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# Fictional or Real? a review of how gamification types effect eco-driving on the road

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ABSTRACT

This study reviews the research on the use of gamification in the eco-driving context. Through a systematic literature review (N=28), it analyzes the effectiveness of different gamification types (i.e., achievement, social, and fictional). Their effectiveness is investigated from a theory of affordances perspective, and gamification affordances, psychological outcomes, and behavioral outcomes are analyzed in detail in the reviewed corpus. The results show that achievement-oriented gamification is the most prominent type of gamification that has been studied and has shown largely positive results in improving energy-efficient driver behavior, such as reduced fuel consumption and acceleration. In contrast, there is little research on the effectiveness of social and fictional gamification. Additionally, there is a need for research to clarify the psychological effects of specific gamification affordances. In light of the current research, the study provides design implications as well as avenues for future research.

## 1. Introduction

World history can be divided into different eras identified by different energy transitions, such as the use of fire, the domestication of animals, waterwheels and windmills, and the use of fossil fuels (Smil, 2004). Today, we face another phase of energy transition due to the environmental, social, and health problems posed by contemporary energy production and use. With the expansion of the human population and shrinking resources of the earth, energy conservation and its effective use have become of utmost importance. In particular, climate change due to energy-related $CO_2$ emissions is threatening future generations. Therefore, there is a global effort to reduce greenhouse gas emissions (GGE). For example, the European Union (EU) passed the European Climate Law to reduce its GGE by 55 % to the levels of the 1990 s (European Commission, 2021), and the United States has established a net-zero greenhouse gas economy target for 2050 (United States Environmental Protection Agency [US EPA], 2023).

Among other sectors, transportation is one of the major sources of GGE. In 2021, it was in the top place, accounting for 29 % of GGE in the US (US EPA, 2022). Europe has similar numbers: transportation represents nearly a quarter of Europe's GGE (Directorate-General for Climate Action, 2023b). Overall, light-duty vehicles are responsible for the greatest proportion of GGE in the transportation sector worldwide. For example, light-duty vehicles produce 15 % of the EU's $CO_2$ emissions (Directorate-General for Climate Action, 2023a), and they take up 49 % of the GGE generated by the transportation sector in the US (United States Environmental Protection

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Agency [US EPA], 2023). One of the dominant strategies for reducing GGE is transportation electrification. However, this strategy can take decades to be adapted around the world considering the infrastructure requirements and varying economic strengths of different countries/regions. Hence, one possible result of transport electrification could be the shift of GGE from developed countries to developing and underdeveloped countries. In addition, the source of electricity used in electric cars can also cause GGE due to electricity being produced using nonrenewable energy resources (e.g., oil, natural gas, and coal).

For these reasons, it is necessary that drivers reduce fuel/energy consumption by adopting eco-driving methods. Eco-driving is the adoption of driving styles that reduce energy consumption (Stillwater & Kurani, 2013). These on-road operational decisions made by vehicle drivers can be related to idling, speeding, aggressive driving, and use of cruise control or air conditioning, and can reduce up to 30 % of energy consumption (e.g., Sivak & Schoettle, 2012). Hence, it is important that vehicle drivers are supported and motivated to eco-drive on the road in an ongoing manner.

To promote eco-driving, different solutions—both simulations and real-time applications—exist: smartphone applications, remote control solutions (mainly for fleet vehicles), advanced driver assistance systems, simulators, and games (Gardelis et al., 2018). There is also a rapidly increasing interest in the use of gamification in the transport and mobility (Avril et al., 2024) and the benefits of gamification in this domain have been shown by previous research (e.g., Degirmenci & Breitner, 2023; Günther et al., 2020). Moreover, previous research has shown that gamification is more effective than motivation for environmental protection and cost reduction in increasing fuel efficiency, depending on the driver's mobility profile (Franke et al., 2017).

Yet, considering different gamification types and the other types of motivators (e.g., monetary and altruistic), and the dependence of these motivators' effectiveness on the driver profile, knowledge on how to ensure continuous motivation for eco-driving is lacking. In addition, there is a call for theory-specific further research to assess the effects of gamification in this field (Avril et al., 2024). Hence, the aim of this research was to provide a detailed outlook of previous research and design implications for practitioners of gamified eco-driving. To that end, the extant literature was reviewed, and the studied gamification affordances and their target driving behaviors and effects were analyzed with respect to the gamification taxonomy (Koivisto & Hamari, 2019). The results show that achievement- and progression-based gamification is most prominent within operational-level eco-driving, and the corpus reports predominantly positive effects on eco-driving behaviors.

Previous reviews on the topic of gamification in the automative domain studied the application of gamification at a very high level taking into account different goals such as safe driving, healthy mobility, and route selection. (e.g., Diewald et al., 2013; Stephens, 2022; Avril et al., 2024). However, eco-driving—at operational level as focused in this study (please see (Sivak & Schoettle, 2012) for a detailed categorization of eco-driving as tactical, strategic, and operational)— significantly differs from other types of mobility goals because designers must consider safety aspects and tailor the system feedback to maximize driver attention and learning to increase the effectiveness of the system (Sanguinetti et al., 2017). Therefore, this review complements previous reviews at the intersection of gamification and eco-driving by focusing on gamified eco-driving at operational level. As such, it provides a detailed and systematic outlook of the gamification types and affordances, and their psychological and behavioral effects. This way, it provides design implications and avenues for future research that can benefit scholars and practitioners working in this domain.

## 2. Background

### 2.1. Eco-driving

Reducing emissions in the transport and mobility sector can be done in three levels considering the Avoid-Shift-Improve (ASI) framework (Ringenson & Kramers, 2021): Avoiding transport by decreasing the number of trips or the distances travelled, shifting to more environmentally friendly transportation modes (e.g., bicycles instead of passenger cars), and improving the environmental performance of car travel by for example reducing its fuel consumption or increasing passenger count (Mårtensson et al., 2023). Considering the ASI framework, eco-driving methods can be classified at the improvement level.

Eco-driving is any vehicle-related behavior aimed at reducing energy consumption and environmental impact (Stillwater & Kurani, 2013). Hence, it encompasses a wide range of strategic, tactical, and operational decisions (Alam & McNabola, 2014). Strategic decisions are those related to vehicle selection (e.g., vehicle class, model, and configuration) and maintenance (e.g., tuned engine, tires, and engine oil); tactical decisions are about route selection (e.g., selection of road type, route grade—flat vs. hilly, and traffic congestion) and vehicle load (e.g., weight and extra cargo); and operational decisions are related to on-road driver behavior, such as idling, speed, cruise control, air conditioner use, and aggressive driving (Sivak & Schoettle, 2012).

Operational decisions are the most frequent and continuous decisions that drivers make with regard to eco-driving, and these decisions can reduce energy consumption by 5 %–30 % (Sivak & Schoettle, 2012). For example, driving speed can affect energy consumption by around 30 %, cruise control by around 7 %, air conditioner use by 5 %–25 %, and aggressive driving by 20 %–30 % (Sivak & Schoettle, 2012). The effects are similar in electric vehicles (e.g., Al-Wreikat et al., 2021; Donkers et al., 2020).

Promotion of eco-driving relies on training programs, in-vehicle devices, regulations, incentives, and social marketing (Huang et al., 2018). However, making continuous operational decisions that will reduce energy consumption while driving can be difficult for several reasons. First, previous studies have shown that eco-driving deteriorated over time after eco-driving training (af Wåhlberg, 2007; Beusen et al., 2009; Huang et al., 2018). Second, demographic differences (e.g., age and gender) also play a role in drivers' energy efficiency (e.g., Nègre & Delhomme, 2017; Zhang et al., 2020). Third, factors such as road rage (Deffenbacher, 2016), misperceptions of one's own driving behavior, and environmental attitudes can also affect eco-driving (Nègre & Delhomme, 2017). Hence, intrinsic and extrinsic motivators may support vehicle drivers in their continuous decision-making regarding eco-driving (Köse, 2021). As such, drivers are motivated by different incentives, such as gamification and financial rewards (Günther et al., 2020).

In that respect, in-vehicle devices can support this continuous decision making towards operational eco-driving by monitoring driving and giving feedback to the drivers (Huang et al., 2018). In-vehicle devices can be in different forms: vehicle dashboards, smartphone applications, GPS navigation systems, haptic pedal feedback, dedicated feedback systems (Gonder et al., 2012). For instance, a recent mapping study showed that there exist 220 mobile apps that help improve driver behavior (El hafidy et al., 2021). The design and research of in-vehicle devices mainly consider three aspects: safety, acceptance, and effectiveness. All these three aspects are dependent on the feedback type chosen that can determine driver attention, learning and motivation. Driver attention is affected by the saliency of the feedback form (i.e., numeric, visual, meter); driver learning is determined by the granularity and precision of the feedback; and driver motivation is determined by the feedback's meaningfulness to the driver, which can be provided by for example gameful or biophilic design (Sanguinetti et al., 2017).

### 2.2. Gamification

Gamification is the design of systems so that their processes and the interactions within them are more game-like, providing users with a sense of fun, immersion, and flow (Huotari & Hamari, 2017). Gamification attempts to create a self-purposeful nature in contexts that are essentially instrumental (Koivisto & Hamari, 2019). With a compound growth rate of 27.4 %, the global gamification market is projected to grow from 9.1 billion USD in 2020 to 30.7 billion USD in 2025 (Growth Engineering, 2023). Considering its potential for improving motivation and engagement in different types of activities, gamification has been implemented in diverse fields, such as education, marketing and advertising, environmental behavior, organizational processes, exercise, and health (Koivisto & Hamari, 2019). It can also yield positive outcomes in energy-efficient driving, and previous research supports these positive outcomes (e.g., Degirmenci & Breitner, 2023; Günther et al., 2020).

Gamification is considered to comprise three levels: affordances, psychological outcomes, and behavioral outcomes (Koivisto & Hamari, 2019). An affordance is a relationship between the capabilities of an agent and the properties of an object that determines the possibilities of how the object can be used (Norman, 2013). In other words, it tells what the object is used for by an agent and answers the question of what the object affords doing. Hence, it is not an independent property of the object but is jointly determined by the agent's capabilities. In the context of gamified services, features embedded in the system (e.g., points and leaderboards) enable different types of affordances depending on the user (e.g., connecting with people and appreciation or recognition of achievement). Psychological outcomes are the emotional and mental states arrived at by the use of affordances. For example, a high ranking on a leaderboard can give a feeling of achievement by comparing oneself to others and hence fulfill a feeling of competence, which is one of the psychological needs that provide intrinsic motivation (Deci & Ryan, 2000). Behavioral outcomes are the activities and behaviors that are motivated and supported by gamification (Koivisto & Hamari, 2019). In the context of eco-driving, behavioral outcomes can include driving at a steady speed and decreased braking, acceleration, and aggressiveness while driving. Accordingly, different gamification types call for different affordances and, as a result, different psychological and behavioral outcomes. The effectiveness of gamification in behavioral change depends on this chain of effects.

Gamification has been classified variously by different scholars (e.g., Koivisto & Hamari, 2019; Toda et al., 2019). The classifications used also depend on the gamification context. For example, in the context of learning environments, gamification has been classified into five groups: performance, ecological, social, personal, and fictional (Toda et al., 2019). A more general classification of gamification divides different affordances into five groups: achievement/progression-oriented, social-oriented, immersion-oriented, real-world-related, and miscellaneous (Koivisto & Hamari, 2019). In the eco-driving context, gamification types are more limited due to the safety aspect of driving. Hence, these can be classified into three groups: achievement, social, and fictional. Fig. 1 illustrates eco-driving gamification types using the theory of affordances. Achievement-oriented gamification is designed to provide feedback to the user. The feedback is given in different forms, such as points, progression, stats, and levels. Social gamification creates interaction between vehicle drivers and comprises elements such as competition, cooperation, reputation, and social pressure. Fictional

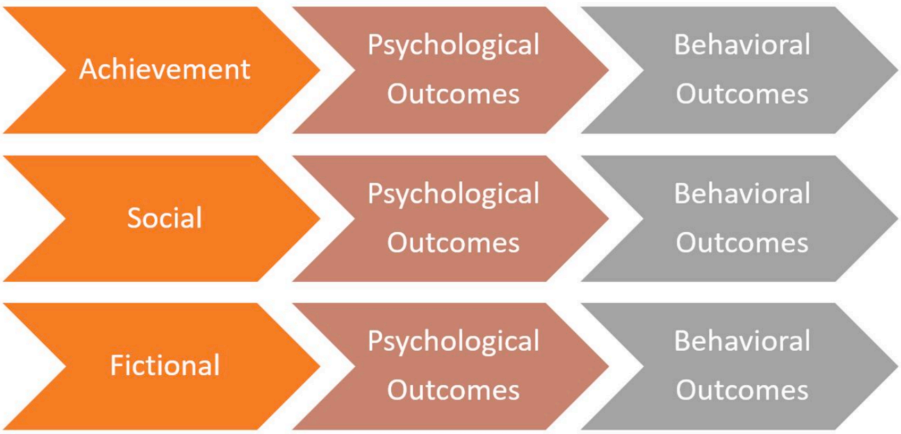


**Fig. 1.** Affordances of gamification types.

gamification creates an experiential link between the user and the environment through the use of narrative and storytelling. For example, the Smooth Driver app turns driving activity into a fictional game in which vehicle drivers try not to drop a ball out of a bowl by reducing their acceleration and hard braking (Degirmenci & Breitner, 2023).

### 2.3. Gamification in sustainability and mobility

Among others, another emerging area where gamification is applied is sustainable consumption. A recent review identified 67 mobile applications for sustainable consumption in the areas of for example waste management, clothing, energy consumption, mobility, and food consumption (Guillén et al., 2022). In the automative industry, gamification has been used in both in-vehicle applications and outside of vehicles. While the main areas of application of gamification outside vehicles is marketing and brand forming, in-vehicle gamification has been applied to the contexts of navigation, eco-driving, and driving safety (Diewald et al., 2013).

There are several review studies on gamification in the transport and mobility sector. However, they either take a very broad perspective (Avril et al., 2024; Diewald et al., 2013; Stephens, 2022), conduct a mapping study of the mobile applications (El hafidy et al., 2021) or focus on very specific domains such as freight transportation (Tomé Klock et al., 2021). Related our study, a recent review of scientific literature on the use of gamification in transport and mobility found 49 studies and showed that the targeted behaviors were eco-friendly mobility, safe mobility, healthy mobility (i.e., promotion of healthier mobility behaviors such as walking and cycling), engagement with commercial services such as taxi booking or bus systems, entertainment in self-driving cars, and driver therapy and triggering (Avril et al., 2024). Overall, previous reviews agree that the application of gamification presents mixed results, despite positive behavior change were shown in terms of eco-driving particularly reduction of speed and fuel/energy consumption (Avril et al., 2024; Stephens, 2022). Yet, lack of methodological rigor and consideration of usability and user experience in the conducted studies necessitate more field-specific focus in the gamification research (Avril et al., 2024). In that respect, this review fills a gap by focusing on the status of gamification research on operational eco-driving and providing the status-quo from the perspectives of gamification types and theory of affordances.

## 3. Methods

The aim of systematic literature reviews is to synthesize existing research and provide an overview of a topic (Webster & Watson, 2002). More specifically, this study can be seen as a descriptive review, whose aim is to reveal identifiable patterns and trends within a research area by extracting relevant characteristics from each study (Paré et al., 2015). To identify relevant research, we identified keywords belonging to three main categories: (1) gamification, (2) eco-driving behaviors and outcomes, and (3) transportation. After conducting the initial test searches, we included additional relevant keywords from the returned studies and excluded keywords that did not return studies relevant to our scope. We searched the following string of keywords in the abstracts, titles, and keywords to extensively identify relevant research proposing gamified interventions to encourage eco-driving behaviors: *(gamif* OR "persuasive interface" OR "persuasive smartphone application" OR "persuasive strategy" OR "persuasive technolog*" OR "reality-enhanced gam*" OR "serious gam*" OR "game element") AND ("eco-driv*" OR "eco driv*" OR ecodriv* OR "eco-efficient driv*" OR "fuel consumption" OR "fuel efficiency" OR "environmentally friendly driv*" OR "fuel saving" OR "energy efficien*" OR "energy saving" OR "energy consumption" AND ("*vehicle*" OR "*car*" OR "transport*" OR "driv*" OR "auto*").*

We conducted the search initially in the Scopus database, which is widely used in systematic literature review studies and indexes many of the most important databases. The search was conducted in June 2023, resulting in 146 hits. Additionally, in July 2024 complementary searches were conducted through PubMed and Web of Science databases, which respectively returned 10 and 120 hits summing up to a total of 277 hits, of which 94 were duplicates. After having removed the duplicates, two researchers independently examined the titles and abstracts of the returned 183 studies according to the following inclusion criteria: (1) written in English, (2) peer-reviewed, (3) related to eco-driving, (4) related to in situ gamification. After the initial examination, the two researchers decided differently in 23 of the studies (0.64 Cohen's kappa). However, these ambiguous cases were discussed among the two researchers and a

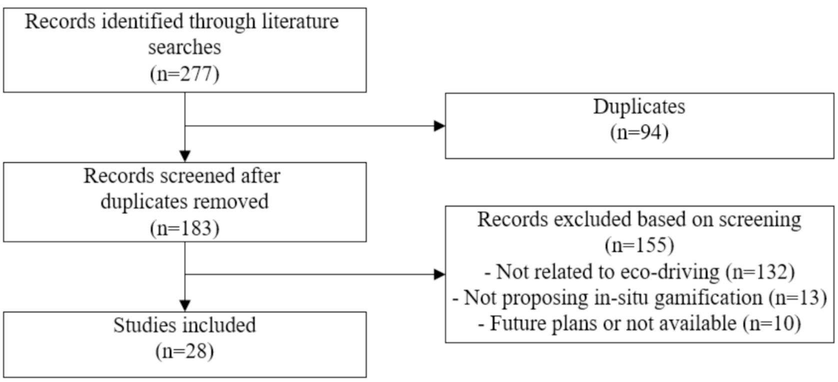


**Fig. 2.** Literature selection.

consensus was reached in all cases on whether to include them or not. As seen in Fig. 2, of the hits, 132 were excluded from the analysis due to not being related to eco-driving (e.g. focusing on energy preserving behavior broadly) and 13 due to not being related to in-situ gamification (e.g., focusing on serious gaming interventions or non-gamified behavioral change technologies). Additionally, studies that reported future implementations or research plans and studies that were unavailable to the authors in full text were excluded (10 studies). Finally, 28 studies were included in the analysis.

Each study that met the inclusion criteria was analyzed independently by a single researcher. Pertaining to eco-driving, the analysis included the behaviors that the gamification intervention described in the manuscript targeted (e.g., driving speed, acceleration, driving aggressiveness, and coasting), the type of vehicle considered (e.g., truck or car), and whether gamification was targeted toward internal combustion engine or electric vehicles. The analysis included the affordances implemented or considered (e.g., feedback, ranking, avatars, and virtual rewards), and the temporality of the gamified feedback (i.e., real-time or ex post). In relation to the studies' details, the analysis covered the evaluation methods used (e.g., quantitative, or qualitative), the sample size, and the behavioral and psychological outcomes derived from the gamification implementation.

## 4. Results

Overall, most studies (n = 18) proposed solutions for private passenger cars (Bihler et al., 2010; Corcoba Magaña & Organero, 2013; Degirmenci & Breitner, 2023; Di Lena et al., 2017; Ecker et al., 2011; Günther et al., 2020; Hrimech et al., 2016; Ibragimova et al., 2015; Kramer et al., 2023; Lee et al., 2011; Magaña & Organero, 2014, 2015; Massoud et al., 2019, 2021; Nousias et al., 2019; Tröster & Mörtl, 2021; Tselios et al., 2019; Vaezipour et al., 2019), while some targeted trucks (n = 3) (Brouwer et al., 2015; Cammin et al., 2020; Klemke et al., 2014), school buses (n = 1) (Pace et al., 2007), buses (n = 1) (Herget et al., 2023) and trains (n = 1) (Ćwil & Bartnik, 2018). Six studies (Degirmenci & Breitner, 2023; Di Lena et al., 2017; Günther et al., 2020; Herget et al., 2023; Kramer et al., 2023; Tröster & Mörtl, 2021) specifically targeted electric vehicles. Others, however, proposed more generic solutions that did not target any specific vehicle type (Degirmenci, 2018; Geva et al., 2022; Hollerit et al., 2021; Vaezipour et al., 2016).

Table 1 presents the studies aimed at encouraging various eco-driving behaviors. Overall, the most common eco-driving behaviors targeted in the studies were acceleration, braking, coasting, and driving aggressiveness (19 studies), followed by optimal driving speed (10 studies), and using the optimal gear to optimize the engine speed (9 studies). Additionally, one study targeted idling (Pace et al., 2007).

The studies proposed or implemented a variety of affordances belonging to all three main categories (i.e., achievement and progression, social, and fictional), as seen in Table 2 and summarized in Fig. 3. Achievement- and progression-based affordances were the most prevalent, with points (17 studies) being the most common, followed by different types of performance feedback (15 studies), leaderboards and ranking (13 studies), badges, virtual rewards, trophies, titles, and achievements (13 studies), levels/missions/quests (6 studies), performance statistics, progress visualization (6 studies), and goal setting (2 studies). Social gamification features were less common, and included social networking (1 study), group competition (1 study), and common goals (1 study). The only fictional affordances were avatars (2 studies) and storytelling (2 studies). Other affordances described in the manuscripts were loot boxes (1 study) and hints (2 studies).

Of the studies, thirteen (i.e., Brouwer et al., 2015; Cammin et al., 2020; Degirmenci, 2018; Degirmenci & Breitner, 2023; Di Lena et al., 2017; Geva et al., 2022; Herget et al., 2023; Hollerit et al., 2021; Hrimech et al., 2016; Kramer et al., 2023; Lee et al., 2011; Nousias et al., 2019; Tselios et al., 2019) proposed systems that focus on real-time gamification, whereas three (i.e., Bihler et al., 2010; Günther et al., 2020; Klemke et al., 2014) provided only ex post gamification. Twelve studies (Ćwil & Bartnik, 2018; Corcoba Magaña & Organero, 2013; Ecker et al., 2011; Ibragimova et al., 2015 Magaña & Organero, 2014, 2015; Massoud et al., 2019; Massoud et al.,2021; Pace et al., 2007; Tröster & Mörtl, 2021; Vaezipour et al., 2016; Vaezipour et al., 2019) combined these two approaches.

The evaluation approaches used in the analyzed studies are presented in Table 3. Six studies were nonempirical research that did not evaluate the impacts of gamification on behaviors or psychological outcomes but either provided technical descriptions of gamification systems or conceptual research or did not specify the evaluation method. Fifteen studies provided a quantitative evaluation of gamification impacts, three used qualitative evaluation, and three used both mixed methods. The sample sizes reported in the manuscripts ranged from 3 to 108, and one study (Hollerit et al., 2021) collected log data from 2455 players who had played the proposed game. Of the studies, six used a sample size smaller than 30.

Six of the studies (Brouwer et al., 2015; Pace et al., 2007; Tröster & Mörtl, 2021; Geva et al., 2022; Hollerit et al., 2021; Hrimech

**Table 1**
Eco-driving behaviors targeted in the studies.

| Eco-driving behaviors targeted | Studies |
|---|---|
| Acceleration, braking, driving aggressiveness, coasting (n = 19) | Cammin et al., 2020; Corcoba Magaña & Organero, 2013; Degirmenci, 2018; Degirmenci & Breitner, 2023; Di Lena et al., 2017; Ecker et al., 2011; Hollerit et al., 2021; Hrimech et al., 2016; Ibragimova et al., 2015; Kramer et al., 2023; Magaña & Organero, 2014, 2015; Massoud et al., 2019, 2021; Nousias et al., 2019; Pace et al., 2007; Tselios et al., 2019; Vaezipour et al., 2016; Vaezipour et al., 2019) |
| Driving speed (n = 10) | (Brouwer et al., 2015; Cammin et al., 2020; Corcoba Magaña & Organero, 2015; Hrimech et al., 2016; Magaña & Organero, 2014, 2015; Massoud et al., 2019, 2021; Vaezipour et al., 2016; Vaezipour et al., 2019) |
| Shifting gears/rpm/engine speed (n = 9) | (Corcoba Magaña & Organero, 2013; Hrimech et al., 2016; Klemke et al., 2014; Magaña & Organero, 2014, 2015; Massoud et al., 2019, 2021; Nousias et al., 2019; Tselios et al., 2019) |
| Idling (n = 1) | Pace et al., 2007 |

**Table 2**
Considered or implemented affordances.

| Affordances | | Studies |
|---|---|---|
| Achievement and progression | Points (n = 17) | (Bihler et al., 2010; Brouwer et al., 2015; Ćwil & Bartnik, 2018; Di Lena et al., 2017; Ecker et al., 2011; Geva et al., 2022; Herget et al., 2023; Hrimech et al., 2016; Klemke et al., 2014; Kramer et al., 2023; Magaña & Organero, 2014, 2015; Massoud et al., 2019, 2021; Nousias et al., 2019; Tselios et al., 2019; Vaezipour et al., 2016) |
| | Feedback (n = 15) | (Brouwer et al., 2015; Ćwil & Bartnik, 2018; Di Lena et al., 2017; Ecker et al., 2011; Herget et al., 2023; Hollerit et al., 2021; Hrimech et al., 2016; Ibragimova et al., 2015; Kramer et al., 2023; Lee et al., 2011; Magaña & Organero, 2015; Massoud et al., 2021; Nousias et al., 2019; Pace et al., 2007; Vaezipour et al., 2016) |
| | Leaderboard/ranking (n = 13) | (Bihler et al., 2010; Brouwer et al., 2015; Degirmenci, 2018; Ecker et al., 2011; Günther et al., 2020; Klemke et al., 2014; Kramer et al., 2023; Magaña & Organero, 2014, 2015; Nousias et al., 2019; Trösterer & Mörtl, 2021; Tselios et al., 2019; Vaezipour et al., 2016) |
| | Badges, virtual rewards, trophies, titles, achievements (n = 13) | (Cammin et al., 2020; Ćwil & Bartnik, 2018; Degirmenci, 2018; Di Lena et al., 2017; Hollerit et al., 2021; Ibragimova et al., 2015; Klemke et al., 2014; Magaña & Organero, 2014, 2015); Massoud et al., 2021; Nousias et al., 2019; Tselios et al., 2019; Vaezipour et al., 2016) |
| | Levels/missions/quests (n = 6) | (Brouwer et al., 2015; Hollerit et al., 2021; Klemke et al., 2014; Nousias et al., 2019; Tselios et al., 2019; Vaezipour et al., 2016) |
| | Performance statistics, progress visualization (n = 6) | (Ecker et al., 2011; Ibragimova et al., 2015; Kramer et al., 2023; Pace et al., 2007; Tselios et al., 2019; Vaezipour et al., 2016) |
| | Goalsetting (n = 2) | (Nousias et al., 2019; Vaezipour et al., 2019) |
| Social | Social networking (n = 1) | (Magaña & Organero, 2014) |
| | Group competition (n = 1) | (Ćwil & Bartnik, 2018) |
| | Common goals (n = 1) | (Ćwil & Bartnik, 2018) |
| Fictional | Avatar (n = 2) | (Nousias et al., 2019; Tselios et al., 2019) |
| | Storytelling (n = 2) | (Degirmenci & Breitner, 2023; Nousias et al., 2019) |
| Other | Loot boxes (n = 1) | (Nousias et al., 2019) |
| | Hints (n = 2) | (Kramer et al., 2023; Massoud et al., 2021) |

et al., 2016) used simulator or game settings for evaluation, while eight (Ecker et al., 2011; Herget et al., 2023; Lee et al., 2011; Magaña & Organero, 2014; Günther et al., 2020; Ibragimova et al., 2015; Kramer et al., 2023; Degirmenci & Breitner, 2023) employed field settings. Additionally, two studies (Di Lena et al., 2017; Vaezipour et al., 2016) used mockup interfaces for evaluation without additional simulator or field settings.

Twelve studies examined one or more psychological outcomes stemming from gamification implementations. As Table 4 shows, these mainly focused on utility, with the most commonly evaluated psychological outcomes being perceived usefulness, effectiveness, or influence on behavior (8 studies), followed by ease of use or usability (4 studies), system acceptance or intention to use (3 studies), attitude toward eco-driving or intention to drive in a more eco-friendly manner (3 studies), joy, fun, or enjoyment (3 studies), engagement or motivation (2 studies), perceived distraction or alertness (2 studies), perceived pressure (1 study), satisfaction (1 study), performance expectancy (1 study), and cognitive absorption (1 study).

Fifteen studies evaluated one or more behavioral outcomes or their proxy, the most common being fuel or energy consumption or emissions (7 studies), driving speed (4 studies), acceleration (4 studies), coasting, braking, or slowing down (3 studies), smooth driving or driving aggressiveness (3 studies), engine speed (1 study), vehicle charging (1 study), and parking behavior (1 study) (Fig. 4). The analyzed studies reported almost exclusively positive results in terms of gamification impacts on eco-driving. The affordances used for each behavioral outcome are presented in Table 5.

## 5. Discussion

This manuscript synthesized the existing available research on gamified eco-driving, analyzing a corpus of 28 studies. Overall, most studies described or implemented solutions to encourage private internal combustion engine passenger car users to drive in an eco-friendlier manner, predominantly aiming to encourage a less aggressive driving style with optimal acceleration and deceleration behavior for reduced fuel consumption. This emphasis is reasonable, given that in the EU, for example, passenger cars account for more than 60.6 % of transport $CO_2$ emissions, representing a key area for improvement (European Parliament, 2023). Additionally, targeting private passenger car drivers' driving aggressiveness, braking, and acceleration has the potential not only to reduce fuel and electricity consumption and emissions but also to improve road safety, as less aggressive driving behavior results in safer and smoother traffic flow and lowers the risk of collisions, fatalities, and injuries.

Overall, achievement- and progression-based affordances were the most considered and applied, the most common being points, different forms of feedback, and leaderboards. This is possibly due to two main reasons. First, features such as points or feedback are easily implemented in driving tasks without compromising driving safety due to distraction, for example, as they potentially require little cognitive demand from the user to follow while driving (Koivisto & Hamari, 2019; Wallius et al., 2022). Second, eco-driving behaviors typically lack any form of direct feedback or the possibility of reliably monitoring one's performance, which might become a motivational hurdle for engaging in eco-driving, as there are few opportunities for the driver to monitor their performance and adapt their behavior accordingly. Thus, the prevalence of achievement- and progression-based features suggests that most studies used gamification to imbue eco-driving with feedback that supports drivers' decision-making, while providing acknowledgment and a

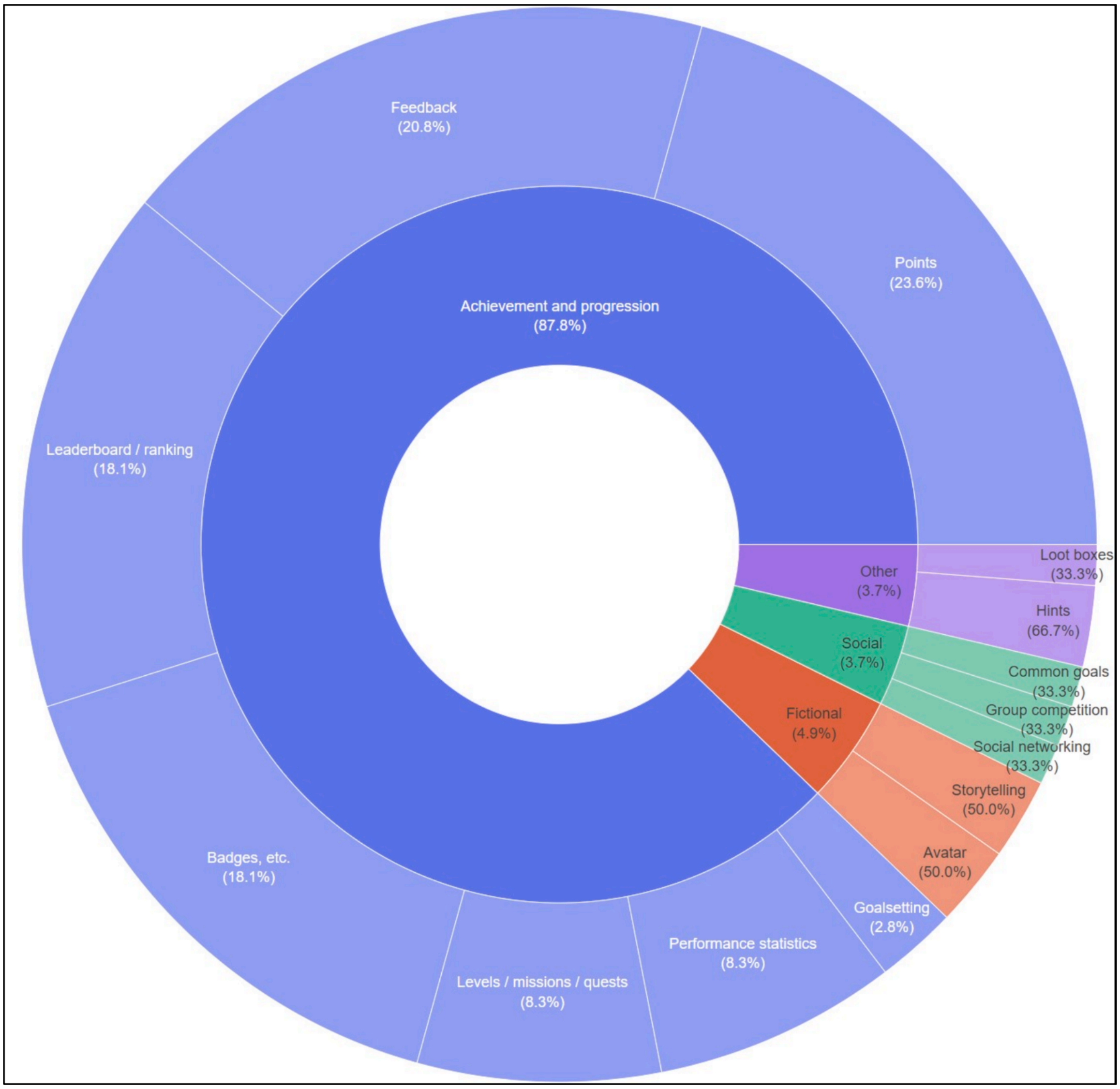


**Fig. 3.** Considered or implemented affordances.

**Table 3**
Evaluation method.

| Evaluation method | Studies |
|---|---|
| Qualitative evaluation (n = 3) | (Ibragimova et al., 2015; Nousias et al., 2019; Vaezipour et al., 2016) |
| Quantitative evaluation (n = 15) | (Brouwer et al., 2015; Corcoba Magaña & Organero, 2013; Degirmenci, 2018; Degirmenci & Breitner, 2023; Ecker et al., 2011; Geva et al., 2022; Günther et al., 2020; Herget et al., 2023; Hollerit et al., 2021; Hrimech et al., 2016; Kramer et al., 2023; Magaña & Organero, 2014, 2015; Tröster & Mörtl, 2021; Vaezipour et al., 2019) |
| Mixed qualitative and quantitative (n = 3) | (Di Lena et al., 2017; Lee et al., 2011; Pace et al., 2007) |
| Nonempirical, no evaluation, or not specified (n = 7) | (Bihler et al., 2010; Cammin et al., 2020; Ćwil & Bartnik, 2018; Klemke et al., 2014; Massoud et al.,2019, 2021; Tselios et al., 2019) |

sense of achievement for behaving in a desired manner (Xi & Hamari, 2019).

Within the relatively small corpus, some studies also considered or implemented social affordances. The aim of social gamification is to provide a sense of connectedness to the user— another feature that is inherently absent in eco-driving, during which individuals are confined to their vehicles, allowing limited possibilities to interact with others (Koivisto & Hamari, 2019). Finally, three studies implemented or considered fictional affordances (i.e., storytelling and avatars). Fictional gamification can make eco-driving more

**Table 4**
Evaluated psychological outcomes.

| Psychological outcome | Studies |
|---|---|
| Usefulness, perceived effectiveness, perceived influence on behavior (n = 8) | (Brouwer et al., 2015; Degirmenci, 2018; Degirmenci & Breitner, 2023; Di Lena et al., 2017; Ecker et al., 2011; Klemke et al., 2014; Trösterer & Mörtl, 2021; Vaezipour et al., 2016) |
| Ease of use, usability (n = 4) | (Brouwer et al., 2015; Degirmenci, 2018; Degirmenci & Breitner, 2023; Vaezipour et al., 2016) |
| System acceptance, intention to use (n = 3) | (Brouwer et al., 2015; Degirmenci & Breitner, 2023; Vaezipour et al., 2019) |
| Joy, fun, enjoyment (n = 3) | (Degirmenci & Breitner, 2023; Ecker et al., 2011; Trösterer & Mörtl, 2021) |
| Attitude toward eco-driving, behavioral intention (n = 3) | (Degirmenci, 2018; Günther et al., 2020; Nousias et al., 2019) |
| Engagement, motivation (n = 2) | (Ibragimova et al., 2015; Nousias et al., 2019) |
| Perceived distraction, alertness (n = 2) | (Ecker et al., 2011; Ibragimova et al., 2015) |
| Perceived pressure (n = 1) | (Ecker et al., 2011) |
| Satisfaction (n = 1) | (Lee et al., 2011) |
| Performance expectancy (n = 1) | (Degirmenci, 2018) |
| Cognitive absorption (n = 1) | (Degirmenci, 2018) |

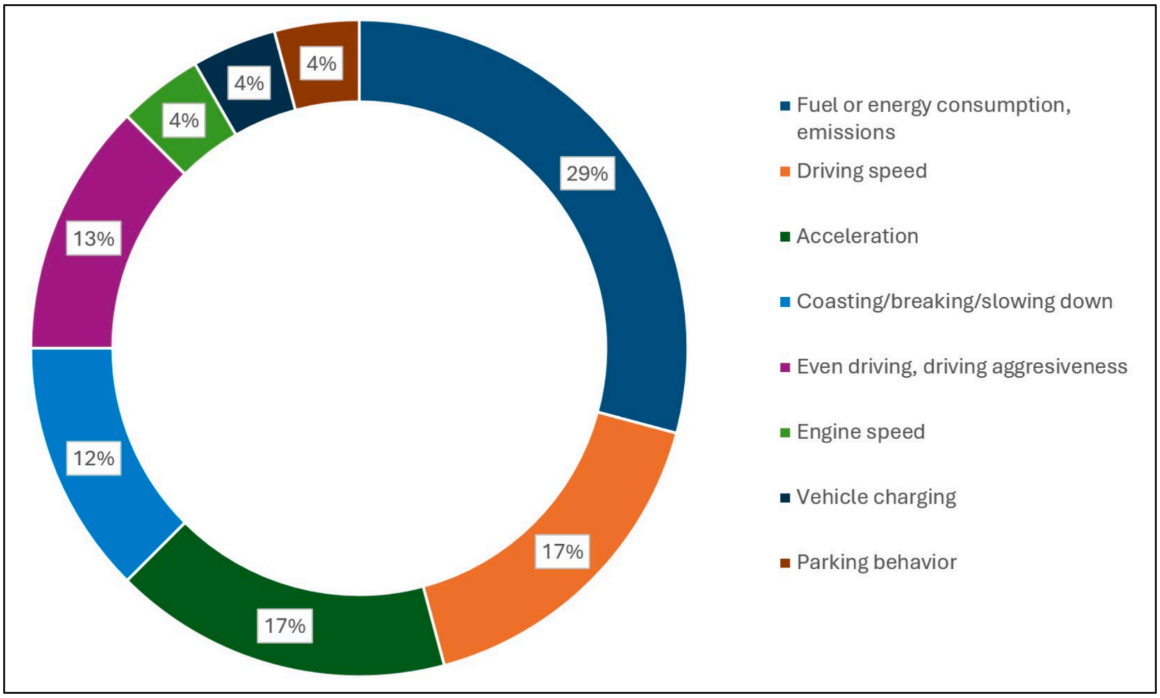


**Fig. 4.** Targeted behavioral outcomes.

engaging by enhancing the driving experience, hence making it less mundane while providing a sense of purposefulness and self-directed action (Xi & Hamari, 2019). However, compared to achievement- and progression-based affordances, fictional affordances can be problematic in this domain, as they generally serve to absorb the user into a narrative or a game world, which might become a safety issue during driving.

Within the analyzed corpus, most studies proposed real-time gamification, which means that drivers receive game-like feedback and rewards during their trips. This approach is effective in positively enhancing drivers' motivation and engagement as well as eco-driving, as immediate feedback generally drives real-time behavioral change more efficiently than delayed feedback (Dijksterhuis et al., 2015). However, real-time gamification also entails some challenges, such as the potential distraction and cognitive overload that drivers may experience if the gamification elements are too intrusive or complex (Degirmenci & Breitner, 2023; Wallius et al., 2022). Possibly for this reason, a smaller number of studies opted for post-trip gamification, which provides drivers with feedback and rewards after they complete their trips. This approach may be less distracting and more informative, but it may also be less effective in motivating and influencing drivers than in real time (Degirmenci & Breitner, 2023; Dijksterhuis et al., 2015).

In terms of the psychological outcomes evaluated, most studies focused on the utilitarian aspects of the implementation, including usefulness, perceived effectiveness, and perceived influence on behavior. Although gamification's central premise in general is to provide positive experiences and imbue mundane activities with intrinsic motivation for long-term engagement and behavioral change (Koivisto & Hamari, 2019), this aspect was less prevalent within the analyzed corpus, as joy, fun, and enjoyment were only evaluated

**Table 5**
Behavioral outcomes and related affordances.

| Behavioral outcome or proxy | Positive | Null or negative | Not applicable |
|---|---|---|---|
| Fuel or energy consumption, emissions (n = 7) | n = 5 (Degirmenci & Breitner, 2023; Günther et al., 2020; Herget et al., 2023; Hrimech et al., 2016; Trösterer & Mörtl, 2021)<br><br>**Affordances used**<br>Leaderboard, ranking n = 2<br>Score, points n = 1<br>Feedback n = 1 | n = 2 (Ecker et al., 2011; Kramer et al., 2023)<br><br>**Affordances used**<br>Points n = 2<br>Ranking n = 2<br>Progress bar n = 1<br>Hints n = 1<br>Performance statistics n = 1<br>Feedback n = 1 | |
| Driving speed (n = 4) | n = 3 (Brouwer et al., 2015; Magaña & Organero, 2015; Trösterer & Mörtl, 2021)<br><br>**Affordances used**<br>Leaderboard, ranking n = 3<br>Feedback n = 2<br>Points n = 2<br>Levels n = 1<br>Social networking n = 1 | | n = 1 (Hollerit et al., 2021)<br><br>**Affordances used**<br>Quests n = 1<br>Feedback n = 1<br>Virtual currency n = 1 |
| Acceleration (n = 4) | n = 3 (Ecker et al., 2011; Magaña & Organero, 2015; Trösterer & Mörtl, 2021)<br><br>**Affordances used**<br>Ranking, leaderboard n = 3<br>Feedback n = 2<br>Points n = 2<br>Performance statistics n = 1<br>Social networking n = 1 | | n = 1 (Hollerit et al., 2021)<br><br>**Affordances used**<br>Quests n = 1<br>Feedback n = 1<br>Virtual currency n = 1 |
| Coasting/braking/ slowing down (n = 3) | n = 3 (Ecker et al., 2011; Magaña & Organero, 2015; Trösterer & Mörtl, 2021)<br><br>**Affordances used**<br>Ranking, leaderboard n = 3<br>Feedback n = 2<br>Points n = 2<br>Performance statistics n = 1<br>Social networking n = 1 | | |
| Even driving, driving aggressiveness (n = 3) | n = 3 (Ecker et al., 2011; Magaña & Organero, 2014; Pace et al., 2007)<br><br>**Affordances used**<br>Feedback n = 2<br>Ranking n = 2<br>Points, score n = 2<br>Performance statistics n = 2<br>Hints n = 1<br>Social networking n = 1<br>Achievements/rewards n = 1 | | |
| Engine speed (n = 1) | n = 1 (Magaña & Organero, 2015)<br><br>**Affordances used**<br>Score n = 1<br>Ranking n = 1<br>Social networking n = 1<br>Feedback n = 1 | | |
| Vehicle charging (n = 1) | n = 1 (Kramer et al., 2023)<br><br>**Affordances used**<br>Points n = 1<br>Ranking n = 1<br>Progress bar n = 1<br>Feedback n = 1<br>Tips/hints n = 1 | | |
| Parking behavior (n = 1) | | | n = 1 (Geva et al., 2022) |

(*continued on next page*)

**Table 5** (*continued*)

| Behavioral outcome or proxy | Positive | Null or negative | Not applicable |
|---|---|---|---|
| | | | **Affordances used**<br>Points n = 1 |

in three studies. This suggests that within the existing research on gamified eco-driving, gamification is mainly considered a utilitarian tool that aids drivers in adopting a more optimal driving style, rather than an approach with playful or meaningful experiences.

The analyzed studies almost exclusively reported positive results on eco-driving behaviors and their proxies, such as fuel or energy consumption, while only two studies reported null or negative impacts. This implies that gamification is a promising approach for encouraging eco-driving. However, due to the reported implementations being holistic gamification designs that incorporated various affordances, the corpus provides only limited evidence of what types of gamification are the most efficient within the context of eco-driving. This is a well-acknowledged limitation of gamification research in general (Koivisto & Hamari, 2019). For overall fuel or energy consumption, driving speed, acceleration, and coasting/braking/slowing down, the most applied affordance within the studies that reported positive behavioral outcomes was ranking or leaderboards, implying that these are likely to have a positive impact on eco-driving behaviors. Other affordances were mainly analyzed by single studies in relation to any behavioral outcomes, therefore preventing making inferences about their behavioral impacts.

### *5.1. Design recommendations*

#### *5.1.1. Considering gamification temporality and driving distraction*

Generally, immediate rather than delayed feedback is more efficient for changing behaviors, such as eco-driving, which are mostly automatic, as it allows drivers to adapt their actions instantly. However, in the driving context, immediate feedback might pose safety risks due to potential distraction from the main driving task if it is too pervasive and cognitively absorbing, as noted by prior research on gamified transportation safety (Wallius et al., 2022). Therefore, designers need to take into account feedback temporality and distraction and find means to overcome them. Within the extant corpus, some solutions opted to use auditory feedback to avoid visual distraction (e.g., Degirmenci & Breitner, 2023), whereas some used haptic feedback for the same purpose (Ibragimova et al., 2015), which could be one solution to address the tradeoff in a manner that brings about an effective change in behavior while not being distracting. Additionally, a viable approach is combining simple ambient gamification with more nuanced or complex feedback along with gamification that the user can interact with outside the driving situation to adjust their driving behavior to be more energy-efficient (e.g., Ibragimova et al., 2015; Trösterer & Mörtl, 2021).

#### *5.1.2. Using gamification to allow social comparison and interaction in eco-driving*

Due to the limited number of studies available on gamified eco-driving, drawing conclusions as to what types of affordances are most efficient in promoting behavioral change is problematic. However, based on the analysis of behavioral outcomes by affordance, the studies using ranking or leaderboards predominantly led to positive outcomes in relation to fuel or energy consumption, driving speed, acceleration, and coasting/braking/slowing down. This suggests that gamification that enables social comparison can be an effective approach for promoting eco-driving. Conversely, social gamification, such as leaderboards, can provide interaction and a sense of belongingness among users, which is a feature that motivates the use of in-vehicle technology (Stiegemeier et al., 2024), yet is inherently absent in eco-driving, during which individuals are confined to their vehicles, allowing limited possibilities to interact with and compare one's behavior to others.

#### *5.1.3. Temporal customization of gamified eco-driving feedback*

Previous research has shown that the effects of gamification may fade away with increasing experience with the system in different gamification contexts (Koivisto & Hamari, 2019) and that eco-driving behavior deteriorated in time after training (af Wåhlberg, 2007; Beusen et al., 2009). Therefore, a gamified eco-driving assistance system should be designed such that it provides different motivational factors to ensure consistent eco-driving practices in the long run (Franke et al., 2017). Clearly different factors (e.g., environmental protection, cost reduction, and personal challenges) motivate drivers to eco-drive (Franke et al., 2017). Hence, it is essential that a gamified eco-driving assistant embeds these different motivators in a manner customizable to the user. The design of these systems can also consider factors that deter eco-driving, such as enjoyment of acceleration/speed or time issues (Franke et al., 2017).

### *5.2. Future avenues*

First, we encourage future research endeavors to be more transparent about the goals of implementing gamification and to evaluate the psychological effects accordingly. For example, while many studies implemented social gamification features whose goal was primarily to foster connectedness, competitiveness, or social pressure, the evaluated psychological outcomes mainly related to perceptions of utility, such as usefulness, or to more abstract hedonic outcomes, such as joy. Thus, the corpus provides little evidence of how gamification implementations reach the goals related to imbuing eco-driving with a gameful experience, and what types of gameful experiences might be the most effective in promoting eco-driving.

Second, we encourage future research to consider a wider variety of gamification designs. Based on the extant corpus, gamified eco-driving mainly focuses on achievement- and progression-based gamification, whereas social and fictional affordances are less prevalent. This is likely due to achievement- and progression-based gamification, such as ranking or points, being easily applicable in eco-driving, while, for example, fictional gamification might pose a risk to safety by absorbing the user into a gameful world while detaching them from the driving task. However, fictional elements such as narrativization and storytelling are a promising approach to promote sustainable behavioral change in other domains, such as health (e.g., Lipsey et al., 2020), and future research should explore how these approaches can be applied within the eco-driving context. Furthermore, social features were scarce within the existing corpus, despite the recognized impact of community engagement on sustainable behaviors (Kang, 2019). Therefore, future research should put more emphasis on social gamification features.

Third, we encourage future research to examine the impacts of isolated gamification design types on eco-driving behaviors. Within the analyzed corpus, holistic gamification implementation that used constellations of affordances to maximize their motivational and behavioral impacts was primarily implemented, which is also a recognized shortcoming of gamification research more broadly (Koivisto & Hamari, 2019). Accordingly, the corpus provides limited evidence of which types of gamification are the most efficient in inducing a behavioral change in drivers. However, as the corpus matures and the overall benefits of gamification become established, we encourage future research to examine the impacts of isolated gamification affordances or designs (i.e., achievement, progression, social, and fictional) and, by comparing their impacts on psychological and behavioral outcomes, to determine what are the most applicable in the eco-driving context.

## 6. Limitations

This study has several limitations. First, this review focused solely on approaches that were explicitly mentioned as gamification or belonging to another game-like approach. However, the difference between gamification and, for example, eco-driving assistant systems that provide persuasive messages or feedback to drivers can sometimes be unclear and ambiguous, and including studies from this domain might have informed our review. Second, we analyzed and grouped the used or considered gamification affordances according to what the authors explicitly mentioned. However, a single type of affordance can be applied in different ways that do not necessarily lead to a similar type of gameful experience. For example, points can be used as a means for social comparison or as an indicator of individual behavior, yet they were considered a single type of affordance in our analysis. Third, the review only focuses on peer-reviewed academic research, excluding types of grey literature, such as industry reports, although they could provide additional insights into the use of gamification in eco-driving.

## 7. Conclusion

This manuscript provided an overview of existing research on the use of gamification to promote eco-driving, analyzing 28 studies on the topic. Based on the results, the corpus mainly considered private passenger cars while tackling a wide variety of eco-driving behaviors, mainly through achievement- and progression-based gamification approaches. Although the studies predominantly reported positive outcomes in relation to eco-driving behaviors, the corpus provided little evidence for what types of gamification design approaches work best in the eco-driving context and what types of psychological outcomes mediate behavioral change. Based on this review of the literature, we provide three broad guidelines for eliciting avenues for future research and design to strengthen knowledge on gamified eco-driving.

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## CRediT authorship contribution statement

**Eetu Wallius:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dicle Berfin Köse:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

## 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

No data was used for the research described in the article.

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