Digital Gamification Tools to Enhance Vaccine Uptake: A Scoping Review

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Table of Contents

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Abstract

Background: Gamification has been used successfully to promote various desired health behaviours. Previous studies have used gamification to achieve desired health behaviours or facilitate their learning about health.

Objective: In this scoping review and environmental scan, we aimed to describe gamified digital tools that have been implemented and or evaluated across various populations to encourage vaccination uptake, as well as any reported effects of identified tools.

Methods: For the scoping review component, we searched Medline, Embase, CINAHL, Web of Science Core Collection, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Academic Search Premier, PsycInfo, Global Health and ERIC for peer-reviewed articles describing gamified digital tools with or without evaluations. For the environmental scan component, we conducted web searches with Google to identify gamified digital tools lacking associated publications. We also consulted 12 experts in the field of gamification and health behaviour to identify any articles or tools we might have missed. We extracted data about the target population of the tool, the interventions themselves (e.g., type of gamified digital tool platforms, type of disease/vaccine, type and design of the study), any effects of evaluated tools, and synthesized data narratively.

Results: Of 1402 records, we included 28 peer-reviewed articles and 10 gamified digital tools lacking associated publications. Experts added one gamified digital tool that met the inclusion criteria. Our final data set therefore included 28 peer-reviewed articles and 11 gamified digital tools. Out of 28 peer-reviewed articles, 7 studies explained the development of the tool, 16 studies described evaluation, and 2 reported both development and evaluation of the tool. The 28 peer-reviewed articles reported on 25 different tools. Of these 25 gamified digital tools, 11 were web-based, 8 mobile (native mobile applications or mobile web applications), and 6 virtual reality. Overall, tools that were evaluated showed increases in knowledge and intentions to receive vaccines, mixed effects on attitudes, and positive effects on beliefs. We did not observe discernible advantages of one type of gamified digital tool (web-based, mobile, virtual reality) over the others. However, few studies were randomized controlled trials, and publication bias may have led to such positive effects having a higher likelihood of appearing in the peer-reviewed literature.

Conclusions: This review demonstrates that gamified digital tools appear to have potential for improving vaccine uptake by promoting vaccine-favourable beliefs and increasing knowledge about vaccines and intentions to receive vaccines. Comparative studies of different features or different types of gamified digital tools could advance the field by identifying features or types of tools that yield more positive effects across populations and contexts.

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Keywords: Gamified digital tools; Digital games, Vaccination; Gamification; Vaccine uptake; Scoping review

Abstract: 439/450

Background: Gamification has been used successfully to promote various desired health behaviours. Previous studies have used gamification to achieve desired health behaviours or facilitate their learning about health.

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Results: Of 1402 records, we included 28 peer-reviewed articles and 10 gamified digital tools lacking associated publications. Experts added one gamified digital tool that met the inclusion criteria. Our final data set therefore included 28 peer-reviewed articles and 11 gamified digital tools. Out of 28 peer-reviewed articles, 7 studies explained the development of the tool, 16 studies described evaluation, and 2 reported both development and evaluation of the tool. The 28 peer-reviewed articles reported on 25 different tools. Of these 25 gamified digital tools, 11 were web-based, 8 mobile (native mobile applications or mobile web applications), and 6 virtual reality. Overall, tools that were evaluated showed increases in knowledge and intentions to receive vaccines, mixed effects on attitudes, and positive effects on beliefs. We did not observe discernible advantages of one type of gamified digital tool (web-based, mobile, virtual reality) over the others. However, few studies were randomized controlled trials, and publication bias may have led to such positive effects having a higher likelihood of appearing in the peer-reviewed literature.

Conclusions: Gamified digital tools appear to have potential for improving vaccine uptake by fostering positive beliefs and increasing vaccine-related knowledge and intentions. Encouraging comparative studies of different features or different types of gamified digital tools could advance the field by identifying features or types of tools that yield more positive effects across populations and contexts. Further work in this area should seek to inform the implementation of gamification for vaccine acceptance and promote effective health communication, thus yielding meaningful health and social impacts.

Introduction

Vaccination is one of the most cost-effective methods of preventing the spread of vaccine-preventable diseases. If vaccination coverage falls below the thresholds that are safe for the prevention of epidemic transmission, the incidence of vaccine-preventable diseases increases [1,2]. For example, measles returned over the past 2 decades and increased the incidence of measles in the European Union in 2017-2018 [3].

In 2019, prior to the COVID-19 pandemic, the World Health Organization identified vaccine hesitancy (i.e., the reluctance or refusal to be vaccinated despite availability of vaccination services) as one of the top 10 threats to global health [4]. Vaccine hesitancy is one of the several reasons for why some people are un- or under vaccinated [5–9]. Interventions addressing vaccine hesitancy are therefore necessary to promote vaccine acceptance and uptake. As the contributors of vaccine acceptance are diverse, no single intervention will solve this issue [10]. Multicomponent interventions tailored to local barriers to vaccine acceptance and uptake are known to be the most effective [11,12]. Misinformation and conspiracy theories spread online, where extensive anti-vaccine content is shared [13–15] potentially negatively influencing views about vaccines [16,17]. Efforts have been made to counter vaccine misinformation, mistrust, delivering information on vaccine risks and benefits by targeting various groups; for example, parents, non healthcare workers [18,19], adolescents [20], and concerning different types of vaccines, for instance human papilloma virus (HPV) vaccination [21] or measles, mumps and rubella vaccines [22,23]. Along with traditional communication strategies, the use of other strategies to inform and educate about immunizations; for example, with gamified digital tools, may help encourage vaccine uptake.

Gamification is defined as the use of game design elements in non-game contexts [24]. It includes several aspects and features like fun interfaces, immediate success or feedback, reward systems (levels, point scores, badges), challenges and competitions, team playing, avatars, and quizzes. Previous studies have used gamification to achieve desired health behaviours [25–27] or facilitate their learning about health [28]. Gamification draws on elements from serious games, meaning fully developed digital games used to train and educate players [29,30]. For example, a serious game, “Land of Secret Gardens,” facilitates conversations about human papillomavirus with preteens. Within the game, preteens need to protect their bodies with a, “potion,” which offers a metaphor for the human papillomavirus vaccine [31]. However, serious games and gamified digital tools are distinct but related concepts. Serious games use gaming as a central and primary medium [32]. By contrast, gamified digital tools (e.g. applications) or gamified interventions are not complete game experiences but have gaming features such as rewards system, scoring of points, or engaging

users in different challenges [33]. In this study, we defined gamified digital tools as digital applications with gaming features such as rewards system, scoring of points, or engaging users in different challenges. Our definition includes serious games that meet the criteria, meaning, they must include such gaming features. This scoping review provides insight into the reported effects of gamified digital tools to increase vaccine uptake. Our review builds upon existing reviews in the field by including a comprehensive search of both published literature and online tools, as well as an examination of both the characteristics and the reported effects of these digital tools. This review is distinct in that it focuses specifically on gamified digital tools and their effects, rather than simply the effectiveness of gamification in general. In doing so, this review aimed to fill a gap in the literature by providing evidence-based answers to the question of whether gamification 'works' to increase vaccine uptake. Therefore, the objectives of this scoping review [34] were first, to review gamified digital tools that have been implemented and or evaluated across various populations to encourage vaccination uptake and second, to describe any reported effects of identified tools in terms of influence on users' knowledge or behaviour towards vaccination. Our research questions can therefore be summarized as, "What gamified digital tools intended to encourage vaccination exist and have been described in the literature? Do these tools demonstrate any effects on knowledge, attitudes, beliefs and behaviors about vaccination?"

Methods:

Search Strategy:

For peer-reviewed articles, we searched Medline (Ovid), Embase (Ovid), CINAHL (EBSCO), Web of Science Core Collection, Cochrane Database of Systematic Reviews (Ovid), Cochrane Central Register of Controlled Trials (Ovid), Academic Search Premier (EBSCO), PsycInfo (Ovid), Global Health (Ovid) and ERIC (Ovid) with no language or date restrictions. The proposed search terms are for example, vaccine, vaccination, immunization,video games, gamification, application, virtual reality, etc. (see Multimedia Appendix 1 for full search strategy). The search was conducted on January 26th & 27th, 2022.

We also conducted an online Google search on May 05, 2022, for any digital tools with gamified features which deliver informative or educative messages on vaccination. The search terms we used were vaccination, immunization, electronic game, computer game, mobile game, interactive game, digital game (see Multimedia Appendix 1 for full search strategy). We reviewed the first 30 results for each search, as it is rare for users to click past the third page of ten search results per page, and therefore, researchers analyzing medical content available on the web often use 30 as a threshold [35–37]. On May 06, 2022, we conducted the same searches in private browsing mode to ascertain

whether our results had been affected by a ‘‘filter bubble” [38]; that is, the way Google search results are adapted to one’s previous browsing activity. Our search strategy was constructed and reviewed by 2 librarians. Following the librarian's advice, we expanded our search strategy to include ERIC and Global Health databases.

Study selection and screening process:

We used PICO (Population, Intervention, Comparison, and Outcome) to structure study inclusion and exclusion criteria (table 1). Our population of interest was the general public or any subgroup, including health care professionals and students. We sought studies describing tools with gamification techniques or gamified elements, including gamified web-based quizzes to deliver informative or educative messages on vaccination. Posters, preprints, editorials, conference proceedings, news bulletins, and paper-based or board games were excluded. Our comparator was any control, including offering no education on vaccination or comparing participants before and after an intervention. Our outcomes of interest included common outcomes associated with vaccination uptake, namely, knowledge (comprehension, understanding), attitudes (attitudes toward or against vaccination, risk perception), behaviours towards vaccines (vaccination intentions; i.e., intentions to be vaccinated or not and vaccine uptake; i.e., receipt of a vaccine or not). We excluded articles that did not present the description or evaluation of a concrete gamified digital tool.

For Google-searched gamified digital tools, our inclusion and exclusion criteria used the same specifications regarding population and intervention. We did not apply comparison and outcome criteria to web-based tools because we did not expect these to report evaluation studies.

We report this review according to PRISMA guidelines [39]. We registered our protocol on the Open Science Framework (Registration DOI: 10.17605/OSF.IO/NV8AF).

Table 1: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion	Questions related to the criteria
Type of report	- Original paper - Evaluated intervention or digital gamification tool	- Posters, preprints, and conference proceedings - Modelling or simulation study - Brochures - Editorials - Bulletins	Has the study or research described the development of the tool and evaluated it?

Population	- General public (any subgroup) - Professionals - Students		Who is the audience for which the key message was intended to?
Intervention	Tools with gamification technique or gamified elements will be included, including gamified web-based quizzes to deliver informative or educative messages on vaccination	- Any study or gamification tools not intended for vaccination/ vaccine uptake. - Studies or apps to reduce vaccine pain and fears, to report immunization status or record keeping, surveillance or vaccine coverage apps, contact tracing or early detection. - Paper games, board games (not digital) - Videos with no gamified element included	Does the study or tool aimed to deliver an informative or educative message on vaccination?
Comparator	Any control, including offering no education or no digital gamified tool		
Outcomes	Common outcomes which encourage vaccination uptake: knowledge (comprehension, understanding), attitudes (attitudes toward or against vaccination, beliefs (includes risk perceptions, etc), behaviours towards vaccines (vaccination intentions i.e., intentions to be vaccinated or not and vaccine uptake i.e., receipt of a vaccine or not)	Outcomes not related to the encouragement of vaccination uptake.	If the study or tool has been evaluated for the outcomes that encourage vaccine uptake?

Expert consultations:

After extracting information from peer-reviewed articles and tools identified via Google search, we contacted experts in the field of gamified digital tools (e.g., developers and researchers working on the topic in Canada and worldwide who were already known to the research team) to complement our online searches and ensure completeness. Specifically, we sent emails to twelve experts containing the results of our searches and asked them to alert us to any games or papers we might have missed.

Data charting:

We developed a form in Microsoft Excel to guide the charting of data. We pre-tested and reviewed the form with team members to ensure we were accurately and adequately capturing relevant data. Data charting occurred independently with verification. Specifically, a reviewer (HH) identified and screened all studies and gamified digital tools for their eligibility. Screening results were verified by a second reviewer (DG). The data charting was then done by a reviewer (HH), and again verified by a second reviewer (DG). Any conflicts throughout screening or data charting were resolved by a third reviewer (ED). From included articles, we charted data about: (1) the type and design of study (developmental or evaluation study, user testing, randomized controlled trial, etc.) (2) the vaccine(s) addressed (COVID-19, Human Papilloma Virus etc.), (3) the purpose of the study or intervention, (4) the gamified digital tool platform (web-based, native mobile application, mobile-enabled web application, virtual reality) and (5) the characteristics of study participants. For evaluated interventions, we charted data about preselected outcomes that are widely used to predict health related-behaviours and to assess outcomes in studies of interventions about vaccination and immunization [11–14]. Specifically, we extracted data about tools' effects on knowledge, attitudes, beliefs (perceived benefits, perceived risks), and behavioural intentions. Emotional, cultural, and social factors can also influence a decision about vaccination [29,30]. Therefore, we also extracted data about other outcomes which the studies may have evaluated. Because we sought to understand all possible effects, we did not prespecify any of these as a primary outcome. We organized the extracted data in tables and synthesized descriptively.

Quality assessment:

To assess the quality of the studies who evaluated their interventions, we utilized the Mixed Methods Appraisal Tool (MMAT) developed by Pluye and colleagues [41]. Two reviewers (CR, CJMT) independently conducted the quality assessment, resolving disagreements through discussion until reaching a consensus. A third and fourth reviewer (HH & HW) intervened to settle any remaining

conflicts.

Data synthesis:

We summarized data using a narrative approach involving framework and content analysis. We classified each gamified digital tools platform using the 5 types of gamified digital tools:web-based, native mobile application, mobile-enabled web application, virtual reality). For the type of gamified digital tool, we classified web-based tools that explicitly noted their suitability for mobile use (e.g., by smartphone or tablet) as mobile-enabled applications. We classified web-based tools without such an explicit statement as web-based only, even though they may be functional on mobile devices. For type and design of study, we grouped randomized designs together, including traditional randomized controlled trials with only 2 study arms and factorial designs with more than 2 study arms. Although these methods are not exactly the same, they all use randomization to minimize potential biases and are therefore functionally equivalent for our purposes of understanding what kinds of evaluations have been undertaken [40]. We summarized the main characteristics of tools, including PICO elements in a tabular display. We used the PRISMA 2020 flowchart to describe the process of study selection [42].

Results:

Articles identified, scope of literature

We identified a total of 2,082 records through database searches. After removing duplicates, we screened 1402 database records. Through Google searches, we identified 10 gamified digital tools and 2 articles. In a private browsing mode search, there was no change in search results. Of 12 experts contacted, 2 experts responded and suggested 2 articles and 2 links, of which one gamified digital tool met the inclusion criteria and was included in our review. Through these methods, our final data set included 28 peer-reviewed articles and 11 gamified digital tools. Figure.1 shows our PRISMA diagram.

Out of 28 peer-reviewed articles, 7 studies explained the development of the tool, 16 studies described evaluation, and 2 reported both development and evaluation of the tool (table 2). To report our results, we grouped studies together that were reporting the same tool, meaning 28 peer-reviewed articles reporting on 25 different tools. Of these 25 gamified digital tools, 11 were web-based, 7 mobile (native mobile applications or mobile web applications), 6 virtual reality, and 1 was offered in both mobile and web-based versions (for details see table 2). The most common single vaccines addressed in the tools were Influenza (6 tools) and Human papillomavirus (6 tools). Other tools addressed COVID-19 (2 tools), measles, mumps, influenza and smallpox (2 tools), a hypothetical

disease (2 tools), other vaccine-preventable diseases (6 tools), and the role vaccines play in preventing the spread of disease with no particular vaccine specified (1 tool). Of 10 gamified digital tools identified via Google search and one suggested by the expert (total of 11 gamified digital tools, see table 3), the largest group (5 tools) addressed COVID-19, and the rest were about other vaccine-preventable diseases. The 11 gamified elements identified in the Google search and expert feedback identified six types of gamified elements : reward points, serious games, physical trading cards, certificates, role-playing, and quizzes (see table 3). The most common type was reward points, which appeared in five cases. Two cases used serious games, one case used physical trading cards and reward points, one case used certificates, one case used role-playing, and one case used quizzes. Additional characteristics of the studies included (e.g., country of origin, sample size, participant characteristics) are detailed in Multimedia appendix 2. The expanded version of table 2 and 3 are provided in multimedia appendix 3.

Studies were conducted in 26 different countries, with the majority of studies coming from the United States (n=13 studies) or United Kingdom (n=5 studies). Study populations included groups such as students at various levels (elementary school to college, speciality programs such as nursing and pediatric residency), parents of vaccine-eligible children, adults from the general population, members of particular socio-cultural communities (e.g., immigrants, Indigenous peoples) and convenience samples such as players of a game, attendees of a conference, and employees of an organization. Sample sizes ranged from 8 to 50,286. Whenever articles reported study participant characteristics such as age, sex or gender, ethnocultural identity, socioeconomic levels, and so on, we extracted summary data, as shown in Multimedia appendix 2.

Table 2: General information of the studies:

Authors name and references of the study	Type of gamified digital tool platform	Type of disease/vaccine	Type and design of the study (Development or evaluation, iterative design, randomized controlled trial etc.)
Evaluation studies			
Betsch & Böhm, 2016 [43]	Web-based	Hypothetical	Evaluation: Online experiment
Carolan et al., 2018 [44]	Web-based	Measles, mumps, influenza and smallpox	Evaluation: Pre-post study
Cates et al., 2020 [31]	Web-based	Human papillomavirus (HPV)	Evaluation: Pilot Randomized Controlled Trial
Dale et al., 2019 [45]	Native mobile application	Influenza	Evaluation: Non-randomized trial
Darville et al., 2018 [46]	Web-based	Human papillomavirus (HPV)	Evaluation: Randomized controlled trial
Eley et al., 2019; McNulty et al., 2011 [47]; [48]	Web-based	Bacteria, vaccine preventable disease	Evaluation: Quantitative followed by qualitative research design
Fadda et al., 2017; Fadda et al., 2018 [49]; [50]	Native mobile application	MMR vaccines	Evaluation: Mixed-methods research design
Ibuka et al., 2014 [51]	Web-based	Hypothetical disease	Evaluation: Experimental design
Kaufman & Flanagan, 2013 [52]	Web-based	Not reported	Evaluation: Experimental design
Lee et al., 2020 [53]	Native mobile application	Influenza	Evaluation: Randomized controlled trial

Authors name and references of the study	Type of gamified digital tool platform	Type of disease/vaccine	Type and design of the study (Development or evaluation, iterative design, randomized controlled trial etc.)
Mitchell et al., 2021; Laplana, 2019 [54]; [55]	Web-based	Influenza	Evaluation: Pre-post study
Mottelson et al., 2021 [56]	Virtual reality	COVID 19	Evaluation: Randomized controlled trial (2x2 factorial design)
Nowak et al., 2020 [57]	Virtual reality	Influenza	Evaluation: A one-way between-subjects design with random assignment
Real et al., 2017 [58]	Virtual reality	Influenza	Evaluation: Quasi- randomized controlled trial[1]
Woodall et al., 2021 [59]	Mobile-enabled web application	Human papillomavirus (HPV)	Evaluation: A clinic-cluster randomized trial
Vandeweerdt et al., 2022 [60]	Virtual reality	COVID-19	Evaluation: Randomized controlled trial
Development studies			
Amresh et al., 2019 [61]	Web-based	Human papillomavirus (HPV)	Development: Iterative design
Bertozzi et al., 2013 [62] *(Data extracted for the game related to vaccines)	Web-based	Influenza	Development: Iterative design
Carolan et al., 2019 [63]	Web-based	Measles, mumps, influenza and smallpox	Development: Iterative design
Kafai et al., 2017 [64]	Virtual reality	Dragon Swooping Cough virus to reflect real-life features of infectious viruses like	Development: User feedback via surveys (asking users questions) and

1 Allocation to a study arm was done according to work schedules, which are often arbitrary. We therefore considered this quasi-randomization.

Authors name and references of the study	Type of gamified digital tool platform	Type of disease/vaccine	Type and design of the study (Development or evaluation, iterative design, randomized controlled trial etc.)
		Ebola.	log files (observing user behaviours)
de Araujo Lima et al., 2022 [65]	Native mobile application	Vaccine-preventable diseases	Development: Heuristic evaluation by users, content evaluation by experts
Real et al., 2021 [66]	Native mobile application	Human papillomavirus (HPV)	Development: Usability testing
Streuli et al., 2021 [67]	Virtual reality	Paediatric vaccines	Development: Community-based participatory research and co-design
Development and evaluation studies			
Davies et al., 2015 [68]	Mobile or web application (multiple formats available)	Hepatitis B	Development and evaluation: Participatory Action Research
Ruiz-López et al., 2019 [69]	Native mobile application	Human papillomavirus (HPV)	Development and evaluation: Iterative design and evaluation via questionnaire

Table 3: Tools from Google search and expert suggestion:

Name of the gamified tool	Link	Type of disease/vaccine	Type of gamified digital tool platform	Gamification elements (e.g., rewards, role playing, leaderboard, serious game, etc.)
Antidote COVID-19	https://www.eurogamer.net/new-mobile-game-in-collaboration-with-who-raises-covid-19-vaccine-awareness	COVID-19	Native mobile application	Reward points
The vaccination game	https://mrcwimm.itch.io/the-vaccination-game	H11N7 and influenza	Web-based	Serious game
Help take down COVID-zilla!	https://www.albertahealthservices.ca/assets/info/ppih/covidzilla/index.html	COVID-19	Web-based	Role play
Just the Vax!	https://media.chop.edu/data/files/vaccine-trivia-game/index.html	Vaccine preventable disease	Web-based	Reward points
COVID invaders	https://www.getonedesk.com/covid-invaders	COVID 19	Web-based	Reward points
Vax pack hero	https://vaxpackhero.com/	Vaccine preventable disease	Web-based	Reward points and physical trading cards
Flu's clues	https://www.familiesfightingflu.org/virtual-flu-game/	Influenza	Web-based	Certificate of completion for solving the influenza mystery
Virus fighter	https://www.virusfighter.org/	COVID-19, Influenza, Ebola, Measles	Web-based	Serious game
Immunization411: for preteens and teens online training	https://health.mo.gov/living/wellness/immunizations/	Tdap, meningococcal, varicella, HPV and influenza	Web-based	Reward points

Name of the gamified tool	Link	Type of disease/vaccine	Type of gamified digital tool platform	Gamification elements (e.g., rewards, role playing, leaderboard, serious game, etc.)
	training/teenspreteens/index.html			
COVID Chronicles	https://covidchroniclesbc.ca/?v=17	COVID 19	Web-based	Reward points
I Boost[2]	https://iboostimmunity.com/	Vaccine preventable disease	Web-based	Quiz

2 Suggested by expert.

Reported effects of evaluated interventions

In total, eighteen (18) studies evaluated at least one of our outcomes of interest. Eleven studies have reported the effects of evaluated interventions of more than one outcome of interest. Summarized outcomes and their MMAT (Mixed Methods Appraisal Tool) quality assessments are shown in table 4. Multimedia appendix 4 provides full details.

Effects on knowledge (includes comprehension/understanding, etc.)

Overall, included studies suggested that gamified digital tools may positively influence knowledge. Of seven (7) studies that assessed knowledge, 6 studies showed an increase in knowledge about immunization in general [31,47,50,54,68,69]. All those 6 studies were of high quality, that is, 80% and above. One study of low quality (25% and below) reported that a digital game was less effective at increasing knowledge compared to its original board game format [52]. When considering only the high-quality studies (80% or higher), we observe that gamified digital tools are associated with increased knowledge.

Effects on attitudes (includes attitudes toward/against vaccination, etc.)

Overall, gamified digital tools appear to have mixed effects on attitudes. Of five (5) studies that assessed attitudes, 2 studies, one of high quality (80%) and other of medium quality (60%) showed an increase in positive attitudes toward vaccination [54,58]. Two studies, one of high quality (80%) and one of low quality (20%) reported no or less effects on attitudes towards vaccination [44,52], and one study comparing voluntary and compulsory vaccines in a game context showed negative attitudes regarding compulsory vaccination [43]. When considering only the high-quality studies (80% or higher), we observe inconsistent effects on attitudes.

Effects on beliefs (includes perceived benefits, perceived risks, etc.)

Overall, gamified digital tools may demonstrate overall positive effects on beliefs. Of three (3) studies, one of high quality (100%), and two medium quality (60%, 40%) evaluating the effects on beliefs towards vaccines, all 3 studies showed positive effects on beliefs towards vaccination [46,57,59]. When considering only the high-quality studies (80% or higher), we observe that digital gamified tools are associated with positive beliefs about vaccines.

Effects on behavioural intentions

Overall, included studies suggested that gamified digital tools may positively influence intentions to receive vaccines. Eleven (11) studies evaluated the effects on behavioural intentions with regard to vaccines. One study of medium quality (60%) showed a decrease in vaccine intentions when compulsory vaccination was introduced within a game context [43], whereas ten (10) studies of which 3 of medium quality (60% & 40%) and rest were of high quality (75% and above) evaluating the effects of gamified digital tools showed increased intentions to vaccinate [31,45,46,50,53,54,56,57,59,60]. When considering only the high-quality studies (80% or higher), digital gamified tools appear to be consistently associated with increased vaccination intentions.

Other outcomes

Nine (9) studies have also evaluated the effects of gamified digital tools on other outcomes. Four (4) studies reported an increase in confidence in vaccines (medium quality, 40%) [59], confidence in information needs (high quality, 80%) [44], decisional balance in support of vaccination (high quality, 100%) [31] and confidence in vaccine decisions (high quality, 80%) [49]. One study of high quality (80%) reported increases in empathy towards those vulnerable to COVID-19, vaccination recommendation [56], and 2 high quality (100%, 80%) reported increase in vaccination self-efficacy and readiness [31,56]. Increase in psychological empowerment (high quality, 80%) [50], and increase in emotions like anger towards compulsory vaccination (medium quality, 60%) [43] was also reported by 2 studies. One study of high quality (80%) reported that the concept of free riding decreases vaccine acceptance [51], whereas another study (high quality, 100%) reported that virtual reality intervention increases collective responsibility [60]. When considering only the high-quality studies (80% or higher), we observe a variety of positive effects associated with gamified digital tools, including confidence in vaccines, confidence in decisions about vaccines, empathy towards vulnerable people, collective responsibility, psychological empowerment, and vaccination self-efficacy and readiness.

Effects of platform (web-based, mobile, virtual reality)

The study designs of included articles do not permit us to formally compare the effects of different platforms in a robust way. By inspection, there does not appear to be a strong effect of platform. In other words, we do not observe evidence in favour of web-based, mobile, or virtual

reality applications over the other two types of application.

Table 4: Outcomes of evaluation studies included:

References of the studies	Knowledge (includes comprehension/understanding, etc.)	Attitudes (includes attitudes toward/against vaccination, etc.)	Beliefs (includes risk perceptions, etc.)	Behavioural intentions (includes getting vaccinated or not, etc.)	Others (e.g., emotions)	*MMAT Quality score (percentage)
Web-based						
Betsch & Böhm, 2016 [43]	–*	Negative vaccine attitudes with compulsory vaccination	–	Decreased vaccine uptake with compulsory vaccination	Increased level of anger with compulsory vaccination	60% quality criteria met
Carolan et al., 2018 [44]	–	No significant effect on attitudes towards vaccination	–	–	Increased confidence in information needs	80% quality criteria met
Cates et al., 2020 [31]	Increase in knowledge about immunization	–	–	Positive increase in intentions to vaccinate	Increase in vaccination self-efficacy, decisional balance towards vaccination	100% quality criteria met
Darville et al., 2018 [46]	–	–	Positive effects on beliefs towards vaccination	Increase in intentions to vaccinate	–	60% quality criteria met
Eley et al., 2019; McNulty et al., 2011 [47]; [48]	Improvements in knowledge about immunization	–	–	–	–	100% quality criteria met
Ibuka et al., 2014 [51]	–	–	–	–	Free riding in vaccination decisions decreases vaccine acceptance	80% quality criteria met
Kaufman & Flanagan, 2013 [52]	The digital version of the game was	The digital version of the game was	–	–	The digital version of the game was	20% quality criteria met

References of the studies	Knowledge (includes comprehension/understanding, etc.)	Attitudes (includes attitudes toward/against vaccination, etc.)	Beliefs (includes risk perceptions, etc.)	Behavioural intentions (includes getting vaccinated or not, etc.)	Others (e.g., emotions)	*MMAT Quality score (percentage)
	less effective at facilitating learning	less effective at attitude change			perceived to be complicated to use	
Mitchell et al., 2021; Laplana, 2019 [54]; [55]	Increase in knowledge	Positive increase in attitudes for vaccination	–	Increase in vaccine uptake after accessing the game	–	80% quality criteria met (Mitchell et al., 2021 [54])
Mobile						
Dale et al., 2019 [45]	–	–	–	Positive increase in intentions to vaccinate	–	80% quality criteria met
Fadda et al., 2017; Fadda et al., 2018 [49];[50]	Improvements in knowledge about immunization	–	–	Increase in intentions to vaccinate	Increase in psychological empowerment and confidence in the decision	80% quality criteria met (Fadda et al 2017[49]; Fadda et al., 2018 [50])
Lee et al., 2020 [53]	–	–	–	Increase in intentions to vaccinate	–	80% quality criteria met
Ruiz-López et al., 2019 [69]	Increase in knowledge after playing the game	–	–	–	–	100% quality criteria met
Woodall et al., 2021 [59]	–	–	Increase in beliefs towards vaccination	Increase in intentions to vaccinate	Increase in vaccine confidence	40% quality criteria met
Virtual reality						

References of the studies	Knowledge (includes comprehension/understanding, etc.)	Attitudes (includes attitudes toward/against vaccination, etc.)	Beliefs (includes risk perceptions, etc.)	Behavioural intentions (includes getting vaccinated or not, etc.)	Others (e.g., emotions)	*MMAT Quality score (percentage)
Mottelson et al., 2021 [56]	–	–	–	Increase in vaccination intention when both the personal and collective benefit of COVID-19 vaccination was communicated	Increase in COVID-19 empathy, vaccination recommendation, and vaccination readiness	80% quality criteria met
Nowak et al., 2020 [57]	–	–	Positive effects on beliefs towards vaccination	Increase in intentions to vaccinate	–	100% quality criteria met
Real et al., 2017 [58]	–	Increase in attitudes in favour of vaccination	–	–	–	60% quality criteria met
Vandeweerdt et al., 2022 [60]	–	–	–	Increase in intentions to vaccinate	Virtual reality intervention increases a sense of collective responsibility	100% quality criteria met
Mobile or web application (multiple formats available)						
Davies et al., 2015 [68]	Increase in knowledge about immunization	–	–	–	–	80% quality criteria met

*– = Not reported; * MMAT=Mixed Methods Appraisal Tool

Discussion:

Principal findings

The broad objective of this scoping review was to map the state of the science regarding gamified digital tools and their effects. In other words, we wished to answer a common question at the intersection of public health and digital health: does gamification encourage vaccination and influence knowledge, attitudes, beliefs, and behaviors related to vaccination? By mapping both published literature and tools currently available online, we observed two principal findings.

First, our results suggest that gamification can increase predictors of vaccine uptake such as knowledge, attitudes, beliefs, behaviour, and vaccine intentions. This finding is similar to the findings of a previous review by Montagni and colleagues [70] suggesting that gamification can contribute to changed behaviors and improved knowledge on vaccination. Similarly, other reviews have suggested the potential benefits of gamification for non-vaccination-related behaviour change, such as a systematic review suggesting that the gamification interventions could be a feasible way to improve health-related outcomes among cancer survivors, [71], and another review suggested its effectiveness on improving the physical activity [72]. Such previous work became even more relevant during the COVID-19 pandemic, as many jurisdictions sought to optimize vaccine uptake in a context of ‘infodemic’ (i.e., overabundance of information - true, false and misleading, on the pandemic and recommended preventive behaviours) [73]. Half of the gamified digital tools identified in our web search addressed COVID-19, suggesting an active interest in using a gamified approach in the pandemic context. Recent research by Plechatá and colleagues [74] published after our data extraction steps were complete suggested that explaining the concept of herd immunity with gamification had a positive impact on COVID-19 vaccination intentions.

Second, our review suggests that while gamification has the potential to enhance the impact of education strategies, gamified tools alone may not wholly address gaps in vaccine acceptance and uptake. Although some of the identified tools did increase vaccination, the increases did not fully close gaps between previous and desired vaccine uptake. This finding aligns with those of Tozzi and colleagues, [75] which suggested that promising results could be achieved by combining gamification with educative and informative tools to improve immunization programs. This finding also aligns with previous reviews suggesting the use of

digital gamified interventions as a public health tool of interest in enhancing vaccine uptake [70,76]. Further research published by Real and colleagues [77] after our systematic search similarly observed that integrating gamification like virtual reality in training modules enhanced uptake of Human Papillomavirus vaccines. Integrating gamified features may work because they make digital tools acceptable and more fun to use, and may reduce the chances of people feeling pushed toward vaccination. In parallel, gamification may be a promising strategy for increasing knowledge, skills, and confidence among health professionals engaging in discussions about vaccines with their patients [78,79].

In addition to the above findings drawn directly from our review of the included tools, we offer a broader observation based on the contents of this scoping review along with the larger landscape of vaccine acceptance research: context is key. While an engaging approach may work for some groups or in some situations, it may be less well-accepted among other groups and in other situations. For instance a casual and approachable style of communication will work for the younger audience to convey vaccine information but might be deemed insufficient to healthcare professionals in a more formal setting such as hospitals. A good understanding of the factors associated with low vaccine acceptance at the local level is needed prior to developing gamified tools [80]. Future research in this area should consider possible contextual factors like local culture, social and demographic characteristics of users, and different influences on vaccine hesitancy and acceptance in different regions. To help to better match games to the context(s) in which they will be played, when developing games, developers and researchers may wish to consider involving potential players from different contexts early and often. This aligns with previous work [81,82] suggesting that involving users earlier in developing tools may help in designing intervention suitable for a targeted context. One of the examples in our review was an intervention by Cates and colleagues [31] designed to explain HPV vaccines for teenagers using a Secret Garden theme. Involving potential game players early in development of the game may have contributed towards its positive effects on vaccine intentions.

The implications of this research extend beyond the immediate reported effects of gamified tools and delve into the strategic dimensions of public health policy and communication efforts. Taking into account the insights gleaned from the findings, this study supports a comprehensive and well-informed approach to integrating gamification into strategies for promoting vaccination. As gamification continues to demonstrate its potential in enhancing

vaccine uptake, it is crucial to navigate this terrain thoughtfully, taking into account the various factors that influence its impact. This includes not only the technological and behavioral aspects but also the larger socio-cultural context in which vaccination decisions are made. Therefore, our study emphasizes the importance of a comprehensive approach that fosters a mutually beneficial relationship between technological innovation, evidence-based strategies, and an intricate understanding of local contexts. This approach has the potential to make gamification a sustainable and adaptable tool in the arsenal of public health interventions, rather than just a passing trend.

The review does not find a clear advantage for any platform in terms of reported effects. This was challenging to measure the impact of platform on behavioural outcomes and calls for more focused research to better understand the specific elements within each platform that drive behavior change. In essence, our study suggests that the reported effects of an application may not be solely determined by its platform, but rather by the strategic incorporation of mechanics and elements that facilitate the desired behavior change.

Gamification can influence knowledge, attitudes, and beliefs about vaccines, which can affect vaccination uptake. This is consistent with theories of change proposing that cognitive changes can lead to behavioral outcomes. Although our study mainly examines the immediate effects of gamification on these cognitive aspects, it also offers some implications for using gamification as a potentially viable strategy to improve vaccine acceptance.

Strengths and limitations

Our study has five main limitations. First, because we aimed to capture all relevant evidence and examples, as is typical in a scoping review, we included a broad range of study designs and ~~ therefore did not apply quality criteria intended for single-design knowledge syntheses nor~~ did not draw conclusions about the relative advantages or disadvantages of different game platforms and features. Given the rapid growth within this field of research, it would be difficult to truly prioritize evidence according to quality criteria at this point. In the future, it may be possible to conduct a systematic review and meta-analysis, restricting included studies to randomized experiments or randomized controlled trials. Such future work may include approaches such as a network meta-analysis to allow for comparison of the effects of different game types or game features. Based on the existing literature, it is difficult to conclude

whether certain games are more or less likely to achieve their aims. Second, our results may be influenced by publication bias. It is possible that groups that have developed gamified digital tools that showed disappointing results simply did not publish their studies. This bias could lead to an overestimation of the reported effects of these tools. This highlights the importance of further research to fully understand the real impact of these tools and thus accurately inform policy decisions about the development and use of these tools.Third, and related to the previous two points, the rapid growth in this area may mean that we missed more recent evidence published literature after January 2022, and web searches after May 2022. Fourth, the majority of gamified digital tools on vaccination represented in publications and online were developed in high income countries. This finding aligns with the findings of previous work by Ohannessian and colleagues [76], who also reported a predominance of high-income countries. This may reflect more widespread internet access and resources for developing gamified digital tools in developed countries. It may also reflect publication bias in the scientific literature (i.e., there may be fewer papers written about gamified digital tools in lower income countries) and online (i.e., tools developed and published in lower income countries may not be ranked highly by search engines and therefore may not have appeared in our web searches.) Tools developed in lower income countries may also take different forms; for example, they may be text message-based interventions (with or without gamification) rather than web-based tools and therefore would be less likely to be identified in web searches. Analog games from higher income countries were similarly excluded from the scope of our study [83]. Non-digital games like board and card games have demonstrated positive impacts on educational knowledge, cognitive function, and social interactions [84,85]. Such games can support diverse learning across subjects and settings, fostering interactions that develop skills like computational thinking and teamwork and have positive impacts on academic achievement and vocabulary acquisition compared to digital games [85–87]. We restricted our scoping review to digital gamified tools because the review was intended to provide an evidence base for digital game development. While non-digital games are also potentially useful interventions, the implementation and distribution of such interventions is more challenging, especially in a geographically-dispersed country like Canada. Fifth and finally, we have used Google and private browsing in Google, there may be a possibility that different search engines would provide different results.

This study also has two main strengths. First, by systematically examining current

literature and currently available tools online, we were able to offer an updated overview of the potential effects of including gamification in digital tools about vaccination. Second, by conducting a scoping review to broadly map the literature, future work can more easily identify and select key outcomes for systematic reviews and meta-analyses in this domain.

Conclusion:

Gamified digital tools have potential for improving vaccine uptake by increasing knowledge and promoting positive attitudes, beliefs, behaviour, and vaccine intentions. Further evaluations of these innovative digital tools, including head-to-head comparisons of different features and different platforms will add more knowledge about what works and what does not to achieve public health goals more efficiently. In the wider context of health policy, gamified digital tools may be useful components of multifaceted strategies to improve vaccination rates throughout society.

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Authors' Contributions

All authors provided substantial contributions to this paper’s conception and edits, and approved the final version of the manuscript.

Conflicts of Interest:

None declared

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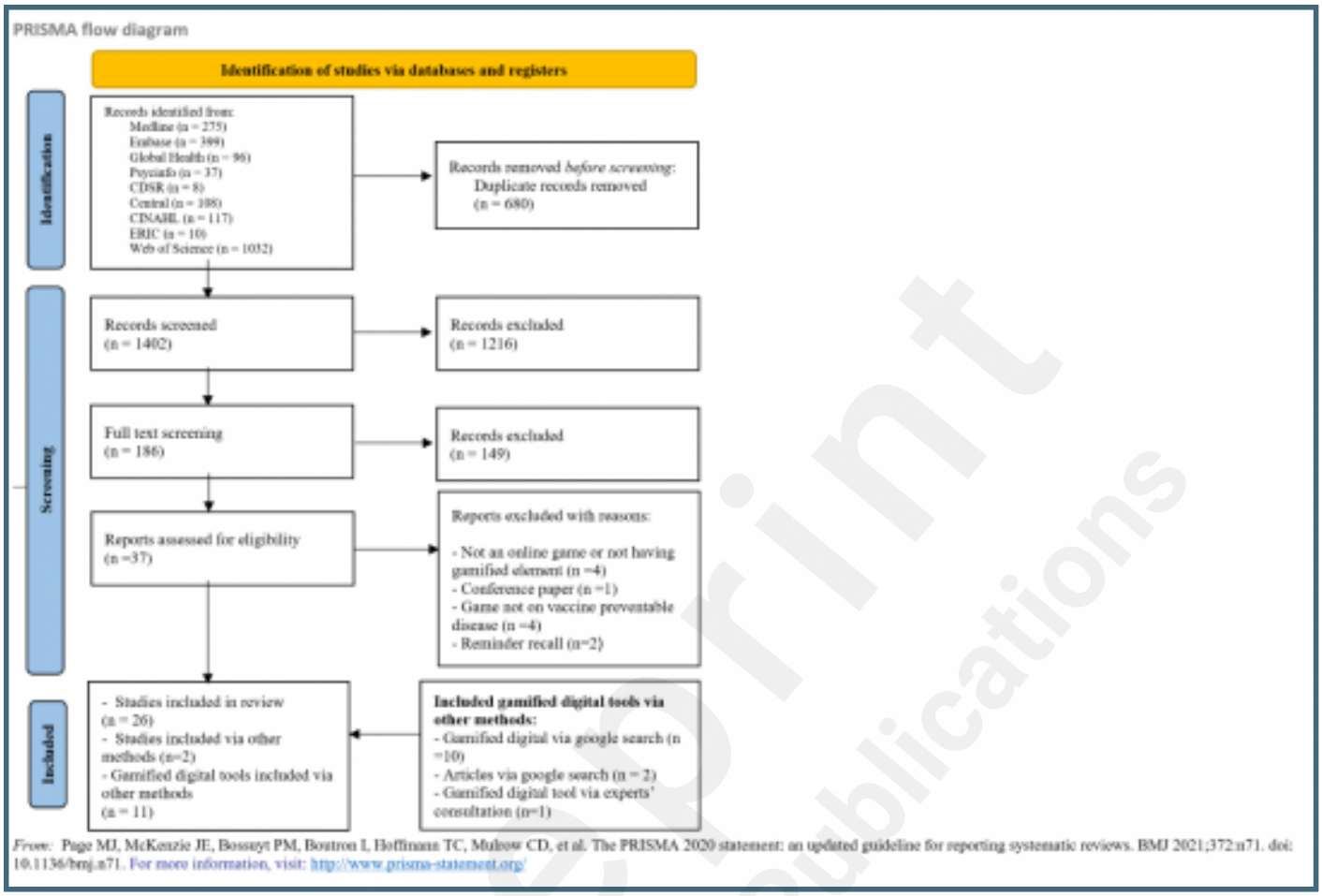
Supplementary Files

Highlighted version of the manuscript.
URL: http://asset.jmir.pub/assets/65b032df6589bb7a4a8ba8d28f4de684.docx

Revised version with tracked changes.
URL: http://asset.jmir.pub/assets/a0d60a658d8395dc6aaab2ca38a1652f.docx

Figures

Prisma flow diagram.



Multimedia Appendixes

Prisma checklist.
URL: http://asset.jmir.pub/assets/2953ddda09057a90ecbd6270796b32c0.pdf

Search strategy.
URL: http://asset.jmir.pub/assets/96b72ed2ba06d4ab7ef0935e332edfab.docx

Characteristics of the studies included in the review.
URL: http://asset.jmir.pub/assets/0aac567303bf630b02a5c338b91d829f.docx

Expanded version of table 2: General information of the studies.
URL: http://asset.jmir.pub/assets/37b3f88572845c3023e8e54d1c61df3b.docx

MMAT quality assessment.
URL: http://asset.jmir.pub/assets/09c5b5ea454c03cff455fb3e6ee202bb.xlsx

CONSORT (or other) checklists

Updated PRISMA-ScR-Fillable-Checklist.
URL: http://asset.jmir.pub/assets/b3b76221bd27ed817414ec4e55d1d323.pdf