



HAL
open science

Gamification in the Transport and Mobility Sector: A Systematic Review

Eugénie Avril, Angèle Picco, Colin Lescarret, Céline Lemerrier, Amaël Arguel,
Loïc Caroux

► **To cite this version:**

Eugénie Avril, Angèle Picco, Colin Lescarret, Céline Lemerrier, Amaël Arguel, et al.. Gamification in the Transport and Mobility Sector: A Systematic Review. *Transportation Research Part F: Traffic Psychology and Behaviour*, 2024, 104, pp.286-302. 10.1016/j.trf.2024.06.004 . hal-04614172

HAL Id: hal-04614172

<https://hal.science/hal-04614172v1>

Submitted on 20 Dec 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



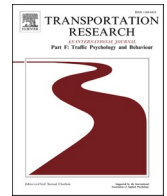
Distributed under a Creative Commons Attribution 4.0 International License



ELSEVIER

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Transportation Research Part F: Psychology and Behaviour

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

Gamification in the Transport and Mobility Sector: A Systematic Review

Eugénie Avril^{a,1}, Angèle Picco^{b,*}, Colin Lescarret^c, Céline Lemerrier^c, Amaël Arguel^c, Loïc Caroux^c

^a Univ. Polytechnique Hauts-de-France, CNRS, UMR 8201 - LAMIH, F-59313 Valenciennes, France

^b Faculty of Behavioural and Social Sciences, University of Groningen, the Netherlands

^c CLLE, Université de Toulouse, CNRS, Toulouse, France

ARTICLE INFO

Keywords:

PRISMA review
Gamified interventions
Transport research
Game elements

ABSTRACT

Gamification is an emerging concept that is often used and cited for its known motivational and engagement qualities. Although gamification is studied and applied in a variety of fields, to our knowledge no overview exists in the field of transport and mobility. There is thus a need for a comprehensive understanding of the research conducted, the empirical evidence it yields and the type of research that could still be lacking. These findings could contribute to more effective and better-accepted transport interventions, whether they aim to improve safety, mobility or eco-friendliness. Our review provides an overview of the literature on gamification in relation to mobility and transport and offers suggestions for future research and interventions. A PRISMA-compliant systematic literature review was conducted on SCOPUS, Web of Science and Pubmed, resulting in 49 eligible papers. The results of the analysis of these papers indicated heterogeneity in multiple areas: objectives of the intervention (e.g., safe or eco-friendly driving), methodologies (i.e., different sample sizes, different experimental designs), types of experiments (e.g., questionnaires, simulation or fleet studies) and gamification processes (e.g., with leaderboards, rewards, narratives), but also and more importantly, in the observed empirical evidence. No consensus seems to have been reached on the effects of gamification nor on the underlying mechanisms in the field of transport. There is a lack of knowledge on the most effective ways to propose a gamified intervention in the field of mobility and transport, whether it aims to change behaviours or attitudes. Further research should rely more on specific theoretical frameworks to justify their approach and assess the effect of gamification more methodologically and empirically in order to build applicable and reliable knowledge. The acquired knowledge could increase road safety or help nudge people towards more eco-friendly modes of transport.

1. Introduction

While the tendency in the 20th century in the field of transport and mobility was to develop multiple and various modes of

* Corresponding author at: Faculty of Behavioural and Social Sciences, University of Groningen, TP, Grote Kruisstraat 2/1, Groningen, the Netherlands.

E-mail addresses: eugenie.avril@uphf.fr (E. Avril), a.picco@rug.nl (A. Picco), colin.lescarret@univ-tlse2.fr (C. Lescarret), celine.lemerrier@univ-tlse2.fr (C. Lemerrier), amael.arguel@univ-tlse2.fr (A. Arguel), loic.caroux@univ-tlse2.fr (L. Caroux).

¹ Joint first authors.

<https://doi.org/10.1016/j.trf.2024.06.004>

Received 15 March 2023; Received in revised form 21 May 2024; Accepted 5 June 2024

Available online 14 June 2024

1369-8478/© 2024 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

transport, witnessing for example a boom in commercial flights and privately owned vehicles, the challenges nowadays fall under another aim: Rather than being more mobile, the focus is on being mobile differently. Indeed, the mobility sector faces two main challenges, in terms of safety and environment, and particular attention is given to ways to change behaviours to achieve safer and more eco-friendly traffic. However, despite multiple opportunities for public transport such as metro systems, buses or tramways, which are largely available across the world and especially in cities, the private car remains the main mode of transport in Europe (Storme et al., 2020) and transportation accounts for a little over 20 % of CO₂ emissions worldwide in 2020 (Statista, 2022). In parallel, traffic safety has improved rather steadily illustrated by a decrease in road-related deaths and crashes since the 1970s, yet road traffic injuries are the leading cause of death for people aged 5 to 29 (WHO, 2022). These two challenges, being addressed but not resolved, and the societal impact that consequences can have, stress the importance of the consideration for the future of transport and mobility, and the need for innovation to tackle human behaviour-related challenges.

A possible answer to those challenges lies in the evolution of technology, particularly in the transport and mobility domain, where Information and Communication Technologies (ICTs) have changed all prior practices. Nowadays, ICTs are predominant in our daily landscape, whether it is the use of a digital car dashboard in a road traffic context or a mobility app on a Smartphone (Gössling, 2018). ICTs are increasingly considered a possible solution to environmental problems and support sustainable behaviour (Alatas, 2021). Such technologies offer the possibility to influence the behaviour and/or the attitude of citizens, as illustrated by the emergence of the concept of gamification. According to Bozkurt and Durak (2018), although it is long recognised that playing can bring about enthusiasm and a feeling of exaltation (Huizinga, 1938), “gamification” as defined nowadays emerged in 2008 in the digital media industry, and attracted more attention from 2010 onwards (Deterding et al., 2011a).

While to our knowledge no consensual definition exists, gamification is mostly defined as “the use of game-design elements in non-game contexts” (Deterding et al., 2011a). The incorporation of game-design elements should intend to be playful (Werbach, 2014), yet the aim of gamification should remain serious (Krath et al., 2021). Gamification indeed differs from actual games, real-world simulations and the use of game theories in organisational matters, and is used typically to change behaviours (Robson et al., 2015) or to improve user experience and user engagement (Deterding et al., 2011b). Although the concept of gamification is relatively new, discussions about introducing fun in more serious contexts have been held for a few decades (e.g., Malone, 1980), and it is even hypothesised to date back a few millennia in a military context (Deterding et al., 2011b; Halter, 2006). The interest in these approaches lies in the motivational potential of game-design elements (Sailer et al., 2017), which is an argument often used to justify adopting a gamification approach. Krath et al. (2021) identified further justifications for the use of and the mechanisms underlying gamification: They reported 118 theoretical frameworks throughout the literature, which rely either on motivation and affect, learning, or behaviour principles. Based on those frameworks, they proposed 10 principles to explain how gamification works, of which some rely on behavioural guidance, others on fostering individual relevance or enabling social interaction (Krath et al., 2021).

To fulfil those principles, the process of gamification is driven by the inclusion of game-design elements, which are also referred to as “game mechanics”. Game mechanics can be described as “building blocks” (Deterding et al., 2011a) and are comparable to game design patterns, such as the ones identified by Björk and Holopainen (2004). The diversity and multitude of game mechanics resulted in many attempts to compile, sort and classify them (Sailer et al., 2017). One of the most cited of these attempts was conducted by Zichermann and Cunningham (2011) who classify game elements into seven primary mechanics: “points, levels, leaderboards, badges, challenges/quests, onboarding, and engagement loops”. According to the theory, each type of game mechanics can be used to meet specific users’ needs, which would explain its effectiveness. For example, points, badges and leaderboards can meet the need for competence, or having teammates can fulfil the need for social relatedness (Sailer et al., 2017).

The concept of gamification, while nascent, has become one of the most well-known methods to influence the individual and collective behaviour of people: It is indeed applied in many areas of human activity, such as the medical context (Sardi et al., 2017; Van Gaalen et al., 2021), education (Kalogiannakis et al., 2021), e-commerce (Behl et al., 2020), transportation safety (Klock et al., 2021) or sustainability (Guillen et al., 2021). This diversity of application domains has led to consider gamification research as an emerging multidisciplinary field (e.g., computer science, social sciences, engineering) (O’Donnell et al., 2017).

Without exception, gamification also sparked interest in the mobility and transport field: The concept has been growing rapidly and led to multiple research outputs, as will be discussed later on, but also to a few noteworthy attempts to gather the acquired knowledge, mostly through systematic reviews. However, most of them do not cover the entire field but, for example, uniquely the driving activity: It is the case for Yen et al. (2019) who reviewed five case studies of gamified interventions to extract a framework for gamification design, or for El Hafidy et al. (2021) who conducted a systematic mapping study on 220 mobile apps designed to improve driving behaviour. Diewald et al. (2013) also focused on the driving activity, reviewing in-vehicle mobile apps focused on navigation, safety or fuel efficiency, as well as Schroeter et al. (2014) who proposed a theoretical framework to apprehend boredom in driving and gamification. A review by Klock et al., (2021) can be mentioned as well, concerning the use of gamification, serious games and simulation games, specifically in freight transportation.

Yet, the use of gamification in transport and mobility is considered underdeveloped when compared to other sectors (Yen et al., 2019), although its potential has been highlighted in a few studies (Coombes & Jones, 2016; Fitz-Walter et al., 2017; Magaña & Organero, 2014). It could be in the context of sustainable transport to influence users towards more eco-friendly behaviour (e.g. Horst et al., 2022) and to help users choose the most sustainable route option. It could also concern the driving activity, with gamification aiming to help drivers, and to some extent, all road users, to be safer (e.g., Steinberger et al. (2017) used a gamified intervention to reduce boredom in drivers and therefore increase their engagement). Finally, gamification could even aim to influence public transport users to adopt a friendlier behaviour towards other users (e.g., Kuramoto et al. (2013) encouraged users to stand in public transport in Japan with the mobile game “Stand up, Heroes”).

Considering the societal challenges in the transport and mobility field, the relevance of gamification to address them, and the lack

of a comprehensive systematic review of gamification in transport and mobility, it seems justified to attempt a description of the state of the art of the topic. The main objective of this systematic review is to develop an overview of the scientific literature on the use of gamification in transport and mobility, which will be addressed through the five research questions below:

- RQ1. How is the research distributed across years, countries and authors' research fields?
- RQ2. What are the frameworks used for the rationale of gamification or of the study?
- RQ3. To what end is gamification used by the authors, in terms of population, modes of transport and behaviour targeted?
- RQ4. Which methods were used by the authors, in terms of game mechanics, type of experimentation and sample sizes?
- RQ5. Which results and empirical evidence were obtained, in terms of behaviour and/or attitude change?

These research questions aim (1) to report the main actors of research and to investigate (2) the background, (3) the goals, (4) the methods and (5) the results reported in the included papers. Together, they aim to provide an overview of the research conducted in the field of transport and mobility and the theme of gamification as well as to suggest recommendations for the use of gamification in traffic interventions.

2. Methods

2.1. Database Search

This systematic review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Moher et al., 2009). A total of 3 databases were used: SCOPUS, Web of Science and Pubmed. The last

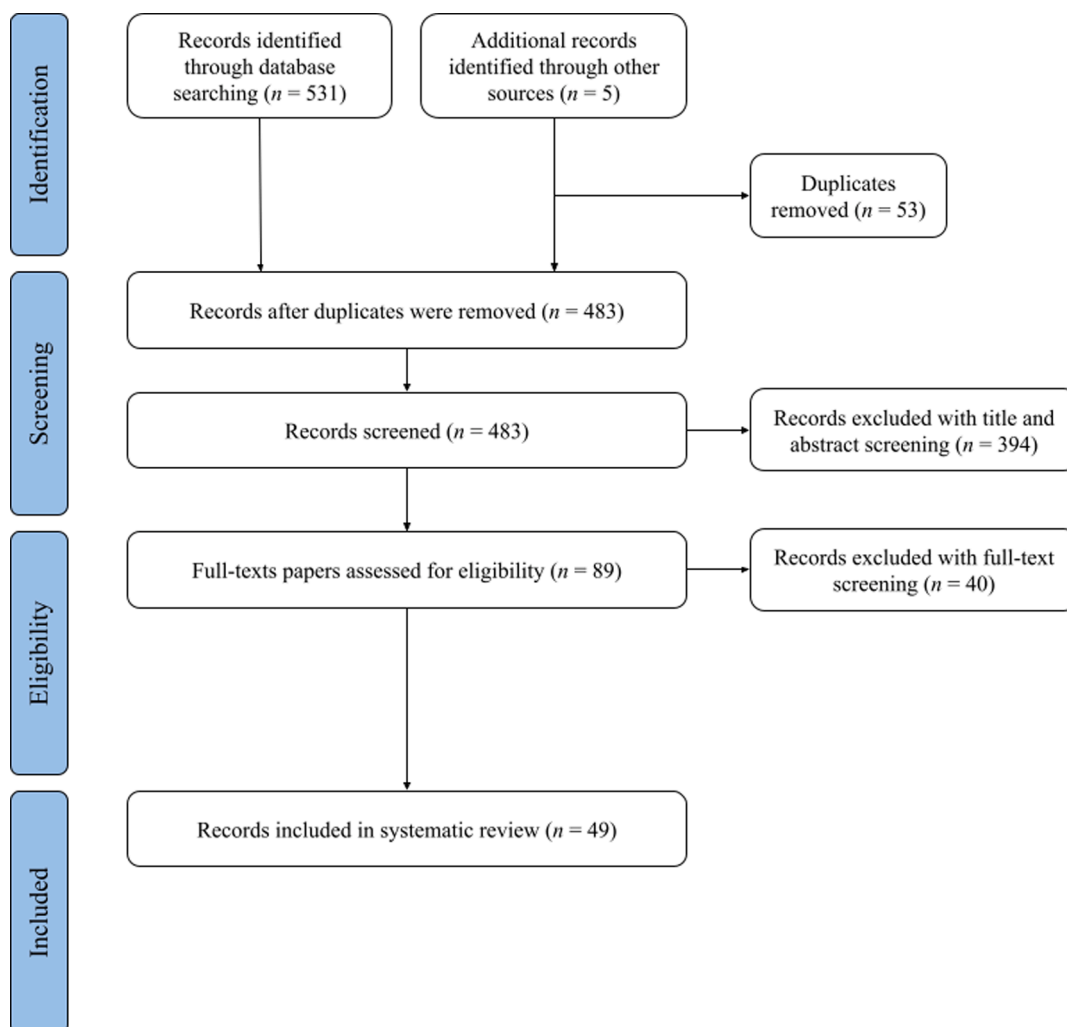


Fig. 1. Flowchart of the Selection Process According to the PRISMA Guidelines.

search was performed on January 30th, 2023. A set of keywords was used comprising two major sets of keywords related to the concept of gamification AND transport/mobility, to obtain a larger set of publications. The following terms were included in the title and abstract search strategy: (“video gam*” OR “computer gam*” OR “digital gam*” OR “electronic gam*” OR “mobile gam*” OR “pervasive gam*” OR “reality gam*” OR “augmented gam*” OR “educational gam*” OR “learning gam*” OR “game-based learning” OR “tabletop gam*” OR “board gam*” OR “online gam*” OR “multiplayer gam*” OR “gamifi*” OR “gameful*”) AND (“transport*” OR “mobilit*” OR “vehicle*” OR “motorist*” OR “cyclist*” OR “driv*” OR “passenger*” OR “pedestrian*” OR “walk*” OR “travel*” OR “automotive” OR “commut*” OR “transit” OR “traffic”). The initial search resulted in a total of 536 papers with 53 duplicates, resulting in 483 papers, as displayed in Fig. 1.

2.2. Eligibility Criteria

The following eligibility criteria (EC) were applied to determine the inclusion or exclusion of the papers obtained through the database search: A paper was included when (EC1) it was written in English, (EC2) it was available, (EC3) it was not published as a poster or a tutorial, (EC4) it was not a systematic review nor an opinion paper, (EC5) it dealt with gamification and (EC6) it dealt with mobility and/or transport. No criteria involved the date nor the type of publication, meaning it did not matter whether the papers were peer-reviewed articles or conference proceedings. Only papers meeting the six criteria were included in the review.

2.3. Screening Process

The screening followed a two-step process: The papers were first screened based on their title and abstract. Papers included at that stage were then re-assessed based on their full text. For each screening phase, Authors 1, 2 and 3 assessed the paper’s eligibility based on the criteria previously described. In the first screening stage, the first author of the present article (Author 1) screened all 483 papers while the second and third authors (Authors 2 and 3) respectively screened 242 and 241 papers, ensuring this way that each paper had been screened twice and independently. The first screening process resulted in a total of 89 papers selected for full-text review. The second screening, now based on full text, unfolded similarly: Author 1 screened the 89 papers and, Authors 2 and 3 divided them, screening 45 and 44 papers respectively. Forty papers were excluded at this stage, resulting in a total of 49 papers included in this systematic review: 27 are conference proceedings (of which 17 were peer-reviewed) and 22 peer-reviewed journal articles.

In each screening phase, each paper was assessed by two authors on whether it should be included or excluded. When the decision was the same from both authors, the common decision was adopted and the paper was either excluded from the process or included in the next step or in the systematic review. When the two authors disagreed on the decision, the paper was also assessed by the third author. Following that third assessment, points of disagreement were discussed between the three authors, and explanations for a decision of inclusion or exclusion were given. This led to a better understanding of each others’ decision, a better assessment of the eligibility criteria and eventually led to an agreement.

2.4. Data Extraction

Data from the 49 papers was collected: Authors 1, 2 and 3 first made a list of key elements to extract from the papers, to provide answers to the six research questions. The papers were shared again among the first three authors (Author 1 had 17 papers, and Authors 2 and 3 had 16 each), and they proceeded to a full-text read and recorded the relevant information in a shared file. This process was counterchecked: Papers were distributed again among the first three authors and the recorded information was reviewed.

The complete process of exclusion and inclusion as well as the data extracted from the 49 papers are available in the [Supplementary Material](#).

3. Results

3.1. RQ1: How is the research distributed across years, countries and authors’ research fields?

Tables 1 and 2 provide the descriptive data regarding the country and field(s) of research of the first author of the papers included

Table 1
Distribution of First Author’s Country.

Country (first author’s)	<i>n</i>	%
Germany	8	16.5
Italy	7	14.5
Australia	5	10
USA	4	8
Canada	3	6
UK	3	6
Portugal	2	4
Greece	2	4
Other (1 paper/country)	15	31

in the present review and Fig. 2 provides their year of publication ($n = 48$).

The study of gamification in mobility and transportation remains a nascent research topic, in that the earliest article selected for this review was published in 2013 (Kuramoto et al., 2013). As shown in Fig. 2, the remaining papers were distributed almost equally between 2013 and 2022. Four countries accounted for almost half of the publications included in this review: Germany (16 %, $n = 8$), Italy (14 %, $n = 7$), Australia (10 %, $n = 5$) and the USA (8 %, $n = 4$). Overall, the majority of publications were from European countries (57 %, $n = 28$).

Based on the publication support, it was found that the majority of the papers were from the field of Computer Science and Engineering (57 %, $n = 28$). The Humanities and Social Sciences were less represented, with seven papers identified in Psychology (Ambrey & Yen, 2018; Degirmenci & Breitner, 2023; Farella et al., 2020; Feinauer et al., 2022; Günther, 2020; Lieberoth et al., 2018; Tsirimpa et al., 2019) and two in Human Factors/Ergonomics (Bier et al., 2019; Xie et al., 2016). At the crossroads of these disciplines, Human-Computer Interaction accounted for eight papers included in the review ((Ebermann & Brauer, 2016; Fitz-Walter et al., 2017; Lakier et al., 2019; Maurer et al., 2019; Rodríguez et al., 2014; Steinberger et al., 2017a; Steinberger et al., 2017b; Vaezipour et al., 2016).

3.2. RQ2: What are the frameworks used for the rationale of gamification or of the study?

Thirty-eight of the included papers did not consider gamification through a specific framework or theoretical background. Most often, the rationale of the studies was built on a review of existing literature and previous studies on gamification, but only 11 papers aligned their methodology with a specific framework. Interestingly, eight different frameworks were identified suggesting a lack of consensus towards theories of gamification in the field of transport and mobility. Four of the frameworks derive from the behavioural sciences, three were specific to the gamification field and one belonged to the economics field.

3.2.1. Behavioural Sciences Frameworks

Six of the 11 papers relying on a specific framework referred to theories from behavioural and social sciences, mostly from the psychology field. The Self-Determination Theory, which examines both extrinsic rewards and intrinsic motivation and their effects on behaviour (Deci & Ryan, 2012) was used in three papers (Feinauer et al., 2022; Seecharan, 2022; Vaezipour et al., 2016). Daniel et al. (2022) relied on the integrated TAM-TPB model: This approach combines both the Technology Acceptance Model (TAM; Davis, 1989) and the Theory of Planned Behaviour (TPB; Ajzen, 1991), resulting in an “augmented TAM” to predict IT usage, as suggested by Taylor and Todd (1995). The Goal-Framing theory (Lindenberg & Steg, 2007), suggesting that people act depending on their “goals frame” was used as support by Ebermann and Brauer (2016). Finally, the Opportunity-Cost-Model, proposing an explanation for task performance deterioration over time and mental effort through the representation of costly computational mechanisms in exchange for benefits (Kurzban et al., 2013) was used by Steinberger et al. (2017).

3.2.2. Gamification Frameworks

The Gamification Design Principles (Liu et al., 2017), are a selection of guidelines for the design of gamified experiences mostly inspired by behavioural economics, psychology and social psychology, such as the “Task Congruence Principle” or “Personalization Principle”, which were used by Degirmenci (2018) and by Degirmenci and Breitner (2023). Cardoso et al. (2019) relied on the Pyramid of Elements, a framework classifying game elements according to three levels: dynamics, mechanics and components (Werbach & Hunter, 2012; as cited by Cardoso et al., 2019). Coombes and Jones (2016) referred to the “Gamification Theory”, defining it as the process of gamifying habits to make them more addictive, hence more recurring.

3.2.3. Economics Framework

The Theory of Nudge (Thaler & Sunstein, 2009), often described as a change in the environment, or “choice architecture”, to influence people towards certain behaviours, was used by Lieberoth et al. (2018).

3.3. RQ3. To what end is gamification used by the authors, in terms of population, modes of transport and behaviour targeted?

3.3.1. Targeted Population and Modes of Transport

Out of the 49 papers considered, the majority focused on the impact of gamification on the use of a private motorised vehicle (59 %, $n = 29$, Table 3). These papers targeted, in the large majority, drivers ($n = 27$), but also, for two studies, car passengers (Dange et al.,

Table 2
Distribution of Field of Research, Based on Publication Support.

Field (first author's)	<i>n</i>	%
Computer Science & Engineering	28	57
Human-Computer Interaction	8	16
Psychology	7	14
Medicine & Health Prevention	3	6
Human Factors & Ergonomics	2	4
Business & Economics	1	2

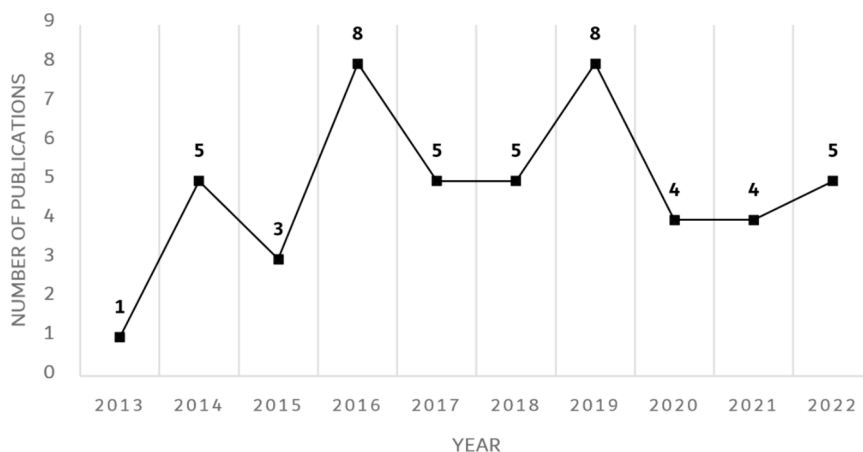


Fig. 2. Number of Papers Included in the Review as a Function of the Year of Publication. Note: The search was conducted in January 2023 and only one paper was already published in the first month of 2023, not represented here.

2017; Lakier et al., 2019). Fewer studies focused on the effect of gamification on the use of public transport (8 %, $n = 4$) and soft mobility (e.g., walking, 12 %, $n = 6$). However, a significant number of studies focused on all modes of transport (20 %, $n = 10$), in the context of applications allowing users to choose the most relevant transport mode – according to their needs (Mobility-as-a-Service, e.g., Horst et al., 2022). Most studies did not target a specific age group (Table 4), but a few studies focused on teenagers and young adults (e.g., to improve their driving skills, Ali et al., 2016), and children (e.g., to encourage them to walk to – and from – school, Coombes & Jones, 2016). Details are provided in Tables 3 and 4.

3.3.2. Targeted Behaviour

Gamification was most often used to nudge participants towards eco-friendly mobility (47 %, $n = 23$), and safer or healthier mobility (respectively, 33 %, $n = 16$ and 12 %, $n = 6$). It was also used to engage participants in commercial services (8 %, $n = 4$), for leisure (6 %, $n = 3$), in one instance to distract drivers and, in another instance, as a tool in exposure therapy. The details for this sub-question are displayed in Table 5 and each targeted behaviour is further explained.

3.3.2.1. Eco-friendly mobility. Almost half of the studies focused on eco-friendly mobility, either by influencing the driving activity in itself or by promoting different modes of transport. On influencing driving behaviour, gamification was used as a part of feedback given to the driver, usually on their fuel consumption (e.g., Magaña & Organero, 2014) or acceleration and braking performance (e.g., Degirmenci et al., 2018). On promoting different modes of transport or travel, Horst et al. (2022) used gamification to inform their users about the fuel consumption of different route options. As another example, Kazhamiakin et al. (2015) and Kazhamiakin et al. (2021) aimed to push travellers towards softer mobility.

3.3.2.2. Safe mobility. Gamification was used 37 % of the time to induce safer mobility, aiming to reduce risks such as boredom, inattention or lack of engagement. Most often, the mechanisms were similar to the usage aiming for eco-friendly mobility: It was used as a part of feedback given to the driver on their inappropriate behaviour such as speeding (e.g., Bahadour & Hosein, 2016; Bier et al., 2019), inattention or distraction (e.g., Steinberger et al., 2017b), or an aggressive driving style characterised by harsh acceleration (e.g., Vaezipour et al., 2016). One paper (Dange et al., 2017) focused on helping novice drivers learn safer driving.

Table 3
Transportation Modality Targeted by the Studies.

Transportation modality	n	%	References
Individual motorised mobility	29	59	Ali et al., 2016; Bahadour & Hosein, 2016; Bier et al., 2019; Dange et al., 2017; Degirmenci, 2018; Degirmenci & Breitner, 2023; Diewald et al., 2015; Feinauer et al., 2022; Fitz-Walter et al., 2017; Günther, 2020; Haidon et al., 2016; Helvaci et al., 2018; Klemke et al., 2014; Lakier et al., 2019; Magaña and Organero, 2014; Maurer et al., 2019; Muguro et al., 2021; Nousias et al., 2019; Olszewski et al., 2018; Paranthaman et al., 2016; Paranthaman et al., 2018; Rodríguez et al., 2014a; Rodríguez et al., 2014b; Secharan, 2022; Steinberger et al., 2017a; Steinberger et al., 2017b; Vaezipour et al., 2016; Xie et al., 2016; Yen et al., 2022.
Multimodality	10	20	Ambrey & Yen, 2018; Bowden & Hellen, 2019; Cardoso et al., 2019; Daniel et al., 2022; Harris & Crone, 2021; Horst et al., 2022; Kazhamiakin et al., 2015; Kazhamiakin et al., 2021; Tsirimpa et al., 2019; Vesco et al., 2020.
Soft mobility (e.g., walking, cycling)	6	12	Coombes & Jones, 2016; Ebermann & Brauer, 2016; Farella et al., 2020; Laine et al., 2020; Riaz et al., 2019; Ritz et al., 2014.
Public transport	4	8	Johannessen & Berntzen, 2016; Kuramoto et al., 2013; Lieberoth et al., 2018; Supriyanto et al., 2015

Table 4
Age Group Targeted by the Studies.

Age group	n	%	References
Unspecified	38	78	Bahadoor & Hosein, 2016; Bier et al., 2019; Bowden & Hellen, 2019; Cardoso et al., 2019; Dange et al., 2017; Degirmenci, 2018; Degirmenci & Breitner, 2018; Ebermann & Brauer, 2016; Feinauer et al., 2022; Günther et al., 2020; Haidon et al., 2016; Harris & Crone, 2021; Helvacı et al., 2018; Horst et al., 2022; Johannessen & Berntzen, 2016; Kazhamiakin et al., 2015; Kazhamiakin et al., 2021; Klemke et al., 2014; Kuramoto et al., 2013; Lakier et al., 2019; Laine et al., 2020; Lieberoth et al., 2018; Magaña & Organero, 2014; Maurer et al., 2019; Muguro et al., 2021; Nousias et al., 2019; Olszewski et al., 2018; Paranthaman et al., 2016; Paranthaman et al., 2018; Ritz et al., 2014; Rodríguez et al., 2014a; Rodríguez et al., 2014b; Steinberger et al., 2017a; Steinberger et al., 2017b; Supriyanto et al., 2015; Tsrimpa et al., 2019; Vaezipour et al., 2016; Vesco et al., 2020.
Teenagers and young adults	8	16	Ali et al., 2016; Ambrey & Yen, 2018; Daniel et al., 2022; Diewald et al., 2015; Fitz-Walter et al., 2017; Seecharan, 2022; Xie et al., 2016; Yen et al., 2022.
Children	3	6	Coombes & Jones, 2016; Farella et al., 2020; Riaz et al., 2019.

Table 5
Main Goal of Using Gamification in the Papers.

Main goal	n	%	References
Eco-friendly mobility	23	47	Ambrey & Yen, 2018; Bowden & Hellen, 2019; Cardoso et al., 2019; Dange et al., 2017; Daniel et al., 2022; Degirmenci, 2018; Degirmenci et al., 2023; Ebermann & Brauer, 2016; Günther et al., 2020; Harris & Crone, 2021; Horst et al., 2022; Kazhamiakin et al., 2015; Kazhamiakin et al., 2021; Lieberoth et al., 2018; Magaña & Organero, 2014; Nousias et al., 2019; Olszewski et al., 2018; Paranthaman et al., 2016; Paranthaman et al., 2018; Seecharan, 2022; Tsrimpa et al., 2019; Vaezipour et al., 2016; Vesco et al., 2020.
Safe mobility	16	37	Bahadoor et al., 2016; Bier et al., 2019; Dange et al., 2017; Feinauer et al., 2022; Helvacı et al., 2018; Klemke et al., 2014; Muguro et al., 2021; Paranthaman et al., 2018; Rodríguez et al., 2014a; Rodríguez et al., 2014b; Steinberger et al., 2017a; Steinberger et al., 2017b; Vaezipour et al., 2016; Xie et al., 2016; Yen et al., 2022.
Healthy mobility	6	12	Bowden & Hellen, 2019; Coombes et al., 2016; Farella et al., 2020; Harris & Crone, 2021; Kuramoto et al., 2015; Laine et al., 2020;
Engagement in a commercial service	4	8	Ali et al., 2016; Johannessen et al., 2016; Ritz et al., 2014; Supriyanto et al., 2015.
Leisure	3	6	Fitz-Walter et al., 2017; Diewald et al., 2015; Lakier et al., 2019.
Others	2	4	Haidon et al., 2016; Maurer et al., 2019.

Note. One article could have two main goals.

3.3.2.3. Healthy mobility. Six papers used gamification to promote the adoption of healthier mobility behaviours, such as walking or cycling. As an example, [Farella et al. \(2020\)](#) proposed a gamified platform (“CLIMB”) to engage children in active behaviours for their home-school trips, with the more steps they take, the more achievements they unlock.

3.3.2.4. Engagement in commercial service. Gamification was also used in a few instances ($n = 4$) as a way to engage users in commercial services, such as a taxi booking system ([Hindersah et al., 2015](#)) or a specific bus system ([Johannessen et al., 2016](#)).

3.3.2.5. Leisure. Relatively anecdotally, gamification sometimes aims to entertain users without any deeper aims. For example, [Lakier et al. \(2019\)](#) proposed a set of games to play in an immersive environment in autonomous vehicles, aiming to make self-driving cars more enjoyable.

3.3.2.6. Others. Two studies presented other specific goals: [Haidon et al. \(2016\)](#) used gamification as a tool to help truck drivers with PTSD, with a gamified driving environment inspired by exposure therapies, and [Maurer et al. \(2019\)](#) used gamification to create a distraction in drivers, essentially to test an experimental means to induce distraction.

3.4. RQ4. Which methods were used by the authors, in terms of game mechanics, type of experimentation and sample sizes?

To better understand the methods employed in the studies, a description of how gamification was provided can be given. The majority ($n = 26$) gamified a smartphone application while some studies ($n = 7$) provided their participants with access to a website or a computer page. For the majority in both these options, participants could access their application/website page on demand, meaning there was no specific frequency of exposure to gamification. Some of the smartphone applications ($n = 5$) were used as in-car displays, participants were therefore exposed to gamification during their drive. Similarly, a few studies ($n = 4$) used in-car displays instead of an application to include gamified elements. The remaining of studies used diverse methods to introduce gamification, such as a head-mounted display, the use of a questionnaire or even a projector.

The way gamification was introduced seems to differ across studies. Only eight of the 49 studies took into account usability or user experience in the design of their gamified intervention, and another four papers mention those terms, without describing how it was taken into account. Most papers, however, ($n = 44$) describe fairly well the media interface they used in their study, with 22 of them providing a visual illustration of their interface.

Table 6
Types of Game Mechanics Reported in the Reviewed Papers.

Authors	Date	Primary elements (based on Zichermann & Cunningham, 2011)							Other game elements						Total	Visual illustration	
		Points	Levels	Leaderboards	Badges	Onboarding	Challenges & quests	Engagement loops	Rewards (in-game)	Rewards (real-life)	Progression & narrative	Avatar	Achievements	Others			Not fully reported
Kuramoto et al.	2013	•	•													4	•
Klemke et al.	2014	•	•	•					•				•			5	•
Magaña and Organero	2014	•		•					•				•			4	
Ritz et al.	2014	•	•	•												4	•
Rodríguez et al.	2014a		•	•					•							4	•
Rodríguez et al.	2014b			•					•						•	3	•
Diewald et al.	2015	•			•								•			3	
Supriyanto et al.	2015	•	•		•											3	
Kazhamiakin et al.	2015	•		•					•							3	•
Bahadoor and Hosein	2016	•		•	•				•							4	•
Coombes and Jones	2016	•						•	•	•						4	
Ebermann and Brauer	2016			•											•	2	
Haidon et al.	2016	•	•					•					•			5	•
Johannessen and Berntzen	2016	•		•												2	
Paranthaman et al.	2016	•	•	•							•					4	•
Vaezipour et al.	2016	•	•					•				•				4	•
Xie et al.	2016				•				•		•					4	•
Ali et al.	2016														•	1	
Dange et al.	2017	•	•	•							•					4	•
Fitz-Walter et al.	2017	•		•							•					4	•
Steinberger et al.	2017a	•						•								2	•
Steinberger et al.	2017b	•													•	2	•
Ambrey and Yen	2018	•									•					2	
Degirmenci	2018			•	•											2	•
Helvacı et al.	2018	•		•									•			3	•
Lieberoth et al.	2018	•			•				•	•						4	
Olszewski et al.	2018	•		•											•	3	

(continued on next page)

Table 6 (continued)

Authors	Date	Primary elements (based on Zichermann & Cunningham, 2011)							Other game elements						Total	Visual illustration	
		Points	Levels	Leaderboards	Badges	Onboarding	Challenges & quests	Engagement loops	Rewards (in-game)	Rewards (real-life)	Progression & narrative	Avatar	Achievements	Others			Not fully reported
Paranthaman et al.	2018	•		•							•					3	•
Bier et al.	2019	•		•			•									3	•
Bowden and Hellen	2019	•					•				•					3	
Cardoso et al.	2019	•	•	•	•		•		•							6	
Lakier et al.	2019	•	•	•												3	
Maurer et al.	2019												•	•		2	
Nousias et al.	2019	•	•			•	•		•		•					7	•
Riaz et al.	2019	•			•						•			•		4	
Tsirimpa	2019	•							•							2	•
Farella et al.	2020						•		•		•					3	
Gunther et al.	2020			•						•						2	•
Laine et al.	2020	•	•	•	•					•	•		•			7	•
Vesco et al.	2020	•	•	•	•											4	•
Harris and Crone	2021	•		•							•					3	
Kazhamiakin et al.	2021	•		•	•		•		•							5	•
Muguro et al.	2021	•												•		2	•
Daniel et al.	2022	•		•							•					3	
Feinauer et al.	2022	•		•	•						•					4	•
Horst et al.	2022		•	•		•					•			•		5	•
Seecharan	2022	•		•	•							•				4	•
Yen et al.	2022	•							•							3	•
Degirmenci and Breitner	2023	•					•							•		2	
Total		39	15	28	13	2	13	1	14	8	13	4	6	4	9		

3.4.1. Game Mechanics

The analysis of the game mechanics used in the papers is done through the classification of Zichermann and Cunningham (2011) and the seven primary elements: “points, levels, leaderboards, badges, challenges and quests, onboarding, and engagement loops”. While these seven elements can be used as a base to classify game mechanics, some adjustments were made. Indeed, the terminology used was not always the same, thus “leaderboards” was used when the authors mentioned “ranking”, “competition” or “social comparison”. In the same way “points” also included “coins” and “scores”. Five additional game mechanics were included in the classification: “Rewards (in-game)”, “Rewards (real-life)”, “Progression and narrative”, “Avatar” and “Achievements”, as they were mentioned at least twice by some authors but do not seem to fit with any primary elements of game mechanics. A category “Others” was added for game mechanics mentioned once (namely, “Quiz”, “Personalisation”, “Timer and dual-task” and “Collaboration”). Lastly, the option “Not fully reported” can be selected when none or only a part of the game elements was reported by the authors.

Some game elements, although classified as the same, may vary: This is the case for example of rewards, which may vary in their definition (e.g., a raffle ticket to win \$100 in Ambrey & Yen, 2018; or discounts in stores in Daniel et al., 2022). Progression and narratives are also typically study-dependent, with for example the visualisation of a flower growing (Horst et al., 2022) or a game of snakes and ladders (Paranthaman et al., 2016). All game mechanics classified as the same are expected, however, to rely on the same principles and mechanisms, as described for example in Zichermann and Cunningham (2011).

With 39 papers using “Points” as a game mechanics, it was the most used mechanics among the 13 identified categories. “Leaderboards” was used in 28 of the papers, “Levels” in 15 and “Rewards (in-game)” in 14. The least frequently used game mechanics were “Engagement loops” and “Onboarding”, respectively used once and twice. An average of 3.4 game mechanics were used per study ($SD = 1.3$), ranging from 1 to 7 ($n = 49$). The details of the game mechanics used in each study are presented in Table 6.

3.4.2. Type of Experimentation and Sample Sizes

Out of the 49 included papers, only 32 included a data collection aimed at assessing the effect of gamification and are therefore included in the analysis for this research question. Indeed, 10 papers did not report data collection nor empirical results, and seven papers only presented prototype testing, often not yielding empirical results on the effect of gamification and aiming instead at validating and testing the usability of the developed application. These seven papers reported an average sample size of $n = 10.6$ ($SD = 11.8$, range 1–36) and most often used field experiments ($n = 5$).

The methods employed in the 32 experimental papers were various: field experiments (47 %, $n = 15$), driving simulator studies (28

Table 7
Sample Sizes per Type of Experiment and per Reviewed Paper.

Authors	Date	Field experiment	Driving simulator study	Questionnaire	Focus groups	Interviews
Kuramoto et al.	2013	9				
Magaña and Organero	2014	14				
Diewald et al.	2015		30			
Supriyanto et al.	2015			40		
Kazhamiakin et al.	2015	20				
Coombes and Jones	2016	80				
Ebermann and Brauer	2016			248		
Vaezipour et al.	2016				34	
Xie et al.	2016		29			
Ali et al.	2016		11			
Fitz-Walter et al.	2017	25				
Steinberger et al.	2017a		32			
Steinberger et al.	2017b					24
Ambrey and Yen	2018			500		
Lieberoth et al.	2018	282				
Olszewski et al.	2018					
Bier et al.	2019		31			
Bowden and Hellen	2019	667				
Lakier et al.	2019		12			
Maurer et al.	2019		7			
Riaz et al.	2019	44				
Tsirimpa et al.	2019	64		235		
Farella et al.	2020	277				
Günther et al.	2020	108				
Harris and Crone	2021	346				
Kazhamiakin et al.	2021	590				
Muguro et al.	2021		13			
Daniel et al.	2022			1253		
Feinauer et al.	2022		57			
Horst et al.	2022	15				
Yen et al.	2022			500		
Degirmenci and Breitner	2023	63				
Mean and SD sample sizes		$M = 173.6$ $SD = 214.9$	$M = 24.7$ $SD = 15.7$	$M = 462.7$ $SD = 425.2$	$M = 34$ $SD = 0$	$M = 44$ $SD = 0$
Total count per type		15 (47 %)	9 (28 %)	6 (19 %)	1 (3 %)	1 (3 %)

%, $n = 9$), questionnaires (19 %, $n = 6$), and more marginally, focus groups, interviews and mathematical modelling (each 3 %, $n = 1$). The categorisation depended on the type of manipulation done in the experiment, rather than the way data was collected. Indeed, field experiments could rely on questionnaires and self-reports to collect data, yet not be categorised as a questionnaire study. The type of manipulation used in the most frequent types of experiments is described below.

Table 7 depicts the sample size per type of experiment and paper: On average, 176.9 participants were included ($SD = 272.0$). Questionnaire studies had on average the largest sample size ($M = 462.7, SD = 425.2$), followed by field experiments ($M = 173.6, SD = 214.9$), while driving simulator studies had an average of 24.7 participants ($SD = 15.7$). The papers describing a focus group or interview study included respectively 34 and 24 participants, and the mathematical modelling (Olszewski et al., 2018) did not include any participants.

3.4.2.1. *Field experiments.* Fifteen papers reported field experiments: Some experiments allowed the participants to use a gamified application in their daily lives while self-reporting their behaviours (e.g., Bowden & Hellen, 2019 on trip modality; Kuramoto et al., 2013 on standing behaviour in public transport; Lieberoth et al., 2018 on behavioural intention) or while their behavioural data were recorded (e.g., Harris & Crone, 2021 on trip modality). Other experiments implemented a large-scale intervention, typically in schools, such as the use of an online platform (e.g., Farella et al., 2020; Riaz et al., 2019) or the Beat the Street intervention (Coombes & Jones, 2016). Field experiments also included driving studies, in which actual driving behaviours were recorded (e.g., Degirmenci & Breitner, 2023; Magaña & Organero, 2014; both on fuel consumption).

3.4.2.2. *Driving simulator studies.* The nine driving simulator studies let their participants drive in a simulated environment, most often with gamified feedback (e.g., Diewald et al., 2015; Steinberger et al., 2017a) and analysed behavioural and/or self-reported data.

3.4.2.3. *Questionnaire studies.* Questionnaires studies were used to collect attitudes towards different inventive schemes and/or towards gamification (e.g., Ambrey & Yen, 2018; Daniel et al., 2022; Yen et al., 2022), or to collect attitudes following the testing of a gamified service (Supriyanto & Hindersah, 2015) or the use of a gamified website (Ebermann & Brauer, 2016).

Table 8
Result of the Main Behavioural Dependent Variable per Included Paper.

Authors	Date	Main behavioural dependent variable	Type of measure		Result
			Obj.	Subj.	
Kuramoto et al.	2013	Standing in public transport		•	/
Magaña and Organero	2014	Fuel consumption	•		+
Diewald et al.	2015	Lane change behaviour	•		/
Hindersah and Prihatmanto	2015	No behavioural dependent variable			
Kazhamiakin et al.	2015	Eco-friendly route choice		•	+
Coombes and Jones	2016	Trip modality (physically active)	•		/
Ebermann and Brauer	2016	No behavioural dependent variable			
Vaezipour et al.	2016	No behavioural dependent variable			
Xie et al.	2016	Glance duration	•		/
Ali et al.	2016	Unclear results			
Fitz-Walter et al.	2017	Time spent on gamified application	•		/
Steinberger et al.	2017a	Speed	•		+
Steinberger et al.	2017b	Speed	•		+
		Eye-gaze (distraction)	•		-
		No behavioural dependent variable			
Ambrey and Yen	2018	No behavioural dependent variable			
Lieberoth et al.	2018	Behavioural intention		•	/
Olszewski et al.	2018	Carpooling behaviour (theoretical)	•		+
Bier et al.	2019	Fatigue and driving performance	•		+
Bowden and Hellen	2019	Trip modality		•	+
Lakier et al.	2019	Take over behaviour	•		+
Maurer et al.	2019	Distraction		•	+
Riaz et al.	2019	Knowledge about traffic safety	•		/
Tsirimpa et al.	2019	Trip modality		•	+
Farella et al.	2020	Trip modality		•	/
Günther et al.	2020	Fuel consumption	•		+
Harris and Crone	2021	Trip modality		•	+
		Traffic data (trip modality)	•		+
Kazhamiakin et al.	2021	Trip modality		•	+
Muguro et al.	2021	Recognition time	•		-
Daniel et al.	2022	No behavioural dependent variable			
Feinauer et al.	2022	Driving performance (interact. with AV)	•		/
Horst et al.	2022	No behavioural dependent variable			
Yen et al.	2022	No behavioural dependent variable			
Degirmenci and Breitner	2023	Fuel consumption	•		+
Total			17 (65 %)	9 (35 %)	

Note. “+” indicates a positive result, “/” a neutral one and “-” a negative one.

3.5. RQ5. Which results and empirical evidence were obtained, in terms of behaviour and/or attitude change?

At first glance, gamification seemed to show positive results on both behaviours and attitudes: Some papers reported behavioural change and overall positive opinions, with participants mentioning fun and higher motivation to engage in the application (e.g., Bier et al., 2019; Günther, 2020; Laine et al., 2020). Yet, a closer look can be taken at the reported effects of gamification per type of measures and types of results of interest to nuance these claims. For this research question, only the 32 experimental papers selected previously are included: Papers without data collection and prototype testings were excluded as they did not yield any results on the effect of gamification. To better discuss the results presented in the studies, they are classified here into positive, neutral and negative results, depending on whether they met the theorised expectations. Indeed, gamification was introduced in the experimental designs with a specific aim (e.g., choosing a more eco-friendly route, slowing down when driving, opting for more sustainable trip modalities). When that aim was met according to the researchers, we classified the result as positive. When no effect was observed, we classified the result as neutral. When the opposite effect was observed, we classified the result as negative.

3.5.1. Behaviour

When investigating in more detail the reported results on behavioural dependent variables, i.e., on the reported effect of gamification on a behavioural measure, it turns out that results were quite mixed. Indeed, out of the 26 reported results, 15 were positive, nine were neutral and two were negative. When taking into account the objectivity of the measure (i.e., whether it was self-reported or measured with an external tool), 66.5 % of subjective results were positive ($n = 6$) and 33.5 % were neutral ($n = 3$); while 53 % of objective results were positive ($n = 9$), 35 % were neutral ($n = 6$) and 12 % were negative ($n = 2$). These results are depicted in Table 8.

Positive results seemed to apply to behaviour change within a transport modality, such as reducing speed or fuel consumption (e.g., Degirmenci & Breitner, 2023; Steinberger et al., 2017b), as well as behaviour change from one mobility to another (e.g., Harris & Crone, 2021): It seems that gamification could be effective in creating behaviour change. Neutral results also could appear when behaviour change within a transport modality was targeted (e.g., Feinauer et al., 2022) or when trip modality choice was targeted (e.g., Farella et al., 2020): It seems that a behavioural change would not be guaranteed. Negative results were found in variables linked to distraction (Muguro et al., 2021; Steinberger et al., 2017b): It seems that gamification could have a distracting effect. As a note, Maurer et al. (2019) reported positive results on distraction, meaning they successfully induced distraction with gamification.

Still, these results should be nuanced further. Indeed, although most studies reported objective results, and although subjective measures also provide relevant insights, the experimental design is critical to giving weight to a result. Most studies included in this review present shortcomings in terms of design: Some did not include a control group (e.g., Harris & Crone, 2021; Riaz et al., 2019) or used a pre-test/post-test design (e.g., Magaña & Organero, 2014; Kazhamiakin et al., 2015; Tsimpa et al., 2019). Some studies included multiple experimental groups, with at least a gamified group and a control group. Yet, often the effect of gamification was not tested alone and there were confounding variables. Typically, gamification was included with feedback or with an intervention such as training; and to create a control group, some participants did not receive any feedback nor intervention, instead of receiving them in a non-gamified form (e.g., Coombes & Jones, 2016; Degirmenci & Breitner, 2023; Diewald et al., 2015; Kuramoto et al., 2013). Feinauer et al. (2022) included a group without any intervention (i.e., a control group), a gamified intervention and a non-gamified intervention, and found no difference between the two intervention groups, yet a positive effect between the control and the intervention groups. This result could question whether the positive effects found in some studies were due to the intervention or the gamification.

3.5.2. Attitudes and Opinions

Through questionnaire studies and attitudes collection, general opinions on gamification could be obtained: In the large majority, gamification received positive ratings, with keywords such as “fun” and “enjoyment” (e.g., Diewald et al., 2015; Farella et al., 2020; Fitz-Walter et al., 2017). The engagement was reported to be higher (Muguro et al., 2021), as well as intrinsic motivation (Feinauer et al., 2022) and sense of usefulness (Daniel et al., 2022). Gamification was also associated with reduced boredom (Steinberger et al., 2017a).

Nuancing the positive attitudes, Lakier et al. (2019) reported that some participants worried about being distracted by gamification, as it was included during a take-over exercise. Vaezpour et al. (2016), identified through focus groups that their participants had rather negative opinions on gamification and would prefer “informative and personalised feedback”. Similarly, Yen et al. (2022) identified that their participants preferred cash rewards rather than gamification.

4. Discussion

This systematic review aimed to provide a detailed overview of the research conducted in the field of gamification in relation to the transport and mobility sector. To that effect, a total of 49 papers meeting the inclusion criteria were included in this review and were analysed to collect specific information of interest. The obtained information is a valuable representation of the state of the art of research and of the knowledge acquired up to this day which can be a support to orientate future research depending on the needs identified.

The first insight of this review, in line with other reviews involving gamification in other sectors (Klock et al., 2021; Sardi et al., 2017; Johnson et al., 2016), is the novelty of the topic in the transport sector, with all included papers being published between 2013 and 2023. Although an increase in the number of publications could be observed about a nascent topic of interest (e.g., the topic of self-driving cars, Parekh et al., 2022), no such trend has been observed here. A second insight is the dispersion of the research, both in terms of location and theoretical background. Indeed, research is spread around the world and does not amass in specific countries or

continents. The authors' research fields, however, do amass more: They are mostly Computer Science and Engineering and only a few derive from human-centred fields such as Human-Computer Interaction, Human Factors/Ergonomics or Psychology. The main approach found in the research on gamification still is an Engineering approach, with most papers focusing on developing a prototype and testing it, perhaps bringing to light a lack of empirical testing of gamification and the theoretical mechanisms at work. Relying on a framework was in fact marginal in the papers included in this review, and in the few instances where it was the case, frameworks were mostly used as a rationale to justify an approach, but were not always explored further, for example, to select specific game mechanics. The variety of theoretical frameworks observed was also a result of [Krath and colleagues \(2021\)](#) who found 118 different theories used as foundations for gamification across the literature. What seemed to be specific to the transport and mobility field, if not the variety, is that about 75 % of papers lacked reliance on specific theoretical frameworks. However, it can be assumed that a more framework-supported approach has simply not yet flourished to address gamification in the mobility and transport sector.

Towards the more specific content of the papers included in this study, the target populations and target behaviours can be discussed. Quite largely drivers, mostly car drivers, were targeted the most by gamification interventions, which can be explained by the fact that private cars are still the most used mode of transport in Europe ([Storme et al., 2020](#)) and are also among the most dangerous and most polluting. Car driving consequently requires more attention in transport and road safety research and behavioural interventions. This observation can also be found in the existing literature, with for example four existing systematic reviews on the topics of gamification and driving ([El Hafidy et al., 2021](#); [Diewald et al., 2013](#); [Schroeter et al., 2014](#); [Yen et al., 2019](#)). In half of the observed cases, the aims of authors when using gamification were to promote safer or more eco-friendly behaviours, in line with actual societal challenges and need for solutions.

To achieve these specific aims of behavioural change, the authors made use of game elements, also termed "gamification mechanics". The first observation was the multitude and the diversity of elements: Even when relying on [Zichermann and Cunningham \(2011\)](#) for a framework of categorisation, about a third of the game elements could not be categorised, resulting in twice as many categories. Another observation was the number of game mechanics at play in each of the studies: With most often three or four mechanics included in the intervention, it was impossible to singularise the effect of a specific element (e.g., the effect of receiving points on behaviour). It was possible, however, to identify the most used game mechanics, points and leaderboards, both answering specific levers in motivation, respectively a sense of achievement (e.g., [Bahadoor & Hosein, 2016](#)) and social comparison (e.g., [Magaña & Organero, 2014](#)). Although a theoretical explanation could be found for the effect of most game elements, for example, relying on motivation theories, it was often not highlighted in the studies. The main rationale was those game elements are theoretically and sometimes intuitively known to be fun and motivating ([Alsawaier, 2018](#)).

Finally, the empirical evidence proposed by the papers included in this review should be discussed. Although at first glance gamification sounds and looks promising and effective, the results were rather mixed between positive and neutral results, with even some negative results. It could be argued that gamification is still promising, yet an issue still lies in the methodology used in the papers and the lack of *empirical* evidence. Indeed, numerous biases were present, such as small sample sizes, but also faulty experimental designs, notably with pre-test and post-test designs, and confounding variables, with multiple game elements at the same time, but more importantly the testing of the effect of gamification together with the effect of feedback, for example. Overall it appears difficult, even unreasonable, to draw conclusions on the effect of gamification on behaviour or attitudes in the transportation and mobility sector at this stage.

The search for empirical proof of gamification has been a topic of investigation and has yielded multiple systematic reviews and *meta*-analyses in recent years. Results are usually somewhat partial, but conclusions are often more positive regarding the potential of gamification. It is the case, for example, in a literature review focused on gamification in relation to motivational affordances ([Hamari et al., 2014](#)): The review findings suggest that gamification is effective, although not all included studies came to that conclusion, and although the authors point out multiple methodological issues. A *meta*-analysis on the effect of gamification on learning outcomes ([Sailer & Homner, 2020](#)) also concludes that gamification is effective, despite a high between-study variance and a lack of methodological rigour in their primary studies. Similar results, i.e., gamification being deemed (somewhat) effective can be found across different specific sectors, e.g., marketing ([Conaway & Garay, 2014](#)), education ([Hallifax et al., 2019](#); [Kiryakova et al., 2014](#)) or health ([Gentry et al., 2019](#); [Johnson et al., 2016](#)). Existing literature forms a positive consensus on the question of the effectiveness of gamification.

Although a lack of empirical evidence was observed here, it is highly unlikely that our systematic review refutes more than a decade's worth of results and expert conclusions arguing that gamification effectively influences cognitive, motivational and behavioural outcomes. When taking into account the literature's consensus and solely the results of the studies we reviewed, a conclusion of our systematic review could be the tendency towards a positive effect of gamification. However, and quite importantly, the observations made in this review reflect a lack of rigorous research with clear research questions and hypotheses in the field of transport and mobility. This can be attributed to the novelty of the research field, which has sparked more interest in the engineering field than in human-centred fields, resulting in numerous interesting and modern prototypes but an absence of empirical evidence.

The complexity of human behaviour when it comes to mobility has to be considered to better discuss the results, whether due to the multitude of determinants for trip modality ([An et al., 2023](#); [Susilo and Cats, 2014](#)), the complexity in driving ([Cantin et al., 2009](#)), or the multiple goals that activity can be subject to ([Dogan et al., 2011](#)). Indeed, it could prove more challenging to influence cognition, motivation and behaviour in the transport and mobility field than in other fields, and it seems necessary, until proven otherwise, to draw conclusions from field-specific studies. In that sense, it should be stated that research on gamification in the field of transport and mobility does not yet yield empirical evidence of its effectiveness. The methodological pitfalls cannot be overlooked and prevent the transport and mobility field from having a clear and empirical answer to whether gamification works.

4.1. Theoretical and Practical Implications

This review highlights a need for effective testing of the interventions, to ensure that gamification is indeed justified as a tool to change behaviours and is not a superfluous distractor. The next step in research could be to test more empirically the effect of gamification on both behaviours and attitudes: More robust experimental designs would be advised. It would be recommended, for example, to test the effect of singular game mechanics by measuring behaviours or attitudes when either simple feedback is provided compared to when gamified feedback is provided. Adopting this approach would allow researchers to test empirically which game mechanics have an effect and the extent of the effect. More research, including longitudinal studies, could lead to a consensus on whether introducing gamification in the mobility and transport field is justified and whether it can have any drawbacks, e.g., distraction during the driving task.

Future research should also further rely on existing theoretical frameworks, such as those identified in Krath et al. (2021), or on specific models, for example, the specific motivational aspects and cognitive processes involved in driving. Indeed, our systematic review identified that very few studies conceived their gamified interventions relying scrupulously on previously acquired knowledge. We argue that future research should first identify the specific mechanisms underlying the targeted behaviour. By doing so, researchers can apply gamification strategies and specific game mechanics more effectively to influence these mechanisms. In other words, the chosen game mechanics should be directly informed by the theoretical understanding of the targeted behaviour.

Suggestions for designers and app developers would be to use gamification with caution: A positive effect of gamification is not guaranteed and potential drawbacks could have been overlooked. No specific approach nor specific game mechanics have been identified to yield the best results, therefore no such advice can be given. While trial and error would be a sufficient way to test, case by case, which approach is the best for a specific population, future research should be able to provide general guidelines for gamified interventions. Indeed, more systematic research could result in general guidelines and guide future gamified interventions, reducing the sparsity in comparable research and the need for developing various prototypes.

4.2. Limitations

This review aimed, *inter alia*, to propose an overview of the literature on the topic of gamification in the sector of transport and mobility. To that effect, papers from all fields and all publication options could be and were included, resulting in a quite heterogeneous pool of studies. This aspect made the summarizing and especially the comparison across studies rather difficult: Some present results of an experiment and a data collection, others present a prototype for a gamified application, and some do both. Although the inclusion of only peer-reviewed and published articles would have made the results smoother and perhaps more distinguishable (as suggested in the PRISMA method, Moher et al., 2009), this review would have suffered from a smaller sample of papers on which drawing conclusions could have been riskier. Moreover, having an overview of the variety of approaches and methods is beneficial to the understanding of the state of the art of the field; it was therefore justified to have larger inclusion criteria.

5 Conclusion

While gamification has the reputation to be an emergent and promising concept, the analysis presented in this systematic review would nuance this claim. Indeed, both the diversity of outcomes and the lack of empirical evidence would tend to question the effectiveness of gamification, at least in the field of transport and mobility. While the diversity of methods, the lack of theoretical foundation and the unadapted experimental designs have been discussed and could explain this conclusion, these results could also be explained by the particularity of the field. Indeed, remaining focused is essential for safety in driving, and gamification could perhaps lower focus and therefore interest of participants, leading to more moderate results. A better understanding of the effect of gamification could be reached by investigating its underlying mechanisms through the support of theoretical behavioural frameworks while accounting for individual variability.

CRediT authorship contribution statement

Eugénie Avril: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing, Visualization. **Angèle Picco:** Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Colin Lescarret:** Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Céline Lemercier:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing. **Amaël Arguel:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing. **Loïc Caroux:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

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 dataset is included as [Supplementary Material](#).

Acknowledgements

This research was carried out with the support of the French government as part of the “Territoire d’Innovation” program, an action of the “Grand Plan d’Investissement” backed by France 2030, Toulouse Métropole and the GIS neOCampus.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.trf.2024.06.004>.

References

Items marked with an asterisk (*) correspond to the paper included in the review

- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- An, Z., Heinen, E., & Watling, D. (2023). The level and determinants of multimodal travel behavior: Does trip purpose make a difference? *International Journal of Sustainable Transportation*, 17(2), 103–117.
- Alataş, S. (2021). The role of information and communication technologies for environmental sustainability: Evidence from a large panel data analysis. *Journal of Environmental Management*, 293, Article 112889. <https://doi.org/10.1016/j.jenvman.2021.112889>
- * Ali, A., Elnaggar, A., Reichardt, D., & Abdennadher, S. (2016). Gamified virtual reality driving simulator for asserting driving behaviors. Proceedings of the 2016 1st international conference on game, game art, and gamification (ICGGAG) (pp. 1–6). doi:10.1109/ICGGAG.2016.8052668.
- Alsawaier, R. S. (2018). The effect of gamification on motivation and engagement. *The International Journal of Information and Learning Technology*. <https://doi.org/10.1108/IJILT-02-2017-0009>
- * Ambrey, C.L., & Yen, B.T.H. (2018). How perceptions influence young drivers’ intentions to participate in gamified schemes. *Transportation Research Part F: Traffic Psychology and Behaviour*, 58, 708–718. doi:10.1016/j.trf.2018.06.047.
- * Bahador, K., & Hosein, P. (2016). Application for the detection of dangerous driving and an associated gamification framework. 2016 IEEE 4th international conference on future internet of things and cloud workshops (FiCloudW) (pp. 276–281). doi:10.1109/W-FiCloud.2016.63.
- Behl, A., Sheorey, P., Pal, A., Veetil, A. K. V., & Singh, S. R. (2020). Gamification in E-commerce: A comprehensive review of literature. *Journal of Electronic Commerce in Organizations*, 18(2), 1–16. <https://doi.org/10.4018/JECO.202004010>
- * Bier, L., Emele, M., Gut, K., Kulenovic, J., Rzany, D., Peter, M., & Abendroth, B. (2019). Preventing the risks of monotony related fatigue while driving through gamification. *European Transport Research Review*, 11, 44. doi:10.1186/s12544-019-0382-4.
- Bjork, S., & Holopainen, J. (2004). *Patterns in game design (game development series)*. Charles River Media Inc.
- * Bowden, H., & Hellen, G. (2019). A data driven, segmentation approach to real world travel behaviour change, using incentives and gamification. In Müller, B., & Meyer, G. (Eds.), *Towards user-centric transport in Europe. lecture notes in mobility* (pp. 173–182). Springer. doi:10.1007/978-3-319-99756-8_12.
- Bozkurt, A., & Durak, G. (2018). A systematic review of gamification research: In pursuit of homo ludens. *International Journal of Game-Based Learning (IJGBL)*, 8(3), 15–33.
- Cantin, V., Lavallière, M., Simoneau, M., & Teasdale, N. (2009). Mental workload when driving in a simulator: Effects of age and driving complexity. *Accident; Analysis and Prevention*, 41(4), 763–771. <https://doi.org/10.1016/j.aap.2009.03.019>
- * Cardoso, B., Ribeiro, M., Prandi, C., & Nunes, N. (2019). When gamification meets sustainability : A pervasive approach to foster sustainable mobility in Madeira. In *Proceedings of the 1st ACM workshop on emerging smart technologies and infrastructures for smart mobility and sustainability (SMAS '19)* (pp. 3–8). doi: 10.1145/3349622.3355449.
- Conaway, R., & Garay, M. C. (2014). Gamification and service marketing. *Springerplus*, 3(1), 1–11. <https://doi.org/10.1186/2193-1801-3-653>
- ** Coombes, E., & Jones, A. (2016). Gamification of active travel to school : A pilot evaluation of the Beat the Street physical activity intervention. *Health & Place*, 39, 62–69. <https://doi.org/10.1016/j.healthplace.2016.03.001>
- * Dange, G.R., Paranthaman, P.K., Bellotti, F., Berta, R., De Gloria, A., Raffero, M., & Neumeier, S. (2017). Deployment of serious gaming approach for safe and sustainable mobility. *IEEE Intelligent Vehicles Symposium (IV)*, 2017, 1222–1227. doi:10.1109/IVS.2017.7995879.
- * Daniel, A.D., Junqueira, M., & Rodrigues, J.C. (2022). The influence of a gamified application on soft mobility promotion : An intention perspective. *Journal of Cleaner Production*, 351, 131551. doi:10.1016/j.jclepro.2022.131551.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340.
- Deci, E., & Ryan, R. (2012). Self-determination theory. In P. A. M. Van Lange, A. W. Kruglanski, & E. Tory Higgins (Eds.), *Handbook of theories of social psychology* (Vol. 1, pp. 416–437). SAGE Publications Ltd. <https://doi.org/10.4135/9781446249215>
- * Degirmenci, K. (2018). Toward a gamified mobile application to improve eco-driving: A design and evaluation approach. Proceedings of the 24th Americas conference on information systems.
- * Degirmenci, K., & Breitner, M.H. (2023). Gamification and sensory stimuli in eco-driving research: A field experiment to reduce energy consumption in electric vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, 92, 266–282. doi:10.1016/j.trf.2022.10.014.
- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011a). From game design elements to gamefulness: Defining “gamification”. In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environment* (pp. 9–15). <https://doi.org/10.1145/2181037.2181040>
- Deterding, S., Sicart, M., Nacke, L., O’Hara, K., & Dixon, D. (2011b). Gamification. using game-design elements in non-gaming contexts. In *CHI’11 extended abstracts on human factors in computing systems*. doi: 10.1145/1979742.1979575.
- Diewald, S., Möller, A., Roalter, L., Stockinger, T., & Kranz, M. (2013). Gameful design in the automotive domain : Review, outlook and challenges. In *Proceedings of the 5th international conference on automotive user interfaces and interactive vehicular applications - AutomotiveUI '13* (pp. 2425–2428). doi: 10.1145/2516540.2516575.
- * Diewald, S., Möller, A., Stockinger, T., Roalter, L., Koelle, M., Lindemann, P., & Kranz, M. (2015). Gamification-supported exploration and practicing for automotive user interfaces and vehicle functions. In Reiners, T., & Wood, L.C. (Eds.), *Gamification in education and business* (pp. 637–661). Springer. doi:10.1007/978-3-319-10208-5_32.
- Dogan, E., Steg, L., & Delhomme, P. (2011). The influence of multiple goals on driving behavior: The case of safety, time saving, and fuel saving. *Accident; Analysis and Prevention*, 43(5), 1635–1643.

- * Ebermann, C., & Brauer, B. (2016). The role of goal frames regarding the impact of gamified persuasive systems on sustainable mobility behavior. In *Proceedings of the European Conference on Information Systems 2016*. https://aisel.aisnet.org/ecis2016_rp/174.
- El hafidy, A., Rachad, T., Idri, A., & Zellou, A. (2021). Gamified mobile applications for improving driving behavior: A systematic mapping study. *Mobile Information Systems*, 2021, 1–24. <https://doi.org/10.1155/2021/6677075>
- * Farella, E., Ferron, M., Giovannelli, D., Leonardi, C., Marconi, A., Massa, P., ... Schiavo, G. (2020). CLIMB: A pervasive gameful platform promoting child independent mobility. *IEEE Pervasive Computing*, 19(1), 32–42. doi:10.1109/MPRV.2019.2939730.
- * Feinauer, S., Schuller, L., Groh, I., Huestegge, L., & Petzoldt, T. (2022). The potential of gamification for user education in partial and conditional driving automation: A driving simulator study. *Transportation Research Part F: Traffic Psychology and Behaviour*, 90, 252–268. doi:10.1016/j.trf.2022.08.009.
- * Fitz-Walter, Z., Johnson, D., Wyeth, P., Tjondronegoro, D., & Scott-Parker, B. (2017). Driven to drive? Investigating the effect of gamification on learner driver behavior, perceived motivation and user experience. *Computers in Human Behavior*, 71, 586–595. doi:10.1016/j.chb.2016.08.050.
- Gentry, S. V., Gauthier, A., Ehrstrom, B. L. E., Wortley, D., Lilienthal, A., Car, L. T., & Car, J. (2019). Serious gaming and gamification education in health professions: Systematic review. *Journal of Medical Internet Research*, 21(3), e12994.
- Gössling, S. (2018). ICT and transport behavior: A conceptual review. *International Journal of Sustainable Transportation*, 12(3), 153–164. <https://doi.org/10.1080/15568318.2017.1338318>
- Guillen, G., Hamari, J., & Quist, J. (2021). Gamification of sustainable consumption: A systematic literature review. In *Proceedings of 54th Hawaii international conference on system sciences* (pp. 1345–1354). doi: 10.24251/HICSS.2021.163.
- * Günther, M. (2020). Can electric vehicle drivers be persuaded to eco-drive? A field study of feedback, gamification and financial rewards in Germany. *Energy Research and Social Science*, 63, 101407. doi:10.1016/j.erss.2019.101407.
- * Haidon, C., Crepont, A., Girard, B., Menelas, B.A.J. (2016). Gamification of a Truck-Driving Simulator for the Care of People Suffering from Post-Traumatic Stress Disorder. In De Gloria, A., Veltkamp, R. (Eds.), *Games and Learning Alliance. GALA 2015. Lecture Notes in Computer Science* (Vol. 9599, pp 312–322). Springer. 10.1007/978-3-319-40216-1_33.
- Hallifax, S., Serna, A., Marty, J. C., & Lavoué, É. (2019). Adaptive gamification in education: A literature review of current trends and developments. In *European conference on technology enhanced learning* (pp. 294–307). Springer. https://doi.org/10.1007/978-3-030-29736-7_22.
- Halter, E. (2006). *From Sun Tzu to Xbox: War and video games*. PublicAffairs.
- Hamari, J., Koivisto, J., & Sarsa, H. (2014, January). Does gamification work?—a literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences* (pp. 3025–3034). Ieee.
- * Harris, M.A., & Crone, D. (2021). Using gamification to encourage active travel. *Journal of Transport and Health*, 23, 101275. doi:10.1016/j.jth.2021.101275.
- * Helvacı, S., Senova, A., Kar, G., & Gören, S. (2018). Improving driver behavior using gamification. In M. Younas, I. Awan, G. Ghinea, & M. Catalan Cid (Eds.), *Mobile web and intelligent information systems* (Vol. 10995, p. 193–204). Springer. doi: 10.1007/978-3-319-97163-6_16.
- * Horst, R., Fuß, T., & Dörner, R. (2022). GreenMile—gamification-supported mobile and multimodal route planning for a sustainable choice of transport. In A. K. Nagar, D. S. Jat, G. Marín-Raventós, & D. K. Mishra (Eds.), *Intelligent sustainable systems* (Vol. 334, p. 191–199). Springer. 10.1007/978-981-16-6369-7_17.
- Huizinga, J. (1938). *Homo ludens. Proeve fleaner bepaling van het spelelement der cultuur*. [Homo ludens: A study in the play elements in culture] (tr. RFC Hull, 1947).
- * Johannessen, M. R., & Berntzen, L. (2016). Using gamification to generate citizen input for public transport planning. In *Proceedings of ongoing research, PhD papers, posters and workshops of IFIP EGOV and ePart 2016*, 23–30. doi: 10.3233/978-1-61499-670-5-23.
- Johnson, D., Deterding, S., Kuhn, K. A., Staneva, A., Stoyanov, S., & Hides, L. (2016). Gamification for health and wellbeing: A systematic review of the literature. *Internet Interventions*, 6, 89–106. <https://doi.org/10.1016/j.invent.2016.10.002>
- Kalogiannakis, M., Papadakis, S., & Zourmpakis, A. I. (2021). Gamification in science education. A systematic review of the literature. *Education Sciences*, 11(1), 22. <https://doi.org/10.3390/educsci11010022>
- * Kazhamiakın, R., Loria, E., Marconi, A., & Scanaganatta, M. (2021). A gamification platform to analyze and influence citizens' daily transportation choices. *IEEE Transactions on Intelligent Transportation Systems*, 22(4), 2153–2167. doi:10.1109/TITS.2021.3049792.
- * Kazhamiakın, R., Marconi, A., Perillo, M., Pistore, M., Valetto, G., Piras, L., Avesani, F., & Perri, N. (2015). Using gamification to incentivize sustainable urban mobility. In *2015 IEEE first international smart cities conference (ISC2)* (pp. 1–6). doi: 10.1109/ISC2.2015.7366196.
- Kiryakova, G., Angelova, N., & Yordanova, L. (2014). Gamification in education. In: *Proceedings of 9th international Balkan education and science conference*.
- * Klemke, R., Kravcik, M., & Bohuschke, F. (2014). Energy-efficient and safe driving using a situation-aware gamification approach in logistics. In De Gloria, A. (Ed.), *Games and learning alliance: Vol. 8605* (pp. 3–15). Springer. doi:10.1007/978-3-319-12157-4_1.
- Klock, A. C., Wallius, E., & Hamari, J. (2021). Gamification in freight transportation: Extant corpus and future agenda. *International Journal of Physical Distribution and Logistics Management*, 51(7), 685–710. <https://doi.org/10.1108/ijpdm-04-2020-0103>
- Krath, J., Schürmann, L., & Von Korflesch, H. F. (2021). Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning. *Computers in Human Behavior*, 125, Article 106963. <https://doi.org/10.1016/j.chb.2021.106963>
- * Kuramoto, I., Ishibashi, T., Yamamoto, K., Tsujino, Y. (2013). Stand Up, Heroes!: Gamification for standing people on crowded public transportation. In Marcus, A. (eds) *Design, user experience, health, learning, playing, cultural, and cross-cultural user experience. DUXU 2013. Lecture notes in computer science* (Vol. 8013, pp. 538–547). Springer. doi: 10.1007/978-3-642-39241-2_59.
- Kurzban, R., Duckworth, A., Kable, J., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance. *The Behavioral and Brain Sciences*, 36(6), 661–679. <https://doi.org/10.1017/S0140525X12003196>
- * Laine, T.H., Normark, J., Lindvall, H., Lindqvist, A.-K., & Rutberg, S. (2020). A distributed multiplayer game to promote active transport at workplaces: User-centered design, implementation, and lessons learned. *IEEE Transactions on Games*, 12(4), 386–397. doi:10.1109/TG.2020.3021728.
- * Lakier, M., Nacke, L. E., Igarashi, T., & Vogel, D. (2019). Cross-Car, multiplayer games for semi-autonomous driving. In *Proceedings of the annual symposium on computer-human interaction in play* (pp. 467–480). doi: 10.1145/3311350.3347166.
- * Lieberoth, A., Holm Jensen, N., & Bredahl, T. (2018). Selective psychological effects of nudging, gamification and rational information in converting commuters from cars to buses: A controlled field experiment. *Transportation Research Part F: Traffic Psychology and Behaviour*, 55, 246–261. doi:10.1016/j.trf.2018.02.016.
- Lindenberg, S., & Steg, L. (2007). Normative, gain and hedonic goal frames guiding environmental behavior. *Journal of Social Issues*, 63(1), 117–137. <https://doi.org/10.1111/j.1540-4560.2007.00499.x>
- Liu, D., Santhanam, R., & Webster, J. (2017). Toward Meaningful Engagement: a framework for design and research of Gamified information systems. *MIS Quarterly*, 41(4), 1011–1034. <https://doi.org/10.25300/MISQ/2017/41.4.01>
- * Magaña, V. C., & Organero, M. M. (2014). The Impact of Using Gamification on the Eco-driving Learning. In C. Ramos, P. Novais, C. E. Nihan, & J. M. Corchado Rodríguez (Eds.), *Ambient Intelligence—Software and Applications* (Vol. 291, p. 45–52). Springer International Publishing. doi: 10.1007/978-3-319-07596-9_5.
- Malone, T. W. (1980). What makes things fun to learn? Heuristics for designing instructional computer games. In *Proceedings of the 3rd ACM SIGSMALL Symposium and the first SIGPC symposium on small systems* (pp. 162–169). <https://doi.org/10.1145/800088.802839>
- * Maurer, S., Schmid, R., Erbach, R., & Ruzkio, R. (2019). Inducing erroneous behavior in a driving simulator with gamification. *AutomotiveUI '19 proceedings of the 11th international conference on automotive user interfaces and interactive vehicular applications: Adjunct proceedings* (pp. 277–281). doi:10.1145/3349263.3351323.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, 151(4), 264–269. <https://doi.org/10.1016/j.ijso.2010.02.007>
- * Muguro, J.K., Laksono, P.W., Sasatake, Y., Matsushita, K., & Sasaki, M. (2021). User monitoring in autonomous driving system using gamified Task: A case for vr/AR in-car gaming [Preprint]. *Engineering*. doi:10.20944/preprints202106.0459.v1.
- * Nousias, S., Tselios, C., Bitzas, D., Amaxilatis, D., Montesa, J., Lalos, A.S., ... Chatzigiannakis, I. (2019). Exploiting gamification to improve eco-driving behaviour: The GameCAR approach. *Electronic Notes in Theoretical Computer Science*, 343, 103–116. doi:10.1016/j.entcs.2019.04.013.
- O'Donnell, N., Kappen, D. L., Fitz-Walter, Z., Deterding, S., Nacke, L. E., & Johnson, D. (2017). How multidisciplinary is gamification research? Results from a scoping review. In *CHI PLAY '17 extended abstracts publication of the annual symposium on computer-human interaction in play*, 445–452. 10.1145/3130859.3131412.

- * Olszewski, R., Pałka, P., & Turek, A. (2018). Solving “Smart City” transport problems by designing carpooling gamification schemes with multi-agent systems: The case of the so-called “Mordor of Warsaw”. *Sensors*, 18(1), 141. doi:10.3390/s18010141.
- * Paranthaman, P. K., Dange, G. R., Bellotti, F., Berta, R., & De Gloria, A. (2016). Gamification of car driver performance. In R. Bottino, J. Jeuring, & R. C. Veltkamp (Eds.), *Games and learning alliance* (Vol. 10056, pp 302–308). doi: 10.1007/978-3-319-50182-6_27.
- * Paranthaman, P.K., Dange, G.R., Bellotti, F., Berta, R., De Gloria, A., Di Zitti, E., Massucco, S. & Sciuotto, G. (2018). A serious game architecture for green mobility. In: De Gloria, A. (Eds.), *Applications in electronics pervading industry, environment and society. ApplesPies 2016. Lecture notes in electrical engineering* (Vol. 429, pp. 66–76). Springer. doi: 10.1007/978-3-319-55071-8_9.
- Parekh, D., Poddar, N., Rajpurkar, A., Chahal, M., Kumar, N., Joshi, G. P., & Cho, W. (2022). A review on autonomous vehicles: Progress, methods and challenges. *Electronics*, 11(14), 2162. <https://doi.org/10.3390/electronics11142162>
- * Riaz, M.S., Cuenen, A., Janssens, D., Brijs, K., & Wets, G. (2019). Evaluation of a gamified e-learning platform to improve traffic safety among elementary school pupils in Belgium. *Personal and Ubiquitous Computing*, 23(5–6), 931–941. doi:10.1007/s00779-019-01221-4.
- * Ritz, T., Tello, C. I., & Damm, S. (2014). Connecting a Pedelec to the cloud as basis for gamification in multi modal mobility planning. In *2014 2nd IEEE International Conference on Mobile Cloud Computing, Services, and Engineering* (pp. 101–108). doi: 10.1109/MobileCloud.2014.25.
- Robson, K., Plangger, K., Kietzmann, J. H., McCarthy, I., & Pitt, L. (2015). Is it all a game? Understanding the principles of gamification. *Business Horizons*, 58(4), 411–420. <https://doi.org/10.1016/j.bushor.2015.03.006>
- * Rodríguez, M. D., Roa, R. R., Ibarra, J. E., & Curlango, C. M. (2014a). In-car ambient displays for safety driving gamification. In *Proceedings of the 5th Mexican Conference on Human-Computer Interaction - MexIHC '14* (pp. 26–29). doi: 10.1145/2676690.2676701.
- * Rodríguez, M.D., Ibarra, J.E., Roa, J.R., Curlango, C.M., Bedoya, L.F., Montes, H.D. (2014b). Ambient gamification of automobile driving to encourage safety behaviors. In: Hervás, R., Lee, S., Nugent, C., Bravo, J. (Eds.), *Ubiquitous computing and ambient intelligence. personalisation and user adapted services. UCAmI 2014. Lecture notes in computer science* (Vol. 8867, pp 37–43). Springer. 10.1007/978-3-319-13102-3_8.
- Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69, 371–380. <https://doi.org/10.1016/j.chb.2016.12.033>
- Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, 32(1), 77–112. <https://doi.org/10.1007/s10648-019-09498-w>
- Sardi, L., Idri, A., & Fernández-Alemán, J. L. (2017). A systematic review of gamification in e-Health. *Journal of Biomedical Informatics*, 71, 31–48. <https://doi.org/10.1016/j.jbi.2017.05.011>
- Schroeter, R., Oxtoby, J., & Johnson, D. (2014). AR and gamification concepts to reduce driver boredom and risk taking behaviours. In *Proceedings of the 6th international conference on automotive user interfaces and interactive vehicular applications* (pp. 1–8). <https://doi.org/10.1145/2667317.2667415>
- * Secharan, T. (2022). A framework for gamification to encourage environmentally friendly driving habits. In Pinto, J.O.P., Kimpara, M.L.M., Reis, R.R., Secharan, T., Upadhyaya, B.R., Amadi-Echendu, J. (Eds.), *15th WCEAM proceedings. WCEAM 2021. Lecture notes in mechanical engineering* (pp. 69–78). Springer. doi: 10.1007/978-3-030-96794-9_7.
- Statista. (2022, January 19). *Distribution of global carbon dioxide (CO2) emissions in 2020, by sector*. <https://www.statista.com/statistics/1129656/global-share-of-co2-emissions-from-fossil-fuel-and-cement/>.
- * Steinberger, F., Schroeter, R., & Watling, C. N. (2017a). From road distraction to safe driving: Evaluating the effects of boredom and gamification on driving behaviour, physiological arousal, and subjective experience. *Computers in Human Behavior*, 75, 714–726. <https://doi.org/10.1016/j.chb.2017.06.019>
- * Steinberger, F., Schroeter, R., Foth, M., & Johnson, D. (2017b). Designing gamified applications that make safe driving more engaging. In *CHI '17 Proceedings of the 2017 CHI conference on human factors in computing systems* (pp. 2826–2839). <https://doi.org/10.1145/3025453.3025511>
- Storme, T., De Vos, J., De Pape, L., & Witlox, F. (2020). Limitations to the car-substitution effect of MaaS. Findings from a Belgian pilot study. *Transportation Research Part A: Policy and Practice*, 131, 196–205. <https://doi.org/10.1016/j.tra.2019.09.032>
- * Supriyanto, Hindersah, H., & Prihatmanto, A. S. (2015, December). Designing gamification for taxi booking system (Case study: Bandung smart transportation system). In: *2015 4th international conference on interactive digital media (ICIDM)*, pp. 1–6. doi: 10.1109/idm.2015.7516316.
- Susilo, Y. O., & Cats, O. (2014). Exploring key determinants of travel satisfaction for multi-modal trips by different traveler groups. *Transportation Research Part A: Policy and Practice*, 67, 366–380. <https://doi.org/10.1016/j.tra.2014.08.002>
- Taylor, S., & Todd, P. (1995). Assessing IT usage: The role of prior experience. *MIS Quarterly*, 19(4), 561–570. <https://doi.org/10.2307/249633>
- Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: Improving decisions about health, wealth, and happiness*. Penguin.
- * Tsirimpa, A., Polydoropoulou, A., Pagoni, I., & Tsouros, I. (2019). A reward-based instrument for promoting multimodality. *Transportation Research Part F: Traffic Psychology and Behaviour*, 65, 121–140. doi:10.1016/j.trf.2019.07.002.
- * Vaezipour, A., Rakotonirainy, A., & Haworth, N. (2016). Design of a gamified interface to improve fuel efficiency and safe driving. In Marcus, A. (Ed.), *Design, user experience, and usability: Novel user experiences*. Vol. 9747 (pp. 322–332). Springer International Publishing. doi:10.1007/978-3-319-40355-7_31.
- van Gaalen, A. E., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., & Georgiadis, J. R. (2021). Gamification of health professions education: A systematic review. *Advances in Health Sciences Education*, 26(2), 683–711. <https://doi.org/10.1007/s10459-020-10000-3>
- * Vesco, A., Di Dio, S., Lissandrello, E., & Schillaci, D. (2020). A gamified mobility experience. In M. Kurosu (Ed.), *Human-computer interaction. Human values and quality of life* (Vol. 12183, pp. 658–670). Springer. doi: 10.1007/978-3-030-49065-2_45.
- Werbach, K. (2014). (Re) defining gamification: A process approach. In *International conference on persuasive technology*, pp. 266–272. Springer.
- World Health Organization. (2022, June 20). *Road traffic injuries*. <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries#:~:text=Every%20year%20the%20lives%20of,a%20result%20of%20their%20injury>.
- * Xie, J.Y., Chen, H.-Y.-W., & Donmez, B. (2016). Gaming to safety: Exploring feedback gamification for mitigating driver distraction. *Proceedings of the human factors and ergonomics society annual meeting*, 60(1), 1884–1888. doi:10.1177/1541931213601429.
- Yen, B. T. H., Mulley, C., & Burke, M. (2019). Gamification in transport interventions: Another way to improve travel behavioural change. *Cities*, 85, 140–149. <https://doi.org/10.1016/j.cities.2018.09.002>
- * Yen, B.T., Fu, C., & Chiou, Y.-C. (2022). Young drivers’ preferences for gamification schemes toward Safer Driving Behaviors: A pilot study. *Transportation Research Record: Journal of the Transportation Research Board*, 2676(8), 279–291. doi:10.1177/03611981221083300.
- Zichermann, G., & Cunningham, C. (2011). *Gamification by design: Implementing game mechanics in web and mobile apps*. O’Reilly Media Inc.