Multimodal Technologies and Interaction

MDPI

Systematic Review

"From Gamers into Environmental Citizens": A Systematic Literature Review of Empirical Research on Behavior Change Games for Environmental Citizenship

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Abstract: As the global environmental crisis intensifies, there has been a significant interest in behavior change games (BCGs), as a viable venue to empower players' pro-environmentalism. This pro-environmental empowerment is well-aligned with the notion of environmental citizenship (EC), which aims at transforming citizens into "environmental agents of change", seeking to achieve more sustainable lifestyles. Despite these arguments, studies in this area are thinly spread and fragmented across various research domains. This article is grounded on a systematic review of empirical articles on BCGs for EC covering a time span of fifteen years and published in peer-reviewed journals and conference proceedings, in order to provide an understanding of the scope of empirical research in the field. In total, 44 articles were reviewed to shed light on their methodological underpinnings, the gaming elements and the persuasive strategies of the deployed BCGs, the EC actions facilitated by the BCGs, and the impact of BCGs on players' EC competences. Our findings indicate that while BCGs seem to promote pro-environmental knowledge and attitudes, such an assertion is not fully warranted for pro-environmental behaviors. We reflect on our findings and provide future research directions to push forward the field of BCGs for EC.

Keywords: serious games; behavior change; pro-environmentalism; environmental citizenship; systematic review

Citation: Georgiou, Y.; Hadjichambis, A.C.; Paraskeva-Hadjichambi, D.; Adamou, A. "From Gamers into Environmental Citizens": A Systematic Literature Review of Empirical Research on Behavior Change Games for Environmental Citizenship. *Multimodal Technol. Interact.* **2023**, *7*, 80. https://doi.org/10.3390/mti7080080

Academic Editor: Keith Cheverst

Received: 10 July 2023
Revised: 7 August 2023
Accepted: 11 August 2023
Published: 14 August 2023

1. Introduction

Over the years, serious games have gained traction as they are argued, among other things, to hold great promise for social change. Serious games have been defined as games designed for education, training, or modification of behavior [1]. Focusing on the latter, in recent decades, an ever-increasing number of serious games have been designed purposely for behavioral change. This trend has resulted in the emergence of behavior change games (BCGs), which form a subset of serious games [2] that are designed to support attitude and behavior change. BCGs, also known as games "for impact" or games "for change", focus on persuasion to form or even change attitudes and behaviors, or simply to increase knowledge and awareness over various social and environmental issues [3]. In this sense, BCGs have the same nature as what are often called "persuasive" games [4]. More specifically, to achieve their goals, BCGs leverage the affordances of serious gaming such as engagement and fun while, at the same time, they adopt procedural rhetoric, defined as the practice of using processes persuasively (i.e., gameplay rules and mechanics) to make an argument about various issues, which makes them highly effective in behavioral and attitudinal

change [5]. Put simply, these games combine a variety of elements in support of persuasive ethos and persuasive rhetoric [6]; in turn, this sets the stage for the significant attitude and behavior change which lies at the core of games for "impact" and "change" [7,8].

It is therefore not surprising that BCGs have been deployed to foster change in human behavior in relation to health, physical activity and fitness or safety, among many other things [9,10]. Importantly, games for persuasion have also been largely embraced in the field of environmental sustainability [11,12]. In particular, BCGs are considered of particular value in the midst of the environmental problems we are currently dealing with. This is to be expected considering that "the current state of degradation to environment is predominantly due to lack of appropriate human behavior" [13] (p. 1). For instance, although the majority of U.S. adults admit that humans are the main cause of this unprecedented environmental crisis, people are not necessarily willing to undertake action and do not prioritize environmental problems above other political issues [14]. In this context, BCGs may play a vital role for the achievement of environmental sustainability, by empowering pro-environmentalism and environmental citizenship (from hereafter EC). Put simply, BCGs may hold great promise for the transformation of citizens from "gamers" into "environmental agents of change" who seek to achieve more sustainable lifestyles.

Despite these arguments, empirical studies on BCGs are thinly spread across various research domains. In a way, this is expected given that BCGs are developed by multidisciplinary research teams comprising various stakeholders such as designers, artists, programmers, media producers, content experts, educators, etc. [15,16]. As a consequence, it is not surprising that BCGs are also a study object in various research domains (e.g., environmental sciences, instructional design, HCI, psychology, etc.). However, this situation results in a fragmented panorama from which meaningful conclusions on the design and impact of these games may not be deduced.

Aiming to address this gap, some major systematic reviews have sought to investigate the persuasive strategies and the gaming elements underpinning BCGs as well as their effectiveness in attitudinal and behavioral change [4,10]. In addition, a recent scientometric review has shed light on how the field has evolved over the years [17]. However, these studies have synthesized research across various domains, such as nutrition, physical activity, or environmental sustainability without focusing per se on the latter. Under these circumstances, the broad scope of prior reviews does not allow researchers to reach a clear consensus regarding the impact of BCGs on players' pro-environmentalism, neither on the conducting of in-depth investigation on the underpinning game mechanics nor on the methodologies deployed to assess the effectiveness of these games.

Therefore, the purpose of this study is to synthesize the results of empirical studies in the field and to produce an updated analysis on these aspects, focusing on BCGs for EC, following the PRISMA methodology. More specifically, this article provides a systematic review and synthesis of available empirical research covering a time span of fifteen years—published in peer-reviewed journals and conference proceedings—to provide a well-informed mapping of the research area.

What follows is the theoretical background of this study. This is focused on a detailed elaboration of EC that also outlines the potential contribution of BCGs to transform players into "environmental citizens". Next, we continue with the problem statement and the research questions guiding this review study, as well as with the deployed methodology. Finally, this paper concludes with the main findings and related discussion, as well as with the main conclusions and implications derived.

2. Theoretical Background

The goal for achieving more pro-environmental behavior is considered a prerequisite for addressing environmental problems and is a key driver of sustainability [18]. This is also reflected in the notion of environmental citizenship (EC), which has regained great attention in recent years due to the environmental crisis and refers to the obligation of each citizen to contribute to the conservation of the surrounding environment [12,19]. On

one hand, EC highlights the need to equip people with an adequate body of knowledge, skills, values, attitudes and behaviors in order to be transformed into "environmental citizens" [20–22]. On the other hand, as presented in Figure 1, EC emphasizes that citizens should be able to participate in society as "agents of change", via the undertaking of both individual and collective pro-environmental actions, situated in the private and public sphere [23–27].

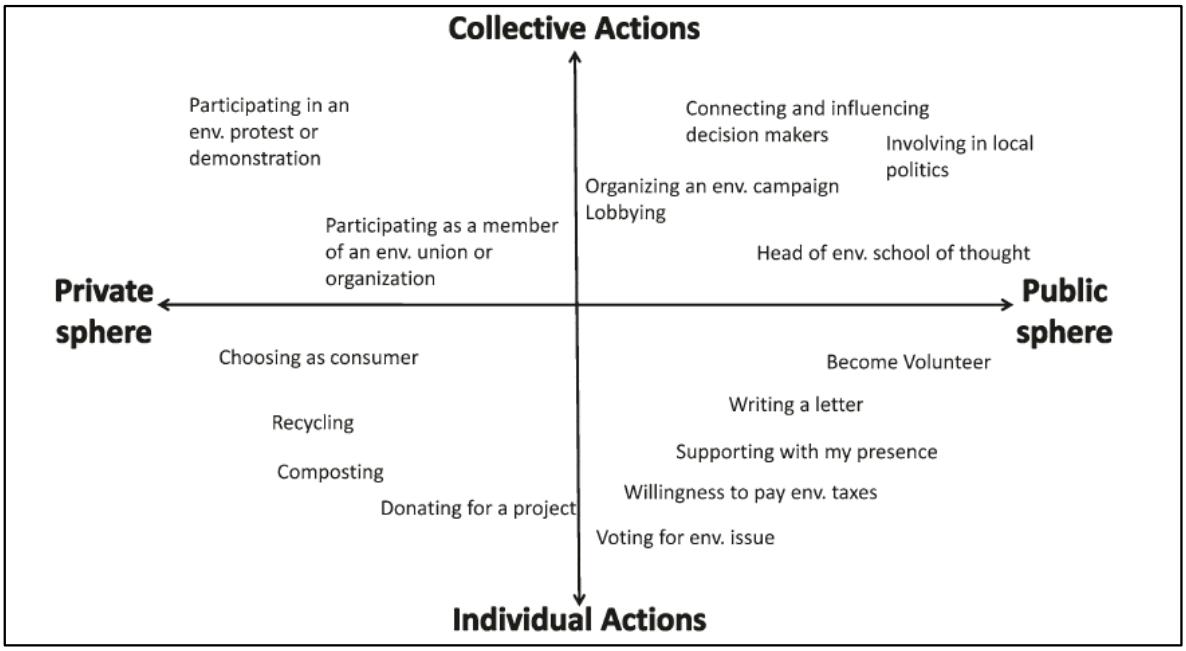

Figure 1. Examples of EC actions in a 4-axis system [16].

Several attempts have therefore been made to promote EC, including governmental laws and coercive measures, large scale information campaigns using mass media, printed materials, or nature documentaries [28–31]. However, changing behavior is not a straightforward and simple task. Though people have awareness of various environmental problems, this does not automatically result in sustainable and pro-environmental behavior because of psychological barriers [32,33]. Resistance to pro-environmentalism is mainly attributed to the psychological distance of environmental threats, which make it harder for people to relate their personal habits and daily routines with global environmental issues [34]. In this way, people cannot relate their unsustainable actions to environmental degradation, and they are often unaware of the alternate behavioral options that are available. Similarly, people may believe that their actions cannot make a difference in large-scale environmental problems [35], while informational campaigns and governmental policies are often perceived as manipulative and their impact therefore diminished [28].

In search of innovative and interactive ways to empower EC, BCGs, or as they are also known "persuasive games", have gained traction during the last years. According to Fogg [36], persuasion is "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action" (p. 225). Designing for persuasion—or change—must therefore focus on both guiding the user towards attitudinal or behavioral changes, while in addition to keeping the user motivated and engaged with the task at hand [37]. One way to achieve these goals is through the design of games, which are extended beyond fun and leverage various persuasive strategies and gaming mechanisms to inform the gamers about environmental issues, while prompting them to adopt pro-environmental behaviors [38]. It can be therefore argued that BCGs may provide an ideal venue for the empowerment of EC.

3. Problem Statement and Research Questions

Despite these arguments, there has been a great skepticism in the use of digital games to drive pro-environmental behaviors, as they may detract players' attentions from real-world environmental problems, thus resulting in an even greater disengagement with these issues [39–41]. It should, therefore, be noted that to have the intended impact, BCGs should be underpinned by appropriate gaming elements and persuasive design strategies [4]. Importantly, though existing studies may often report the effectiveness of BCGs, insights regarding the selected gaming elements and persuasive strategies are less emphasized [42,43]. As such, this information remains fragmented across different studies [44,45]. Taking into consideration these concerns, various scholars have stressed the need for robust impact evaluations of game-based interventions as well as for the synthesizing of the existing corpus of relevant empirical studies [46–48]. Of course, to effectively synthesize existing empirical research on game-based outcomes, emphasis should also be given on the methodological characteristics of these studies, i.e., research design, sample size, data collection methods, etc. [49].

Intrigued by the aforementioned concerns and recommendations, this study provides a systematic literature review (SLR) of 44 empirical articles employing BCGs for EC, published in relevant academic journals and conference proceedings, covering a time span of 15 years (2007–2021). As part of this review, we focused on the impact of BCGs on players' EC competences (i.e., EC behaviors, values, attitudes, skills, knowledge) in conjunction with the methodological characteristics of the reviewed articles, the gaming elements and persuasive strategies underpinning the deployed BCGs, as well as the EC actions supported by the reviewed BCGs. In particular, this SLR is driven by the following four (4) research questions:

RQ1: Which are the main methodological characteristics of the reviewed articles?
RQ2: Which are the main gaming elements and persuasive strategies underpinning the reviewed BCGs?
RQ3: What kind of EC actions are supported by the BCGs?
RQ4: What is the impact of the BCGs on players' EC competences (i.e., EC behaviors, values, attitudes, skills, knowledge)?

4. Methodology

4.1. Data Collection

The studies included in this SLR covered empirical research published from 2007 to 2021. We decided to focus on a timespan of fifteen years, having as starting date 2007, which was a milestone year in the field due to Bogost's book "Persuasive Games: The Expressive Power of Videogames". Bogost's book became a landmark as it is considered the starting point which triggered researchers' interest in the question of how we can design serious games to change the attitudes or behaviors of players. More precisely, this book served as a trigger for initiating discussions and research supporting the idea that serious games have the potential to change the world for the better [50].

The retrieval of the reviewed studies followed the PRISMA standards for SLRs (http://prisma-statement.org/ accessed on 23 September 2021) and was based on a multi-step procedure comprising three sequential stages, as follows: (a) identification, (b) screening, and (c) eligibility (Figure 2). In addition, a detailed protocol was developed and registered prior to the completion of this review study (PROSPERO 2023 CRD42023445621).

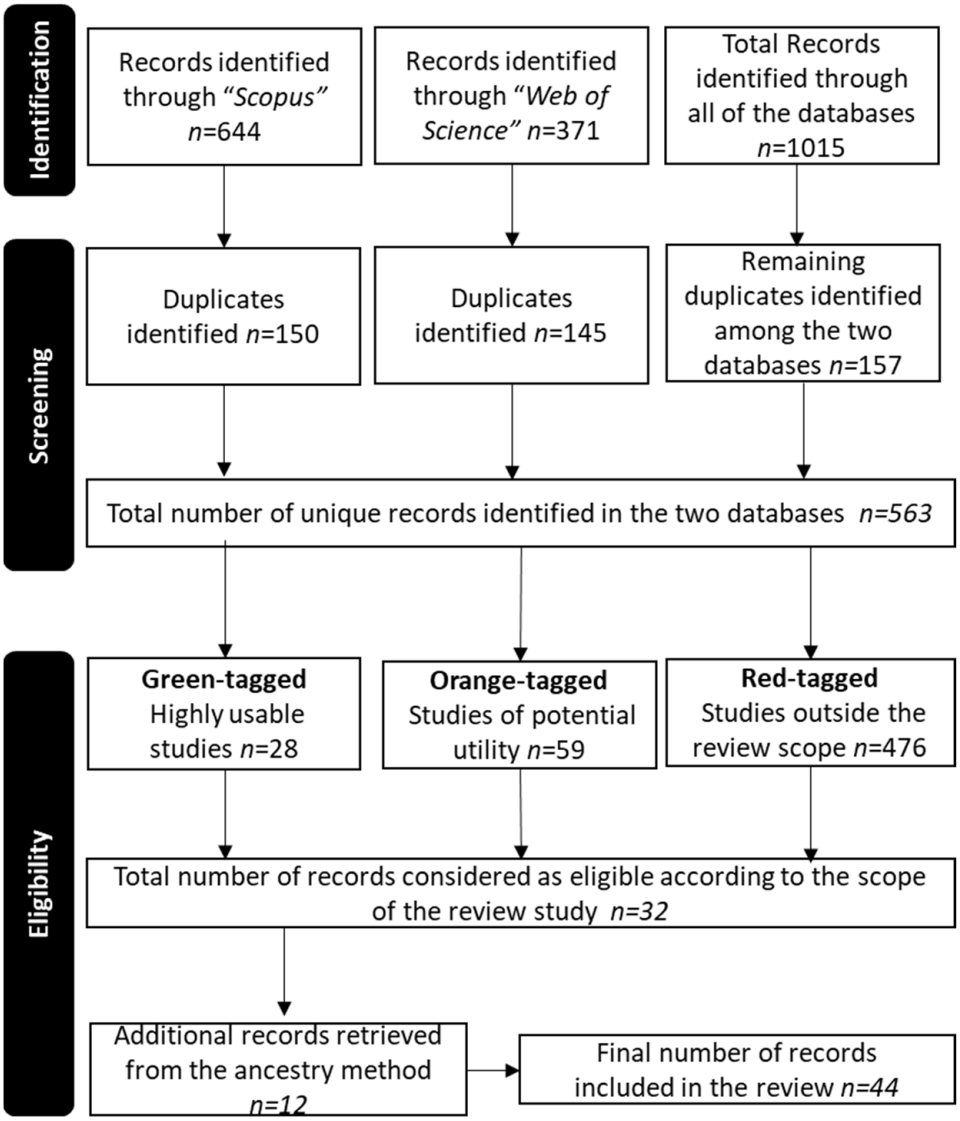

Figure 2. Flow diagram illustrating the review selection process.

Initially, in the first step, the published literature was surveyed using two electronic databases—Scopus (Document Search→Article title, Abstract, Keywords) and Web of Science Core Collection (Basic search→Topic [article title, abstract, author keywords]). The selection of the specific databases was purposeful as Scopus and Web of Science Core Collection are two large bibliometric databases covering a broad range of subject areas.

We constructed our search strings, taking into consideration the overarching research goal of this SRL, namely the synthesis of the available empirical research on Behavior Change Games (BCGs) for EC. Toward this end, our search strings were grounded on combinations of retrieval keywords related to "Games" with retrieval keywords related to "Environmental Citizenship (EC)" (see Table 1). More specifically, we retrieved both databases using the following search strings: "Serious games" OR "Digital games" OR "Behav* change games" OR "Persuasive games" OR "Impact games" OR "Games for change" AND "Attitud* change" OR "Behav* change" OR "Environmental citizens" OR "Sustainable behav*" OR "Sustainability" OR "Pro-environmental behav*" OR "Pro-environmental attitudes" OR "Pro-environmental actions".

Table 1. Retrieving keywords.

Game-Related Keywords	EC-Related Keywords
• Serious game(s) • Digital game(s) • Behavio(u)r change game(s) • Persuasive game(s) • Impact game(s) • Game(s) for change	• Attitudinal change/Attitude(s) change • Behavio(u)ral change/Behavio(u)r(s) change • Environmental citizenship • Environmental citizen(s) • Sustainable behavio(u)r(s) • Sustainability • Pro-environmental behavio(u)r(s) • Pro-environmental attitude(s) • Pro-environmental action(s)

After performing all possible combinations, we retrieved a total of 1015 records from the two databases. In the second step, the results of each retrieval were uploaded into Mendeley software (https://www.mendeley.com/?interaction_required=true, accessed on 9 July 2023), where all the records were screened and both internal duplicates, as well as duplicates between the two databases (n = 452) were removed, resulting in a total of 563 records. In the third step, the remaining records (n = 563) were filtered to identify their eligibility on the basis of four selection criteria.

In particular, to be included in the corpus of the reviewed studies, a study ought to have met four criteria, as follows: (1) Source type: the study should have been published in English as a peer-reviewed paper in the format of a journal or a conference paper; (2) Research methods: the study should be empirical, providing primary data derived from quantitative, qualitative, or mixed designs; (3) Type of intervention: the study should report on the deployment and investigation of a BCG; (4) Research focus: the study should be related to the research foci of the present review, e.g., reporting on the methodological characteristics of the empirical studies, on the impact of BCGs on EC outcomes, as well as on the gaming elements/persuasive strategies of the BCGs.

More specifically, the title, abstract and keywords of the studies retained through steps 1 and 2 (n = 563) were filtered according to these four inclusion criteria. As part of this process, the studies were evaluated in relation to their eligibility, using the following color coding: (a) green-tagging, for highly usable studies aligned with the criteria posed; (b) red-tagging, for studies outside the review scope, not aligned with the criteria posed; and (c) orange-tagging, for studies of potential utility, given that these studies seemed quite relevant to the scope of this review, but in which it was not absolutely clear from their title, abstract and keywords whether all the inclusion criteria were met. In this latter case, full-text versions of the studies were also obtained, read and filtered, in order to confirm whether these studies were aligned with the criteria posed or not. This final selection process resulted in 32 publications.

Finally, the ancestry method [51] was also adopted, according to which we searched the references of the identified research articles for empirical studies that could be included in the present review. This process yielded 12 additional articles. Overall, a total of 44 empirical studies met all the inclusion criteria and were selected for this review.

4.2. Coding and Analysis

To answer the first research question, focused on the methodology of the reviewed articles, we conducted a bottom-up content analysis of the empirical studies without having any predetermined categories in mind to identify their methodological characteristics (i.e., research focus, study type, game type, game duration, sample, data collection).

To address the second research question, we conducted a top-down content analysis of the articles to identify the main gaming elements and persuasive strategies underpinning the reviewed games. In particular, we adopted the classification of Toda et al. [52] that emerged via the compilation of prior gaming taxonomies in educational contexts. In its

essence, and extending prior taxonomies in the field, Toda et al. [52,53] proposed a new classification to group the previously defined gaming elements along five (5) dimensions, as follows: (a) performance elements, (b) ecological elements, (c) social elements, (d) personal elements, and (e) fictional elements. In addition, we adopted the persuasive system design framework of Oinas-Kukkonen and Harjumaa [54], which has been largely used in the design of persuasive technologies, due to its comprehensive nature. This framework combines a total of 28 persuasive mechanisms derived from previous frameworks such as Cialdini's principles of persuasion [55,56] and the Fogg behavioral model [57], grouped along four dimensions, as follows: (a) primary task support, (b) dialogue support, (c) social support, and (d) system credibility support.

To investigate the third research question, we initially conducted a bottom-up content analysis of the empirical studies to identify the focus of the EC actions supported by the reviewed BCGs. Subsequently, we adopted the EEC model [22] to identify and code the dimension (individual/collective) as well as the sphere (private/public) of the EC actions supported by the reviewed BCGs.

Finally, to address the fourth and final research question we identified the impact of the reviewed BCGs on players' EC competences in terms of: (a) knowledge (i.e., information and awareness), (b) skills, (c) attitudes, (d) values, and (e) behaviors. More specifically, we categorized the reviewed articles according to their reported effectiveness on the EC competences, as follows: (a) positive effect (positive impact on EC competences), (b) no effect (no impact on the EC competences), and (c) mixed effect (inconclusive findings regarding the impact on the EC competences).

To facilitate the coding and the analysis process detailed information of all fully read and included studies was entered into an Excel spreadsheet (e.g., year of publication, type of publication, scope of journals/conferences in which these studies were published, distribution of studies per country). In addition, an Excel spreadsheet was also set up per research question, as a matrix so that frequency counts and data searches could be easily achieved.

5. Results

An overview of the 44 empirical articles included in the reviewed corpus of this SRL is illustrated in Table 2.

Table 2. Overview of the reviewed empirical articles.

	N of Articles	%
Type of publication		
Journal article	23	52.3
Conference articles	21	47.7
Scope of journals/conferences		
Computers/informatics	16	36.3
Environmental sciences	10	22.7
Education	6	13.6
Human–computer interaction	5	11.4
Games	5	11.4
Psychology	1	2.3
Design	1	2.3
Year of publication		
2007–2011	8	18.2
2012–2016	13	29.5
2017–2021	23	52.3

As presented, twenty-three of these articles were published in journals (52.3%), while twenty-one articles in conference proceedings (47.7%). The vast of majority of the reviewed articles were mainly published in computer/informatics (n = 16, 36.3%) or environmental-related journals and conferences (n = 10, 22.7%), followed by a smaller corpus of articles which were published in journals and conferences related to education (n = 6, 13.6%), human–computer interaction (n = 5, 11.4%), games (n = 5, 11.4%), psychology (n = 1, 2.3%) and design (n = 1, 2.3%). Focusing on the publication dates, a total of 8 articles were published between 2007 and 2011 (18.2%); another 13 articles were published during 2012–2016 (29.5%), while 23 articles were published during 2017–2021 (52.3%). A considerable peak in the published articles can be observed during the last 5 years (2017–2021), indicating the increasing interest in the topic as well as the emerging nature of research in this field. Finally, as presented in Figure 3, most of the research/academic institutions which conducted the reviewed articles were found in Netherlands, USA, and UK.

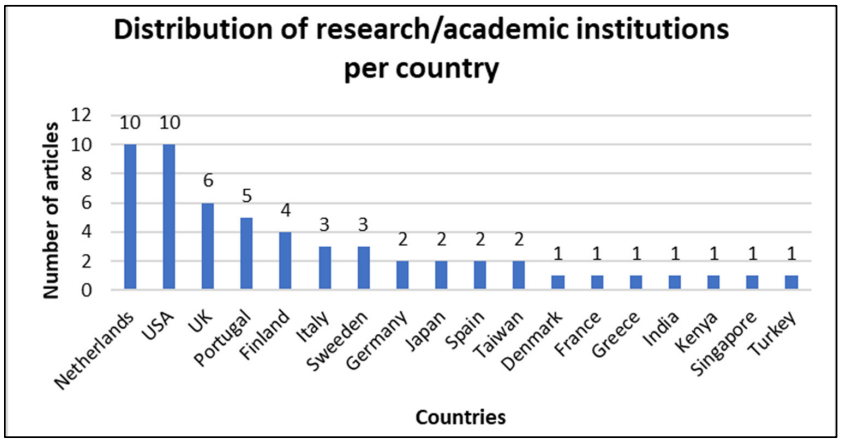

Figure 3. Distribution of research/academic institutions per country.

What follows, is the presentation of the main findings per research question guiding this SRL.

5.1. Methodological Characteristics

The 44 articles (n = 44) included in our review corpus, presented a total of 50 (n = 50) empirical studies (i.e., 6 of the reviewed articles presented two empirical studies). An overview of the methodological characteristics of these studies is presented in Table 3.

To begin with their research focus, most of these studies were primarily focused on the effectiveness of the deployed BCGs on users' EC (n = 35 studies, 70%), rather than addressing the usability (n = 8 studies, 16%) or exploring the design of the adopted BCGs (n = 7 studies, 14%). Focusing on the research design, approximately half (n = 24 studies, 48%) were experimental studies (e.g., pre-posttest studies, experimental or quasi-experimental studies), while the rest (n = 26 studies, 52%) were small scale and preliminary evaluation research studies (e.g., usability studies, field trial studies, pilot studies). Regarding the types of the BCGs deployed, the most prominent were pervasive games, 3D virtual games or 2D digital games (n = 9 studies per type). Focusing on the duration of the BCGs, only eight (16%) demonstrated long-term game-based interventions, as most of the reviewed studies (n = 19 studies, 38%) enacted short-term interventions which lasted from some minutes to some hours. Regarding the sampling, in the vast majority of the studies (n = 43 studies, 86%) the sample comprised adults or mixed-age samples and included up to a maximum of 100 players (n = 39 studies, 78%). On the other hand, we have identified only seven studies (14%) with children and/or adolescents as well as only nine studies with large samples comprising more than 100 players Finally, the most prominent data collection approaches were surveys (n = 41 studies, 82%), interviews (n = 15 studies, 30%), and energy consumption measures (n = 14 studies, 28%).

Table 3. Methodological aspects of the reviewed empirical articles *.

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
1	**Banerjee et al. (2014) [58]**	**Effectiveness** To evaluate the impact of BCG on engaging parents and children in learning about energy consumption in their homes	**Qualitative case study**	**Pervasive game** "Ghost hunter"	**30–60 min**	**Mixed age** ***n* = 22**	• Interviews • Video-recordings
2	**Bardhan et al. (2015) [13]**	**Effectiveness** To present and evaluate a conceptual framework for the development of a BCG on waste management	**Pilot study**	**Point-and-click game** "Trashwar"	**90 s** (per round)	**Non-adults** ***n* = 70**	• Game-based performance • Observations • Surveys
3	**Böhmet al. (2021) [59]**	**Effectiveness** To assess the impact of a BCG on empowering players' sustainable diet via a preliminary evaluation	**Pre-Posttest study**	**Idle game** "Veganity, your journey"	**5 days**	**Adults** ***n* = 10**	• Surveys
4	**Brewer et al. (2015) [60]**	**Effectiveness** To assess the impact of a BCG on encouraging players to reduce and shift their electricity use	**User research**	**Causal game** "Share Buddy"	**8 days**	**Adults** ***n* = 32**	• Application logs • Energy consumption measurements • Interviews • Surveys
		Effectiveness To assess the impact of a BCG on encouraging players to reduce and shift their electricity use	**User research**	**Causal game** "Share Buddy"	**3 weeks**	**Adults** ***n* = 30**	• Application logs • Energy consumption measurements • Interviews • Surveys
5	**Casals et al. (2017) [61]**	**Effectiveness** To assess the impact of the BCG on enhancing social tenants behavioral change towards energy efficiency in comparison with a control group	**Experimental study** • Experimental condition: game • Control condition: no game	**3D virtual game** "Energy Cat: The House of Tomorrow"	**n/a**	**Mixed age** ***n* = 80 households (randomly assigned per condition)**	• Energy consumption measurements • Surveys

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
6	**Centieiro et al. (2011) [62]**	**Usability** To evaluate the usability, gameplay and persuasive effects on users of a BCG regarding waste management	**User research**	**Location-based game** "Gaea"	**10 min** (per gaming session)	**Mixed age** ***n* = 15**	• Observations • Surveys
		Usability To evaluate the usability, gameplay and persuasive effects of a BCG regarding waste management	**User research**	**Location-based game** "Gaea"	**15 min** (per gaming session)	**Mixed age** ***n* = 37**	• Observations • Surveys
7	**Cowley and Bateman (2017) [63]**	**Effectiveness** To assess the impact of a BCG on relative changes in energy savings in three test sites as well as players' preferences, decisions and frequency of playing	**Pilot study**	**Social online game** "Green my place"	**n/a**	**Adults** ***n* = 419**	• Application logs • Energy consumption measurements
		Effectiveness To assess the impact of the BCG on promoting pro-environmental knowledge, attitudes and behaviors regarding energy conservation in comparison with a control group	**Experimental study** • Experimental condition: game • Control condition: no game	**Social online game** "Green my place"	**n/a**	**Adults** ***n* = 79**	• Surveys
8	**de Vries and Knol (2011) [64]**	**Effectiveness** To assess the impact of the BCG on several energy-related attitudes in comparison with a control group	**Experimental study** • Experimental condition: game • Control condition: no game	**3D virtual game** "EnerCities	**15–45 min**	**Non-adults** ***n* = 653** (Experimental condition = 325/ Control condition = 328)	• Surveys
9	**Dunn et al. (2013) [65]**	**Effectiveness** To assess the impact of the BCG on the participants' knowledge, attitudes, and pro-conservation behaviors in relation to a comparison group deploying a conservation documentary	**Experimental study** • Experimental condition: game • Control condition: wildlife conservation documentary	**AR game** "Wildverse"	**3 h**	**Adults** ***n* = 182** (Experimental condition = 91/ Control condition = 91)	• Surveys

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
10	**Fijnheer et al. (2019) [66]**	**Effectiveness** To assess the impact of a BCG on knowledge, attitudes, and behaviors with respect to energy conservation in the household, in comparison with control group	**Experimental study** • Experimental condition: game • Control condition: dashboard	**Point-and-click game** "Powersaver Game"	**5 weeks**	**Mixed age** ***n* = 49** (21 households randomly assigned per condition)	• Energy consumption measurements • Surveys
11	**Fijnheer et al. (2021) [67]**	**Design** To compare the impact of a BCG including a competition feature versus the same game excluding this feature with respect to energy conservation in the household	**Experimental study** • Experimental condition: game with "competition" • Control condition: game with "no competition"	**Point-and-click game** "Powersaver Game"	**5 weeks**	**Mixed age** ***n* = 31** (18 households randomly assigned per condition)	• Energy consumption measurements • Surveys
12	**Fox et al. (2020) [38]**	**Design** To compare the impact of BCG on pro-environmental behaviors, manipulating the design features of interactivity and contingency	**Experimental study** • Condition 1: near contingent game • Condition 2: far contingent game • Condition 3: near non-contingent game • Condition 4: far non-contingent game	**3D virtual game** "Recovery Rapids"	**10 min**	**Adults** ***n* = 190** (Near contingent condition = 50/ Far contingent condition = 46/ Near non-contingent condition = 46/ Far non-contingent condition = 48)	• Surveys
13	**Gamberini et al. (2011) [68]**	**Usability** To assess users' satisfaction/ acceptance and usability of a BCG	**User research**	**Web-based game** "EnergyLife"	**3 months**	**Mixed age** ***n* = 24** (8 households)	• Application logs • Interviews • Surveys • Usability tasks

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
14	**Gamberini et al. (2012) [69]**	**Design** To describe the design of smart advice tips and to assess the impact of this tailoring strategy on users' acceptance and electricity conservation behaviors	**Field trial**	**Web-based game** "EnergyLife"	**4 months**	**Mixed age** ***n* = 10**	• Application logs • Energy consumption measurements • Interviews • Surveys
15	**Gardeli et al. (2017) [37]**	**Effectiveness** To present the development and an initial evaluation of a number of games and interactive systems for influencing users' pro-environmental behaviors	**User research**	**Digital game (2D)** "Bag to the future"/ "Finding bags"	**n/a**	**Non-adults** ***n* = n/a**	• Interviews • Observations • Surveys • Video-recordings
16	**Geelen et al. (2012) [70]**	**Effectiveness** To assess the impact of a BCG on household energy consumption and savings	**Pilot study**	**Pervasive game** "Energy Battle"	**4 weeks**	**Mixed age** ***n* = 20 households** (2–5 people per household)	• Application logs • Energy consumption measurements • Interviews • Surveys
17	**Gustafsson et al. (2010) [71]**	**Effectiveness** To evaluate and analyze a BCG designed to encourage energy conservation	**Field trial**	**Pervasive game** "Power Agent"	**10 days**	**Mixed age** ***n* = 6 players and their families (in two teams)**	• Artifacts (i.e., pictures taken) • Energy consumption measurements • Instant message conversations • Interviews
18	**Gustafsson et al. (2009) [30]**	**Effectiveness** To investigate if a BCG can achieve post game behavioral effects regarding energy conservation	**Field trial**	**Pervasive game** "Power Explorer"	**7 days**	**Non-adults** ***n* = 15**	• Application logs • Energy consumption measurements • Interviews • Observations • Surveys

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
19	**Hafner et al. (2020a) [72]**	**Effectiveness** To assess the impact of a BCG on encouraging household energy reductions in the UK social housing sector in comparison with a control group	**Quasi-experimental study** • Experimental condition: Game • Control condition: No game	**3D virtual game** "Energy Cat: the House of Tomorrow"	**12 months**	**Mixed age** ***n* = 82 households** (Experimental condition = 42 households/ Control condition = 40 households)	• Surveys
20	**Hafner et al. (2020b) [73]**	**Effectiveness** To assess the factors affecting energy demand after using a BCG and the main psychological barriers that prevent users from using less energy	**Qualitative case study**	**3D virtual game** "Energy Cat: the House of Tomorrow"	**12 months**	**Mixed age** ***n* = 20 households**	• Interviews
21	**Hedin et al. (2017) [74]**	**Effectiveness** To evaluate a BCG designed to help people learn how to use energy more efficiently, and to support behavior change toward more sustainable energy habits	**Field trial**	**Pervasive game** "Energy Piggy Bank"	**3 days**	**Adults** ***n* = 39**	• Application logs • Surveys
22	**Janakiraman et al. (2021a) [75]**	**Design** To compare the impact of a collaborative versus an individual-based BCG on students' pro-environmental attitudes and behaviors	**Quasi-experimental study** • Condition 1: individual play • Condition 2: collaborative play • Control condition: no game	**3D virtual game** "EnerCities"	**50 min** (for 2–3 rounds)	**Non-adults** ***n* = 131** (Individual play condition = 45/ Collaborative play condition = 44/ Control condition = 42)	• Game-based performance • Interviews • Observations • Surveys
23	**Janakiraman et al. (2021b) [76]**	**Effectiveness** To explore the influence of a BCG on environmental attitudes and behaviors	**Quasi-experimental study** • Experimental condition: game • Control condition: no game	**3D virtual game** "EnerCities"	**50 min** (for 2–3 rounds)	**Non-adults** ***n* = 110** (Experimental condition = 64/Control condition = 36)	• Interviews • Surveys

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
24	**Janakiraman et al. (2021c) [77]**	**Effectiveness** To assess the impact of a BCG in producing environmentally friendly attitudes and behaviors	**Quasi-experimental study** • Experimental condition: game • Control condition: no game	**3D virtual game** "EnerCities"	**5 weeks**	**Adults** ***n* = 94** (Experimental condition = 52/Control condition = 42)	• Game-based performance • Interviews • Surveys
25	**Kimura and Nakajima (2011) [78]**	**Design** To explore the design, the strategies applied a BCG to encourage users to reduce their CO_2 footprint	**Pre-Posttest study**	**Pervasive game** "Ecoland"	**4 weeks**	**Mixed age** ***n* = 6 households (20 participants)**	• Energy consumption measurements • Surveys • Households' reports
26	**Lobo et al. (2009) [79]**	**Usability** To present the results of user tests regarding the usability of a BCG as well as its impact on encouraging recycling activities	**User research**	**AR game** "Smart bins"	**5 min**	**Non-adults** ***n* = 17**	• Observations • Surveys
27	**Orland et al. (2014) [80]**	**Effectiveness** To assess the impact of a BCG in reducing plug loads in a mid-size commercial office in comparison with a control group	**Quasi-experimental study** • Experimental condition: game • Control condition: no game	**Digital game (2D)** "Energy Chickens"	**12 weeks**	**Adults** ***n* = 57** (Experimental condition = 41/Control condition = 16)	• Energy consumption measurements • Surveys
28	**Ouariachi et al. (2018) [81]**	**Design** To analyze the communication and educational aspects of a BCG by making use of a validated framework for serious games analysis	**Delphi study**	**Role-playing game** "We energy game"	**n/a**	**Adults** ***n* = 13**	• Checklists • Surveys
		Effectiveness To assess the effectiveness of a BCG in achieving cognitive, affective, attitudinal and behavioral engagement on energy consumption	**Qualitative case study**	**Role-playing game** "We energy game"	**40 min**	**Adults** ***n* = 15**	• Group discussion

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
29	**Ouariachi et al. (2019) [82]**	**Effectiveness** To assess the effectiveness of a BCG in achieving awareness and understanding of the complexity of energy transition	**Pre-Posttest study**	**Role-playing game** "We energy game"	**30 min**	**Adults** ***n* = 100**	• Surveys
30	**Ouariachi et al. (2020) [83]**	**Effectiveness** To assess the effectiveness of a BCG on pro-environmental awareness, understanding and self-efficacy about energy conservation	**Pre-Posttest study**	**Role-playing game** "We energy game"	**30 min**	**Adults** ***n* = 100**	• Surveys
31	**Özgen et al. (2020) [84]**	**Effectiveness** To assess the impact of a BCG on users' pro-environmental awareness, attitudes and behaviors	**Pre-Posttest study**	**Digital game (2D)** "Save the planets"	**n/a**	**Adults** ***n* = 22**	• Surveys
32	**Panagiotopoulou et al. (2020) [85]**	**Usability** To qualitatively assess users' satisfaction/acceptance and usability of a BCG	**User research**	**Digital game (2D)** "Contact from the future"	**n/a**	**Adults** ***n* = 15**	• Observations • Surveys
		Usability To quantitatively assess users' satisfaction/acceptance and usability of a BCG	**User research**	**Digital game (2D)** "Contact from the future"	**n/a**	**Adults** ***n* = 7**	• Observations • Interviews
33	**Rai and Beck (2017) [86]**	**Effectiveness** To assess the effectiveness of a BCG on solar energy adoption by residential energy customers in comparison to a control group	**Experimental study** • Experimental condition: game • Control condition: no game	**Real-time trivia game** "Contact from the future"	**2 weeks**	**Adults** ***n* = 103** (Experimental condition = 27/Control condition = 76)	• Surveys

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
34	**Reeves et al. (2015) [87]**	**Effectiveness** To assess the impact of a BCG on energy efficient behaviors	**Quasi-experimental study** • Experimental condition: serious game • Control condition: entertainment game	**Digital game (2D)** "Power House"	**30 min**	**Adults** ***n* = 40**	• Observations
		Effectiveness To assess the impact of a BCG on the decrease of electricity usage	**Field trial**	**Digital game (2D)** "Power House"	**17 days**	**Adults** ***n* = 51**	• Energy consumption measurements
35	**Rogers et al. (2018) [88]**	**Effectiveness** To assess the persuasive effects of a BCG on users' sustainable consumption	**Pre-Posttest study**	**Point-and-click game** "Textile manager"	**30 min**	**Adults** ***n* = 57**	• Application logs • Surveys
36	**Salvador et al. (2012) [89]**	**Usability** To evaluate the usability, gameplay and effects on users of MAID	**User research**	**Gesture-based game** "MAID"	**n/a**	**Mixed age** ***n* = 26**	• Surveys
37	**Santos et al. (2013) [90]**	**Usability** To evaluate the usability of a BCG as well as its impact on users' environmental awareness and attitudes	**User research**	**AR game** "eVision"	**20 min**	**Adults** ***n* = 20**	• Surveys
38	**Simon et al. (2012) [91]**	**Effectiveness** To introduce and evaluate a BCG on motivating energy-saving behavior in office spaces	**Pilot study**	**Pervasive game** "Climate Race"	**10 days**	**Adults** **n/a**	• Energy consumption measurements • Interviews • Surveys

Table 3. *Cont.*

	Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
39	**Soekarjo and Oostendorp (2015)** [92]	**Effectiveness** To assess the impact of a BCG on energy related attitudes and behaviors in comparison with an informative control group	**Experimental study** • Experimental condition: game • Control condition: informative PowerPoint presentation	**3D virtual game** "EnerCities	**20 min**	**Adults** ***n* = 46** (Experimental condition = 23/Control condition = 23)	• Surveys
40	**Takayama et al. (2009)** [93]	**Effectiveness** To describe the concept and the theories behind a BCG, and provide preliminary results regarding its effectiveness	**User research**	**Pervasive game** "Ecoland"	**4 weeks**	**Mixed age** ***n* = 6 households (20 participants)**	• Surveys
41	**Tolias et al.** (2015) [94]	**Effectiveness** To introduce and evaluate a BCG designed to raise awareness and promote behavior change in relation to energy waste in the workplace	**Field trial**	**Pervasive game** "IdleWars"	**2 weeks**	**Adults** ***n* = 26**	**Mixed methods** • Application logs • Group discussion
42	**Wang et al. (2021)** [95]	**Effectiveness** To evaluate the impact of a BCG on pro-environmental knowledge and attitudes	**Pre-Posttest study**	**AR game** "PEAR"	**n/a**	**Adults** ***n* = 37**	• Surveys
43	**Yang et al. (2012)** [96]	**Effectiveness** To examine how a BCG affects users' self-awareness, learning motivation and willingness to conserve energy	**Pre-Posttest study**	**Digital game (2D)** "ECOPET"	**90 min**	**Adults** ***n* = 23**	• Surveys • Video-recordings
44	**Yang et al. (2017)** [97]	**Effectiveness** To examine the effects of locus of control on behavioral intention and learning performance of energy knowledge in the context of a BCG	**Pre-Posttest study**	**Digital game (2D)** n/a	**60 min**	**Adults** ***n* = 40**	• Surveys

Table 3. *Cont.*

Articles	Research Focus	Study Type	Game Type	Game Duration	Sample	Data Collection
44 reviewed articles presenting 50 empirical studies	**N of studies per research focus** • Effectiveness: 36 • Usability: 8 • Design: 6	**N of studies per study type** ***Experimental research studies: 24*** • Pre-Posttest study: 9 • Experimental study: 9 • Quasi-experimental study: 6 ***Small-scale/Preliminary evaluation research studies: 26*** • User research: 12 • Field trial: 6 • Pilot study: 4 • Qualitative case study: 3 • Delphi study: 1	**N of studies per game type** • Pervasive game: 9 • 3D virtual game: 9 • Digital game (2D): 9 • AR game: 4 • Point-and-click game: 4 • Role-playing game: 4 • Web-based game: 2 • Social online game: 2 • Location-based game: 2 • Causal game: 2 • Real-time trivia game: 1 • Gesture-based game: 1 • Idle game: 1	**N of studies per game duration** • Short term (minutes to hours): 19 • Medium term (days to month):13 • Long term (months to year): 8 • n/a: 10	**N of studies per sample type** • Adults: 28 • Mixed age: 15 • Non-adults: 7 **N of studies per sample size** • $n < 30$ players: 20 • $n = 30$–100 players: 19 • $n > 100$ players: 9 • n/a: 2	**N of studies per data collection measures** • Surveys: 41 • Interviews: 15 • Energy Consumption measurements: 14 • Observations: 10 • Application logs: 10 • Video-recordings: 3 • Game-based performance: 3 • Group discussion: 2 • Checklists: 1 • Usability tasks: 1 • Households' reports: 1 • Instant message conversations: 1 • Artifacts: 1

* Some articles reported in more than one empirical study that sometimes employed more than one study, game, samples, data collection methods, etc. In case information was not available in a reviewed article this is indicated with "n/a".

5.2. Gaming Elements and Persuasive Mechanisms

Though not to the same degree, all forty-four articles (n = 44), provided insights regarding the gaming elements and the persuasive strategies underpinning the BCGs.

Focusing on the gaming elements (Table 4), the most reported were the performance/measurement elements, e.g., "points", "stats", "levels" (n = 43 articles, 97.7%); followed by social elements, e.g., "competition", "collaboration", "social pressure" (n = 29 articles, 65.9%); and ecological elements, e.g., "economy", "time pressure", "chance" (n = 29 articles, 65.9%). However, we have also noticed that there were gaming elements such as "reputation", "imposed choice", "rarity", "novelty" and "renovation" which were not deployed at all.

Table 4. Overview of the gaming elements underpinning the reviewed BCGs.

Game Elements	N	%
Performance/Measurement Elements	**43**	**97.7**
Points	35	79.5
Stats	32	72.7
Levels	25	56.8
Progression	15	34.1
Acknowledgment	10	22.7
Social Elements	**29**	**65.9**
Competition	26	59.1
Collaboration	16	36.4
Social Pressure	5	11.4
Reputation	0	0.0
Ecological Elements	**29**	**65.9**
Economy	15	34.1
Time Pressure	9	20.5
Chance	3	6.8
Imposed choice	0	0.0
Rarity	0	0.0
Personal Elements	**28**	**63.6**
Objectives	24	54.5
Puzzles	12	27.3
Sensation	5	11.4
Novelty	0	0.0
Renovation	0	0.0
Fictional Elements	**10**	**22.7**
Narrative	5	11.4
Storytelling	5	11.4

Focusing on the persuasive mechanisms (Table 5), the most reported were the dialogue support ones, e.g., "rewards", "suggestions", "praise" (n = 44 articles, 100%), followed by primary task support mechanisms, e.g., "simulation", "self-monitoring", "tunneling", (n = 34 articles, 77.3%). However, as in the case of the gaming mechanisms, we have also noticed that there were persuasive mechanisms, especially in the category of system credibility support, which were not deployed at all.

Table 5. Overview of the persuasive mechanisms underpinning the reviewed BCGs.

Persuasive Mechanisms	**N**	**%**
Dialogue Support	**44**	**100.0**
Rewards	30	68.2
Suggestions	27	61.4
Praise	11	25.0
Liking	5	11.4
Reminders	4	9.1
Similarity	0	0.0
Social role	0	0.0
Primary Task Support	**34**	**77.3**
Simulation	23	52.3
Self-monitoring	20	45.5
Tunnelling	6	13.6
Personalization	5	11.4
Tailoring	4	9.1
Reduction	1	2.3
Rehearsal	1	2.3
Social Support	**27**	**61.4**
Competition	26	59.1
Cooperation	16	36.4
Social comparison	12	27.3
Social facilitation	7	15.9
Social learning	6	13.6
Normative influence	3	6.8
Recognition	1	2.3
System Credibility Support	**5**	**11.4**
Expertise	5	11.4
Trustworthiness	0	0.0
Surface credibility	0	0.0
Real-world feel	0	0.0
Authority	0	0.0
Third-party endorsement	0	0.0
Verifiability	0	0.0

5.3. EC Actions

All 44 articles (n = 44) also report that the adopted BCGs urged players to undertake certain EC actions during the gameplay. An overview of these actions is presented in Figure 4.

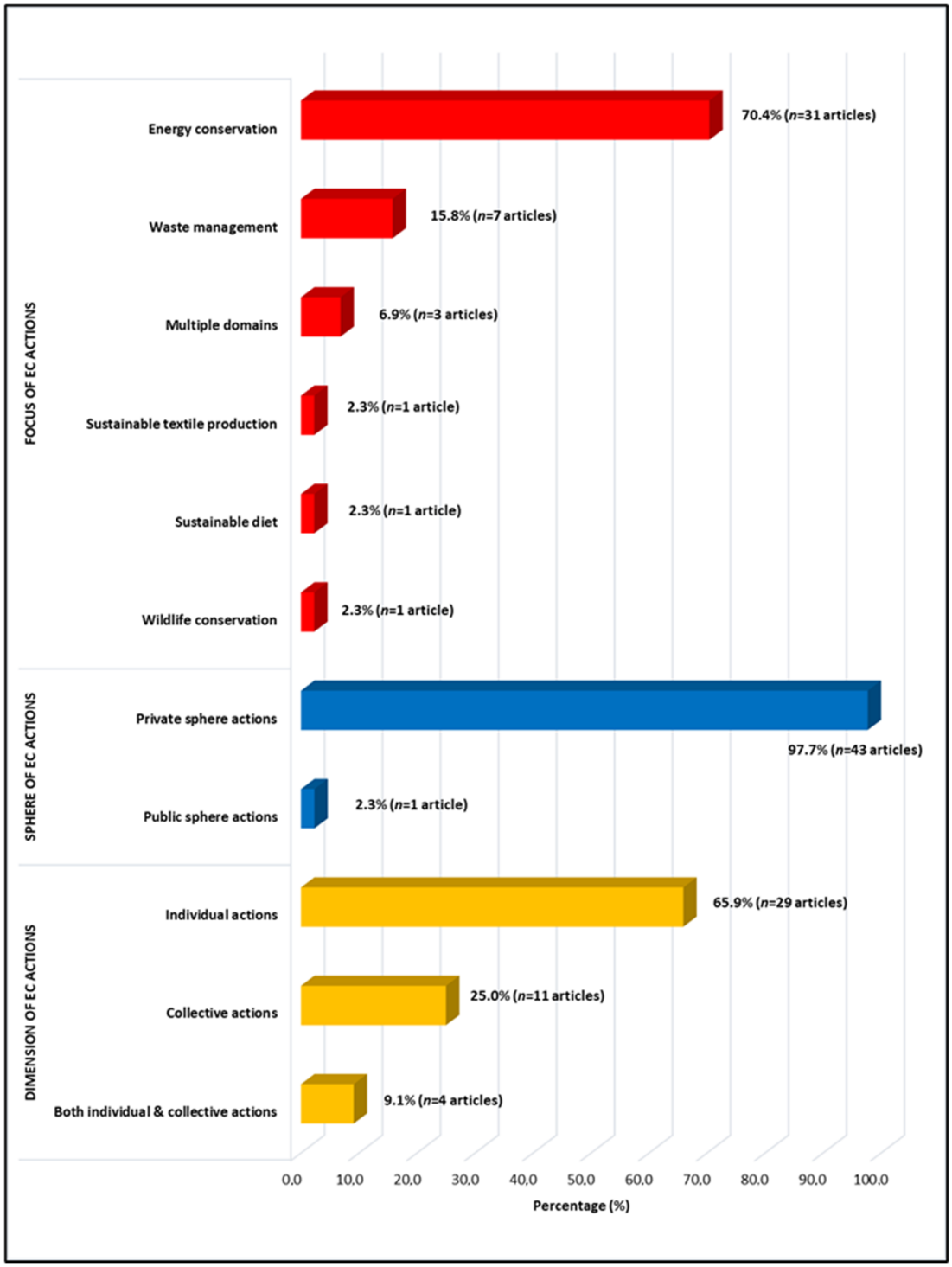

Figure 4. Distribution of EC actions per focus, sphere and dimension.

In their vast majority, these actions were mostly focused on energy conservation (n = 31 articles, 70.4%), as well as on waste management (n = 7 articles, 15.8%). In addition, focusing on the sphere of the EC actions, almost all the reported EC actions were classified in the private (n = 43 articles, 97.7%), rather than in the public sphere (n = 1 article, 2.3%). Put simply, most of the reported EC actions were found to affect the relations between individuals and societies (e.g., saving energy, recycling, following a more sustainable diet), rather than affecting the relation in societies (e.g., lobbying local councils and policymakers, participating in environmental campaigns, voting for environmental issues). Finally, we

have found that most of the reviewed articles report on individual EC actions (n = 29 articles, 65.9%), namely actions taken on an individual basis, but a significant portion of articles also report on BCGs which supported collective actions (n = 11 articles, 25%).

5.4. Impact on EC Competences

The reviewed articles also report on the impact of BCGs on knowledge, in terms of players' acquisition of new information and/or environmental awareness (n = 29 articles, 65.9%), attitudes (n = 24 articles, 54.5%), and behaviors (n = 26 articles, 59%) (Table 6).

Table 6. Impact of the reviewed BCGs on EC knowledge, attitudes and behaviors.

Study	Knowledge	Attitudes	Behaviors
Banerjee et al. (2014) [58]	+	n/a	n/a
Bardhan et al. (2015) [13]	+/−	n/a	n/a
Bohm et al. (2021) [59]	+	+	n/a
Brewer et al. (2015) [60]	+	n/a	−
Casals et al. (2017) [61]	n/a	n/a	+
Centieiro et al. (2011) [62]	+	+	n/a
Cowley and Bateman (2017) [63]	−	+/−	+/−
De Vries and Knol (2011) [64]	n/a	+	n/a
Dunn et al. (2013) [65]	+	+	−
Fijnheer et al. (2019) [66]	+	−	+
Fijnheer et al. (2021) [67]	+	−	+
Fox et al. (2020) [38]	n/a	+	+
Gamberini et al. (2011) [68]	+	n/a	n/a
Gamberini et al. (2012) [69]	n/a	n/a	+
Gardeli et al. (2017) [37]	+	n/a	n/a
Geelen et al. (2012) [70]	n/a	n/a	+/−
Gustafsson et al. (2010) [71]	n/a	n/a	+/−
Gustafsson et al. (2009) [30]	+/−	+	+
Hafner et al. (2020a) [72]	−	n/a	−
Hafner et al. (2020b) [73]	+/−	n/a	+/−
Hedin et al. (2017) [74]	n/a	n/a	+
Janakiraman et al. (2021a) [75]	n/a	+	+
Janakiraman et al. (2021b) [76]	n/a	+	+
Janakiraman et al. (2021c) [77]	n/a	+	+
Kimura and Nakajima (2011) [78]	n/a	n/a	+
Lobo et al. (2009) [79]	+	+	n/a
Orland et al. (2014) [80]	n/a	n/a	+
Ouariachi et al. (2018) [81]	+	−	−
Ouariachi et al. (2019) [82]	+	n/a	n/a
Ouariachi et al. (2020) [83]	+	+	n/a
Özgen et al. (2020) [84]	+	+	+

Table 6. *Cont.*

Study	Knowledge	Attitudes	Behaviors
Panagiotopoulou et al. (2020) [85]	+	n/a	n/a
Rai and Beck (2017) [86]	+	+	+
Reeves et al. (2015) [87]	n/a	n/a	+
Rogers et al. (2018) [88]	+	+	n/a
Salvador et al. (2012) [89]	+	+	n/a
Santos et al. (2013) [90]	+	+	n/a
Simon et al. (2012) [91]	n/a	n/a	+
Soekarjo and Oostendorp (2015) [92]	−	−	n/a
Takayama et al. (2009) [93]	+	n/a	n/a
Tolias et al. (2015) [94]	n/a	n/a	+/−
Wang et al. (2021) [95]	+	+	n/a
Yang et al. (2012) [96]	+	+	n/a
Yang et al. (2017) [97]	+	+	+
44 articles	**29 articles** • + impact: 23 • − impact: 3 • +/− impact: 3	**24 articles** • + impact: 19 • − impact: 4 • +/− impact: 1	**26 articles** • + impact: 17 • − impact: 4 • +/− impact: 5

The majority of these articles presented empirical findings supporting the effectiveness of the BCGs in profoundly promoting players' environmental knowledge (n = 23 articles, 52.3%) and attitudes (n = 19 articles, 43.2%), but to a lesser degree on players' behavioral change (n = 17 articles, 38.6%). Likewise, while a limited portion of the studies showed mixed or no impact on players' environmental knowledge (n = 6 studies, 13.6%) and attitudes (n = 5 studies, 11.4%), an increased number of studies (n = 9 studies, 20.4%) showed mixed or no impact on players' behavioral change. For instance, in their study, Dunn et al. [58] found that the "Wildverse" BCG was not successful in encouraging players to donate to wildlife conservation. In addition, in their study, Hafner et al. [65] concluded that the "EnergyCat" BCG did not lead to any substantive changes in energy consumption practices due to several reasons but mainly attributed to the unsuccessful game design and usability issues. On the other hand, the studies of Gustafsson et al. [64] and Geelen et al. [63] demonstrate that while the adopted BCGs contributed to short-term behavioral changes, they did not result in any long-term behavioral impacts.

6. Discussion

Growing concern due to the intensification of the global environmental crisis has served as springboard for the development of technological solutions aiming at the empowerment of citizens' pro-environmentalism. Toward this direction, behavioral change games (BCGs) may play a significant role, as they are assumed to promote environmental citizenship (EC) [11,12]. Put simply, using a combination of persuasive strategies and gaming elements, these games are hypothesized to equip players with an amalgam of pro-environmental competences. Following this reasoning, our study has provided a systematic review of 44 empirical articles, aiming to explore if the adoption of BCGs can, indeed, transform people from "gamers" into "environmental citizens". What follows is the discussion of our main findings per research question.

6.1. Impact on EC Competences

Though labeled as BCGs for having the empowerment of pro-environmental behaviors as their ultimate goal, according to our findings, the BCGs deployed in the reviewed articles were more successful in promoting pro-environmental knowledge and attitudes, rather than behaviors. More specifically, about one third of the reviewed articles indicated no impact of BCGs on EC behaviors or provided inconclusive findings. Therefore, while the outcomes of BCGs have often been argued to go beyond the cognitive (i.e., environmental knowledge and awareness) and toward influencing behavior [82,96,97], our findings question the success of BCGs in affecting and transforming players' pro-environmental behaviors. These findings may be attributed to the way in which influencing behavior is often made a challenging task due to people's resistance [32,98–100], while environmental knowledge and attitudes can be altered much more easily. In the next sections, we will also provide some additional plausible explanations for this issue, drawing on our findings about the design of the reviewed BCGs (i.e., gaming elements and persuasive mechanisms), the EC actions supported by the reviewed BCGs, as well as the methodological aspects of the reviewed studies.

6.2. Gaming Elements and Persuasive Mechasnisms

Focusing on the design of the reviewed BCGs, the most prevalent category of gaming elements were the performance/measurement elements and more specifically, "points" and "stats". Then, focusing on the persuasive mechanisms, the most prevalent category was the dialogue support mechanisms and more specifically, "rewards" and "suggestions". The prevalence of "points" is reasonable given that a scoring system is the most common element to engage the players with the gameplay and urge them to perform certain desired behaviors [4,101]. Likewise, an ever-increasing literature corpus has pointed out the role of rewards in motivating players to complete the required tasks and reach the game objectives, while also providing them a sense of pleasure and satisfaction [102–104]. In addition, our findings are well-aligned with prior research in the field of gaming, considering that "stats" and "suggestions" served as the major feedback mechanisms of the deployed BCGs. More specifically, researchers in the field have associated feedback with clear goals and challenges which contribute to the sense of flow during the gameplay [105], while also keeping the player motivated [106]. Importantly, feedback has also been argued to enhance learning effectiveness, mitigate poor performance [106], and have an impact on behavioral intention [107].

According to our review, the aforementioned gaming elements were supplemented by additional elements classified in the categories of "social" and "ecological", while the aforementioned persuasive mechanisms were supplemented by additional elements classified in the category of "primary task support mechanisms". However, we have also found that there were some gaming elements and persuasive mechanisms which were not adopted at all; researchers could therefore pay more attention to these neglected elements and mechanisms. In addition, despite the variance of the gaming mechanisms and the persuasive mechanisms deployed, we have noticed that only a small portion (14%) of the reviewed articles had a straightforward focus on evaluating the design of the deployed BCGs, seeking to identify the most effective gaming elements and persuasive strategies for empowering players' EC (see for example [38,67,69,78]). This finding echoes Hammady's and Arnab's remark that "existing studies and reviews often report the effectiveness of game interventions on behavior change without offering any insights into why and how games and gameplay are effective on a granular design level by reflecting on the choice of game elements used in the design" [4] (p. 3). Hence, as successfully posed by Fijnheer et al. [66], future studies should systematically examine which persuasive features of BCGs exactly promote lasting changes in pro-environmental knowledge, attitudes, and behaviors.

6.3. Empowerment of EC Actions

Regarding the EC actions supported by the reviewed BCGs, we have observed three main breakthroughs in relation to the EC actions' focus, spheres and dimensions. Firstly, the EC actions undertaken by the players during these games were narrowed down to the aspects of energy conservation and waste management. This can be attributed to the way in which unsustainable energy and waste management patterns are often considered among some of the greatest barriers to environmental sustainability [78,93]. However, we argue that there are several other areas in which future BCGs may focus, such as water spending, transportation, food consumption etc., which could also serve as the subject of the BCGs. Secondly, the EC actions undertaken by the players during the BCGs were, except in one case (see Dunn et al. [65]), situated in the private sphere. Put simply, the reported EC actions were oriented toward affecting the relations between individuals and societies, rather than affecting relations in societies [108]. However, EC is not limited to private sphere actions, which simply relates to personal lifestyles and everyday behaviors (e.g., purchasing choices, energy conservation, waste management). Instead, EC expands beyond private sphere actions into embracing public sphere actions, which are often related to more activist behaviors such as donating, lobbying policymakers or being a member of environmental associations [22,109,110]. We therefore argue that future BCGs should invest more effort towards this direction, by providing equal attention toward the transformation of players both into "private", as well as "public" EC actors. Finally, the deployed BCGs supported to a much greater degree individual EC actions, rather than collective actions. However, building a sense of community-based responsibility encourages the citizens to work collectively towards the common good, which is a crucial aspect of EC [111,112]. Following this reasoning, another suggestion for the design of future BCGs is the integration of collaborative gameplay modes to a greater degree, to encourage collective action when addressing a given socio-environmental issue.

6.4. Methodological Aspects

Our review has also shed light on the methodological aspects (i.e., study type, game duration, sample, and data collection) underpinning the reviewed studies. Drawing from these findings, we argue these methodological aspects may define the effectiveness of a game-based intervention.

Focusing on study type, it should be noted that approximately half of the reviewed studies were small-scale and/or preliminary research. These studies took the form of pilots, field trials or user studies and, as such, were mostly structured around prototypes of BCGs. However, as reported, these prototypes were often not well-aligned with users' needs [72,73] and the targeted behaviors [94], or presented several technical issues which ranged from glitches to crashes [65]. In turn, this may have limited the impact of the games, while also indicating the need to deploy more robust BCGs in order to induce the intended behavior changes [65,85]. Next, focusing on the duration of the enacted BCGs, about half of the studies report short-term game-based interventions ranging from minutes to hours, while only a small portion (16%) of the reviewed studies report long-term interventions ranging from months to a year. However, considering the idea that pro-environmental values and behaviors are deeply rooted in the personality and, as such, are rather constant and difficult to change [110,113], it is also quite reasonable that game-based interventions of limited duration usually have limited impact on players' pro-environmental behaviors.

In terms of the data collection, most of the reviewed studies are dominated by the use of self-report measurements (i.e., surveys). In a way this can be problematic, given that such subjective data collection techniques are characterized by a degree of uncertainty [114], as they "do not necessarily reflect the practical changes and implications in the activities and behaviors of players" [95] (p. 12). To overcome this issue, according to Janakiraman et al. [75] future studies should combine, when possible, self-report measurements with more objective measurements, such as observations and measurements of daily habits (i.e., energy consumption, electricity shifting, consumption patterns, transportation

modes, etc.). Finally, our findings point out that the dominance of small sample sizes is another methodological challenge for the generalizability of the reviewed articles' empirical findings. This relatively low number of participants may be related to the emphasis placed on adult recruitment. More specifically, it may be more challenging for adults to take part in such research studies due to their busy schedules, the intrusiveness of BCGs in their everyday routines and contexts (e.g., households, workplaces), their lack of interest/skills in gaming, and sometimes, due to their low ICT literacy and confidence when using computers [72,73,115]. Future studies in the field could therefore focus on the recruitment of children and adolescents in K-12 education.

7. Limitations and Future Research

Though the findings of this review study may help to flesh out a more comprehensive picture of the state of the art regarding empirical research on BCGs for EC, some limitations of this work are important to note.

From a methodological point of view, our literature review was limited in terms of the keywords and databases we used for the articles' retrieval during the document search. Using specific keywords and databases for searching may not have retrieved all of the possibly relevant articles. However, the selection of multiple keywords and search strings in combination with the deployed ancestry method limits the influence of this bias. Additionally, this systematic review of the literature included only empirical studies, thus excluding theoretical studies in the field, which may provide more insights into BCGs and their impact on pro-environmentalism. However, all of the studies included were thoroughly analyzed using a coherent and well-crafted data analysis procedure, thus providing evidence-based substantiation to the research questions guiding this study. Finally, our review addressed only empirical studies on BCGs, also known as persuasive games, excluding other empirical studies on persuasive systems and technologies or mobile apps for EC. However, we argue that BCGs, as a specific media genre, have unique properties and characteristics, and, as such, they deserve to be studied on their own. Furthermore, the decision to limit the scope of this review solely to BCGs promoting pro-environmentalism allowed for a more focused lens, thus providing deeper insights regarding the empirical research in the field.

From a theoretical point of view, the focus of this review study on environmental citizenship (EC) and the implementation of the EEC model to guide our analysis on the impact of BCGs on players' pro-environmentalism (i.e., pro-environmental knowledge, attitudes, and behaviors) may be considered another limitation. In particular, when adopting this top-down approach on coding and analysis, we left out the potential impact of these games on other aspects, such as, for instance, on the development of players' soft skills, which may be an interesting direction for future studies. In addition, it should be noted that the main purpose of this study was to identify and record the main gaming and persuasive elements underpinning BCGs, rather than isolating and comparing their effectiveness. Future studies should therefore proceed a step further and, adopting a meta-analysis approach, investigate this issue. Finally, as part of this review study, we have acknowledged the multidisciplinary nature of research in the field of BCGs. However, investigating and analyzing the retrieved data, in order to understand how synergies and collaborative partnerships of research networks exist in this field, was out the scope of this systematic review. As the corpus of empirical studies increases, future studies could shed light in this area by investigating the research synergies among the different domains underpinning the development, deployment and evaluation of BCGs for EC (e.g., HCI, computer science, environmental science, education and psychology).

8. Conclusions and Implications

In conclusion, BCGs promoting environmental citizenship (EC) form a nascent but growing research area. An ongoing debate exists as to whether these games are more about promoting pro-environmentalism or just playing. In a systematic review of literature, we

have identified and analyzed 44 empirical articles in the field, seeking to shed light on this issue. Our analyses indicated that, while BCGs seem to promote EC competences in terms of pro-environmental knowledge and attitudes, such an assertion is not fully warranted for pro-environmental behavior. In other words, our findings cannot fully support the idea that BCGs have the capacity to transform the players from "gamers into environmental citizens". Future research should therefore explore this topic further, considering the design, EC content and implementation/evaluation of these games. What follows is a sequence of implications and recommendations in relation to these aspects, which may support the development of practical contributions in the field.

8.1. Design-Related Implications

We advocate that research on BCGs needs to move away from "victory narratives" (e.g., successful evaluation stories on the effectiveness of BCGs) to focus instead on the design of BCGs (i.e., identification of the most influencing gaming elements and persuasive mechanisms) which can contribute to the promotion of EC. This is of great importance, given that, while several studies have supported the idea that game features can provoke behavioral change, when testing any given media product, the combination of the selected media features can easily produce different results [116]. Future research on BCGs should therefore focus on identifying those game characteristics which may have a significant impact on players' EC [117]. In addition, from a design point of view, we also suggest the adoption of co-design approaches aiming at the co-development of BCGs in collaboration with the gamers; this may also ensure that the produced BCGs will be fully aligned with the needs and expectations of the target group.

8.2. Content-Related Implications

We argue that content-wise, BCGs need to integrate EC to a greater degree, by embracing a larger repertoire of EC actions situated in the broader context of attempts to address biodiversity loss, climate change, deforestation, water depletion and desertification, rather than being narrowed down to decontextualized and fragmented EC actions related to energy conservation and waste management practices. We also suggest that, according to the EC conceptualization [22], BCGs should include EC actions situated in both private and public spheres, as well as in both the individual and collective dimensions.

8.3. Methodological-Related Implications

From a methodological point of view, we suggest the use of more robust BCGs (rather than testbeds and prototypes) as well as their deployment for longer periods of time. Many researchers have also proposed the need for more longitudinal interventions to achieve long-term and sustained behavioral changes, which will last after the end of a game [13,70,76]. In addition, when evaluating the impact of BCGs, we recommend the adoption of a mixed-based approach comprising both self-report measurements and more objective measurements, such as observations and measurements of daily habits. Such an approach will not only allow a more holistic and in-depth evaluation, but at the same time will also contribute to the data triangulation given that the strengths of one type of data may mitigate the weaknesses of the other. Finally, we also suggest the implementation and evaluation of BCGs with bigger samples, mainly comprising children and adolescents rather than adults. Young children and adolescents are considered 'digital natives' who are inherently competent and confident with digital technologies [118], and as such they may be also more eager to take part in such studies. Furthermore, EC should be promoted beginning from childhood onwards, and BCGs may provide an ideal venue for this purpose. If the research community shifts its focus to these directions, then game on!

Author Contributions: Conceptualization, Y.G.; methodology, Y.G., A.C.H., D.P.-H. and A.A.; formal analysis, Y.G.; investigation, Y.G., A.C.H. and D.P.-H.; writing—original draft preparation, Y.G.; writing—review and editing, A.C.H., D.P.-H. and A.A.; visualization, Y.G. and A.A.; project administration, Y.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: This study is partly inspired by ENEC—European Network for Environmental Citizenship.

Conflicts of Interest: The authors declare no conflict of interest.

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