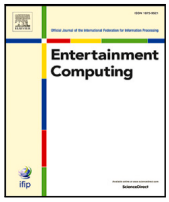
Collocated interactive outdoor games for children

Entertainment Computing 49 (2024) 100615

Contents lists available at ScienceDirect

Entertainment Computing

journal homepage: www.elsevier.com/locate/entcom



Review

Collocated interactive outdoor games for children: A systematic literature review

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ARTICLE INFO

Keywords:
Outdoor gaming
Pervasive gaming
Head-up gaming
Active video games
Exergaming
Technology supported outdoor games
Children
Adolescents
cci
hci

ABSTRACT

Outdoor play is an important component in the development of children and adolescents. Nevertheless, there is a growing trend towards replacing outdoor play with sedentary indoors activity, related to media consumption and computer games. Researchers in child computer interaction and related fields have been developing games that can be played outside, encouraging physical activity and social interaction. This article reviews this niche but substantial body of work, aiming to provide an overview of these games, the evidence provided regarding the benefits they claim to provide and related methodological issues. The paper takes a critical reflection on the role of technology in outdoor play and suggests areas for future research, including the learning and developmental benefits that these games can provide to children in the long term.

1. Introduction

Outdoor play is important for the development of children, providing them with various developmental benefits that can be social skills (e.g., learning to negotiate on fairness of the rule set or cheating), motoric skills, cognitive (e.g., creative thinking, tactics) and emotional (e.g., learning to deal with winning or losing) skills as well as physical activity [1,2]. Researchers [3] even coin the term "outdoor play benefits" referring collectively to such benefits gained from outdoor play.

Stimulating outdoor play is particularly beneficial for children, particularly in the face of some worrying developments worldwide. A recent report by [4] shows that the levels of physical activity amongst children and adolescents globally are considerably low, with more than 80% of adolescents throughout the world not attaining the recommended amount of physical activity [5]. This trend is partly attributed to an increasingly sedentary lifestyle amongst children and adolescents [5]. Based on the large and growing body of evidence demonstrating the positive effects of regular physical activity [6] and the negative effects of the lack thereof mentally [7] and physically [8] it seems of key importance to reduce sedentary behaviours, encourage physical activity and increase exposure to outdoor play benefits for children and adolescents through play.

Play can take many forms, from fantasy play and role-play to sports and team play across almost every modality imaginable, varying from simple sticks used as make-believe swords to fully immersive virtual reality setups. Over the years, outdoor play has lost ground to gaming [9]. As most digital indoor games take place on a computer, handheld, or console, the physical activity involved is quite limited. Secondly, with less time spent outdoors playing, children and adolescents receive less of the well described outdoor play benefits.

Researchers have approached the challenge of enhancing outdoor play and physical activity for children and adolescents from multiple angles, such as: psycho-social (e.g., increasing self-regulation of a child to play outside), parenting skills (e.g., limiting screen time [10], and more design-centred remedies such as landscape design that promotes active play and interactive games that promote active behaviour. Especially the latter have been gaining traction within the scientific fields concerned with game design and with child–computer interaction. We can discern at least three categories of such games in related literature (also summarized in Fig. 1). (A) Exergames & Active Video Games, (B) Intelligent Playgrounds, and (C) Technology Supported Outdoor Games.

A — Exergames & Active Video Games

Exergames and the less frequently mentioned: Active Video Games are built on the premise that by adding physical activity to video games (new or existing) the game remains desirable to play, and the induced physical activity will generate health benefits. Exergaming has become one of the more prevalent fields of study over the past few years

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https://doi.org/10.1016/j.entcom.2023.100615
Received 19 February 2023; Received in revised form 23 July 2023; Accepted 18 October 2023
Available online 20 October 2023

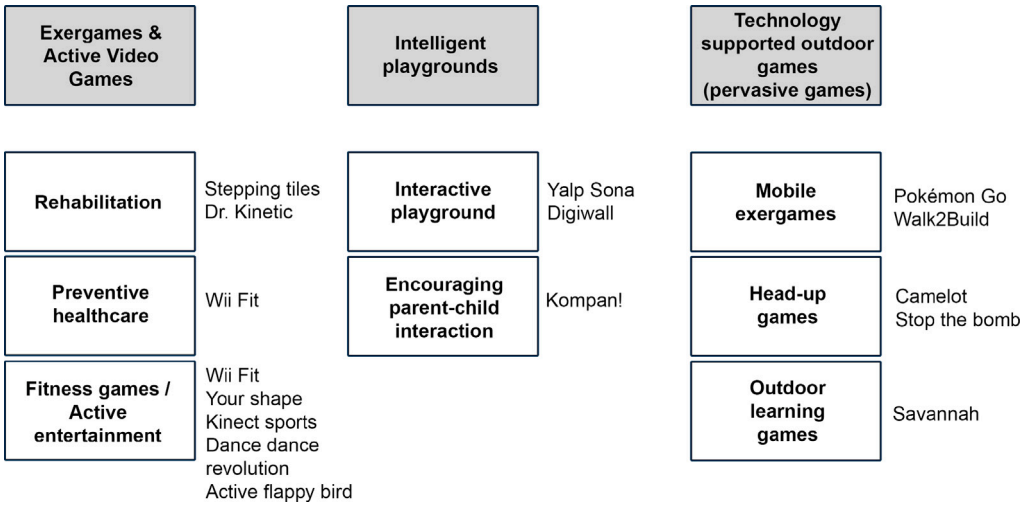

Fig. 1. Overview of categories of games.

to combat sedentary lifestyles among children [11]. Various studies have examined the effectiveness, exertion, social benefits but also the deficits of exergaming [12,13]. Exergaming has gained traction within the health sciences for rehabilitation [14], prevention of illnesses and even curing of certain ailments [15,16].

There are many commercial exergames supported by popular gaming platforms such as the XBox Kinect, Nintendo Wii & Switch, including popular titles such as Dance Dance Revolution, Wii Fit, Kinect Sports, Just Dance, EA Sports Active and other less known exemplars such as: Dr. Kinetic[1] and Stepping Tiles.[2] Using devices such as Head-Mounted Displays (e.g., Oculus Rift and HTC Vive) researchers have experimented with exergaming in virtual reality [17]. On the other hand, Nurkkala, Kalermo & Järvilehto (2014) [18] propose using exergaming in physical gym locations. Lastly, there are studies that incorporate physical activity interfaces to pre-existing games. Such as, [19] who created two "active" versions of popular video games (Flappy bird and Temple Run).

Widespread academic attention has been given to this category of gaming, generating a variety of literature reviews. An overview of Active Video Games (AVG) [20] that Exergame and AVG's evoke higher exertion than traditional video games. Similarly, [12] generated an overview AVG's that promote physical play and their energy expenditure. While claims on higher energy expenditure are echoed by several studies when exergames are offered in laboratory settings or paediatric obesity programs, these results are far less when the game is offered in an unstructured place, such as the child's home [21].

B — Intelligent Playgrounds

Intelligent playgrounds, occasionally mentioned as interactive playgrounds, [22,23] are related concepts referring to playgrounds or specific objects therein are designed to be interactive objects that have a high affordance drawing children to play with them. What differentiates these playgrounds from "ordinary" playgrounds is the usage of interactive objects allowing to sense, interact, or respond to users. Examples of these playgrounds are discussed in [22–25]. Notable examples can be found both in research works but also as commercial offerings: *Yalp Sona and Memo*, interactive playground devices, *Yalp Fono*, Interactive DJ-booth, *Yalp Toro and Sutu*, interactive sporting playgrounds, *DigiWall*, an interactive climbing wall, *TacTower*, Interactive installation for running games, *Kompan! Smart Playground* and *the Biba Playground* which both use an app to bring elements of the playground to life. Most of these playgrounds are aimed at children and adolescents. Sometimes the design incorporates interaction between parent and child through imagination and fantasy (e.g., Kompan! and Biba) or contains several affordances such that it can also be used for more training related purposes (e.g., TacTower, Yalp Toro and Sutu). Yalp Toro, Sutu, Sona, Memo, Fona, Digiwall, Biba playground and the Kompan! Smart playground are all commercially available products, whereas TacTower has been used only in a research context so far. Empirical user evaluations of these intelligent playgrounds are challenging. As Poppe et al. states: "*Such evaluations are difficult as the goals of the playground are typically not explicit and might be achieved unconsciously*" [25]. To evaluate such playgrounds with regard to children's activities, Researchers have proposed gathering observational data of play sessions or using the interactive components of the intelligent playground to measure interactions and movements objectively [25].

C — Technology supported outdoor games

The games considered in this category, also called pervasive games, are outdoor games which use pervasive technology to support the game. This (technological) support can serve different purposes, such as: providing a highly immersive play experience [26–28], limiting the possibility to cheat [29] and supporting new forms of interaction [3,30,31]. Differing ideas have been put-forward regarding the level of influence technology should have, as well as the benefits that result from playing the game. Roughly, we can distinguish between the following types: (1) *mobile exergaming* [32,33], in which the players physically exert themselves to gain points, credits or simply to interact with a digital device. For example, Walk2Build generates a digital city with buildings that differ in height based on the amount of steps the player made that specific day, thereby motivating the player to take more steps a day. (2) *HUG's* [Head-Up Games34,35], emphasize behaviours that have traditionally been characterized as outdoor play, such as physical activity and fluent social interactions. HUG's avoid the use of screens that draw the players' attention away from their surroundings and other players. Camelot is designed as such a game, where the player has to collect "digital" resources by physically touching them and transport them to different locations. Lastly, (3) *outdoor learning games* [36], which focus on learning goals with physical activity. One such example is the game Savannah [37,38], in which children have the opportunity to experience life as a pride of lions via a PDA in an outdoor playing field, thereby learning about the behaviours of a lion. [36] offers an overview of mobile location-based games and evaluates their impact and relation to learning across physical and virtual spaces.

The objective of achieving higher levels of physical activity as well as decreasing sedentary lifestyles could possibly be attained by using

[1] https://doctorkinetic.com/

[2] https://www.uts.edu.au/research-and-teaching/our-research/social-futures/our-research/interactive-stepping-tile-rehabilitation

any game described in the categories above. Additionally, some of these games will strengthen other benefits arising from play behaviour, such as the before mentioned outdoor play benefits. Throughout the development of games, attention has grown towards games tailored to aid in specific purposes, such as more social and inclusive gaming. Some examples can be found in the forms of Playground Architect [39], pOwerball [40] and Scorpiodrome [41] which are all forms of tabletop games that focus on promoting social interactions among children. This ambition to support social interactions in a game can also be found in most of the above-mentioned categories, with discussions most prominently revolving around the influences of existing video gaming on social development of a child or adolescent. Shoshani & Krauskopf (2021) define this as the social paradox of video games [42]. As [31] points out, pervasive games (i.e., technology supported outdoor games) could potentially address both physical and social benefits. Others go further to claim that these games have the potential of addressing the whole host of outdoor play benefits [3]. A wide range of game genres made possible in the realm of pervasive gaming could help deliver these benefits. As boundaries between device, user and the real world fade, new forms of interaction may arise.

The overview of related research above, demonstrates how this growing field pursues divergent aims sometimes addressing adult players, sometimes health benefits, and can be played in a variety of contexts that may or may not be suitable for children players. Given the vital importance of outdoor play for children's well-being and development, we are interested specifically in outdoor games for children. While there is an abundance of research, a synthesis of results regarding design concepts and empirical evidence regarding their benefits for children is still lacking. The need arises to describe progress booked and identify future directions for this subfield of child–computer interaction. Specifically, with many game designs being proposed and evaluated that have overlapping goals and related approaches to engage with children, it seems timely to classify the games created and evaluated by researchers, to assess the evidence that research has delivered as to whether outdoor play benefits are attained by playing such games, the role of technology in outdoor play, gaps in categories of games, and challenges that future research should address.

We propose the following research question:

What kind of interactive outdoor games have researchers proposed to address the challenges related to sedentary lifestyles and decreases in exposure to outdoor play benefits?

- A-1: What are the different genres of games that fit this overall scope?
- A-2: What are the claimed benefits that could arise from these games?
- A-3: What levels of evidence are provided by researchers towards the effectiveness of their games?
- A-4: How is age reflected in game design?

To answer these questions capturing the state of the art in this field we engaged in a systematic literature review. In the remainder of this paper we report the methods used and an analysis of a selection of papers that help identify priorities and themes for future research in the field of (digital) outdoor gaming.

2. Method

2.1. Data sources and search query iteration

We conducted a literature review with the SCOPUS indexing service. The latest and definitive search was issued on 28th of November 2021. SCOPUS indexes the most relevant conferences and journals for the field of human–computer interaction, so no journals or conference proceedings were additionally included in our initial search. We considered additional papers if they were cited in the included papers, however only once a thorough keyword research determined that the paper had a valid reason for not being in the initial scope. Our search query was initially generated by breaking up the research question in 5 components, namely: (1) a form of outdoor, physical or exertion play, (2) a technological aspect (e.g., an interface or device), (3) a social component, (4) targeted at children, teenagers and/or adolescents, (5) an intervention, observation or other form of evaluated study (see also: Table 1). Synonyms, abbreviations and variations were added to each individual clause, after which the initial search commenced. Several relevant papers were obtained and scanned for additional keywords, tags, and phrases currently not present in the search query, until the query was deemed exhaustive.

Table 1
Number of papers per search clause deemed relevant.

Search clauses	Papers	Papers relevant
Outdoor, Technology, Social, Children & Study	180	22
Outdoor, Technology, Children & Study	696	46
Outdoor, Technology & Children	789	50
Outdoor, Technology, Children & Active	409	34

The initial search query resulted in 180 papers, of which 22 were found to be relevant by title and abstract. Upon reviewing the initial 22 papers the researchers found that several previously known papers were not included in this dataset. Therefore, widening of the search query was deemed useful. First, the Social clause was removed (3), yielding 696 papers. The delta was evaluated (again, based on relevance of title and abstract), resulting in an additional 24 potentially relevant papers. After dropping the study c.q. experiment clause (5) the total number of papers rose to 789 papers of which an additional 3 papers were added as relevant. The final query is presented in listing: 1. The omitted clauses are presented in Appendix. Please note, as more papers got published after the initial query iteration, the definitive amount of papers scrutinized differs from the previously mentioned amounts.

Conference Proceedings

Within this set, we found several entire conference proceedings. These conference proceedings contained a number of papers, varying from work in progress to full papers. To ensure no relevant papers were lost in the process, all papers within these proceedings were reviewed on title and abstract in accordance to the selection criteria mentioned below. However, all relevant papers within these proceedings were already in our selection of papers, as they had been individually identified by our search query.

Commercial Games

There may be relevant commercial games which are developed by companies and possibly tested internally. These are out of the scope of our survey, unless the study is reported in a peer-reviewed scientific publication.

2.2. Selection process and review protocol

All 833 papers were considered for review of title and abstract first in accordance to the criteria described below. When it was found that the title and abstract did not provide a definitive reason to exclude the paper, the paper was scanned and the full-text was again matched in accordance to the criteria below.

- The study describes a (mobile) game;
- The game takes place in an outdoor context;
- The study has evaluated the game in some form;
- The evaluated game includes a technological element (e.g., electronic device/hardware, smart-phone or otherwise);
- The target group for this game was either a child or an adolescent.

Listing 1: Search Query

```
TITLE-ABS-KEY (
    ( "outdoor play" OR "outdoor games" OR "outside play"
        OR "playing outside" OR "outside gaming" OR
        "outdoor gaming" OR "exertion gaming" OR exergam*
        OR exer-gam* OR ( exertion AND game ) OR
        ( exertion AND games ) OR "head-up games" OR
        "head up" OR "HUG's" OR "gaming outdoor"
        OR "pervasive gaming" OR "pervasive game" )
    AND ( interaction OR mobile OR device OR handheld OR
        computer OR hci OR cci OR hti OR pervasive OR
        "ubiquitous computing" OR ubicom OR
        "augmented reality" OR ar OR vr OR
        "virtual reality" OR tangible OR interface
        OR interactive OR technical OR virtual )
    AND ( child* OR juvenile OR adolescent* OR
        kid* OR teen* OR youth OR tween OR "pre-teen" ) )
```

We specifically opt to only include studies that have some form of evaluation to be able to assess whether the claimed benefits yielded the promised results. The other criteria are merely to define the scope of an outdoor game that uses technology for the target group, children or adolescents. After full-text reading, several papers were omitted for various reasons. First, a workshop description by [43], describing the intended evaluation of smartwatch exergaming. Next to these, six more papers did not contain an evaluation of the proposed game [32,44–48]. Seven papers described indoor games: [49–55]. Although the game setup might not necessarily enforce this, we opted to exclude these from our review. In total, an additional 23 papers were thus excluded, leaving 27 papers to be included in the review.

Reverse Lookup

Lastly, a reverse lookup was performed on the games' mentioned in the included papers on Google Scholar and SCOPUS, to ensure no additional information was missing from the final dataset. From this search, one additional paper was included.

The entire selection process is also denoted in the PRISMA diagram [56] shown in Fig. 2.

2.3. Pre-registration

The review was pre-registered on Open Science Foundation under DOI: 10.17605/OSF.IO/39PW6. All previously described procedures were followed, and additional findings are marked as post-hoc in the discussion section.

2.4. Data extraction and synthesis

In line with our review protocol, a data extraction scheme was devised to extract information relevant to our research questions. During the extraction of data, post-hoc findings were noted and where necessary other papers were revisited to gather additional information. These post-hoc findings will be presented separately in the following sections.

Two sets of papers require a specific mention, the first by [26] as it describes a game which can be used underwater. Whilst tested indoors, this is just incidental to the particular evaluation location and the game can easily be played outdoors. Secondly, we considered the papers by [3,30,57–63]. Their focus was on developing interactive devices for open-ended play, rather than any game specific (e.g., offer a way for children to create their own games). Therefore, in two cases, no specific game is mentioned by name, but rather the set of games is named by the underlying platform (Scratch Nodes and IoT games respectively). We chose individual games as the unit of analysis in our survey for which we combine our presentation of papers referring to the same game (e.g., [64,65]). Conversely, where one article describes multiple games, these games are considered separately in our analysis. Lastly, the game: "Defuse the Bomb" mentioned in the paper by [35] is not accounted for in our review as this game is transformed directly to another game: "Stop the bomb" which is based on "Defuse the Bomb" and "Africans and Lions" and uses largely the same mechanics. This is in contrast to the game: "Follow the Light" by [66], which was not developed further after evaluation of the game turned out poorly and is included fully in our evaluation.

3. Results

3.1. Overview of games

The initial overview of extracted games can be found in Table 2. Research findings are discussed per games. However, where better insights can be gained by doing so, we discuss also research findings per research paper or researcher.

3.2. Genres

We classified games by similarity into 'genres' based on the descriptions of the game by the researchers. If the game was part of a series resulting from an iterative design process, the latest version of the game was considered. The full overview of genres can be found in Table 2. In Fig. 3 we have visualized the grouping and the frequency of occurrence for each genre within our data-set. High-level descriptions of the genres are provided further down.

Tag — The act of tagging, catching, or holding onto another person or item which changes the state of the game, person, or item. Whereby, possibly transferring an item, a property, a state, or a task upon this person. The physical activity for achieving this is competitive.

Treasure hunt — Finding one or more specific items or places as the main goal of the game. The location of this specific item or place is often cryptically presented or unknown to the player. Treasure hunts are often location bound, or have to be set up in a predefined area.

Gathering — Acquiring one or multiple items. The locations of these items are often known, and the act of acquiring entails a challenge. Furthermore, the game may or may not support a trading system of some sorts.

Catch and throw — The act of throwing, catching and/or passing along a certain item with the intent of getting this item in a certain place or time to score points. These areas of scoring (e.g., a goal) or

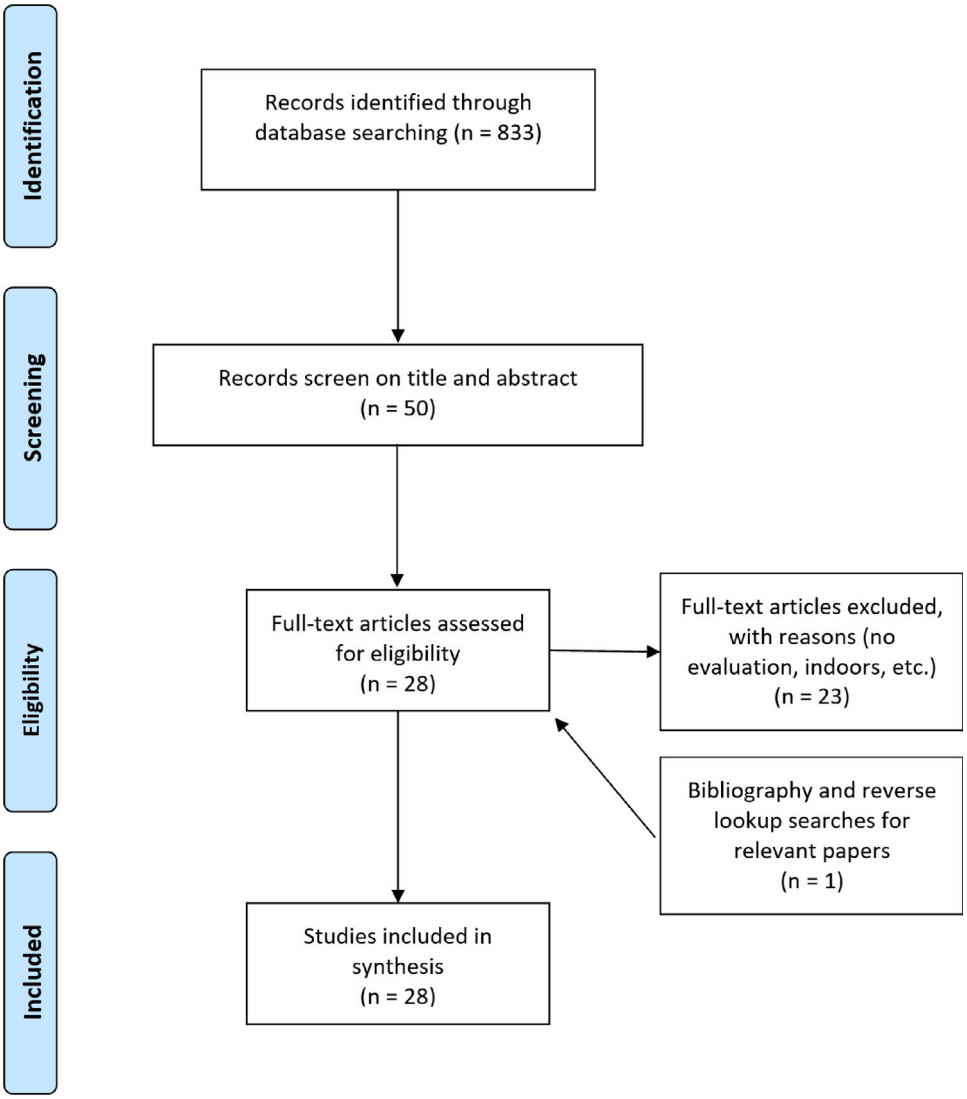

Fig. 2. PRISMA Diagram of paper selection criteria.

Tag	Gathering	Exertion	Capture the Flag	Catch and Throw	Multi-genre	Outdoor Exploration	Treasure Hunt	Memory	Luck	Smuggling
[65]	[65]	[75]								
[35]	[35]	[75]	[65/66]	[75]						
[72]	[26]	[75]	[65]	[35]	[62/30]					
[69]	[29]	[75]	[35]	[63/64]	[56/3/57/58]	[27]	[74]			
[69]	[29]	[73]	[29]	[70]	[59/60]	[71]	[27]			
[67/68]	[29]	[73]	[31/66]	[70]	[61]	[28]	[28]	[35]	[65]	[66]

Fig. 3. An overview of games per genre, more cases were reported due to the possibility of multiple genres per game.

Table 2
Overview of all games found in the data collection.

#	Game	Paper(s)	Genre	Individual or Team	n	Ages
1	HeartBeat	[31] [67]	Capture the Flag	Team	32 32	8–12 11–13
2	Cato	[29]	Gathering	Team	10	7–10
3	Quattro		Gathering	Individual	10	7–10
4	Wizards and Witches		Capture the Flag	Team	10	7–10
5	Camelot		Gathering	Team	10	7–10
6	SoundTag	[68] [69]	Tag	Individual	7	5–10
7	GiggleBat	[62]	Multi-genre	Individual	7[a]	3–5
8	The Mystery of Elin	[28]	Outdoor Exploration /Treasure hunt	Individual	82	7
9	Escape the Ghost	[70]	Tag	Individual	25	12–15
10	Collect the Coins		Tag	Individual	25	12–15
11	Ultimate Swinxsbee	[71]	Catch and Throw	Individual	32	8–12
12	Multibee		Catch and Throw	Individual	32	8–12
13	UbiBall	[64] [65]	Catch and Throw	Team	12	7–9
14	AREEF	[26]	Gathering	Individual	36	7–12
15	ABBOT	[72]	Outdoor Exploration	Individual	170	3–7
16	ShadowHunter	[27]	Outdoor Exploration /Treasure hunt	Individual	10	4–6
17	SoundWear	[60] [61]	Multi-genre	Individual & Team	16	10–11
18	BuzzTag/BuzzThief	[73]	Tag	Individual & Team	65	7–11
19	Scratch Nodes	[57] [3] [58] [59]	Multi-genre	Individual & Team	6 48 15 24	8–12 8–12 8–12 9–12
20	IoT games	[63] [30]	Multi-genre	Individual & Team	N.R.	7–12
21	Grow the Garden	[74]	Exertion	Individual & Team	16	6–11
22	Capture the Crown		Exertion	Individual & Team	16	6–11
23	Africans & Lions	[35]	Tag/Memory	Team	57	6–12
24	Timeball		Catch and Throw	Team	57	6–12
25	Pet Care		Gathering	Individual	57	6–12
26	Stop the bomb		Capture the Flag	Team	57	6–12
27	Skattjakt	[75]	Treasure hunt	Individual & Team	38	12–15
28	F.A.R.M.	[66]	Tag/Gathering	Team	16	7–10
29	Follow the Light		Luck	Individual	16	7–10
30	Invade the Castle		Capture the Flag	Team	16	7–10
31	Save the Safe	[66] [67]	Capture the Flag	Team	16 27	7–10 8–9
32	Lighthouse	[67]	Smuggling	Individual & Team	24	10–11
33	Dance it	[76]	Exertion	Individual	20	8–14
34	Join My Move	[76]	Exertion	Team	20	8–14
35	Make My Sound	[76]	Exertion	Individual & Team	20	8–14
36	The blind mirror	[76]	Exertion	Individual & Team	20	8–14
37	The bomb	[76]	Catch and Throw	Team	20	8–14

If one n value is reported, all studies referenced the same evaluation. N.R. (Not Reported), n value: (M = 33.70, SD = 35.71), ages: (M = 9.19, SD = 2.51).
[a] (*researchers stated: for each parent, "at least" 1 child participated*).

losing (e.g., the ground) may be defined in either physical space or time (e.g., most catches after 3 min wins or carry an item longer than 10 s, and you lose). The physical activity for achieving this is cooperative.

Outdoor Exploration — The goal of the game is to get acquainted with your surroundings. This may be done by following a predefined path or searching for specific items or places. This differs from Gathering in the sense that outdoor exploration does not physically acquire these resources. Also, outdoor Exploration differs from the Treasure Hunt genre by not being location or item specific (e.g., an example exploration task could be to capture the most windmills on camera).

Capture the Flag — An item or person represents the "flag" which when captured, returned or saved means instant victory for the opposing team. This item might be static (e.g., hidden) or dynamic (e.g., a

person running around). Reaching this item or person might require additional hurdles (e.g., tagging, outranking or physically reaching a place without being observed or captured).

Smuggling — An item or person needs to be transferred over a certain space without drawing the attention of an observer. This observer may either be human or inanimate.

Memory — Relies on the memory of the player to figure out a piece of information regarding the game (e.g., a role, order, or location). These games are often prone to trial and error (e.g., uncovering multiple pieces of information to generate a holistic overview) and can be greatly influenced by the elements of luck (e.g., uncovering the goal or truth) and tactics (e.g. strategically determining the order of uncovering information).

Luck — Success in this game is largely based on chance or luck. The player often has a form of influence, but this is comparatively small to other games (e.g., dressing appropriately or carrying a flashlight). Many games have a component of luck (e.g., drawing the right card, picking the right spot to stand, etc.), however this genre comprises games that rely on luck as their main element, thereby greatly eliminating the influence (e.g., skill level) of the player.

Exertion — The goal within this genre is to exert the player. The game mechanics in these games support this exertion by means of points, ranks and other systems to motivate the player to be more physically active. These games can be either competitive or non-competitive and occur either parallel or non-parallel in reference to other players.

Multi-genre — A single or collection of games in a multitude of genres made possible by a technological device. These technological devices do not enforce a specific game, genre or rule set. Therefore, these devices can be used to the extent of a players' imagination and technical abilities within the scope of the interactivity afforded by the device. This closely relates to the open-ended play principle.

3.3. Claimed/anticipated benefits

Benefits were often described in a general sense by researchers as part of introductions to the field of research or as motivations to design a certain game. Whilst researchers were cautious in claiming benefits directly arose from their games, two general themes emerged: (1) physical & social benefits and (2) Outdoor exploration benefits. Games focusing on the physical and social benefits were by far the largest group (28 out of 32). Within this group there were several more specific focus areas, such as: the mechanics of the game (e.g., game adaptation (BuzzTag/BuzzThief, Scratch Nodes), specific technological innovations such as physiological sensing (Heartbeat) and IoT technology (IoT Games) or targeting a specific target group (e.g., 3–5 year-olds, GiggleBat). Overall, research has focused on the generalized concept of an interactive outdoor game, and more specifically on how to design and evaluate such a game according to a framework. A full overview of benefits researchers expect players to reap from outdoor games can be found in Table 3. An interesting case that does not adhere specifically to one category is the game: ShadowHunter [27] which is considered beneficial for outdoor exploration. The researchers however point out that the very act of playing the game can be considered a form of physical activity, albeit a fairly low intensity one.

3.4. Empirical methods

From a methodological perspective, we can distinguish papers presenting the design process leading up to the game prototype as its empirical foundation, and those that focus on the evaluation as such. We report on both types of methodology separately: (1) Design Methods (Table 4) (2) Evaluation Methods (Table 5). In some cases, these methods might overlap when a design iteration provides evidence for the evaluation and vice versa.

3.4.1. Design methods

As many of the studies used the same form of evaluation for the design iterations as well as the final evaluation, many of these are mentioned in the section on Evaluation Methods. Several of the studies opted to gather data in advance to make an informed first design iteration. These include methods such as Expert interviews (3 studies, 7 games) and focus groups (3 studies, 4 games). The prototype was often tested in some form either by evaluating a specific piece of the prototype (6 studies, 9 games), a small pre-test (3 studies, 3 games) or as a whole within the first design iteration. Lastly, there were some creative activities to gather information from the participants, such as *KidReporter* by [77], in which the child produces their own newspaper (1 study, 4 games), *Collage Making* (2 studies, 8 games), *Unstructured drawing activity* (1 study, 1 game) and *Mission from Mars* by [78], a method in which an "alien" interviews the player on the topic at hand, (1 study, 4 games).

3.4.2. Evaluation methods

Observation (both direct and video) was by far the most often used evaluation method (26 studies, 30 games). Using a structured *coding method* to examine the data is quite common, as several studies employed some form of coding structure (10 studies, 15 games). The most commonly used coding scheme is OPOS. *Interviews* (12 studies, 18 games) and *focus groups* (9 studies, 15 games) are also commonly employed as evaluation method. Furthermore, these evaluations are quite often combined with another task such as filling out a *questionnaire* (8 studies, 14 games) or *ranking* method (3 studies, 8 games). In addition to these methods, *design probing* was used in the form of a camera-phone to self-report situations (1 study, 1 game) as well as stickers to mark points of interest for the researchers (1 study, 1 game). To assess how well a game was understood, the *peer tutoring* method was used (2 studies, 5 games). Peer tutoring is a protocol where children who have played the game explain it to those playing it for the first time, in order to obtain spontaneous verbalizations of their thoughts and to gain insight into how they understand and experience playing the game. Lastly, *data logging* in prototypes was used (2 studies, 2 games) to support a narrative.

3.5. Sampling methods of participants

An overview of the sampling methods which were used by the researchers to recruit participants can be found in Fig. 4.

3.6. Ages

Ages are reported individually per paper/game in Table 2. A distribution of these age ranges can be found in Fig. 5.

To determine whether age has a relation to the genre of gaming provided, a plot combining both the age and the genres in our data-set was generated. This plot can be found in Fig. 6.

3.7. Requirements for game play: objects & environment

Lastly, we present a tabulation of necessary objects and environment to play a certain game. This overview is presented within Table 6

4. Discussion

In order to investigate the research question: *What kind of interactive outdoor games have researchers proposed to address the challenges related to sedentary lifestyles and decreases in exposure to outdoor play benefits?* a literature study has been conducted. Within this section, we will consider the proposed sub questions and consider several post-hoc findings.

Table 3
An overview of claimed benefits derived from each game.

Overall benefit	Evaluation context	Game
Physical & Social benefits from an interactive outdoor game	Whether a game could be prototyped which would elicit physical and social benefits.	UbiBall SoundTag
Targeting a specific age group	3–5 years 12–15 years 12–15 years	GiggleBat Collect the Coins Escape the Ghost
Provide evidence for a framework	Assessing the reliability of an observation scheme.	Lighthouse Heartbeat Save the Safe
	Proof that high-fidelity prototyping should be used early when designing outdoor games.	Save the Safe F.A.R.M. Invade the Castle Follow the Light
	Extending research literature on design methodology for children.	Wizards & Witches Cato Quattro Camelot
	Create and playtest various HUG concepts.	Africans & Lions Timeball Stop the Bomb Pet Care
Prototype mechanics of an interactive outdoor game	Easy adaptation of outdoor games supported by interactive technology	BuzzTag/BuzzThief Scratch Nodes
	Determine the effect of a shared object on physical activity and social interaction	Ultimate Swinxsbee Multibee
	Incorporate physiological sensing into pervasive gaming	Heartbeat
	Potential role of IoT technologies as a resource within active free outdoor play	Colours game
	Determine the effect of non-speech sound augmentation on outdoor play	Soundwear
Testing social strategies in smartphone applications	Comparing synchronous vs asynchronous play and competitive vs collaborative	Grow the Garden Capture the Crown
Exercise as a learning environment	Bridging the gap between formal and informal learning	Skattjakt
Outdoor exploration	Create the possibility to experience the underwater world without the risks posed by snorkling or diving.	AREEF
	Awaken the fantasy and curiosity of children about cultural heritage	The Mystery of Elin
	Stimulate exploration of outdoor environments	ShadowHunter ABBOT

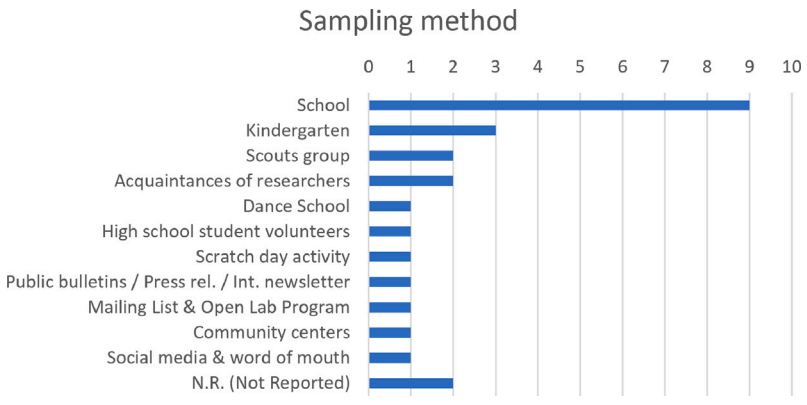

Fig. 4. An overview of sampling methods for participants per participant group. If the same group was used for multiple games or papers, the sampling method is only mentioned once.

Table 4
Overview of design methods used per game, if the method was also used for evaluation this can be found in Table 5.

Method	Distinction	Game
Interviews	Expert Interview	Escape the Ghost, Collect the Coins Africans & Lions, Timeball, Pet Care, Stop the Bomb, Skattjakt
Ethnographic methods	Hanging around, general observations	Skattjakt
Creative activities	KidReporter	Cato, Quattro, Wizards and Witches, Camelot
	Collage Making	Cato, Quattro, Wizards and Witches, Camelot, F.A.R.M., Follow the Light, Invade the Castle, Save the Safe
	Mission from Mars	Cato, Quattro, Wizards and Witches, Camelot
	Unstructured drawing activity	ABBOT
Prototype evaluation	Playtested the game rules with paper prototyping	HeartBeat
	Shape Evaluation (fixed choice)	Cato, Quattro, Wizards and Witches, Camelot
	Technical limitations test	SoundTag
	Technology test	ABBOT
	Workshop applicable sounds	SoundWear
	Application to evaluate movements	SoundWear
	Form evaluation (exploratory)	Scratch Nodes
Pre-test		UbiBall, AREEF, Skattjakt
Focus groups/ Discussions	Think out loud session	Scratch Nodes
	Critique session (Wii Fit)	Escape the Ghost, Collect the Coins
	Parents via Questions, options and criteria technique	GiggleBat
Bodystorming		Make My Sound, The Blind Mirror Join My Move, The bomb

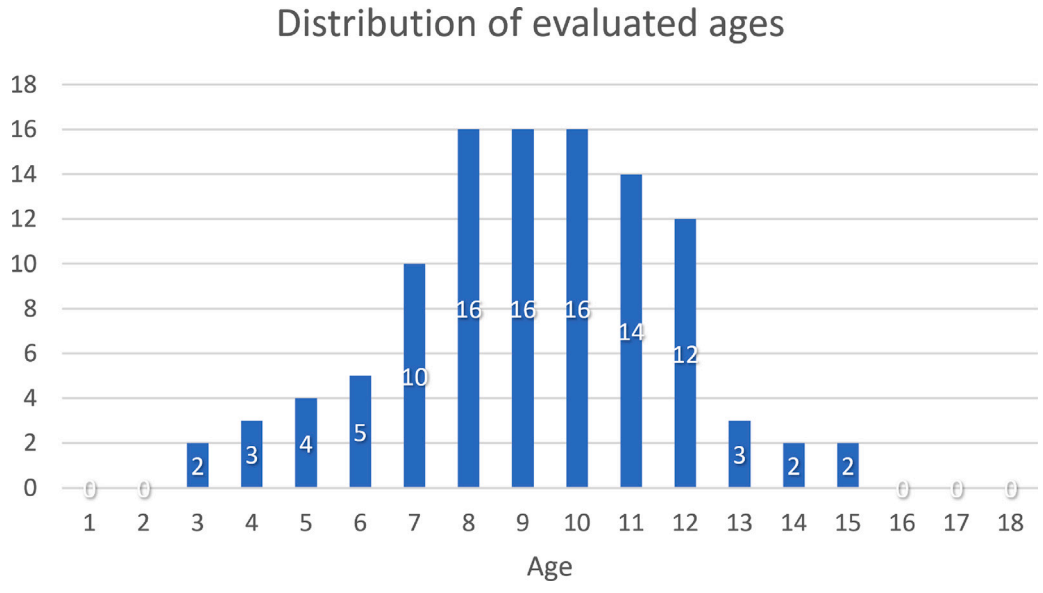

Fig. 5. The number of papers that involved children of a certain age (M = 9.19, SD = 2.51), when a study provided a range, each year was counted individually, studies using the same participants were counted once).

Table 5
Overview of evaluation methods used per game.

Method	Distinction	Described game
Observation	Direct observation	GiggleBat, The Mystery of Elin, Escape the Ghost, Collect the Coins AREEF, ShadowHunter, BuzzTag/BuzzThief Scratch Nodes, IoT Games, Skattjakt F.A.R.M., Follow the Light, Invade the Castle, Save the Safe
	Video observation	Cato, Quattro, Wizard and Witches, Camelot, SoundTag, HeartBeat, Ultimate Swinxsbee, Multibee, UbiBall, SoundWear, Scratch Nodes, IoT Games, Save the Safe, Lighthouse
Observation Coding/Analysis	OPOS	HeartBeat, SoundWear Scratch Nodes, Save the Safe, Lighthouse
	Hitron et al./Tsiakara et al.	SoundWear, Scratch Nodes
	Verbal/Non-verbal	GiggleBat
	Thematic analysis	IoT Games
	Meaningful categories	ShadowHunter
	Based on Social Play Continuum	Ultimate Swinxsbee, Multibee
	Complexity, Fun, Social interaction, Physical activity	Africans & Lions, Timeball, Pet care, Stop the Bomb
	Structured (but not specified)	The Mystery of Elin
Interviews	Semi-structured interview Participants	Cato, Quattro, Wizards and Witches, Camelot (5 categories) The Mystery of Elin, UbiBall, AREEF[a], ABBOT[a], ShadowHunter SoundWear, IoT Games, Skattjakt[b]
	Unreported form Parents	Grow the Garden, Capture the Crown
	Semi-structured interview Expert	BuzzTag/BuzzThief, IoT Games
	Unstructured interview Participants	F.A.R.M., Save the Safe, Invade the Castle
Questionnaires	Post-test evaluation	The Mystery of Elin, Escape the Ghost, Collect the Coins Dance it, Make My Sound, The Blind Mirror, Join My Move, The bomb
	Likeliness of gameplay items	Africans & Lions, Timeball, Pet Care, Stop the Bomb
	Background questions	Escape the Ghost, Collect the Coins (pre-test), UbiBall
	Enjoyment measures	Escape the Ghost, Collect the Coins
	Adaptation of Read and MacFarlane's Fun toolkit	ABBOT
	Based on Kids Game Experience Questionnaire & theories by Broadhead	Ultimate Swinxsbee, Multibee
	Usability survey	Skattjakt
Ranking methods	FunSorter	HeartBeat (game elements)
	GroupSorter	Lighthouse, Save the Safe, HeartBeat
	Simple Fun Ranking	F.A.R.M., Follow the Light, Invade the Castle, Save the Safe
Focus groups / Discussions	Semi-structured focus groups with participants	HeartBeat (sorting), BuzzTag/BuzzThief (think out loud rules) Scratch Nodes, Africans & Lions, Timeball, Pet Care, Stop the Bomb
	Short unstructured conversations with Parents	SoundTag, GiggleBat
	Informal focus groups to clarify questionnaire answers	Escape the Ghost, Collect the Coins
	Conventional Content Analysis	Lighthouse, Save the Safe, HeartBeat
	Paper prototype evaluation	ABBOT
In-game data	Log files & Exertion levels	Escape the Ghost, Collect the Coins
	Statistics & Event Logging	AREEF, Grow the Garden, Capture the Crown
Design Probing	Camera-phone self report	Skattjakt
	Marking visited places with stickers	ABBOT
Peer Tutoring	Having the game setup explained by one participant to another	Cato, Quattro, Wizards and Witches, Camelot, BuzzTag/BuzzThief
Bodystorming	Through simulation and/or roleplay gather feedback	Dance it, Make My Sound, The Blind Mirror, Join My Move, The bomb

[a] [26,72] describe this as a "questionnaire in interview fashion" and "questionnaire-based interviews". We have opted to categorize these as: semi-structured interview.
[b] Presumably, the paper did not report what form the interviews were given nor, only that data from the interview was combined with other sources.

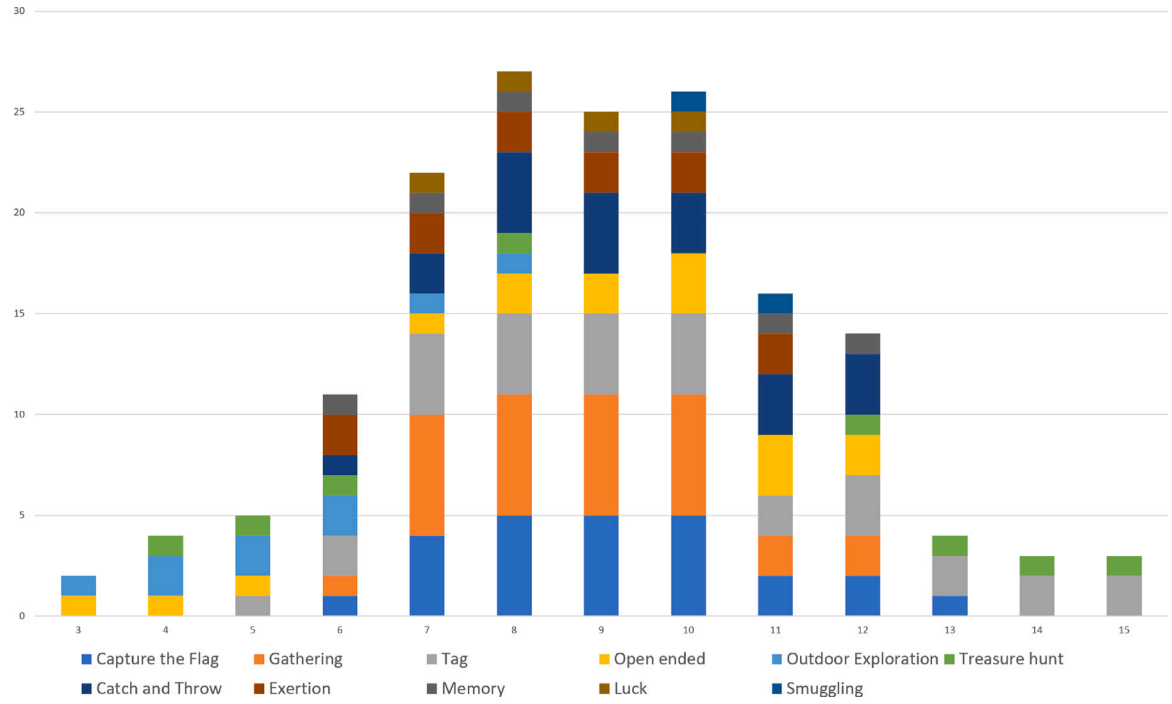

Fig. 6. A count per genre plotted in relation to the age of the participants.

4.1. Genres

Considering Fig. 3, a quite even distribution can be observed amongst genres of games. There is a small, but obvious inclination towards games that intrinsically support physical activity (Capture the Flag, Gathering, and Tag). This relates to the most common claimed benefit: physical activity. In contrast, games which rely more on chance and cognitive skill (e.g., Luck and Memory) are used less in games developed in academia. Smuggling was also one of the lesser used genres, which can be explained by the fact that this genre either relies on physical activity (e.g., outrunning the observer) or tactics (e.g., distracting the observer). For this reason, physical activity might not always be ensured. When considering these games together with the targeted age groups (Fig. 6), we observe that genres such as Tag are considered for every age (capable of running) as well as treasure hunts.

A specific mention should be made towards the game: Follow the Light [66], which was dropped by the researchers in their design iterations. This game adhered to the luck genre, as players were allowed to take steps forward associated with the step-size of a particular animal if the colour that was displayed equalled a colour that the player was wearing in clothing. Due to time constraints the teams had to be increased and thereby increasing the chances of a player, or in this case, team to take a step forward. "*Since the amount of players in a team got bigger, each team also had a larger variety of coloured clothes on them; almost all teams were allowed to take steps on every turn.*". This poses interesting challenges for game design in evaluations, as in the design of [66] the player wearing a single colour would already be at a major disadvantage. In such conditions, it is not unlikely for a researcher to influence (via Wizard of Oz method) the condition in favour of some participants, thus influencing the evaluation outcomes. Whilst the element of luck is a great building block for any game (e.g., roll a die or swing the colour board of a game of Twister), an inherent methodological challenge when considering this genre pertains to a trade-off between experimental control and the amount of true luck/chance allowed in the play testing.

Whilst we have inductively constructed an overview of the genre in the games explored by researchers over the years, future researchers should be wary of survivor bias. The list of genres provided is non-exhaustive and in designing new games, other genres not mentioned could be explored as well (e.g., fantasy or role play). One could also categorize outdoor games for children using an existing taxonomy. However, the literature on outdoor gaming taxonomies is limited. There are some more generalized theories such as the definitions by [79] who defines games along the categories of: Agôn (Competition), Alea (Randomness/Luck), Mimicry (Imitation) and Illinx (Vertigo) and across a scale from Paida (Structured Play) to Ludus (Unstructured Play). Games have been plotted along these categories and scale as examples of these conceptual definitions by [79] (e.g., chess being a pure Agôn game, reaching the far end of Paida on the scale). In addition, Callois points out that certain categories lend themselves for either Paida or Ludus play and that games could change depending on their "placement" along this scale (i.e., a game of cup-and-ball, Diabolo or yo-yo leaning towards Ludus or Paida). To grasp how these categorizations might work specifically for outdoor games, a plot has been made of the games from our dataset, as is visible in Fig. 7. Some patterns clearly emerge from this plot such as the overwhelming amount of games leaning towards Paida, which can be explained by the very specific game designs and rule sets and also provides reasoning why devices designed without a clear purpose (multi-genre) are more prevalent in Ludus. Other underrepresented categories, across both Ludus and Paida, include Alea and Illinx. Designing interactive outdoor games for children in either category might not be as straightforward, albeit not unthinkable, as games in the Alea category (randomness/luck) are well suited combined with interactive devices. Considering that this field of games is in its early stages of development, such games might still be developed.

4.2. Claimed/anticipated benefits

As depicted in the overview in Table 3, most of the games proposed were designed with physical and social benefits in mind (29 out of

Table 6
Overview of objects and environment requirements to play a game.

Game	Objects	Environment Constraint
HeartBeat	HeartBeat sensor and device	Hiding places
Cato	Resources, Castle building	Running area
Quattro	Sets of 4 cards to gather	Running area
Wizards and Witches	Glass ball, ranking cards	Running area
Camelot	Resource collectors & zones Castle building blocks	Running area
SoundTag	SoundTag vest and glove Laptop with concert app	Running area
GiggleBat	GiggleBat	Open area, optionally: sport specific field
The Mystery of Elin	iPad with Elin's Mysterium app	City of Skövde
Escape the Ghost	Mobile phone, app	Running area
Collect the Coins	Mobile phone, app	Running area
Ultimate Swinxsbee	Swinxsbee	Running area
Multibee	Swinxsbee	Running area
UbiBall	UbiBall, trail objects	Area for a trail
AREEF	AREEF tablet & Markers	Large body of clear water (e.g. swimming pool)
ABBOT	ABBOT device & tablet	Unexplored area with interesting things
ShadowHunter	Tablet, Shadow presets	Shadows present and pre-loaded into the ShadowHunter software
SoundWear	SoundWear Bracelet, outdoor toys to play with	Depends on the type of toy
BuzzTag/BuzzThief	RaPIDO, GameBaker	Running area
Scratch Nodes	Scratch Node, laptop (initially)	Depends on the game configured
IoT games	IoT devices: play poles/cans Beacon boxes, light meter or play watch	Depends on the game configured
Grow the Garden	Fitbit, Phone & App	Anywhere
Capture the Crown	Fitbit, Phone & App	Anywhere
Africans & Lions	Role division cards	A well area (designated) otherwise running area
Timeball	Timeball prototype, baskets	Running area
Pet Care	Stuffed animal, food items	Places to put the fictive food
Stop the bomb	Stop the Bomb belt	Running area
Skattjakt	Phone, App, Server	Castle at Växjo university
F.A.R.M.	RaPIDO, game tags	Running area
Follow the Light	RaPIDO, game tags	Large area
Invade the Castle	RaPIDO, game tags, several designated posts	Hiding places
Save the Safe	RaPIDO, game tags, Safe with RFID tag on it.	Running Area
Lighthouse	Lighthouse device	Chalked areas per team
Dance it	Bodybug device	Dancing area
Make my sound	Bodybug device	Dancing area
The Blind Mirror	Bodybug device	Dancing area
The bomb	Bodybug device	Room for a circle

37 games). 4 games were specifically designed for outdoor exploration and reported little regarding physical or social benefits, with the exception of ShadowHunter. Additionally, most papers described a separate contribution, such as: *Providing evidence for a framework*, *Designing game components and mechanics*, *Targeting a specific age group*, *Outdoor Exploration* and *Learning benefits*. Most games contributed as evidence for a category of games. More specifically, providing evidence for Head-Up Games. Some writings emphasized on design methodology, emphasizing that high-fidelity prototyping should be used earlier in the design process, as opposed to conventional wisdom in the field of human–computer interaction regarding low-fidelity prototyping [66]. A special mention should be given to the game AREEF, which is the only game played underwater [26].

4.2.1. Social play vs outdoor play benefits

Within the literature, different notions are given for games eliciting social play and games providing a social learning opportunity. Many games can be considered social play games, as a game design might already enforce collaborative play (e.g., a team-based game). For the same game to also generate social learning benefits, however, one simple social interaction would arguably not elicit a learning response. As per example, [46] note that during their research they found that: "*[. . .] social interaction was a big part of almost any kind of playful activity. Even playing a single-player game on a single-player console, like the Game Boy was definitely a social activity. Boys would stand around the player and watch how far he got and if he made a new high score, comment on it and suggest actions.*" [46]. One could argue that whilst this activity is indeed social, the social learning benefit might be less in comparison to activities directly promoting team play.

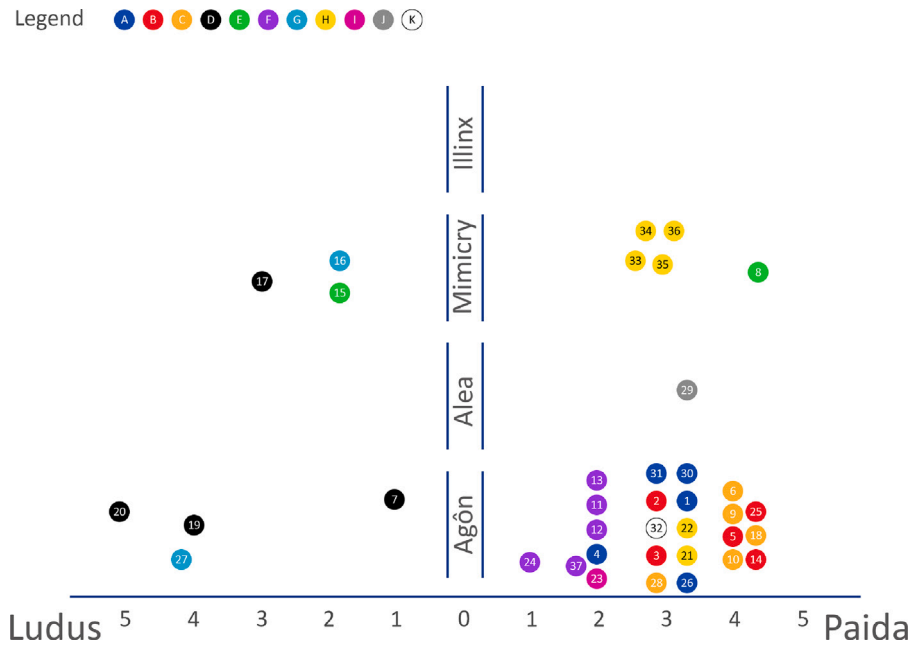

Fig. 7. Games from the dataset plotted along Ludus-Paida vs Categories (Agôn, Alea, Mimicry and Illnix). The colours in the legend represent the genres of games: (A) Capture the Flag, (B) Gathering, (C) Tag, (D) Multi-genre, (E) Outdoor Exploration, (F) Catch and Throw, (G) Treasure Hunt, (H) Exertion, (I) Memory, (J) Luck and (K) Smuggling.

The consideration that technology could also be used in an outdoor setting to promote outdoor play, without distracting the user, is described in the concept of HUG's. This concept describes that the design of technology should not demand too much of the user's attention and to not get in the way of social interaction and physical activity. This concept gives way to a more fundamental discussion: whether technology has a place within outdoor play at all. Outdoor play is traditionally an attractive activity without the need for any computing technology. Therefore, for technology to justify its place, it must also deliver some compelling added value. The benefits that technology can bring according to the papers reviewed, (e.g., enforcing game rules, enhancing play experiences, etc.) all come with a flip-side: when game rules are enforced children miss out on the opportunity to learn how to apply and negotiate the rules of the game they agree with, which is arguably itself an important benefit of typical playground games. When cheating is automatically controlled, children may miss out on learning about fair play, perspective taking and negotiation, which are some social skills involved when negotiating and enforcing rules without technology support. And when interactivity and audio/visual effects are added to the games, children perhaps focus on the concrete sensorial experience rather than their fantasy and creativity. Thus, we argue that the role of technology should be considered with great caution both in design and in evaluation of the game. One should be especially cautious when research makes the claim that playing, through their game or prototype, supports social learning (or development). This social learning is often based on the fact that children argue about rules, setups and discuss the fairness of the game [80].

Thresholds, Settings, and Rules

One of the limitations of using variables set by technology is that these often are not easy to change. The game may need to be reset, and a certain amount of technological expertise may be needed to be able to intervene at that moment. This is quite often not readily available to the children playing these games. Some researchers focus on this point specifically, such as: [57,59,73]. Although these studies provide interesting insights, we are still quite a long way off from an everyday implementation of such systems. Also, it is in our nature to find ways to "beat the game" even if this means sometimes cheating a bit and getting called out on it and technology would be quite limiting if it would set unbreakable boundaries on how we can interact with the game and influence game play. Perhaps, if finding the correct rule set for playing the game is something children will like to negotiate, then being able to change the game becomes a basic requirement for this kind of games.

[29] stated: "*Pervasive games have a lot of potential, though a lingering issue throughout this design was what the role of technology was and whether it was necessary for the game.*". Although the researchers at first held some doubts, later on they stated: "*[. . .] technology enriched the game by ensuring that game rules were applied, by providing feedback regarding game-related interactions and by making some actions in the game more challenging.*"

Only a few papers consider that technology, whilst broadly considered as a key enabler for the game experience, could have adverse effects. The paper by [3] mentions three important benefits of outdoor play, namely: social interaction, creative thinking, and physical activity. The authors state that these benefits of outdoor play may be compromised due to the addition of technology, and therefore technology usage should be carefully evaluated. On this premise, they propose an interaction design perspective in which they compare a non-digitally-enhanced prototype in comparison to a digitally-enhanced prototype. A study by [62] states that "*Unfortunately, many of the digital applications of technology have led to a lack of social learning within children's education and early development both at home and school.*" on which they cite a paper by [81]. [62] refers to a broad spectrum of technology usage and considers the application of technology to a sporting attribute not to compromise this "lack of social learning". [27], states: "*By embedding novel technology into social and physical interaction experience, more immersive and intriguing outdoor exploration activities have great potential of changing natural outdoor play routine and facilitating children's engagement and motivation in the outdoor experience.*". Whilst these researchers do point out the potential of technology, they do not elaborate what this "changing natural outdoor play routine" enthrals, let alone, whether this change has a positive or negative effect. [3] notes on pervasive games: "*Pervasive games commonly involve screens and hand-held devices that may interfere with natural play patterns and are thought to compromise the known benefits of natural play.*". The

researchers then refer to the paper by [29] on the principle of Head-Up Games. In evaluation of the HUG game by [29] the children communicated, debated, and cheered on one another as they collaborated towards a common goal.

To summarize, the influence of technology can often be considered a trade-off. Using technology can create incredible immersive experiences, provide extensions to what is humanly possible, and make quick configurations easily possible. However, the trade-off is that by adding more technology the game becomes more restrictive as rules have to be programmed and behaviours of technology have to be determined beforehand.

4.3. Levels of evidence provided

Considering the levels of evidence provided, we should take note of the broad range of studies included in our data-set. The level of realization per game differs extensively, ranging from Wizard of Oz reliant prototypes in which the participants operated a paper prototype that allowed them to set the rules of the game which the researchers would set on the game device [73], all the way to fully functioning autonomous games [26,28]. In the case of [28] the researchers developed a fully functioning application on a tablet which participants could take along with them on their treasure hunt and interact with markers in the real world. [26] developed a fully functioning underwater application that allowed children to experience scuba diving through augmented reality.

Likewise, the levels of evidence per study differ greatly. Notable works include [3,57–59] who have used the same prototype across multiple studies to assess different theoretical angles. [72] who used a considerably large sample size for their evaluation (n = 170). [29] for using and evaluating experimental design methods to elicit responses of children such as Mission from Mars and thereby strengthening the empirical evidence for this methodology.

Whilst having many different prototypes helped in broadening the field of outdoor interactive games, in the direction of scientific rigour there are still steps to be made. This is also described by [67]: "*While existing evaluations of pervasive games reported in the literature often mention that observations were carried out, these seem to be for the most part unstructured observations, and the analysis procedure is frequently undisclosed.*", which is congruent with our findings that 30 out of 37 games used some form of observation to evaluate their game. Of these observations, only half used a coding scheme, and only 12 of those had a theoretical grounding in previous literature. Arguably, a rigorous and standardized evaluation method for outdoor (pervasive) games is called for, as previously noted by [67]. For which [67] proposed the concepts of OPOS and GroupSorter, two empirically founded methods of evaluating outdoor pervasive games for children. Such methodology may be valuable in drawing comparisons across studies and reaching conclusions that transcend the single artefact centred nature of research in child–computer interaction which has been noted in previous literature surveys of this field [82–84].

4.3.1. Diversity in research methods

Most researchers stick to empirically proven methodology (observations, interviews, focus groups, etc.). Partly, because these methodologies are quite familiar and probably also due to the target group: children and adolescents. Children in these age groups often have a quite limited attention span, which cannot be overdrawn with endless questionnaires, focus groups and evaluation sessions, especially after an already exhausting playtest. This often leads researchers to opt for observations, supported with brief questionnaires and focus groups. Brief questionnaires targeting children and adolescents may be particularly useful for quantitative comparisons, e.g., the FunQ questionnaire originally developed to assess fun in learning could provide a suitable measurement instrument for game designers and researchers [85]. One limitation to these observations should be mentioned: our dataset contains solely peer reviewed research which might favour certain methodology. Therefore, survivor bias in this dataset cannot be ruled out entirely.

As research methods within our data-set can be grossly divided amongst design and evaluation, we will see a tendency to use well established (favouring tried and tested methods) methods towards evaluations as opposed to less established methods within design (favouring innovation and inventiveness). Design is often a high-paced iterative process, which is quite forgiving when an error is present in the current iteration. A fix can be presented in the next iteration, and play-testing swiftly determines whether the intended effect arises. In contrast, evaluating behavioural effects of a certain design with the intent to provide a scientific rigour evaluation demands a different methodology. These methods should ideally be replicable, and large sample sizes are deemed preferable. Considering the sample sizes in our data-set, which ranged from 6 to 170 (M = 33.70, SD = 35.71) these sample sizes would, mostly, not lend sufficient statistical power to the tests reported and the papers reviewed in their majority did not report a power analysis for determining the sample size, and the sampling strategy was not always explicitly explained or justified.

4.3.2. Introduction of biases

Baseline & order effect

In their vast majority, the study designs of the papers reviewed did not include a control condition. Thus, the reported levels of fun and activity cannot be explained by some specific aspect of the game design or meaningfully compared to non-intervened settings. In a few studies, a comparison was undertaken, e.g., as a baseline measurement [31,67,71], or by comparing two conditions [74]. In other cases, [3,35]. [3] participants in an iterative design process experienced initially a "non-digital" version of the game first, and later a digitally-enhanced version, confounding any comparisons by order effects. Future comparisons specifically aiming to demonstrate the added value of the digital games should include experimental designs with proper controls and counter-balancing to overcome these limitations.

Novelty & Longitudinal

As the average study length was relatively short (mostly one day or moment of play testing), the time in which participants could get acquainted and repeatedly experience a certain game was considerably low. With some studies only offering one play-test, on which the final (mostly preliminary) evaluation was based. Within design for children, one should be wary, as the "novelty" of a prototype might give an initial skewed image of benefits gained from the design. These responses to novel forms of interactions should not be confused with long-lasting positive benefits to this form of interaction.

Longitudinal evaluations could mitigate this hiatus by evaluating the effects over a prolonged period of time. In this review, we found one study [30] which could be considered longitudinal with 4 months of evaluation. The practical and financial implication of such a study are unfortunately not always possible or feasible. Another method of mitigating the novelty effect was presented by [26] who used in-game data on success ratio's to correlate with the subjectively reported enjoyment of the player. Hypothesizing that when a player is good at a game they will enjoy it more as opposed to all players in general liking the game.

Sampling

The sampling method (as displayed in Fig. 4) was in most cases cluster sampled (e.g., school classes, kindergartens, scouts groups and a community centre). Some convenience sampling was found for the study of [64,65] which invited children of co-workers, leaving the study open for researcher bias. Moreover, one should consider the effects of sending an open invite for an exercising game, as the probability of getting participants that like exercising are quite high, such as done by: [70]. By inviting entire classes or groups, researchers decrease the chance of having any specifically inclined participants.

4.3.3. Logging and automated measurements

Automated observation methods such as physiological sensing, which were once deemed "*too bulky*" [64,65] have improved greatly over the past years and could therefore be valuable additions to playtesting of outdoor games. Already [31] provided the players with a Heart rate monitor as an integral part of the game evaluated, they though did not use it for the purposes of comparing physical activity in the experimental and control conditions, as the game design aimed for a balance of physical and social activity rather than optimizing exertion among players. Logging game devices can potentially provide very rich information as, for example, the amount of points scored, the rounds played or the exertion levels. In our retained papers, only 3 studies used some form of automatically gathered data [26,70,74]. Given the recent developments in activity trackers, smartphone sensors and other sensing technologies, the opportunity arises for much richer quantitative evaluations than previously attempted, both for the purposes of validating research claims about this genre of games and understanding the nature of the play and the play experience, but also for informing the iterative design and development of this class of games.

4.3.4. Conclusion on evidence provided

A growing body of research already demonstrates some of the anticipated benefits of these games, but the empirical evidence on the added value of technology enhanced outdoor games, on the health and developmental benefits of these games, and on the different interaction design trade-offs, is still rather tentative. Next to improvements on the experimental designs that would allow stronger conclusions to be drawn, improvements can be expected by developing suitable psychometric tools for assessing experiential aspects of the play and by extending the use of logging and sensing technologies in evaluation studies.

4.4. Ages of target groups

Foundations for choosing a specific target group

Many of the reviewed papers focus their game designs on children in the ages of 7 to 12 years (Fig. 5). Often this age group is targeted without any particular justification, though it is likely that this relates to the relevance of the games for the children's developmental stage and the practicalities of involving them in research studies. Exceptionally, a justification is given in one article [29] which states: "*The design focuses on 7–10 year old children. These children are learning to read and have started to engage in structured team play. In child development literature, it is well accepted that social interaction plays a crucial role in child development.*". In other cases, this age group is targeted as a matter of convenience, because of access to children of co-workers or a specific school that is willing to participate in experiments [26,57,59,65]. In one study, the prototype was deployed in situ [63] and evaluated how children (regardless of age) interact with the design. In order to examine the suitability of designed games for different ages or, even better, to address the needs of different age groups with relevant game concepts, this subfield of child–computer interaction would benefit from a more deliberate approach to target different age groups in the design and evaluation processes.

An interesting example of such an approach is reported in [70]: "*With adolescents regularly experiencing what is known as the 'adolescent slump', a dramatic downturn in physical activity around the age of 12, adolescent children remain a prime target for physical activity interventions.*". For which, they cite previous research on children's' physical exercise. Conversely, the Gigglebat game by [62] was specifically targeted at children aged 3–5 years, as children older than this age had, according to the researchers, a large variety of sports to choose from for their (outdoor) activities. After evaluation, the prototype designed by [62] was deemed suitable for children well over the age of 5.

For older ages, we note that children older than twelve are less likely to participate in "games". This also becomes evident in the paper by [46] when they interviewed children from ages 14 to 15 on what kind of games they played after school and during recess, which was reported as: *"They dress up and they attempt to no longer (admit to) play games. "We're not kids, you know", as they responded when we asked if and what kind of games they played after school and during recess"*.. It could be considered that sports takes a greater role in the lives of children over the age of twelve, making outdoor games less attractive. However, it could also be the case that outdoor game could be specially designed to address this target group and specific contexts where they would enjoy playing these games (e.g., youth organizations, outdoor events).

4.5. Post-hoc findings

4.5.1. Build-up of skill

When designing a game, one should take into account the level of skill of the player, either physically, cognitively or even emotionally in comparison to the level of challenge provided, such as described by the Flow theory of Csikszentmihalyi et al. [86]. As children grow into adolescents, these individual skill levels tend to spread out, making designing for children specifically even more challenging. In our dataset there were but a few mentions of adjustable skill levels, such as: iFitQuest [70] who stated that challenges should be tailored to the individual. Specifying that physical interventions for these ages (12 and up) are very individual [70]. To tackle this challenge, they created an adjustable skill level setting which could be initially set as well as automatically adjusted when the player was thriving in the game. Also, [66] mentioned skill balancing for the game F.A.R.M. as a potential feature for this game "*[. . .] is to implement some sort of skill balancing, i.e., making it harder to win for the faster children and at the same time making it easier to win for the slower children.*".

To grasp whether a game adheres or adjusts to an individuals' skill level, the game should be evaluated over a longer period of time, as opposed to a single evaluation. The evaluations reported in our dataset were either low in frequency or short in time (or both), ranging from a single short evaluation to a few evaluations spread over a couple of weeks. Most game designs did not implement a form of skill level adjustment. The game was provided as is, and differences in skill were visible between players. When games are designed for prolonged usage, a form of skill build-up should be accounted for to keep the player engaged.

4.5.2. Game devices

As is clearly visible from the overview in Table 6 the devices used per game are uniquely designed to be game specific. Set for a handful of papers, all researchers opted to design and develop a new game as opposed to for example altering an existing commercially available game. It is not unlikely to consider that development of additional games, or longitudinal studies, are obstructed by these unique designs. Dissemination of updates towards these uniquely build platforms is already a challenge in itself. Researchers could lean more on existing devices and platforms targeting outdoor play for children, as for example the Picoo game set which is a product based on the research by Soute et al. [66,87,88], or focus on a symbiosis with smartphones. This would potentially allow for shorter development time, lower the cost for deployment and iteration (e.g., using a smartphone with an application which gets regular updates) and for easier comparison between studies. Lastly, building forth on existing platforms decreases the pricing of individual devices and thus enables these games to be more inclusive.

4.5.3. Game rules

Another setting in which technology has a great influence are the game rules. Children have a tendency to play nice [80]. To do so, children often negotiate the rules of a game to ensure fair play (e.g., in tag immediately tagging back might not be allowed, or when playing marbles the premise might be that marbles are not won over). This

negotiation allows children to construct their concept of fair play and to gain confidence in addressing related concerns in interaction with others. In contrast to the studies found in our data-set, this generates questions such as: If the rules are set by a form of technology which is not easily changed, are we removing a valuable learning benefit from outdoor games? Or further: If some children are the only ones "capable" of changing the game (e.g., due to better programming skills or because they own the device hosting the game mechanics) will this be considered unfair? What patterns of play or negotiation might then emerge?

4.5.4. Social-economic status of target groups

Except for the study by Delprino et al. [72] none of the studies reported details on the social-economic backgrounds of the participants. Whilst this might not be of utmost importance for the results of the researchers' study, this variable does have an impact on the feasibility of the game to reach the market for a broader audience. Dedicated devices have a significant production cost and contrary to Smartphones and Smartwatches they do serve many different purposes. In making the transition from research prototype to a marketable product, it is important to consider how not to exclude children from the benefits these games can provide, and how to access as wide as possible a population of children.

4.5.5. 21st century skills

On a positive note, research into learning methods describe that "computational thinking" or "ICT-related competences" are one of the skills children will need to learn as part of the 21st century skills [89]. These skills will help them in the future in tasks such as pattern recognition or evaluation of information. One could imagine that children, if provided with the right platform, would be more than willing to design their own games and discuss rules with others. By learning computational thinking at an early age, this might promote creating technologically advanced adaptations to outdoor games. One could for example consider a collection of IoT devices (Internet of Things) that children could configure to play with, such as described in [30] which children could program themselves to combine into a game setting.

5. Conclusion

The field of child–computer interaction has invested considerable effort in designing, developing interactive technology supported games for an outdoor setting, aiming for a variety of benefits for children and adolescents. This niche of games separates itself from earlier areas of gaming by focusing on the (social) interactions and physical activity in the first place.

A review study was conducted on the SCOPUS database, to establish what outdoor games for children and adolescents have been proposed of late. This survey yielded a total of 28 papers which described 37 unique games, which constitute a very promising niche in terms of design opportunities and the potential benefits these games could provide to children. This survey contributes to an effort to transition from point-solutions and their evaluation to building up higher level concepts and knowledge that can better guide future design and development efforts [82].

In general, the games reviewed were evaluated positively as fun to play. Our review highlighted some shortcomings of the empirical evidence that has been accumulated over the years, noting the need for enhancing validated quantitative measures for observation or psychometric measurement, more refined experimental designs and longer term studies. Design and evaluation efforts paying attention to longer term play related experiences, behaviours, and benefits, would be much needed extensions to the current state-of-the-art. Explicit attention to different age groups, designing for different ages and assessing how such games can better address different ages are also recommended. Lastly, the current research lacks discussions on the inclusiveness of using technology in interactive outdoor games and democratizing access to these games.

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.

Data availability

The data for this literature review is accessible via the search statements given in the article for Scopus.

Appendix. Omitted search clauses

Listing 2: Additional clause active

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AND  ( physical* OR active OR exertive )
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Listing 3: Additional clause Social

```
AND ( social )
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Listing 4: Additional clause Evaluation

```
AND ( intervention* OR experiment* OR
    playtest* OR
    study OR evaluation* OR analys?s OR
    observation*
    OR UX OR "user-experience" OR "user
    experience"
    OR usability OR play* OR playing OR test
    OR tested )
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