. Concrete examples of such game mechanics, that are often used for gamification, are: points, leaderboards, achievements/badges, levels, and challenges [22,23]. In the following paragraphs these game mechanics are explained based on [23].

2.3.1. Points

Points are a core component of gamification, either visible to the user, invisible to the user, or any form in between. They can have many different forms, with different purposes, but in essence points are a way to track the behaviour of users and tie reactions to that behaviour. In a game you can use different point systems, either one or more at the same time, to stimulate the motivation of the players. In [23] five possible interpretations of points are discussed:

- Experience points (XP): XP is rewarding user behaviour to motivate usage on the long term. By assigning XP to certain activities, the objectives of the designer can be aligned with the player in a long-term way. With XP you can inform your players about what activities are important. XP never maxes out, typically only increases over time (and cannot decrease), and it is not redeemable. Sometimes however, XP can be reset to create goal loops.
- Redeemable points (RP): RP can have many different implementations and names (such as cash or coins). In contrast to XP, RP can fluctuate as players can use their points for rewards. In essence, using RP means that you build an economy, which you have to monitor to ensure it keeps its value to the user. RP systems are useful if you have broad behaviours and/or large groups that you want to motivate. However, it can be challenging to use RP systems for multiple reasons. First of all, there are legal regulations you have to take into account. Moreover, it is important how players perceive the rewards they can get; rewards have to be meaningful and realistic for the users in order for the system to work as motivation.
- Skill points: skill points are assigned to specific activities alongside the core of the game. Users are directed to certain tasks in order to get skill points for specific activities.
- Karma points: Karma points are rare in classic games. The intention of karma points is to stimulate altruism and user reward, the purpose of such points is namely to give them away. They can be used for example as a way to let users reward others for their behaviour in a challenge.
- Reputation points: these points can be used to build trust between different parties that have to work together. It is very complex to build reputation points, as they have to include a wide variety of activities and take into account the different incentives of users. However, in some situations (for example for reviews) it might be necessary to know something about the reputation of a user.

2.3.2. Leaderboards

Leaderboards are intuitive for many users to understand, showing them simple comparisons, and putting the earnings of the player in perspective. There are two different types: non-disincentive leaderboards and infinite leaderboards. In a non-disincentive leaderboard the player always sees him- or herself in the middle of the leaderboard, unless (s)he has a high rank. In such cases the leaderboard should show this directly as such a rank might have meaning to the user. If the rank of the player is lower, the emphasis is more on comparing itself with the next-best score for example. Infinite leaderboards are long lists of scores. To make sure that somebody does not fall off the leaderboard different orderings can be used, such as filtering on local or global scores or scores of players with the same level.

Sometimes however caution is needed when using leaderboards, to ensure the privacy of users. It is however not impossible to use sensitive

data for leaderboards; it is possible to find ways to do this while ensuring the users privacy.

2.3.3. Badges

Badges or achievements can be a way to show accomplishments or progress in a game. Moreover, badges can also serve as a means of social promotion. Badges can be used to replace the level system of a game. Levels are explained in 1.3.4.

Badges can be implemented in different ways. It might be clear to the user what behaviours result in earning a badge, but this might also be hidden to them. In some cases, it is not even clear what badges exist.

2.3.4. Levels

Levels are used to indicate the progress of users. However, nowadays levels are also used in a broader way. In gamification, levels are not used in the traditional way as they were in classic games. When designing levels, you can think of how the difficulty and complexity increases, this could be linear (for example you level-up after earning 100 points), but it could also be exponential or something in between. Creating the levels at a right difficulty and complexity (level balancing) is important to avoid drop-outs, however difficulty can also serve as a way to motivate people as they feel special if they passed a specifically difficult level for example.

Progress bars are a visual way to show users their progress in a level, for example in the form of a percentage of completion.

2.3.5. Challenges

Challenges give players a direction for their behaviour. Although it is comparable to badges, it gives more context to the goal that needs to be achieved. Players have something to accomplish within their overall experience. In social games, involving a community of players, cooperative quests or challenges can be created. These challenges are more difficult to build, but also more powerful due to their social component.

2.3.6. High-level game mechanics

The abovementioned game mechanics are quite concrete. More high-level mechanics are defined by Schell [24]:

- **Space:** the space of a game is the area in which the player can move around. In this space the player can have different degrees of freedom in its movements. A space can be discrete or continuous, where discrete spaces limit the player to a certain number of possible steps. Furthermore, designers need to think of connections between different spaces.
- **Time:** timing and length of the game are important mechanics that need to be taken into account for the design process. Using time as a game mechanic can be frustrating, but also motivating. One way in which time can be used is as a constraint, limiting the time that a player can spend on a specific task.
- **Objects, attributes, and states:** games contain many different objects, all with their own attributes and states. It should be carefully thought out what they are and how they become visible to the user. This also includes what type of knowledge there is in a game, and to what extend the players have this knowledge.
- **Actions:** this involves the actions that a player can perform and the impact of these actions on the game.
- **Rules:** rules determine how the game is played. Not only should game designers think of what rules a game has, they should also think about how the rules are communicated and enforced. Furthermore, as described earlier, it is important to make goals in a game achievable and rewarding, or design the right level balancing.
- **Skill:** games involve different (types of) skills from the players. Which skills and which level of skill is needed can influence the gaming experience? It is also possible to create a gaming experience for users that improves the skills of the players.

- **Chance:** novelty is a motivating factor in games, which can be created by using chance. However, chance is not always positively experienced by players. For the use of chance, a right balance is important.

3. Method

This section explains the structure of the review and the concepts used for the review, followed by the process of finding and selecting papers for the review.

3.1. Review structure and concepts

The goal of this review is to gain insight in the field of serious games and gamification to empower vulnerable target groups. The results of the structured literature study will be presented in the two steps in the next two section. First, [Section 4](#) will focus on the *contexts* of the found interventions, rather than the game or research aspects. The following questions will be answered:

- Which vulnerable target groups are studied?
- How can the target group's risk(s) be characterized?
- In what way do the interventions empower the target group?

[Fig. 1](#) gives an overview of the terms that are used to describe the papers for those three questions. Each of the above questions is answered with one classification only. In cases in which multiple classifications could fit, the classification that described the most important aspect was used.

With target group we mean the group that the intervention is designed for. In some cases, this can be different from the participants that are used in the evaluation study of the intervention. For example, participants from the same demographic groups as the intended target group, but without a medical condition, to research the user experience without burdening patients. Moreover, the vulnerable target groups are characterized by terms that are mentioned in the paper, rather than doing additional research about their vulnerability. We identify five different target groups, namely people that are vulnerable due to their age, psychological health condition, mental health condition, cultural background or socio-economic status.

The vulnerability risks can be characterized as either health, safety or social risks. Health risks can be related to the current or future health of the targeted user. Safety risks include all types of risks that (could) form a danger to the safety of a person, for example in traffic. Social risks are related to the social wellbeing of a person, for example social exclusion.

With the third question, the focus is on the empowerment methods. For this we do not focus on the technical details, but on the way of empowerment. We identify three different ways of empowerment.

- In order to empower the players, some interventions aim to teach specific skills. These interventions do not aim to teach the player knowledge that could ultimately change its behaviour, to improve its situation, but it teaches a skill that improves the player's situation. Moreover, the intervention does not reward existing behaviour, but rather teaches the user a new skill. We call this empowerment method *training skill*.
- The second category is called *supporting behaviour*. Interventions in this category support the behaviour of the player, both by giving feedback and stimulating specific behaviours. Within this empowerment method, different domains can be identified. On the one hand there is physical activity that can be supported by interventions. On the other hand, there are behaviours, such as substance use or medication usage, that are supported or discouraged by interventions. This type of behaviours will be called lifestyle behaviours in the remainder of this review, and include all other behaviours than physical activity.

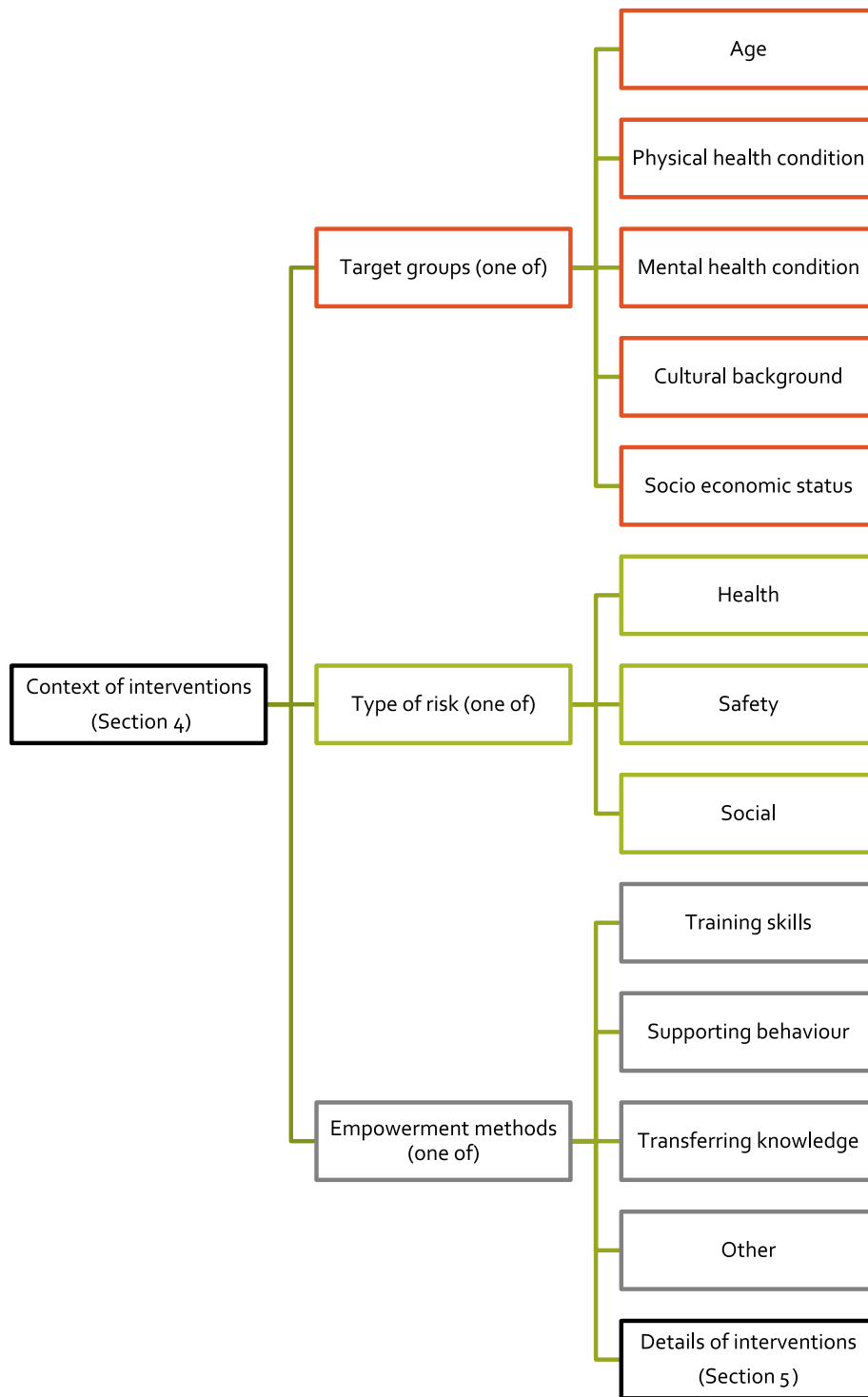


Fig. 1. Overview concepts of taxonomy in Section 4.

- In the third category aim to transfer knowledge to the player. This could ultimately be causing different behaviours of players, but the main goal of such interventions is to inform the player about a specific topic. This category is called the *transferring knowledge* category.
- When it is not possible to classify an intervention with one of these labels, we will label them with *other*.

Subsequently, Section 5 focuses on the *content* of the interventions and the research. The following aspects are studied in this section:

- Technologies (platforms and hardware) used;
- Game characteristics and game mechanics;
- Types of (intended) evaluation studies and their results.

Fig. 2 summarizes the concepts that are used to describe the details of the interventions in Section 5.

The technology used for an intervention can be described using the following categories:

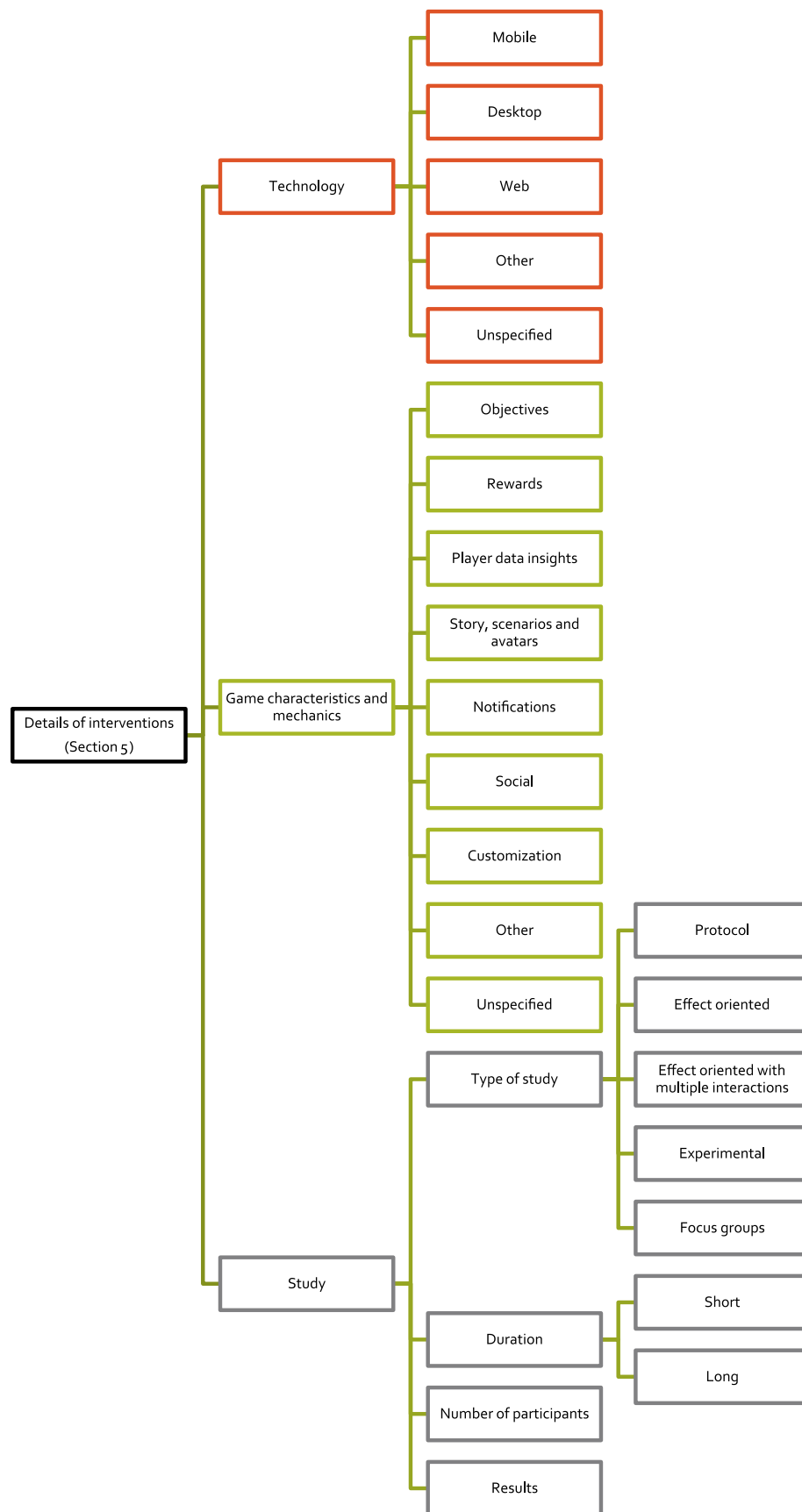


Fig. 2. Overview concepts of taxonomy in [Section 5](#).

- Mobile: applications and games designed for mainly tablets and/or smartphones;
- Desktop: applications designed for computers or laptops;
- Web: web-based applications used in the browser. Sometimes designed for a specific platform;
- Other: this category contains all technology that is used but does not fit under one of the larger categories, such as VR-technology or Kinect.
- Unspecified: when the paper does not mention or is unclear about the technology used

It is possible that an intervention is designed for multiple platforms, these platforms will then all been included in the overview.

The game characteristics and mechanics are described using the following concepts:

- Objectives: some game mechanics are used to steer the behaviour of players within the application or in real life. Such mechanics create a goal for the user to work towards. Examples of these mechanics are: challenges, levels, achievements, and goals. Many of these mechanics are a variation on each other; they all give the player a goal to work towards. Time restrictions or time pressure can also steer the behaviour of the player and the objective for the player is to stick within those time restrictions.
- Rewards: rewarding players is an important component of many games. In some games players receive feedback on their performance, which can be in many different forms such as visually or via audio. However, rewards can also have the form of badges, medals, or prizes. Another way to reward players, is by giving them points. Sometimes these points are used as in-app currency, and sometimes it is only used to show progression or performance. Points are used in many of the games. Another rewarding component can be unlocking something new in the game, for example new content. Finally, rewards are not always positive. Punishment can also be used as a game concept.
- Player data insights: a lot of applications collect data about the player. Interventions sometimes give the player insight in this data, often via a profile page. This sometimes includes a diary function or self-monitoring functionalities.
- Story, scenarios, and avatars: stories, scenarios and avatars can be used in interventions in different ways.
- Notifications: many interventions remind their users of the intervention with emails or notifications outside of the applications. In some cases, these notifications are actual reminders, but in other cases these notifications contain updates about the performance of the user or educational information. As they are delivered outside of the application, it can also serve as a reminder.
- Social features: different social features can be used in interventions. Social features include: teams, user-content generation, interaction with others, social support and competition with others.
- Customization: interventions including customization options in their application.
- Other: some game mechanics cannot be categorized in one of the abovementioned categories, and appear less often. These mechanics are labelled with the category 'other'.
- Unspecified: when it is unclear what characteristics and mechanics are used, we classify these interventions under unspecified.

Again, interventions can contain different game characteristics. Different categories can be assigned to a single intervention, but when different examples within one category is used, this is only counted once per intervention. It needs to be noted that different papers describe their game or application with another level of detail. It might therefore be that some characteristics and mechanics will not be clearly mentioned in this review, as they were not clearly mentioned in the papers.

To describe the studies and results of the found papers, we study

different things. First of all, it is studied whether the reviewed paper includes a study with results, or is a study protocol or design description of an application, without an evaluation. In the case that it includes a study with results, the following aspects are studied:

- Whether the study is a short study (data collected over less than 6 months), or a long study (data collected over at least 6 months).
- We identified different types of studies. An evaluation can be characterized by one of the following types, or multiple if the evaluation consists of multiple studies:
 - Effect oriented studies: these studies offer the intervention to participants for one time and measure the effect of the intervention afterwards. Moreover, other aspects such as usability can be measured as well.
 - Effect oriented studies with multiple interactions: these studies offer the intervention to the participants multiple times, and it measures the effect of the intervention. Again, other aspects such as usability can be measured as well.
 - Experimental studies: these studies distribute their participants over multiple conditions, to compare the results of these different conditions. Experimental studies at least have an experimental condition and a control condition, but can have more conditions.
 - Focus groups: these studies focus on qualitative data from groups discussions or interviews. In this review we also categorize studies with the main focus on usability testing under focus groups. Focus groups are mainly used to improve a serious game or intervention, or as a pilot study, but not to quantitatively measure the effect of the intervention.
- The number of participants in the study.
- The type of results that are reported.

In some cases, multiple studies are described in one paper. In such cases, the different study types and sizes are mentioned separately.

Section 4 describes the different interventions in two different Sections: Section 4.1 describes the target groups and their vulnerability, and Section 4.2 describes the empowerment methods. In Section 5, the different aspects are studied separately for each empowerment method. It is explored whether and, if any, which patterns are found between the findings of Sections 4 and 5. Appendix A summarizes the results from Sections 4 and 5 in a table. The only missing concept in this table is *results*, as this is a more descriptive concept that cannot be captured in a table.

3.2. The search query

As Scopus includes research from many different sources, it is chosen for this review. A comparable search has been performed in the Web of Science database. This resulted in fewer results, but within the most cited papers comparable papers were found. As Web of Science did not result in more sources, it is chosen to use Scopus.

The following query has been executed (on August 2nd, 2019) and resulted in 286 results from the Scopus database:

```
PUBYEAR > 2014 AND TITLE-ABS-KEY ((gamif* OR ("serious gam*")) AND (vulnerable OR disabled OR prevent* OR inclusive OR risk OR empower*) AND (evaluat* OR trial OR experiment* OR "user study" OR pilot) AND NOT (rehabilitation OR review)) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar"))
```

As we want to focus on recent research, to show the current movements within the field, the query only includes work published after 2014 (*PUBYEAR > 2014*). We executed the query on the title, abstract and keywords of all references in the Scopus database (*TITLE-ABS-KEY*).

The first part of the query (*gamif* OR ("serious gam*")*) describes the field that is explored within this review: serious gaming and gamification. The asterisk means that words can have multiple endings (e.g.

‘gamification’ and ‘gamify’). To describe the target group, the terms ‘vulnerable’ and ‘disabled’ are added to the query (*vulnerable OR disabled*). Furthermore, four keywords are added to describe the purpose of the applications this review focusses on (*prevent* OR inclusive OR risk OR empower**). The ‘prevent*’ keyword is used because the goal of the application can be to prevent something (for example risky behaviour or an unhealthy situation) from happening. As the application deals with specific groups, inclusive design can be important. Moreover, ‘inclusive’ also refers to the fact that the applications can contribute to a more inclusive environment for the target group. The vulnerability of the target groups often comes from a certain ‘risk’. Finally, the application could target empowerment of the vulnerable groups. As the target group is not always identified as explicitly vulnerable or disabled, it is chosen to combine all the above-mentioned keywords with OR statements.

In order to compare the results of the different researches, or study the effectiveness of different applications, papers are searched in which an evaluation study has been performed. The query includes different keywords that can be used to describe different types of evaluation studies (*evaluat* OR trial OR experiment* OR “user study” OR pilot*).

Two keywords are used as exclusion criteria (*rehabilitation OR review*). ‘Rehabilitation’ is excluded as it is used often in combination with ‘disabled’, but this combination is not within our field of interest. ‘Review’ is used to exclude review papers from the query result. Moreover, we limit our results to conference papers (*LIMIT-TO (DOCTYPE, “cp”) OR LIMIT-TO (DOCTYPE, “ar”)*).

3.3. Assorting the papers

The titles and abstracts (and if needed the introduction and conclusion/discussion) of all the papers are used to exclude papers that are out of the scope of this research. Fig. 3 summarizes the process of assorting the papers. After deciding whether a paper should be included or excluded in the review, 120 papers remained. After this duplicates were removed, reducing the number of papers to 103. These papers are used to study the research questions that will be answered in the first part of this paper (Section 4). By answering these questions for each of the included papers, it became clear that although the papers did not meet any exclusion criteria earlier, the papers still did not meet the inclusion criteria. This led to the exclusion of another 44 papers due to different reasons. Some papers were excluded because the target group was not vulnerable due to a personal characteristic, but rather due to a situational characteristic, or the target group was not a specified group. In other cases, the empowered behaviour was not aimed at a vulnerability of the target group, or the target group was not the vulnerable group. Researches describing a game that was not digital, or not primarily designed for the vulnerable target group were also excluded.

After excluding these papers, 59 papers remained that will be used in this review paper.

4. Review of context of empowering interventions

This section describes the context of serious games and gamification to empower vulnerable target groups, specifically the target groups,

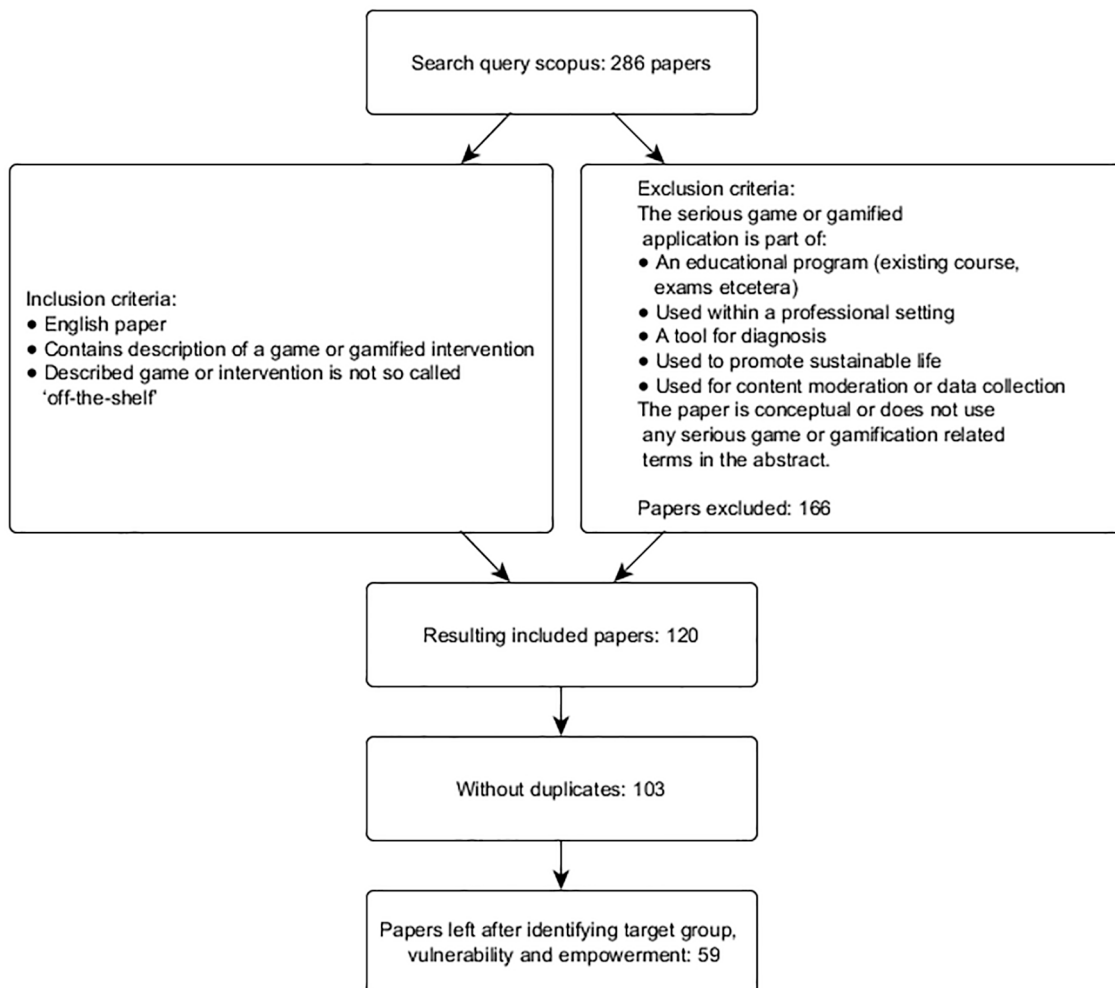


Fig. 3. Review process.

their risks, and the empowerment methods used. Analysing the papers included in the review on the concepts described in Fig. 1 are used.

4.1. Vulnerable target groups and their vulnerability risk(s)

Note that we do not study the underlying relations between vulnerability and the vulnerability risks. In this section we only report the vulnerable groups and vulnerability risks found in the reviewed papers.

The age group was the largest target group. Fig. 4 shows the distribution of the five different characteristics in the reviewed papers.

Fig. 5 shows the division of the characterization of vulnerability risks over the papers. From this figure it is clear that 80% of the vulnerabilities are related to health. Although this is a large category, it is found to have different meanings for different target groups. These different meanings will be discussed in later paragraphs in this section.

Fig. 6 gives an overview of the division of the characteristics of the risks of each vulnerable target group. From this figure it becomes clear that each target group is vulnerable for some health related risks. In the following paragraphs, each target group and its vulnerabilities will be discussed in more detail to give more insights in the different risks for each of the target groups.

4.1.1. Age groups

Within the review 26 papers were found in which the target group is vulnerable due to their age [25–50]. Among these age groups are: children [27,43–45], adolescents (with subgroups such as students) [25,26,29–35,38,40,48,49], adults [36] and elderly [28,37,39,41,42,46,47,50].

In the papers reviewed, it was found that only the age group was vulnerable for all types of vulnerability risks. This is also shown in Fig. 6. However, the majority of the papers describe an age related health risk. This concerns health risks that are not coming from or are related to an existing health condition (as these are included in the target groups of health conditions), but the target groups are vulnerable to influencing their health by some behaviour risk that is related to their age. The following health risks for age groups were found:

- Children and obesity [43]
- Adolescents and substance use [25,33–35], depression [26], obesity [31], physical activity [32], eating behaviour [38,40], HIV/AIDS [48], or bad emotion regulation [49]
- Adults and physical activity [36]

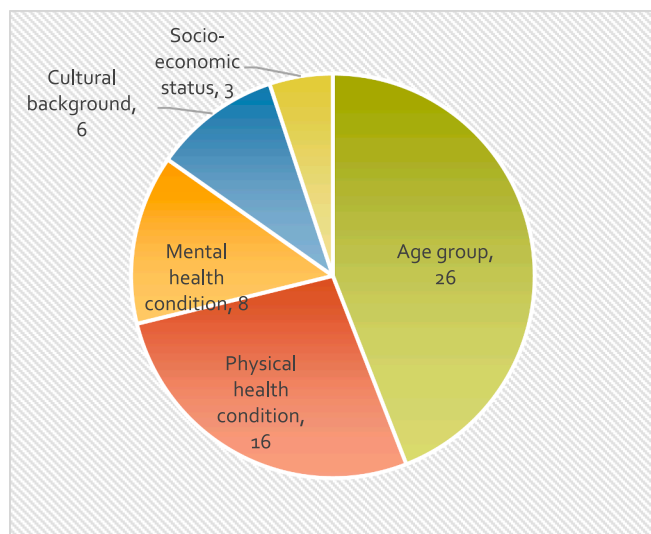


Fig. 4. Vulnerable target groups.

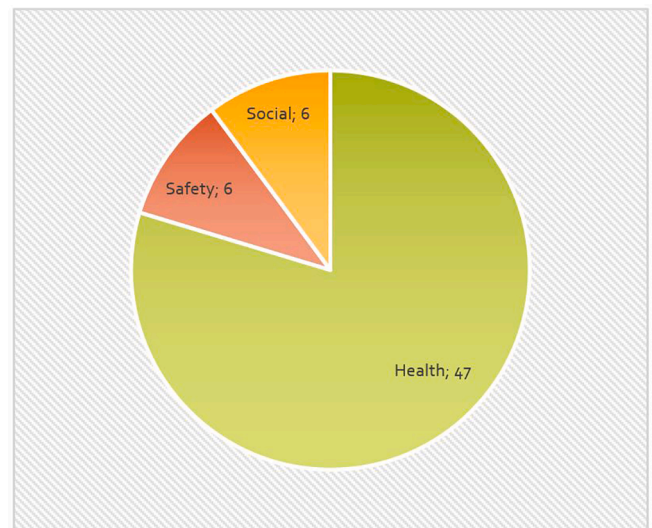


Fig. 5. Characterization of the vulnerability risks.

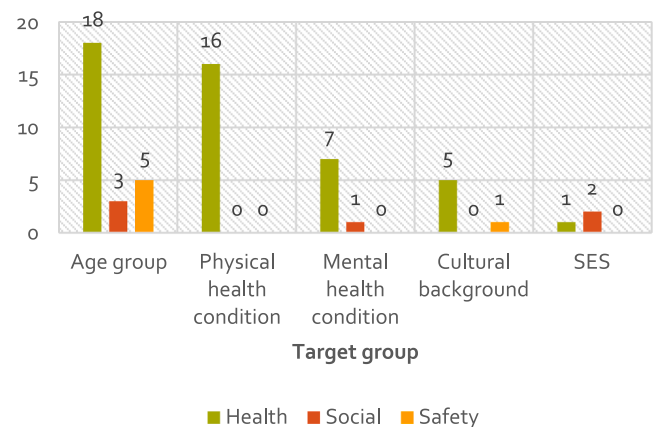


Fig. 6. Characteristics of risks for the target groups.

- Elderly and falling [39,41,47,50] or physical activity [42]

A smaller category is the group of papers that describe a safety risk for a vulnerable age group. The following safety risks were found:

- Children and traffic [27] or bicycle safety [45]
- Adolescents and food safety [29]
- Elderly and traffic safety [37] or doorstep scams [46]

Finally, three papers describe social risks of vulnerable age groups: children and their vulnerability for bullying [44], adolescents and their vulnerability for conflicts with peers [30] and elderly with their risk for loneliness [28].

4.1.2. Physical health conditions

There are 16 papers in which the target group is defined by a physical health condition [51–66]. Some papers specify an age group as well, but the physical health condition of these groups is the most distinguishing factor indicating their vulnerability. Physical health conditions that are found are: Rheumatoid arthritis [51], caries [52], Fetal Alcohol Spectrum Disorders (FASD) [53], overweight or obesity [54,58,60,62,64], HIV-positive [55,57], people during or after cancer treatment [56,59], cardiovascular disease [61], and diabetes (both type I and type II) [63,65,66].

It is found that in all cases the risk can be characterized as a health

risk, as shown in Fig. 6. In most cases this means that the risk is coming from the physical health condition of the person; for example: children with FASD and disruptive behaviours due to their disorder, or HIV-positive people and the influence of their medicine adherence on their condition. Two papers have a more indirect relation between the condition of the person and health risk they are vulnerable for. In the first paper, people with overweight/obesity are aimed. Their health risk is coming from inactivity; the application focuses on their physical activity [62]. However, the inactivity is not necessarily caused by the overweight/obesity. Another paper in which such a relation is described, is also about physical activity, but among patients with diabetes type II [63]. Again, the inactivity is not caused by the diabetes, but does influence the physical health condition of a patient.

In the age group, the health risks are dispositional; the target group is still healthy, but has a potential risk of harming its health. In this target group, the health risk is more occurrent (while still being a risk and not a certainty) as the current situation of the person is already harming its health.

4.1.3. Mental health conditions

Comparable to the target groups in the category physical health conditions, there are eight papers that fit in the category mental health conditions [67–74]. The following mental health conditions are targeted by these papers: acrophobia [67], Post-Traumatic Stress Disorder (PTSD) [68], addiction: including smokers [69,70], first episode psychosis [71], dyslexia [72], Obsessive-Compulsive Disorder (OCD) [73], and intellectual disabilities [74].

As shown by Fig. 6, all papers, but one, describe a health risk. In all these papers, (symptoms of) the mental health condition is the health risk that is targeted by the described intervention. The other paper describes a social risk, namely the risk of social exclusion due to intellectual disabilities [74].

4.1.4. Cultural background

For some groups their cultural background contributes to their vulnerability [75–80]. The following six vulnerable groups in this category were identified: African Americans in the rural Southern United States [75], Chinese adolescents [76], Young people in the Caribbean region [77], Young Africans [78], Adolescents from Sub Saharan Africa [79], and African Caribbean men [80].

Fig. 6 again shows that all papers but one, describe a health risk. The following health risks have been identified:

- HIV/AIDS for African Americans in the rural Southern United States [75] and young Africans [78]
- Sexual behaviour for Chinese adolescents [76] and adolescents from Sub Saharan Africa [79]
- Prostate cancer for African Caribbean men [80]

The other paper is about a safety risk, namely domestic violence, for young people in the Caribbean region [77].

4.1.5. Socio-economic status

For three papers the SES status and/or educational level is the characteristic that makes the group vulnerable [81–83].

As shown in Fig. 6, this is the only target group in which the health vulnerability risk is not the biggest vulnerability risk group, but social risks are. The health risk that was found was overweight-related behaviours for adolescents from low SES families [82]. The social risks that are found are parenting related problems for vulnerable parents [81] and the negative effects of unemployment for disengaged and long-term unemployed young people [83].

4.2. Empowerment

So far, it has become clear which vulnerable groups are targeted and

which risks are addressed by the interventions. This section focusses on how the interventions aim to empower their users to overcome or minimize their vulnerability. The target groups that use the interventions or serious games are from now on also called players or users.

Fig. 7 shows the distribution of the different categories of empowerment methods that have been identified.

4.2.1. Training skills

Within this review, a wide variety of skills that are trained through interventions are found:

- Skill training such as behaviour control, or changing the associations with substances, is used in the domain of substance use [35,69,70]. One of these interventions is an exergame in which players have to make physical moves (kicking, hitting etcetera) to counter substance cues [69].
- In the domain of mental health, different skills are trained by the found interventions. Some interventions aim to train skills that can be used to treat or prevent a mental health condition, which is sometimes used in the treatment of the mental health condition [26,53,67,71,73]. Interventions are also used to train emotional competences or emotion regulation, which is beneficial for the aimed mental health condition [30,49]. Sometimes games train skills that are less closely linked with the mental health condition. One intervention aims to reduce the loneliness of elderly by motivating and stimulating their motor skills, used to work with computers, by introducing VR to their computer classes [28].
- Next to mental health, also skills related to physical health are trained by interventions. One of the papers researches an intervention for elderly that undergo cancer treatment, to teach them symptom self-management [56]. A game called Virtual Coach is used for children with diabetes type 1, to teach them about lifestyle adaptations that they can make to have a good life quality [66]. Play-Forward: Elm Street Stories is a game for HIV patients to teach them about behaviour and knowledge skills that can reduce the risks of HIV [48].
- To increase the safety of specific target groups, interventions train various skills. For children, the bicycle safety can be increased by training their situational awareness [27], or skills are trained to increase traffic safety in general [45]. Elderly can also be vulnerable in traffic. By training their cognitive functioning, their driving safety can be increased [37].

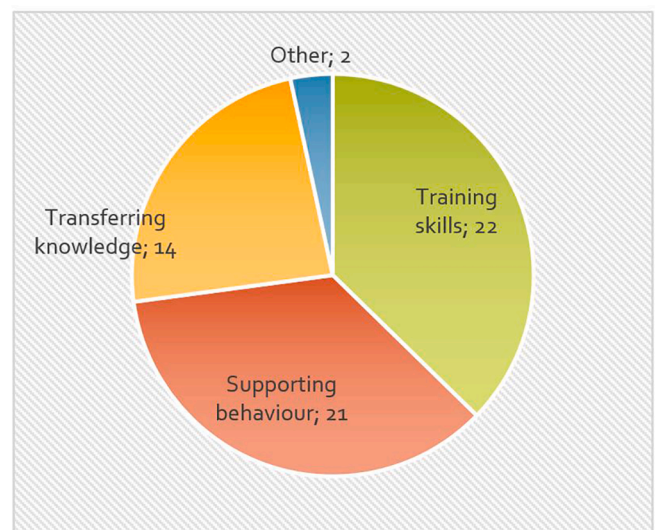


Fig. 7. Division of empowerment methods.

- With an intervention that includes gamification elements, vulnerable parents' parenting skills can be trained [81].
- IntegraGame is a game for persons with intellectual disabilities, and is used in their vocation training [74].
- For bullying, there is a game that aims to prevent bullying by for example promoting empathy among bystanders [44].
- In order to decrease the chance of elderly to become a victim of a doorstep scam, 'Trucs tegen de Babeltrucs' aims to train elderly their verbal assertiveness [46].
- Dyslexic children can train their letter recognition with the game Lets find letters [72].

4.2.2. Supporting behaviour

It is found that a distinction that can be made within this empowerment method, is about the form of the intervention. Although the technical details of the interventions will not yet be studied and discussed in this section, it has already become clear that there are two types of interventions that support behaviour. First, there are so called exergames, in which the physical behaviour of the user is used as control for the game. Second, there are games that support everyday behaviour. This means that the behaviour of the player is used in a more indirect way in the game. The player does not necessarily be actively playing the game to perform the behaviour (for example walk steps during the day and open the app only once in a while).

Within this review, the following interventions that support behaviour of the users are found:

- Two different interventions support behaviour that is related to substance use. The first game called Alcohol Alert uses the amount that adolescents indicate that they have drank in the game [25]. Another game about alcohol, is a social game concerning peer norms about alcohol usage [33].
- Different games concern overweight or obesity. Their give feedback on behavioural goals of the users or on healthy lifestyle behaviour, sometimes including social pressure as well [54,60,82].
- Two interventions support the engagement in care and medication adherence of HIV patients [55,57]. Both interventions have a slightly different target group.
- When behaviour support can be used to motivate (an increase of) physical activity, for example with step counting or exercises [32,36,62,63]. Another option to support physical activity is using exergames. One research explores whether this could be a way to stimulate physical home training with gamification for elderly [42].
- Eating behaviour is another lifestyle behaviour that can be empowered by behaviour support. In both interventions self-monitoring and feedback plays an important role [38,64].
- Falling is a risk typical for older people. In order to reduce or assess the risk of falling, exergames are used, these exergames give real-time feedback on movements and thereby support or assess specific behaviours of users related to fall prevention [39,41,47,50].
- Patients with cardiovascular disease have a risk of reoccurrence, and related health risks. To prevent this, MyHeartMate promotes physical activity and other preventive behaviours [61].
- An app, together with a thermal camera, are used for the prevention and management of diabetic foot disease complications [65].
- BUZZING is an intervention to engage young, disengaged and long unemployed, people in their transition into employment. The intervention stimulates experiences that contribute to this [83].

4.2.3. Transferring knowledge

Most of the knowledge transferring games are concerning health vulnerabilities, either for existing patients or as preventive measures:

- An informative website with gamification techniques for rheumatoid arthritis patients [51].
- A health education game for children with a high risk for caries [52].

- Games with information about HIV and sexual behaviour, aiming to prevent HIV [75,78].
- To prevent or reduce obesity and related health risks, interventions educate on nutrition [31,43] or healthy habits [58].
- An informative game to prevent prostate cancer among African Caribbean men [80].

Next to these points which are closely related to a specific health problem, other interventions were also found in this review:

- Knowledge transferring games about safety. One game is about food safety [29]. Another game is about domestic violence prevention, for young people in the Caribbean region [77].
- Two games are found that educate adolescents on the topic of sexual health [76,79].
- The game Pure Rush is about substance use [34]. This game has a twofold goal, of which the first goal could also fit the empowerment method of skill training. Namely, to link negative associations with substances and to inform people about drugs.
- One game is about healthy nutrition for university students [40].

4.2.4. Other

In some special cases, the empowerment of the target group is not achieved by one the above mentioned methods. The first game within this category is a working memory taxing game that is used for people with PTSD to prevent intrusions [68]. In this intervention, the game is empowering the vulnerable target group in a way that it is a tool for them; the game is used in a moment to directly reduce their vulnerability.

The second game in this category is the INTERACCT serious game [59]. This is a communication tool with gamification that is used for children after their cancer treatment, used in the communication with care takers. It is used within the care after their cancer treatment, while for the children it can also be seen as an entertaining tool.

4.3. Conclusions about target groups, vulnerability risks, and empowerment

In Fig. 8 it is shown how the empowerment methods are used for the different vulnerability risks. This figure shows that only for health risks all empowerment methods have been used in the literature reviewed. Most popular within this category is the support of behaviour, followed by transferring knowledge. For safety risks mostly training skills and transferring knowledge is used. For social risks this is comparable, with the only difference that instead of transferring knowledge, supporting behaviour is used.

In Fig. 9, an overview of the target groups, vulnerability risk

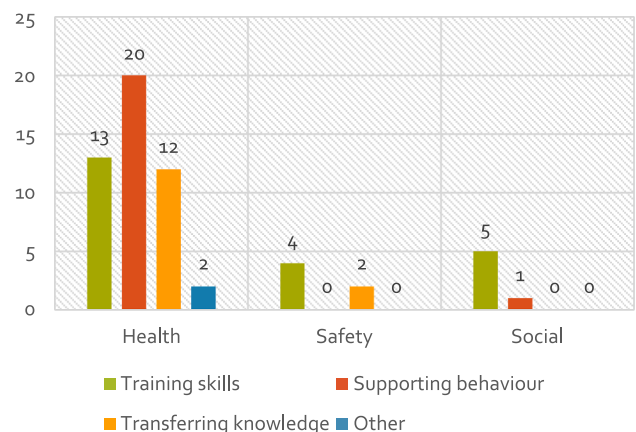


Fig. 8. Empowerment methods for different vulnerability risks.

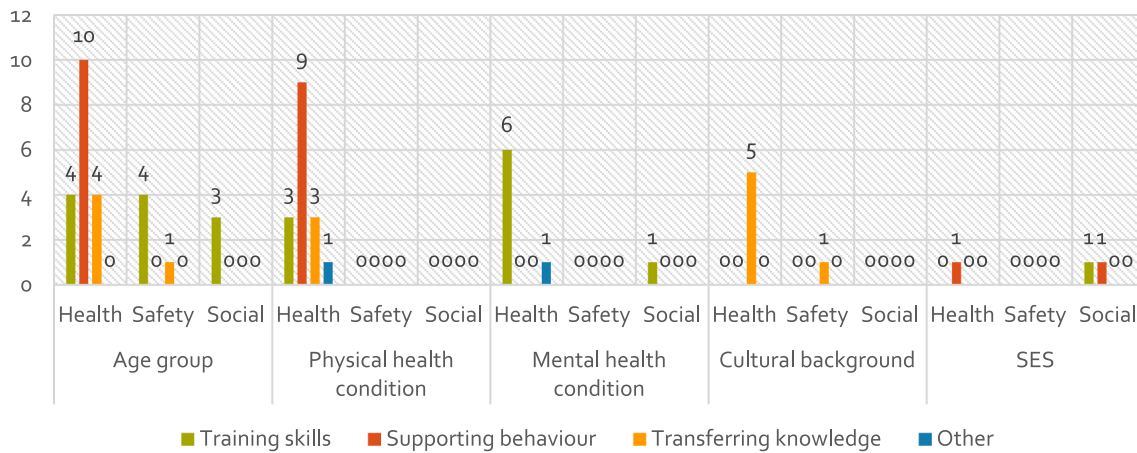


Fig. 9. Empowerment methods for different risks for vulnerable target groups.

categories and empowerment methods is shown. This figure shows that age group is the most diverse category, having both the most diverse types of risks as well as using the most diverse set of empowerment methods. What stands out is that supporting behaviour and transferring knowledge are almost exclusively used for health risks, of mainly age groups but also for the physical health condition and the cultural background groups.

The target group physical health condition is only empowered in their health risks. In the mental health condition target group, there is one intervention aimed at a social risk (social exclusion), instead of all risks being a health risk. For physical health conditions, one would also expect the presence of social risks, however those risks are not found within this review. Risks that are targeted by the interventions are closely related to the current condition of the person, but less closely related risks are not addressed in the found literature. In the introduction the term pathogenic vulnerability is explained. It seems that these types of vulnerabilities are not often addressed by the described applications. One example of such a vulnerability that is addressed is the domestic violence in the Caribbean [77]. However, other larger themes of pathogenic vulnerabilities are not found.

5. Review of technologies, game characteristics and study results

So far, we studied the papers in the scope of our review on a high level to give an overview of the serious games to empower vulnerable target groups. However, this only says something about the contexts of the intervention, but not about the specifics of the serious games and applications. This section will investigate the papers on a detailed level, to give an overview of the following specifics of the research reported on:

- Technologies (platforms and hardware);
- Game characteristics and game mechanics;
- Types of (intended) evaluation studies and their results.

Fig. 2 shows which concepts are used to describe these three elements. In the remainder of this section, the three points are analysed for each empowerment method. Finally, for each point the general conclusions are drawn.

Note: one of the included papers could only be studied for the first part of this research, as only the abstract and introduction could be accessed by us [76]. This paper falls in the categories: cultural background, health risk, transferring knowledge. In this second part of the review, this paper is excluded.

Moreover, note the following for the sections about transferring knowledge: The game used in the research of [36] is previously

described in a pilot study [84]. For the remainder of this section, the reference of the paper found in this review will be used. However, some information comes from the earlier paper. Similarly, the game described in [63] refers to a previous paper about the game [85], which is also used for the review of the game mechanics.

5.1. Technologies

5.1.1. Technologies for training skills

Some games can be played on a mobile device (smartphones or tablets) or a device with a touch screen [27,37,46,67,70,73]. Sometimes additional hardware is needed, such as VR goggles, for a smartphone application [67]. Other games are played on a computer or laptop [30,35,45,53], are VR computer games [28], or other categories such as exergames played with the Kinect technology [69]. One of the video-games within this empowerment method is used in the classroom to empower students to overcome social conflicts [30]. Another game that is played on a school computer, is an online game for depression prevention that is used together with a paper notebook [26]. For one game, the physical device was not specified, but the target platform has been mentioned, in this case web browsers [71].

Games can also be suitable for different platforms. A game to prevent bullying is designed for both desktop as well as tablet devices, and can be used both in a private session or in a session with a therapist [44]. Another gamified intervention for parenting skills has a responsive design so that it can be played on both mobile and desktop devices [81]. There is one VR game that is tested on three different devices: computer, smartphone, and rgb-d camera [49]. However, there are also some

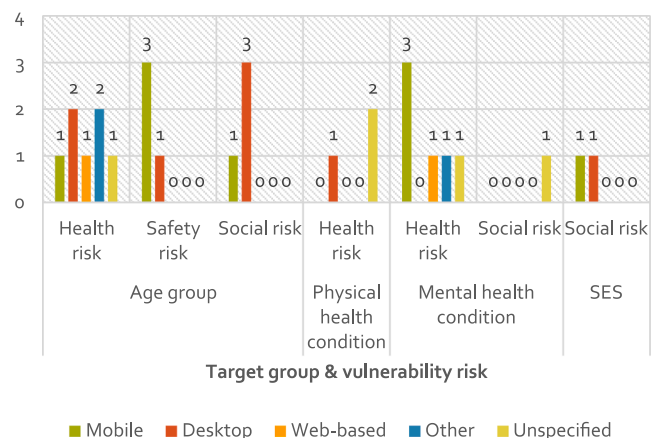


Fig. 10. Technologies used for training skills in different target groups.

papers that do not specify their target platform [48,56,66,72,74].

Fig. 10 shows how the different technologies are used for the different target groups and their vulnerability risks. All technologies are quite scattered over the different groups.

5.1.2. Technologies for supporting behaviour

Most interventions are mobile applications [33,36,50,54,55,60,61,63–65,82,83] sometimes using the sensors of a smartphone or wearable [61,63], non-invasive wearable sensor [50] or an additional thermal camera [65]. One of these interventions also includes an online platform [83]. Two interventions can be played via a website, but are both accompanied by some additional material: a workbook [32] or a wearable device to track the steps and sleep of the user [62]. Another game accessible via a website, is played on a computer [25], while another game mentions different target devices as an online game [38].

As discussed in Section 4.2.2, exergames are also used to support behaviour of players. For these exergames slightly different technology is used, such as Kinect technology [39,42], wearable devices [41], or Wii Balance board [47]. Moreover, these games are often played on a larger screen or television screen. These technologies belong to the category ‘other’ as they are only used in a limit number of applications and do not belong to the other categories.

Another paper [57], does not specify which target device or platform is used.

Fig. 11 shows that mobile apps are the most popular platform, and are used for each target group. Mostly they are used for health risks in the physical health condition group. Exergame technology, labelled as category ‘other’, is only used for age groups with a health risk, more precisely for elderly and mostly for fall prevention.

5.1.3. Technologies for transferring knowledge

Most applications that aim to transfer knowledge to their players, are web-based [29,31,34,40,51,75]. Most of these games do not specify their target device. However, one of these games is meant to be played on a computer [31]. One of the games is not exclusively for web browsers, but it can also be found as an installable app [34].

Other games are either meant for mobile devices, smartphone [78] or tablet [52], or desktop/computer [43,77,79]. One of these computer games is only played at school [79].

One intervention consists of multiple components, including apps and commercial material such as the game Wii Fit Plus [58]. Finally, one intervention does not mention its target platform [80].

Fig. 12 shows that web-based applications are mostly used for health risks, but also for the safety risk of the age group. The other technologies are scattered over the different target groups and risks.

5.1.4. Technologies for other interventions

The first application from the other category is a communication tool

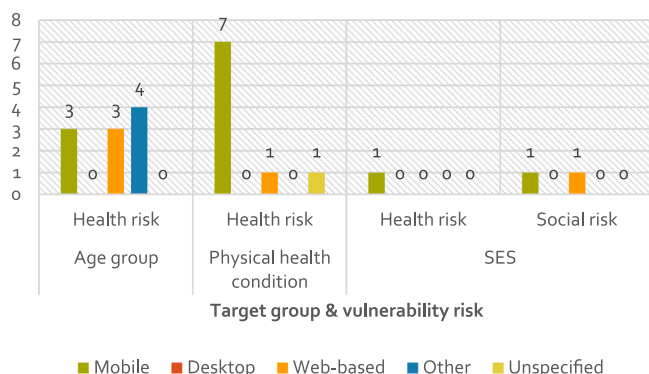


Fig. 11. Technologies used for behaviour support in different target groups.

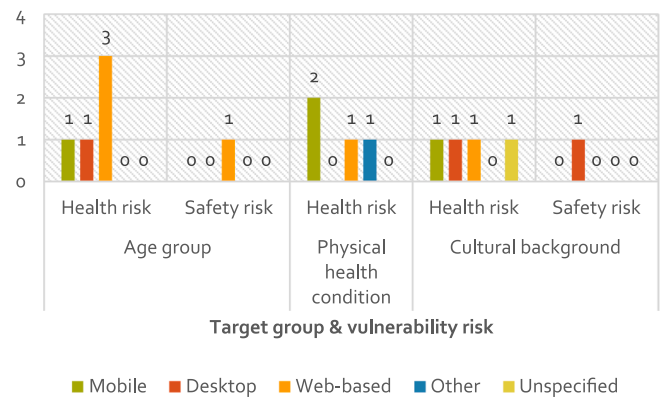


Fig. 12. Technologies used for transferring knowledge in different target groups.

for children after cancer treatment [59]. This is a web platform that uses data gathered with a Kinect or Android device.

The second game in this category, is a working memory taxing game, used for people with PTSD to reduce intrusions [68]. The platform or target device of this game is not defined.

5.1.5. Conclusions about technologies

In total, 66 types of technologies¹ are used by the 58 papers that are included in this part of the review. Fig. 13 shows that the biggest category is mobile technology, making 38% of all technologies used. For both the empowerment method of training skills as well as for supporting behaviour, mobile technology is the preferred platform.

Training skills moreover uses the desktop platform often, supporting behaviour on the other hand does not use the desktop platform at all. Exergames, often using ‘other’ technology, are only found for the supporting behaviour category.

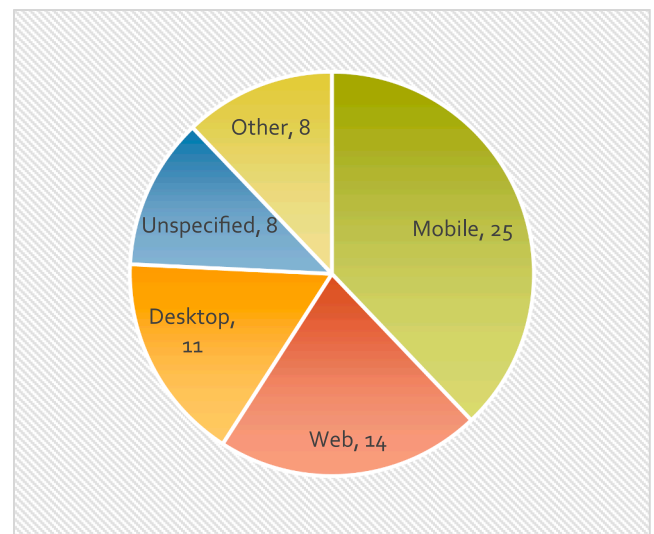


Fig. 13. Technologies used for all empowerment methods.

¹ When more than one platform within the same category is used, this is counted as one.

5.2. Game characteristics and game mechanics

5.2.1. Game characteristics and game mechanics for training skills

5.2.1.1. Objectives. Steering the behaviour of users can be done using challenges, missions, targets, tasks, goals, or levels [26,35,37,44,48,53,67,70,72,74,81], sometimes with increasing difficulties. Another way to steer the behaviour of a player in the application is by using time pressure, which can be in the form of limited time (for specific levels) or a timer [45,49,70,72].

5.2.1.2. Rewards. In some games this feedback is provided in a visual way [27,35,37], as advice [67] or via audio [72]. Other papers mention giving feedback, but do not specify the type of feedback [44,49,53,81]. One game gives both visual feedback as well as textual feedback, on different aspects of the users choices and behaviour in the game [46]. Another type of reward can be unlocking new modules [67]. However, points [35,37,44–46,66,69,71,72] are also a way to give feedback on performance or behaviour. Points can have different names and values. Furthermore, points can be represented with numbers, but also in a visual way, for example in the form of a glucose bar [66] in an game about diabetes. Other forms of rewarding feedback are badges and progress bars [45,81].

5.2.1.3. Player data insight. Giving players insight in their data and performance can be another form of feedback [45]. Another game includes a profile showing the players information about themselves [67].

5.2.1.4. Stories, scenarios, and avatars. Some games use a story or scenario component in their game, for example to give players insight in the consequences of their actions [30,35,44,46,48,56,67,71]. Sometimes these stories consist of different levels that can be unlocked consecutively [44,67]. In another scenario game, players can choose between different profiles (bystander or victim), resulting in different games. Moreover, different characters can be chosen [44].

While in most of these scenario games, it is about making choices and progressing through the scenario which ultimately teaches the player a new skill, one game also has an additional component. In this game, players also have to use their voice to influence the progress of the scenario. One of the skills that is taught by this intervention is an assertive way of using the voice, which is trained with this component of the game [46].

One game uses stories in a different way. In OnTrack > The Game, stories of hope and recovery, told by people who have already experienced first order psychosis (the target vulnerability of this game) are included [71]. Next to this, the player can customize their character's appearance and explore an imaginary world. In this world they can have experiences that provides them with skills that help them to deal with their real world problems.

Another way to give a player insight in their behaviour, and learn them about behaviour that suits their physical health condition (in this case diabetes type I), is by using a virtual avatar that the player needs to take care of [66]. In this game not only a virtual avatar is used to take care of, but another virtual avatar has the role of coach. Other games that use an avatar, or user character, is a game about traffic safety [45], an anti-smoking game [70], and an intervention for vulnerable parents [81].

5.2.1.5. Notifications. Notifications in the form of emails to stimulate the adherence of participants is used in one intervention [67]. Reminders for an intervention are also used in [81].

5.2.1.6. Social. Social (media) features are used in an intervention for vulnerable parents [81].

5.2.1.7. Customization. As mentioned before, the character of the player in OnTrack > The Game can be customized [71].

5.2.1.8. Other game mechanics. Two games make use of mini-games [48,73]. Moreover, one paper describes an intervention consisting of two different games for emotion regulation strategies for adolescents [49]: one game in which you have to pop as many balloons as possible, within a time limit. The second game is a game which teaches the player breathing strategies: by breathing in a specific pattern, the player controls a feather through the game.

An intervention for vulnerable parents also includes professional moderation in the network of the intervention [81].

5.2.1.9. Unspecified game mechanics. For one paper the game characteristics and mechanics were unclear. This paper is about preventing loneliness among elderly by using VR in their computer classes [28]. The paper describes various games, all with their own mechanics, that are used in this study, but the games were not designed within this study, but rather reused from others.

5.2.1.10. Summary. The most used game mechanic categories for training skills are²: objectives (including challenges, targets, tasks, levels and time pressure), rewards (including points, feedback and badges), and stories, scenarios and avatars. In Fig. 14, it is shown how often these categories are used. Rewards is by far the most popular category. All three popular categories are used in more than half of the interventions.

Fig. 15 shows for the different target groups, in how many of the games the most popular game mechanics are used.

5.2.2. Game characteristics and game mechanics for supporting behaviour

5.2.2.1. Objectives. Behaviour support applications are built around mechanics to motivate behaviour of the player in real life through game mechanics. Mechanics such as goals (setting), tasks, and planning [38,55,61,63,82,83] play a role in this. Chance [33] and challenges (performed in the real world) or achievements [25,36,54,55,57,61] are other game mechanics that can be used for this. One game challenges the user by showing its streak of medication usage [57]. Levels can also be used as a way to stimulate repetitive usage of the app, and it is used in different applications [32,47,55,61,62,64]. Also a progress bar can be used to motivate users [65]. Finally, one of the exergames uses time in some of its mini-games to ensure that the exercises are performed in the right way (fast or slow) [41]. Time can also be used in another way, when high scores are recorded to stimulate players to improve their own

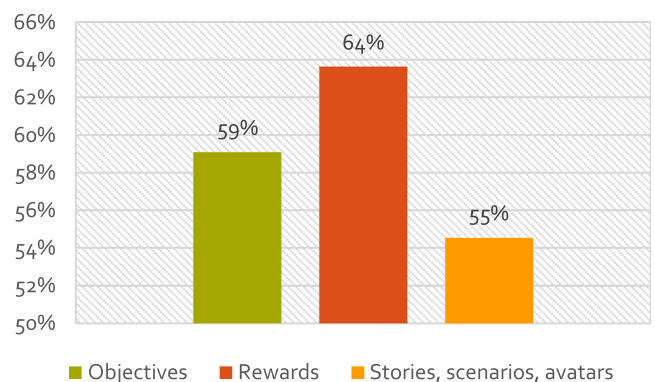


Fig. 14. Popular game characteristics for training skills.

² >5 times, excluding the category 'other'.

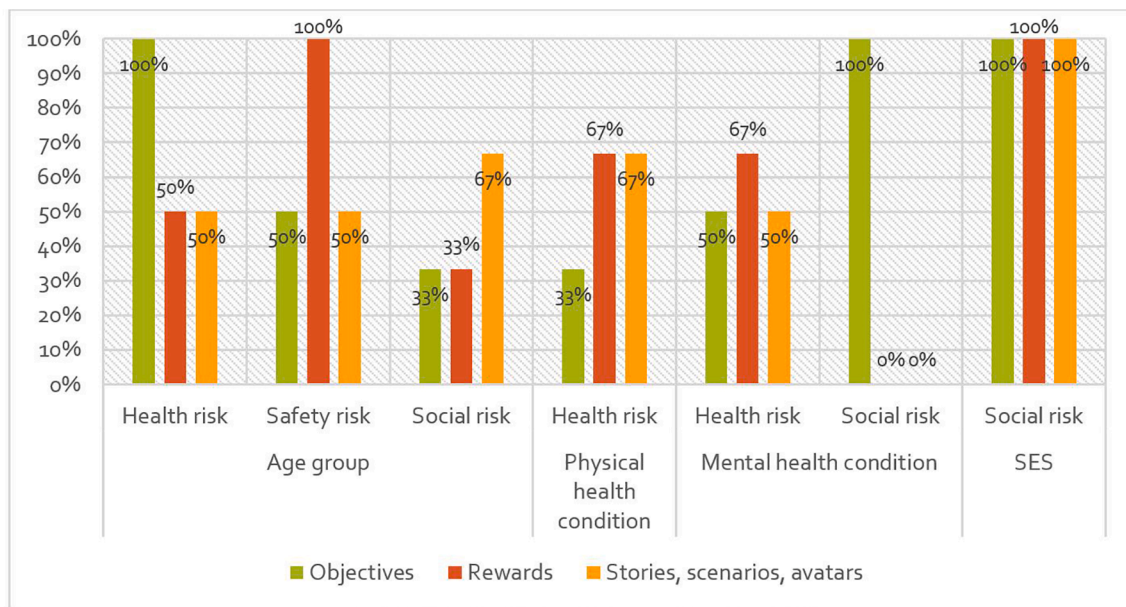


Fig. 15. Popular game mechanics used for training skills for different target groups.

performance [47].

5.2.2.2. Rewards. Games give players feedback on their performance [25,33,38,41,42,47,60,61,63,64,82]. Feedback can also be given to the player by giving them rewards, which is done in different forms [32,36,55,57,60,61,65,82], for example with badges or trophies. One game gives tips written by comedians as reward to the player [36]. Unlocking levels, features or mini-games in the game can also be a way of rewarding players [47,55,57,64,65]. However, negative rewards, in the form of punishment, are also used [60].

Another form of rewards is points [33,54,57,60,62,64] or in-app currency points [55,61,63] can be used to reward the player's performance as well.

In one game players need to clean and improve a garden [63]. It was mentioned that the choice for a garden was made as previous research pointed out that this can have relaxing rewards on users.

5.2.2.3. Player data insights. The component of giving players the option to track their behaviour and give insight in their data, for example via a user profile, is also used in different behaviour support applications [36,38,54,55,57,61,63–65,83]. In one case, the app uses an additional thermal camera to collect real world data [65].

5.2.2.4. Story, scenario, and avatars. There are three papers that use the mechanic of a story to achieve its goal, namely to motivate the players (HIV patients) to stick to their treatment and give them support to this behaviour [55], or a storyline in a game about healthy eating [64]. Finally, in an intervention about binge drinking, players need to find out what happened to their character [25].

One of the exergames for fall prevention describes the user-centred design process that is used to explore what a game for the purpose of physical activity among elderly should look like and include [42]. Prototypes are created for evaluating different aspects, it is described that part of it will be an avatar that gives motivational feedback and tips.

Another game that uses an avatar is a game in which the player needs to take care of a virtual avatar [61]. As the target group for this app is people with cardiovascular disease, this avatar is in the form of a heart.

5.2.2.5. Notifications. Many applications use notifications to enhance the usage of the application [25,55,61,63,65,82]. Some applications

send the player weekly updates about its performance, which is also a way to remind them of the application [36,62]. Another application sends their users daily tips and messages [64], while another reminds its users to take their medication and gives them a daily newspaper [57].

5.2.2.6. Social features. Many of the games of this empowerment method incorporated a social component. However, the games used this in different ways. It can be that players are visible to others [33], that there is a leaderboard [61], or that players can interact with other players [57] or for user-content generation [33]. Various games also include competition [32,33,60,82].

However, more often it includes social (media) support [55,60,62,63,82,83] or teams [32,36,41,60,62]. An example of a game that uses teams, makes these team members report to each other on a daily basis [60]. Components like peer support, accountability and team discussion, are used within this intervention.

Another intervention uses both the social component of using groups, and individual components [32]. There are competitions for teams of players, and individual users can play different levels. Moreover, teams can earn trophies and both schools, teams, and individual users can earn different types of real-world prizes for their performance. Comparable, in the intervention described in [36] players can earn rewards for their individual performance, as well as their team performance. Players can also exchange gifts with their team mates. One of the theories that is used as foundation for this application is the fun theory [86]. This is represented in for example the tips that players receive. These tips are written by comedians. Comedians also picked the names for the awards that players and teams can unlock.

One intervention does not only provide online support, but also organizes activities outside of the application [83].

5.2.2.7. Customization. Three papers describe using a personalisation approach. In the first application the player is provided with games and activities that have an educational value in the domain of weight loss [54]. The second paper adjusts the level of its exercises to the level of the player [63]. Personalisation is also used by a game in which the players can customize their avatar's appearance [57].

5.2.2.8. Other game mechanics. One of the exergames for fall prevention consists of three mini-games for two teams of maximum three players. Each game has its own rules and mechanics. The overall theme of the

exergame is Antarctic, there are many penguin avatars used. To control the games, the players need to perform different exercises. The wearable device that is needed for this exergame, can be used in different ways, depending on the game and exercise [41]. Mini-games are also used in another game [61].

5.2.2.9. Unspecified. Some interventions do not specify their game mechanics. The intervention includes balance tests and exercises, based on existing tests and exercises [50].

One of the exergames consists of different exercises, that can be performed under the supervision of a therapist [39]. However, the exercises are not further described in the paper.

5.2.2.10. Summary. The most frequently used³ types of mechanics for supporting behaviour are objectives (such as goals, levels, challenges), rewards (such as feedback, badges, points), social elements, and notifications and player data insights.

Fig. 16 shows how many games of the empowerment method of supporting behaviour use the most used game mechanics. This shows that rewards and objectives are by far the most popular mechanic in this category. Social aspects are used in more than half of the games; notifications and player data insights are used in slightly less than half of the games.

Fig. 17 shows the percentages of games from each of the vulnerable groups that uses the most popular game mechanics. This figure shows that especially the physical health condition group with a health risk uses all the popular mechanics very frequently, the SES groups as well, but these only contain one paper.

One of the papers of this empowerment method is a good example of how a paper can clearly explain the game mechanics and the rationale behind the choices for these mechanics [32]. The paper includes a table that explain the intervention components and connected behaviour change techniques. By doing this is a table, it is easy to get a clear and complete overview of all components and rationale behind these.

5.2.3. Game characteristics and game mechanics for transferring knowledge

For one intervention in this empowerment method [31], the game is described in a previous paper [87]. In addition to the example mentioned at the end of the previous section, this is an example of a game description that is very clearly and schematically presented to the reader in a table. In the remainder of this section we will use the reference from the paper found in this review is used (reference [31]), while information might come from the previous paper.

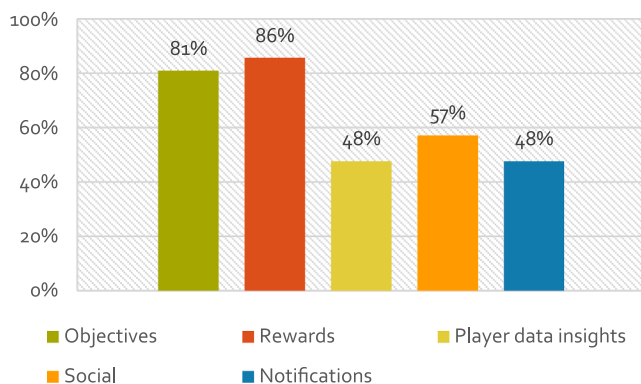


Fig. 16. Popular game characteristics for supporting behaviour.

5.2.3.1. Objectives. Interventions with the purpose to transfer knowledge use, just like all other methods so far, game mechanics to steer the behaviour of the user through the intervention, such as missions, levels, time restrictions [29,31,58,77,80].

5.2.3.2. Rewards. Rewards and feedback are used in different ways to reward users during the game [29,31,34,40,51,58,75,79]. Examples of rewards use are points, gifts, medals, badges, and prizes.

5.2.3.3. Player data insights. One intervention is registering physical activity and eating behaviour [58]. Another game gives personalized advice based on the game [80].

5.2.3.4. Stories, scenarios, and avatars. Different games within the category of knowledge transferring games use stories or scenarios. Often, players influence the story with the choices they make. In a point-and-click game about domestic violence, users can interact with different characters and play different levels [77]. Another game, about prostate cancer, also uses characters and levels [80]. A 'choose-your-own-adventure' game, about HIV, is designed in such a way that the player can replay it, to see how different choices influence the story [78]. Another game with story elements is about sexual health [79]. Stories and questions are used to transfer knowledge to the player in this game. In a game about food safety, players have to solve a mystery and play different mini-games to do so [29]. Avatars are also used in a game for drugs education [34].

'Space adventures' is a game made for children to learn about healthy eating to reduce the risk of obesity and related health risks [43]. The game mechanics of this game are not explained in much detail. It is mentioned that they use a narrative component, and on the pictures of the game it is shown that the game also has characteristics of a platformer. Players have to make choices about food in the game.

5.2.3.5. Notifications. One intervention sends regular emails to inform players about their performance [40].

5.2.3.6. Social features. Social features are used by different informative platforms. Competition is an important aspect used in different games in the form of, for example, leaderboards [40,51,79].

5.2.3.7. Customization. Avatar appearance or gender can be customized in two different interventions [34,78].

5.2.3.8. Other game mechanics. It was already mentioned that questions or choices were used in stories, but there are also interventions that use it in the form of quizzes [40,51,79]. One intervention includes different games and apps in order to prevent childhood obesity [58]. Mini-games are also used in [29,78].

5.2.3.9. Unspecified. One paper is not discussed in this section [52], this game is an improved version of a previously described game. However, it was not possible to find the game mechanics of the game.

5.2.3.10. Summary. The most popular categories⁴ of game mechanics for transferring knowledge are objectives (such as levels, missions and time restrictions), rewards and feedback (including points), and a story element.

Fig. 18 shows that only rewards are used in more than half of the interventions, the other popular mechanics are used in less than half of the interventions.

Fig. 19 shows the percentages of games within each vulnerable target group using the popular mechanics. This shows that the games with a

³ ≥ 10 times.

⁴ > 5 times, excluding category 'other'.

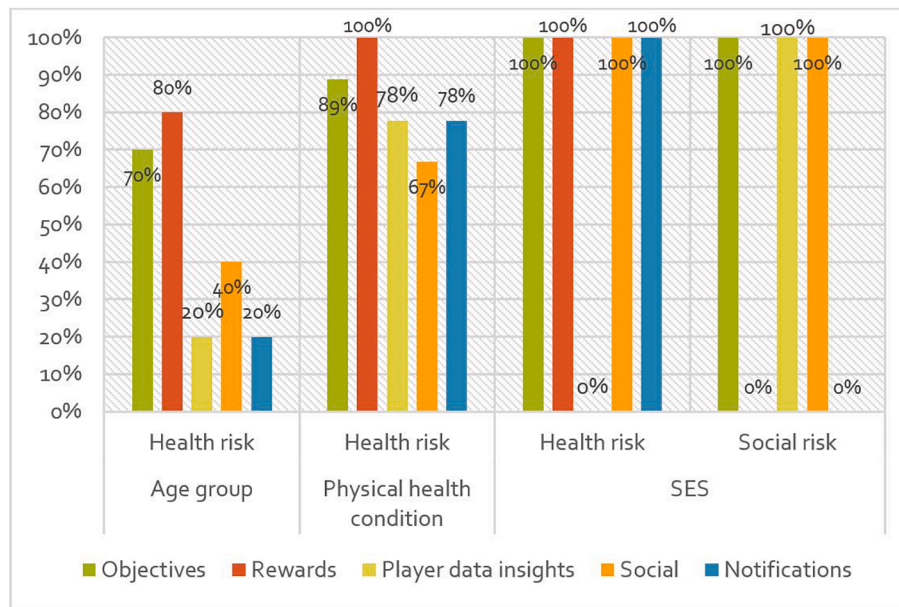


Fig. 17. Popular game mechanics for supporting behaviour used for different target groups.



Fig. 18. Popular game characteristics for transferring knowledge.

safety risk for an age group include all three mechanics. Rewards is a very popular element for age groups with a health risk or people with a physical health condition and a health risk. However, for vulnerable people due to their cultural background, this mechanics is less popular.

5.2.4. Game characteristics and game mechanics for other interventions

The first application, for children after their cancer treatment, explains how it serves different purposes [59]. On the one hand it is a form of entertainment for the children but this is not the only purpose; the platform can also be used to facilitate the communication between the child patient and the professionals. The game uses challenges (objectives), games (other), social elements and competitions (objectives) to achieve its goals.

In the second research in this category two different experiments were performed with two games to reduce intrusions after a traumatic event [68]. The first game is a 'collect and avoid' game with different levels with time limits and stars to collect during the game. The second game is a Tetris like game, but instead of making lines the player has to make squares.

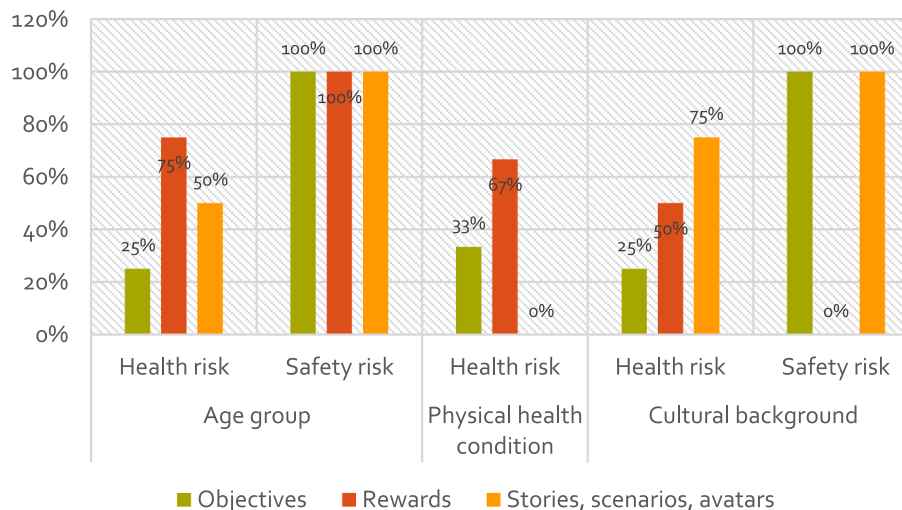


Fig. 19. Popular game mechanics for transferring knowledge used for different target groups.

5.2.5. Conclusions about game characteristics and mechanics

In total, 168 different implementations of categories of game mechanics are used in the 58 interventions included in this section. From Fig. 20 it is clear that rewards (24%) and objectives (23%) are the most often used mechanics. These categories are also the most diverse categories, as many different types of game mechanics are mentioned in these categories.

For all empowerment methods, rewards were the most used game mechanic. It is most used for supporting behaviour, namely in 86% of the applications. Whereas for training skills and transferring knowledge, rewards are used in just over 60% of the applications. Training skills and transferring knowledge further have the same most popular mechanics, but the order and percentages of applications in which it is used differ. Supporting behaviour has different mechanics, while it also uses objectives in many of the applications (81%), it also uses social elements in more than half (57%) of the applications, and notifications and player data insights in 48% of the applications.

5.3. Evaluation studies and results

In this section, it is studied how the serious games and gamified interventions are evaluated and what kind of results are found.

5.3.1. Evaluation studies and results for training skills

Most of the reviewed papers within this empowerment method, concerned a study [26,27,30,35,37,44–46,48,49,53,56,66,69–74,81]. Only two papers [28,67] describe a protocol or design. Of all these studies, only two studies had a duration of six months or more. One has a follow-up after 6 months [81], and the other has the last follow-up after 18 months [26]. This second study is also the study with the longest duration found in this review. Noticeable is that the protocol for this study has previously been described in another paper.

Most of the studies use an experimental setup [26,30,35,48,53,73,74], mostly consisting of two different conditions. Sometimes different versions of an intervention were compared with each other and a control group [35,53]. In one of the experiments, healthy participants were compared with participants with OCD [73].

Moreover, effect oriented studies [27,49,70,71] and effect oriented studies with multiple interactions [37,45,66,69,81], were also found in the review of this empowerment method. In one of the effect studies, three different version of the game were compared with each other [71], another study compared three different target devices [70]. However, both studies did not use a control condition to compare with, and it is therefore not seen as an experiment.

Finally, focus groups were used [44,46,56,72]. Focus groups were either done with experts or professionals [72], or potential end users [46], or a combination of both [56]. One of the studies had four different evaluation stages, in which both potential end users and experts were

used as participants [44].

The number of participants were very different. Most of the studies include between 11 and 100 participants (see Fig. 21⁵), however 2 studies have >500 participants [26,30]. Most of the participants are in the target group of the application, with some exceptions, for example one paper includes not only the target group (children) but also young adults [27]. Other previous examples are of focus groups with experts or professionals as participants.

When studying the sample sizes of the different types of studies (see Table 1⁶) it becomes clear that experiments have the highest average number of participants, but also a high standard deviation for the number of participants. Focus groups have, on average, the lowest number of participants. Both results are in accordance with the numbers one should expect based on the nature of the study type.

Most of the studies both study the effect of the intervention, as well as how players perceive it. Often, positive and/or promising results are found, although not always for all measurements. For example, in one of the studies it was found that the participants already had good knowledge about the topic of the game, and increases were only found for some measures [45]. The game that compared healthy participants with participants with OCD studied brain images to measure the effect of the intervention [73]. The longitudinal study found that results remained after six months, but not after 18 months [26].

5.3.2. Evaluation studies and results for supporting behaviour

Slightly less than half of the papers reviewed within this empowerment method, describe a protocol for a study or design of an intervention [36,50,54,57,60–62,64,83]. Of the other papers, only one describes a longitudinal experimental study with a follow-up after one year [32], this study also describes a focus group as part of their research.⁷

Most of the studies are experiments [25,32,33,39,63,82]. Two effect oriented studies were found: one in which there was only one interaction with the system [47], and one consisting of a usability test, and a 28-day pilot trial [55]. A high variety of participants in this category was found: while the usability test had 10 participants, and the pilot trial of the same intervention had 20 participants [55], the other effect study included 104 participants [47].

The remaining studies are focus group studies [32,38,41,42,65]. Some focus group used the System Usability Scale (SUS) as an evaluation method for the usability of the system [38,41,65]. One of the focus groups consisted of multiple trials, with different numbers of participants [41], these are taken into account separately for the following analyses.

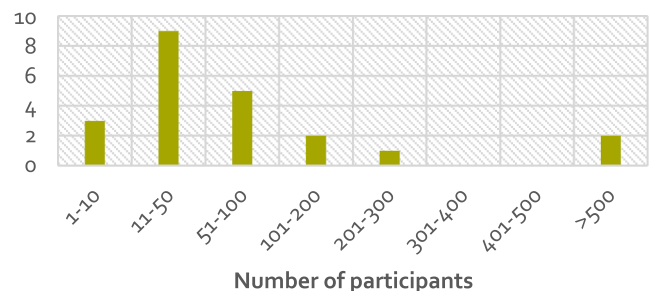


Fig. 21. Number of participants in studies for training skills.

⁵ As one of the studies consisted of 4 different stages, for 3 of which the sample size was mentioned separately, these 3 studies are taken into account separately for this figure.

⁶ For this table the same holds as for the previous figure, see Footnote 5.

⁷ The number of participants for both studies different, and are used separately in the analysis of the participant numbers.

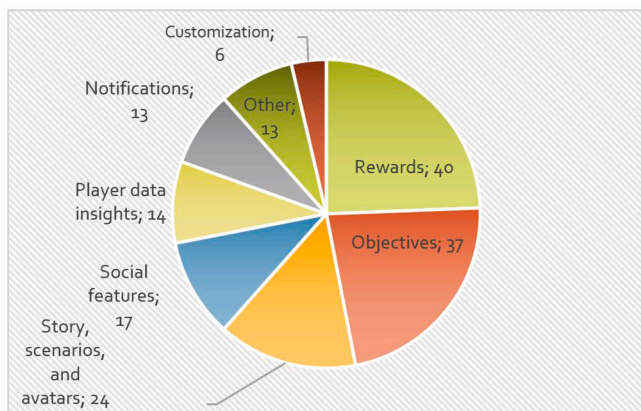


Fig. 20. Game characteristics used by all empowerment methods.

Table 1
Participants for different study types for training skills.

	Minimum	Maximum	Average	Standard deviation
Effect oriented	20	80	55.75	22.00
Effect oriented multiple interaction	11	155	58.2	51.51
Experimental	21	574	235.29	220.86
Focus groups	3	82	22.33	27.88

Overall, the most studies have less than 50 participants (see Fig. 22). The highest number of participants is 824 for an experimental study with Dutch adolescents [25].

For the experimental studies and focus groups⁸, see Table 2, this shows that the average of experimental studies is around 270, but with a high standard deviation, while the average of focus groups is much smaller, 14, and with a much lower standard deviation.

Most of the studies study the effect of the intervention and/or the experience of the users with the intervention. Besides this, one paper studied how the response time of a step with their system was related to the Berg Balance Score [47]. Another remarkable result was that of the study with the highest number of participants. It reported a low intervention completion, initially 2649 participants were included in the research but only 824 remained [25]. Moreover, this research only found an effect on the binge drinking behaviour of some subgroups in the study. One study found results that were negative and opposite of existing literature. It found that elderly explicitly refused gamification elements in a physical training programme [42].

5.3.3. Evaluation studies and results for transferring knowledge

Most of the studies describe a study [29,31,34,43,51,58,75,78–80], only three study protocols or designs of games were found in this category [40,52,77]. Only one of the studies uses data from at least half a year [29].

Four of the studies are effect oriented studies [29,31,34,43] and four have an experimental setup [51,58,78,79]. Of the effect oriented studies, most measure the effect after one interaction with their intervention [31,34,43]. For the development of ‘Pure Rush’ there were three stages, with different numbers of participants: the formative consultation ($n = 115$),⁹ feasibility and acceptability testing ($n = 25$) and the final evaluation ($n = 281$). The feasibility and acceptability phase was in the form of a focus group, the final evaluation is an effect study [34]. The only effect oriented study with more than one interaction moment was the longitudinal study; which also consists of different phases (exploratory, implementation, administration, and evaluation). In which again

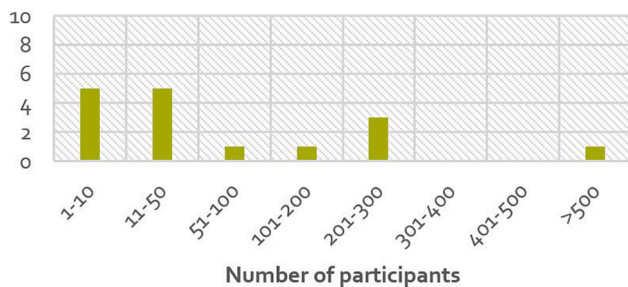


Fig. 22. Number of participants in studies for supporting behaviour.

⁸ As there were only two effect oriented studies, with a big difference in the number of participants, there are not taken into consideration here.

⁹ As this is not part of the evaluation of the game itself, this phase is not taken into account for Fig. 24.

Table 2
Participants for different study types for supporting behaviour.

	Minimum	Maximum	Average	Standard deviation
Experimental	36	824	271.5	257.97
Focus groups	6	21	13.5	5.06

also a focus group was incorporated [29]. One of the studies with an experimental setup also includes a focus group with a subset of the participants [78]. Other focus groups are described in [75,80].

Fig. 23 shows that most studies have 11–100 participants. Most of these participants are also the target group of the application. Table 3 shows that the effect oriented studies, on average, have the highest number of participants, and the focus groups have the smallest. Again, comparable to previous discussed empowerment methods, the focus groups also have a small standard deviation compared to the other categories.

Most studies focus on the effect of the intervention or how players perceived it. Often positive results are found and/or results can be used to further improve or extend the applications. For example, one study used a focus group approach and learned that while their game was educational and somewhat entertaining, the game was lacking real-life scenarios and player control [75].

5.3.4. Evaluation studies and results for other interventions

The first intervention is a study with a focus group setup with 81 participants [59]. The participants, children from the same age group as the target group, were asked to draw for example characters, to study what storylines and characters could be used in the game.

The second intervention was evaluated with two experiments in which different conditions were compared, as well as a control condition [68]. The first experiment had 92 participants, the second experiment 120. However, it concerned healthy student participants, while the target group is people with acrophobia. No significant differences were found for the two conditions of the intervention that were compared.

5.3.5. Conclusions about evaluation studies and results

Fig. 24 shows that 24% of the reviewed papers describes a protocol or design of a game. For the empowerment method of supporting behaviour, most of the reviewed papers concerned such a protocol or design, while for other empowerment method, most papers described a study.

Fig. 25 shows that most of the studies are focus groups or studies with an experimental setup. It was found that focus groups are sometimes used in combination with other types of studies.

Fig. 26 shows how many participants are used in all the studies. This shows that most studies have between 11 and 50 participants, followed by studies with 51–100 participants. The empowerment method of supporting behaviour is an exception to this, with the most participants between 1 and 50.

Experimental setups and effect oriented studies have the largest numbers of participants, but they also have a high standard deviation. Focus groups on the other hand often have a lower number of

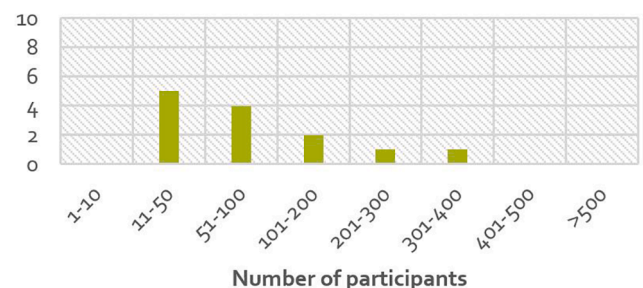


Fig. 23. Number of participants in studies for transferring knowledge.

Table 3
Participants for different study types for transferring knowledge.

	Minimum	Maximum	Average	Standard deviation
Effect oriented	65	354	193.75	126.46
Experimental	45	157	95.5	45.26
Focus group	25	74	39.4	18.29

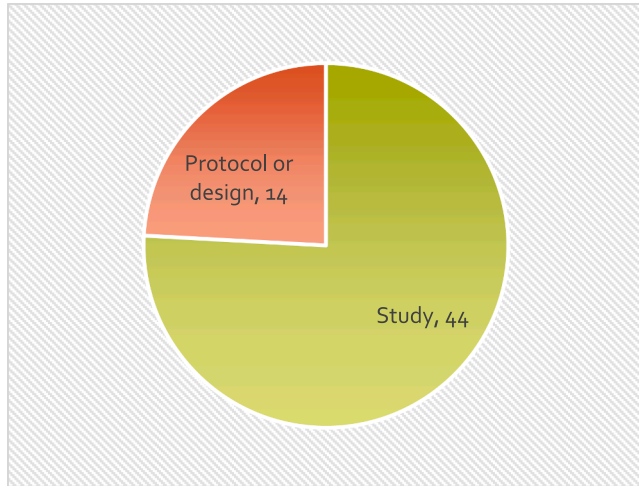


Fig. 24. Ratio papers describing studies and protocols.

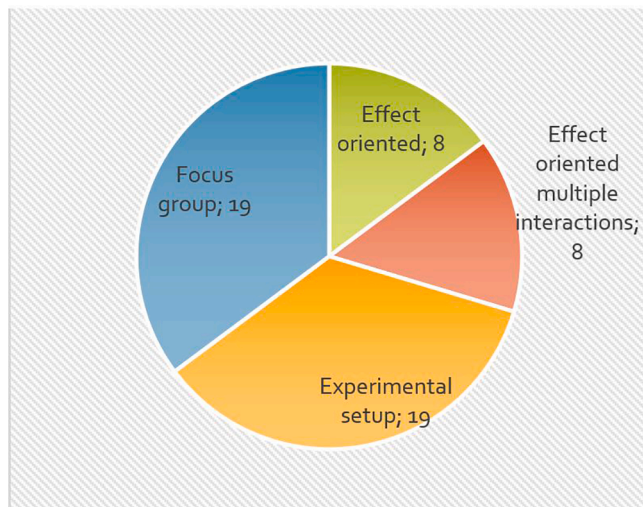


Fig. 25. Ratio of study types.

participants (<100, often <50), but also with a lower standard deviation.

The differences between the empowerment methods are small. Remarkable is that for supporting behaviour, most of the reviewed papers describe a protocol or design. Most of the studies are experiments, which could be related to the fact that there are many protocols. However, the number of participants for most of the studies is, on average, lower for this empowerment method, while it could be expected that, given the number of experimental setups, larger numbers of participants would have been used. However, it seems that there is a high variety in the sample sizes of the experimental studies.

The results of studies are often oriented on improving the current intervention, or measuring the effect. Sometimes specific aspects, such as target device or the affiliation of the target group with the game characters and story. However, only four of the studies contained data

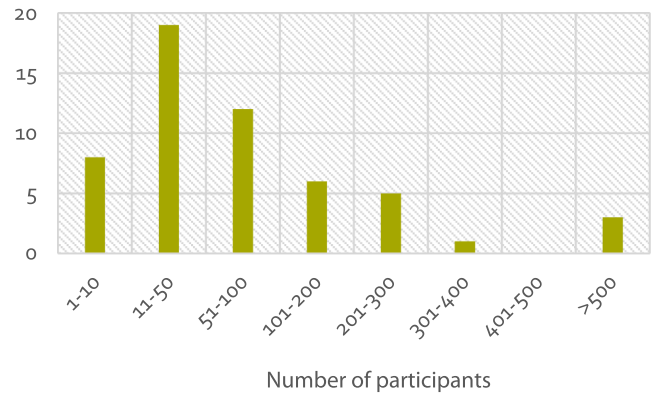


Fig. 26. Number of participants in all studies.

from more than 6 months. This, together with the fact that many results are very specific for the evaluated game (as they describe possible improvements), makes the generalizability of the results questionable. Moreover, the study with the follow-up after 18 months showed that results did not hold for so many months. As many of the studies lack such longitude results, it is unclear whether reported results will hold in the future. Moreover, the measurements used to evaluate a system are often specific for the system itself, this makes comparing and generalizing results also harder. In some papers it was found that the SUS was used for measuring the usability, such measurement methods make it possible to compare results from different studies with each other.

6. Conclusions

6.1. Summary and findings

The current paper gives an overview of the domain of serious games and gamification to empower vulnerable target groups. In the introduction of this paper the concepts vulnerability and empowering were explained. Next, this paper explained how large target groups and goals of applications within the domain of serious gaming and gamification can be distinguished from each other by studying their objectives. With a classification based on different objectives, it is explained how applications differ from each other on their goal and target group, taking into account the context in which they are used. This classification explains how the specific objective that is studied in this review, differs from other serious games and gamified applications.

To give an overview of the domain of serious games and gamification with the objective to empower vulnerable target groups, the first part of this structured review focused on three questions:

- Which vulnerable target groups are studied?
- How can the target group's risk(s) be characterized?
- In what way do the interventions empower the target group?

Five different categories of target groups are found within the review, namely people vulnerable due to their (ordered on size): age, physical health condition, mental health condition, cultural background or socio-economic status. Age is the biggest target group, making 44% of all the papers.

Three large categories of how vulnerability risk are identified have been found within this review: health, safety and social. 80% of the vulnerabilities are related to health risks. However, different meanings for this category were found. For most target groups, their health risk is of a preventive nature, meaning that the application aims to prevent a future health risk. However, when it comes to people that are already having a specific health condition, the application most often aims to reduce the risks of that health situation, rather than prevent another health risk.

When studying how applications aim to empower their users, three main methods are found (ordered by size): training a skill, supporting behaviour, and transferring knowledge. For supporting behaviour, a division was found between applications that support physical activity, such as exergames, on the other hand applications were found that support so called lifestyle behaviours.

The age target group is the most diverse group: it has the most different types of risks and empowerment methods. Health risks, for the different target groups, are addressed with all types of empowerment methods, but mainly with behaviour support. Moreover, behaviour support is almost exclusively used for health risks. Training skills and transferring knowledge is mainly used for the other two vulnerability risks. Furthermore, it is found that for people with a physical health condition, only health risks are addressed. For people with a mental health condition this is almost the same, with one exception.

In this first part of the research it becomes clear that interventions often aim for vulnerabilities that are closely related to the characteristics of the vulnerable group, and that are often occurring, such as substance abuse among adolescents or the health risks of a health condition. More indirect vulnerabilities, such as social vulnerabilities for people with a specific health condition are rarely found. It seems that pathogenic vulnerabilities (situational vulnerabilities that are caused by injurious social phenomena) are not targeted by the current research projects. This is a gap in the current research, that is very interesting to study in the future.

In the second part of the review, the technologies, game mechanics and evaluation methods and results have been studied. We did not differentiate between serious games and gamification, as the descriptions of the interventions differ from paper to paper, it can be sometimes challenging to distinguish between these two concepts. We therefore decided to not make this distinction, also to avoid mistakes.

Concerning the platforms that are used it is shown that mobile and web-based applications are mostly used, but also desktop applications or other technologies such as Wii Balance boards and Kinect are used.

When studying the game mechanics and characteristics, it became clear that they can be summarized in different categories, such as objectives, rewards, and story elements. While in each empowerment method it is clear that objectives and rewards play a major role, the different methods have a different preference for these mechanics.

Skill training uses rewards in 64% of the applications, and objectives in 59% of the applications. Story elements are also used in just over half of the applications (55%). For behaviour supporting applications, rewards are a very important component, 86% of the applications use this. This is again followed by objectives (81%). Stories are not often used for this empowerment method, but social elements (57%) and notifications and player data insights (48%) are. In knowledge transferring games, again rewards are the most used mechanic (62%). In the other empowerment methods, the second most used mechanic is objectives, but for knowledge transferring this is the story mechanic (46%). In the other methods, objectives are used in more than half of the applications, but for knowledge transferring this is only 38%.

Finally, the evaluation methods and results were analysed. 24% of the reviewed papers did not describe any results, but describe a study protocol or game design. In all empowerment methods but one, the majority of the papers describes a study. Only for the empowerment method of supporting behaviour the majority of the papers is a protocol or design. Of the studies, most studies have an experimental setup or focus group setup (35%), other studies measure the effect of an intervention after one or more interactions with the intervention (30%). Notable is that only four out of the 54 studies collected data over a period of six months or more. In general, studies have 11–100 participants. Focus groups often have a smaller number of participants (on average around 30), while experimental studies have a high number of participants (on average around 200). However, the standard deviation for the average number of participants for experimental studies guide high; while some there are three studies with more than 500

participants, there are also five studies with less than 50 participants. For focus groups this diversity is less big. Most focus groups contain at most 20 participants.

The results of the studies are mostly about the effect of the game, or about the attitude of participants towards the game. Often, these results are used to as preliminary results about the effect and/or to further improve the intervention. However, as most studies do not include a longitude follow-up, it is unclear how these effects hold. Moreover, the longest study showed that their effects did not hold after a certain amount of time [26]. Due to the lack of data for this amount of time, most studies cannot say anything about this.

6.2. Recommendations

It is often stated in reviews that papers in the domain of serious gaming and gamification lack a longitudinal and large effect study. Based on the performed literature review, a more specific observation can be made. While it is indeed a problem that studies often lack a large and long effect study, a more notable problem is the lack of generalizability of the research results. This might not only be a problem of the studies itself, but also of the descriptions of the applications. When looking at the descriptions of serious games and gamified applications, the descriptions of the games are very different from each other. While some papers describe their application with a high level of detail and by using commonly used terms for game mechanics, other games are described in a more story-like description in which the actual game mechanics might be less clear or make it harder to understand the role of certain game mechanics. In Sections 5.2.2 and 5.2.3 two good examples of a description were mentioned ([32,87]), that clearly explained which components are used in the game, and, in the case of the game from Section 5.2.2, how they are connected to behaviour change techniques [32]. Another good example is shown in the paper about AllyQuest [55], in which the game mechanics and scientific reasoning behind them is schematically shown.

Other domains, such as medicine, usually describe their studies in a very high detail, explaining a lot of factors so that others can reproduce the same study. Such an approach could also be beneficial for the domain of serious games and gamification. However, in addition to explaining how the study is setup (which is already done in papers with a study protocol), it is also important to explain the used components, their functioning and the scientific reasoning behind them. As the components of a serious game or gamified application are important for knowing how to reproduce a comparable intervention and subsequently compare studies.

However, describing games in such detail might be difficult. One reason for this is that game mechanics can have different meanings in different contexts. When assigning points to exercises in a game with a leaderboard, this might have a completely different effect compared to using points in a game in which users unlock rewards based on their points. Moreover, aspects that were not meant as game mechanics might turn out to influence the behaviour of users. For example, if you have a wardrobe with unlockable clothes for an avatar, users might not be motivated by the fact that they can customize their avatar, but instead be motivated by the fact that they want to unlock every item from the wardrobe. This can also be influenced by personal preferences of players. Measuring the effect of individual game mechanics is often not performed in studies.

This review identified different labels to characterize serious games and gamified applications; this is done for the target groups, vulnerability risks, empowerment methods and game mechanics. As the domain of serious gaming and gamification is very broad (in the sense of target groups and vulnerabilities), there are different disciplines involved in the different projects. Therefore, it might be challenging to find one universal way to describe games (and their mechanics) in a more standardized way. However, doing so, such as is attempted in this review, makes the field more transparent which can lead to more generalizable

results and thereby more effective serious games and gamified applications. No previous attempts for this specific domain of empowering vulnerable target groups have been found.

Finally, what also contributes to the lack of generalizability is that the measuring instruments used in the evaluations of the serious games and gamified application are often developed for that specific purpose. By using more frequently used measures, such as the SUS for usability, it is possible to compare the outcomes of different studies.

In conclusion, this paper has contributed to showing the diversity in a promising field of serious gaming and gamification. As this review has shown, it is possible to apply serious gaming and gamification to many different behaviours, which is often positively evaluated by the potential users and has positive effects. However, this review has also shown that the field lacks a generalizability of the described results, which we believe is due to the lack of standardized ways to describe serious games

and gamification. For future research it is interesting to apply labels to describe different types or genres of games, in order to make it easier to find clusters of games that are somewhat comparable. More advanced would be to move towards a more standardized way to describe games in research papers, or at least identify the most important game mechanics that form the core of an application. Moreover, making sure that the described intervention and the code publically available, would also be beneficial for this research field as it allows other researches from outside the project to reuse existing material.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Overview of reviewed papers and their classifications

Description	Target group	Type of risk	Empowerment methods	Technology	Game characteristics and mechanics	Study characteristics		
						Type of study	Duration	Number of participants
Alcohol alert: game to reduce binge drinking among adolescents [25]	Age	Health	Supporting behaviour	Web (played on computer)	Objectives Rewards Story, scenarios & avatars Notifications	Experimental	Short	>500
SPARX-R: preventing depression for adolescents [26]	Age	Health	Training skills	Web (played on school computer) Other (paper notebook)	Objectives	Experimental	Long	>500
Learning game for training child bicyclists' situation awareness [27]	Age	Safety	Training skills	Mobile	Rewards	Effect	Short	51–100
Using virtual reality in computer classes to reduce loneliness among elderly [28]	Age	Social	Training skills	Desktop (VR)	Unspecified	Protocol		
Serious game about food safety for young customers [29]	Age	Safety	Transferring knowledge	Web	Objectives Rewards Story, scenarios & avatars Other	Effect multiple interactions Focus group	Long	301–400 51–100
Happy 8-12: Emotional education program for the assertive resolution of conflicts among peers (adolescents) [30]	Age	Social	Training skills	Desktop	Story, scenarios & avatars	Experimental	Short	>500
Gnam's Planet: intervention for healthy lifestyle promotion in adolescents [31]	Age	Health	Transferring knowledge	Web (played on a computer)	Objectives Rewards	Effect	Short	51–100
Step Smart Challenge: gamified intervention for encouraging physical activity in adolescents [32]	Age	Health	Supporting behaviour	Web (with workbook)	Objectives Rewards Social	Experimental Focus group	Long	201–300 11–50
CampusGANDR: college alcohol intervention [33]	Age	Health	Supporting behaviour	Mobile	Objectives Rewards Social	Experimental	Short	201–300
Pure Rush: an online serious game for drug education for adolescents [34]	Age	Health	Transferring knowledge	Mobile Web	Rewards Story Customization	Effect Focus group	Short	201–300 11–50
The Fling: serious game to train behavioural control in adolescents related to alcohol usage [35]	Age	Health	Training skills	Desktop	Objectives Rewards Story, scenarios & avatars	Experimental	Short	101–200
Active Team: app-based physical activity intervention for inactive adults [36]	Age	Health	Supporting behaviour	Mobile	Objectives Rewards Player data insights Notifications Social	Protocol		
Cognitive Function Training System Using Game-Based Design for Elderly Drivers [37]	Age	Safety	Training skills	Mobile	Objectives Rewards	Effect multiple interactions	Short	11–50
	Age	Health		Web		Focus group	Short	1–10

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Description	Target group	Type of risk	Empowerment methods	Technology	Game characteristics and mechanics	Study characteristics		
						Type of study	Duration	Number of participants
Healthy teens @ school: online program for promoting a healthy lifestyle and reducing the risk of eating disorders and obesity for adolescents [38]			Supporting behaviour		Objectives Rewards Player data insights			
Strength and balance exergames to reduce falls risk for elderly [39]	Age	Health	Supporting behaviour	Other (Kinect)	Unspecified	Experimental	Short	51–100
Online educational program using game-based learning to improve nutrition and physical activity for students [40]	Age	Health	Transferring knowledge	Web	Rewards Notifications Social Other	Protocol		
FallSensing Games: fall prevention multiplayer game for senior care centres [41]	Age	Health	Supporting behaviour	Other (wearable sensor + tv)	Objectives Rewards Social Other	Focus group	Short	2x 1–10 11–50
Train and Win: digital home-based physical training program for elderly [42]	Age	Health	Supporting behaviour	Other (Kinect)	Rewards Story, scenarios & avatars	Focus group	Short	11–50
Space Adventures: a serious game for childhood obesity prevention [43]	Age	Health	Transferring knowledge	Desktop	Story, scenarios & avatars	Effect	Short	51–100
A serious game-based solution to prevent bullying for children [44]	Age	Social	Training skills	Mobile Desktop	Objectives Rewards Story, scenarios & avatars	Focus group	Short	1–10 11–50 51–100
Gamified e-learning platform to improve traffic safety among elementary school pupils [45]	Age	Safety	Training skills	Desktop	Objectives Rewards Player data insights Story, scenarios & avatars Other	Effect multiple interactions	Short	11–50
Trucs tegen babbeltrucs: A serious game for training verbal resilience to doorstep scams [46]	Age	Safety	Training skills	Mobile	Rewards Story, scenarios & avatars	Focus group	Short	1–10
A stepping game for older adults [47]	Age	Health	Supporting behaviour	Other (Wii Balance Board)	Objectives Rewards	Effect	Short	101–200
PlayForward: Elm City Stories: public health videogame intervention about HIV for adolescents [48]	Age	Health	Training skills	Unspecified	Objectives Story, scenarios & avatars Other	Experimental	Short	201–300
GAMETEEN SYSTEM: a VR-based serious game to regulate joy in adolescents [49]	Age	Health	Training skills	Mobile Desktop Other (RGB-D camera)	Objectives Rewards Other	Effect	Short	51–100
A gamified application for assessment of balance and fall prevention for elderly [50]	Age	Health	Supporting behaviour	Mobile (with non-invasive wearable sensor)	Unspecified	Protocol		
ONESELF: web-based intervention for rheumatoid arthritis patients [51]	Physical health condition	Health	Transferring knowledge	Web	Rewards Social Other	Experimental	Short	101–200
An oral health education video game for high caries risk children [52]	Physical health condition	Health	Transferring knowledge	Mobile	Unspecified	Protocol		
GoFar: reducing disruptive behaviour in children with Fetal Alcohol Spectrum Disorders [53]	Physical health condition	Health	Training skills	Desktop	Objectives Rewards	Experimental	Short	11–50
Smartphone application for weight loss in overweight and obese adolescents [54]	Physical health condition	Health	Supporting behaviour	Mobile	Objectives Rewards Player data insights Customization	Protocol		
AllyQuest: smartphone application to support engagement in care and medication adherence for HIV-positive young men [55]	Physical health condition	Health	Supporting behaviour	Mobile	Objectives Rewards Player data insights Story, scenarios & avatars Notifications Social	Effect multiple interactions	Short	1–10 11–50
Serious game for older adults undergoing treatment for cancer [56]	Physical health condition	Health	Training skills	Unspecified	Story, scenarios & avatars	Focus group	Short	11–50

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Description	Target group	Type of risk	Empowerment methods	Technology	Game characteristics and mechanics	Study characteristics		
						Type of study	Duration	Number of participants
Epic Allies: a gamified mobile phone app to improve engagement in care, antiretroviral uptake, and adherence among HIV positive [57]	Physical health condition	Health	Supporting behaviour	Unspecified	Objectives Rewards Player data insights Notifications Social Customization	Protocol		
PROVITAO: gamified educational programme for childhood obesity [58]	Physical health condition	Health	Transferring knowledge	Mobile Other (variety of games, also commercial games like Wii Fit Plus)	Objectives Rewards Player data insights Other	Experimental	Short	11–50
INTERACCT: serious game for health of children after cancer treatment [59]	Physical health condition	Health	Other	Web (with Kinect or Android data)	Objectives Social Other	Focus group	Short	51–100
Exercise intervention program using social incentives and gamification for obese children [60]	Physical health condition	Health	Supporting behaviour	Mobile	Rewards Social	Protocol		
MyHeartMate: a game-based app to promote behaviour change in patients with cardiovascular disease [61]	Physical health condition	Health	Supporting behaviour	Mobile (with wearable)	Objectives Rewards Player data insights Story, scenarios & avatars Notifications Social Other	Protocol		
STEP UP: social incentives to encourage physical activity and understand predictors for overweight and obese adults [62]	Physical health condition	Health	Supporting behaviour	Web (with wearable device)	Objectives Rewards Notifications Social	Protocol		
Mission: Schweinehund: behaviour change technique-based smartphone game to improve intrinsic motivation and physical activity adherence in patients with type 2 diabetes [63]	Physical health condition	Health	Supporting behaviour	Mobile	Objectives Rewards Player data insights Notifications Social Customization	Experimental	Short	11–50
SIGMA: an evidence-based gamified mHealth intervention for overweight young adults with maladaptive eating habits [64]	Physical health condition	Health	Supporting behaviour	Mobile	Objectives Rewards Player data insights Story, scenarios & avatars Notifications	Protocol		
A holistic technology-based solution for prevention and management of diabetic foot complications [65]	Physical health condition	Health	Supporting behaviour	Mobile (with thermal camera)	Objectives Rewards Player data insights Notifications	Focus group	Short	1–10
Virtual Coach: intelligent agent and virtual game to support education in e-health for children with type 1 diabetes [66]	Physical health condition	Health	Training skills	Unspecified	Rewards Story, scenarios & avatars	Effect multiple interactions	Short	11–50
Ophobia: serious game for patients with acrophobia [67]	Mental health condition	Health	Training skills	Mobile (with VR goggles)	Objectives Rewards Player data insights Story, scenarios & avatars Notifications	Protocol		
TraumaGameplay: game for people with PTSD to reduce intrusions [68]	Mental health condition	Health	Other	Unspecified	Objectives	Experimental	Short	51–100 101–200
Take Control: virtual reality cue refusal video game for alcohol and cigarette recovery support [69]	Mental health condition	Health	Training skills	Other (Kinect)	Rewards	Effect multiple interactions	Short	51–100
Trash that cigarette: an avatar-based anti-smoking game on smoking cessation intent [70]	Mental health condition	Health	Training skills	Mobile	Objectives Story, scenarios & avatars	Effect	Short	51–100
		Health	Training skills	Web		Effect	Short	11–50

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Description	Target group	Type of risk	Empowerment methods	Technology	Game characteristics and mechanics	Study characteristics		
						Type of study	Duration	Number of participants
OnTrack>TheGame: computer-based role-playing game for young people with psychosis [71]	Mental health condition				Rewards Story, scenarios & avatars Customization			
Let's find letters: learning aid for dyslexic children [72]	Mental health condition	Health	Training skills	Unspecified	Objectives Rewards	Focus group	Short	1–10
RAW HAND: mobile serious game in the treatment of OCD [73]	Mental health condition	Health	Training skills	Mobile	Other	Experimental	Short	11–50
IntegraGame: vocational training tool for persons with intellectual disability [74]	Mental health condition	Social	Training skills	Unspecified	Objectives	Experimental	Short	11–50
Fast Car: Web-based HIV prevention game for rural adolescents [75]	Cultural background	Health	Transferring knowledge	Web	Rewards	Focus group	Short	11–50
Making smart choices: a serious game for sex education for young adolescents [76]	Cultural background	Health	Transferring knowledge					
None in Three: violence prevention game for young people in the Caribbean region [77]	Cultural background	Safety	Transferring knowledge	Desktop	Objectives Story, scenarios & avatars	Protocol		
Tumaini: A smartphone game to prevent HIV among young Africans [78]	Cultural background	Health	Transferring knowledge	Mobile	Story, scenarios & avatars Customization	Experimental Focus group	Short	11–50 51–100
Improving sexual health education programs for adolescent (in Sub Saharan Africa) through game-based learning and gamification [79]	Cultural background	Health	Transferring knowledge	Desktop (at school)	Rewards Story, scenarios & avatars Social Other	Experimental	Short	101–200
PROCEE: a PROstate Cancer Evaluation and Education serious game for African Caribbean men [80]	Cultural background	Health	Transferring knowledge	Unspecified (only mentions tablet used for focus group)	Objectives Player data insights Story, scenarios & avatars	Focus group	Short	11–50
Online evidence-based parenting program for vulnerable parents [81]	Socio-economic status	Social	Training skills	Mobile Desktop	Objectives Rewards Story, scenarios & avatars Notifications Social Other	Effect multiple interactions	Long	101–200
Balance it: game intervention for overweight-related behaviours for adolescents [82]	Socio-economic status	Health	Supporting behaviour	Mobile	Objectives Rewards Notifications Social	Experimental	Short	201–300
BUZZING: a serious game for unemployed young people their transition into employment [83]	Socio-economic status	Social	Supporting behaviour	Mobile Web	Objectives Player data insights Social	Protocol		

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