Energy Efficiency (2018) 11:2057–2075
https://doi.org/10.1007/s12053-018-9691-z

ORIGINAL ARTICLE

Examining community-level collaborative vs. competitive approaches to enhance household electricity-saving behavior

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Received: 10 October 2017 / Accepted: 24 May 2018 / Published online: 9 June 2018

Abstract To test the effectiveness of a competitive or collaborative approach on engaging people to change their household electricity-use habits, a mobile app, called Social Power, is developed to provide electricity meter feedback in two gamified environments. The project aims at stimulating social engagement and promoting behavioral change to save electricity at the household level by forming teams of neighbors in two Swiss cities. The household participants are assigned to one of two teams: either a collaborative team where citizens in the same city try to reach a fixed, 10% electricity savings target collectively or a competitive team which tries to save the most electricity in comparison to another city. The collaborative and competitive gamified structures are run in parallel as a 3-month field experiment (February to May 2016) involving 108 recruited household participants in two cities, with ultimately 46 who actively play. In this paper, we present the result of the two gamified structures on the sustainability of reported behavior, as well as on actual saved electricity. Overall, a collaborative or a competitive intervention contributes to electricity savings and reported behavior as compared to the control group; however, no significant difference is found between the two gamified structures.

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Keywords Household · Electricity-saving behaviour · Community-level · Intervention · Gamification · Smart metering

Introduction

Many countries, ranging from the European Union members to large single consumers like China, set national electricity consumption targets with the aim to reduce CO_2 emissions, avoid hazardous nuclear waste products, release the dependencies on foreign imports, or mitigate long-term infrastructure investment in grid expansion and production capacity, among other things (Andrews-Speed and Ma 2016; European Commission 2015). This is the case also for Switzerland, the country in focus of this study, where the Swiss Federal Office of Energy has set a goal of 13% reduction in electricity demand by 2035 compared to the demand of the year 2000 (Swiss Federal Council 2013). A part of this reduction is possible within domestic consumption, and thus citizens must be engaged to help reach this target. However, reducing individual electricity use is not driven by the above-mentioned governmental level motivations. Individual engagement, as a means to creating real change at the individual level, has been studied from various motivational approaches in order to capture different drivers of decision-making and behavior adoption in the design of the intervention (Bamberg 2013; Frederiks et al. 2015b). An engagement intervention must in fact be designed with specific objectives, target audience, and local environmental needs in mind, to guide the multitude of approaches to effective short and long-term impacts (Schultz 2014).

Interventions may come in the form of information, a program, measure, or regulation (Kurz et al. 2015; Wilson and Dowlatabadi 2007). Combining different approaches into one or multiple interventions is most effective; however, the social and political contexts, and the type of intervention itself, play critical roles in the outcome (Breukers et al. 2013; Ohnmacht et al. 2017; Scheuthle et al. 2005). Often, interventions are aimed at the individual to address personal decision-making and behavioral habits. A commonly understood economic incentive, such as a tax or bonus, can punish unwanted behavior or reward the desired behavior, respectively. Additionally, the use of personal norms can drive behavioral change through the perception of one's own responsibility and ability to make a decision and act out the change (Stern 2000). In other approaches, interventions may try to use social norms to impact behavior of individuals who belong to a social group, such as a family, sports team, or neighborhood, where social expectations create external pressure to change (e.g., Moser et al. 2015). Alternatively, communities of practice of intrinsically motivated people can form and diffuse new behavior by engaging people within a pre-existing, or newly forming, social setting (Kurz et al. 2015). Particularly in the energy context, many of these approaches have been tested (for an overiew see Frederiks et al. 2015b).

Promoting energy saving by providing information feedback

As energy savings, along with other sustainability topics, are related to intangible public goods, the intrinsic motivation to take action is often much weaker as compared to other more perceptible issues (Giddens 2009). In the energy field, therefore, information feedback is acknowledged as critical for increasing recognition and knowledge of a desired behavior, as well as spurring action, not only on the individual but also on the collective level (Boucher et al. 2012). However, information feedback on its own is insufficient to change behavior (Abrahamse et al. 2007; Sabadie 2014). Real-time electricity consumption feedback is a necessary starting point for bridging the gap between understanding actual volume and timing of consumption and ultimately being able to connect the electricity use to daily habits (Abrahamse et al. 2005; Attari et al. 2010; Schley and DeKay 2015). However, as seen in experiments of in-home electricity feedback monitors that trigger an initial interest and subsequent understanding of one's own consumption patterns, the information ultimately becomes quite consistent and the monitors no longer provide new and motivating input (Hargreaves et al. 2010, 2013). Even at larger scales and over longer time periods, such as in the case of the continuing work by Opower, behavior is very slow to change, and thus, repeated interventions still have an effect on behavior and importantly, when a change does occur, it tends to be maintained longer (Allcott and Rogers 2014). However, with the development of ubiquitous digital devices and Internet of Things, the opportunities to provide timely, personal, and contextualized information feedback are increasing (Kjeldskov et al. 2012).

Promoting energy saving by exploiting social interactions

In this framework, considering the growing opportunities arising from the latest demand-side management approaches in the energy sector, Breukers et al. (2013) argue for an evolution from one-directional information transfer to a more participative, interactive, personalized, and contextualized intervention. Also, many field studies show effective reduction in individual energy consumption from the inclusion of interactive, social, competition-like feedback, goal-setting, and peer or neighborhood comparisons (Abrahamse et al. 2005; Carrico and Riemer 2011; Darby 2006; Harding and Hsiaw 2014; Sintov and Schultz 2015; Vine and Jones 2016; Vine et al. 2013; Welsch and Kühling 2009).

Providing opportunities for social influence, which we understand as a process of peer evaluation and learning from each other, reinforces contextualized learning (Ohnmacht et al. 2017) as these social settings develop a sense of connection and belonging between individuals which can lead to the creation of informal spaces for learning (Gee and Hayes 2011; Schrier 2016). The peer evaluation, or comparative feedback, induces social norms, both descriptive and injunctive, and is shown to motivate behavior change (Schultz et al. 2007). However, the effect is seen mostly in the short term (Geelen et al. 2012), and Alberts et al. (2016) show that the addition of an economic incentive (prize) reduces this effectiveness. Considering electricity as a public good, social dynamics may also be persuasive when they build on the common perception that "my action will only make a difference if everyone is doing it" (Fischer 2008). Collaboration can mean a commitment to a common goal and, in this context, influence individual actions for the benefit of society, which may be more powerful than rational economic arguments (Dietz 2015; Fogg 2002). Also, goal-setting has been shown to trigger energy saving behavior and is most effective when combined with frequent feedback in order to track progress to the goal (Becker 1978; McCalley and Midden 2002).

We conclude from the literature review above that cooperation, competition, feeling part of a community, and other forms of social interaction are significant influencers of behavior change; however, it is not clear whether an electricity savings intervention would be more effective with a competitive or collaborative approach.

Promoting energy saving by "gamification"

One option for integrating these different motivational features is the relatively recent approach using game-inspired design elements, commonly defined as gamification. Gamification refers to the implementation of elements typical of digital games to create challenging experiences, which can be applied in non-entertainment contexts (Deterding et al. 2011). Morganti et al. (2017) synthesize three main fields where gamification is successfully applied to energy topics, which is environmental education, consumption awareness, and energy efficiency behaviors, with each covering a slightly differing gamification approaches and evaluation techniques.

The play activity specifically allows for contextual real-life learning, as well as self-evaluation, which is an integral part of making feedback constructive to better align behavior (Rieber 1996). The use of gamification in typically non-game environments, with the additional connection to real-world data that make one's own behavior more tangible, can encourage participation in public issues, enhance problem solving, and improve the understanding of our behavior (Lee et al. 2013; Thiel and Fröhlich 2017). Gamified technologies leverage on the intrinsic enjoyment of play through mastering skills or a sense of accomplishment to increase the player's motivation and engagement in an activity context of well-defined and significant purpose (e.g., mobility choice or energy use), thus being meaningful and effective in stimulating behavior change (Castri et al. 2014; Cellina et al. 2016; Deci and Ryan 1985; Hamari et al. 2014; Malone and Lepper 1987). Reaching a level of engagement to prompt actual behavior change is however closely dependent on the framing and the motivational setting of playful contexts (Amory and Seagram 2013). For instance, Salen and Zimmerman (2006) describe how social interaction evolves from the rules of the game, with players becoming part of a larger community even if they are not directly playing together. Moreover, through the shared practice of participating in real-world problems and challenges, players feel part of a bigger purpose, increasing the sense of belonging (McGonigal 2011). Therefore, both play and social influences can increase participation, which in turn can improve opportunities for practicing and developing new behaviors (Thiel and Fröhlich 2017).

Content of this paper

In the above framework, we implemented the "social power" study to test (i) whether engaging households in app-based competitive and collaborative gamified activities, with different goal settings, can motivate short-term electricity savings through behavior change and (ii) if there is a difference in the effectiveness of competitive and collaborative activities.

The study aim and hypotheses are presented in detail in the "Aim and hypotheses" section while the "Methodology: real-life intervention" section introduces the design of the related intervention. The "The social power app" section presents the Social Power smartphone app, namely the tool used to perform the intervention. The "Results" section presents the short-term impacts of the intervention, both in terms of the electricity savings during the intervention period and the reported behavior change after the intervention. In the "Discussion" and "Conclusions and future directions" sections, we discuss results and conclude on their impact for future energy saving interventions.

Aim and hypotheses

Social Power is a real-life intervention study developed and implemented by a consortium of Applied Science Universities and electricity utilities in Switzerland with independent funding from a foundation. The research objective is to determine if there is an effect on the level of engagement and consequent electricity savings at the household level, due to a combination of in-game learning experiences, social interaction, and individual gameplay elements, delivered by means of a smartphone app in the framework of a gamified approach. We acknowledge that although sustainable energy use is an individual behavior, it can be significantly improved through collective action. Also, we hypothesize that a collaborative or a competitive group perspective differs in the impact on people's actions due to the differences in intrinsic motivation arising from the difference in social comparison (Deci et al. 1999). In particular, in Social Power, we compare two different social interaction and goal-setting schemes, by referring to two gamified structures (competitive and collaborative), while maintaining other aspects of the intervention constant (i.e., individual information feedback, gamification elements, energy knowledge, etc.).

There are very few studies in general that compare the different motivational contexts of a collaborative vs. competitive approach (Frederiks et al. 2015b; Pareto et al. 2012), and results weakly show that competition increased in-game learning and could have a higher impact due to the strength of hedonic goals whereas collaboration decreased performance (Lin et al. 2006; Lindenberg and Steg 2007; Malone and Lepper 1987; Plass et al. 2013). However, within the energy field, the direct comparison between individuals of whether a competitive approach is always better, at least in the short-term, or whether a collaborative approach may be equally strong and relevant, has not been fully explored (Delmas et al. 2013; Dillahunt and Mankoff 2014; Foster et al. 2010; McCalley and Midden 2002). Furthermore, studying the effectiveness of gamification on energy savings behavior remains understudied (Morganti et al. 2017).

To answer these research objectives, we recruit household members and divide them in two groups. Both groups are provided with information feedback and learning elements regarding their electricity consumption. One group is treated within a collaborative gamified structure, while the other one is treated within a competitive gamified structure.

Participants in the collaborative structure are treated as a team and encouraged to work together to reach a goal set by the experimenters (10% electricity savings as a team, which is chosen as a realistic but ambitious average savings as compared to other studies (Delmas et al. 2013)) and receive *individual-to-group* comparison feedback. This feedback is expected to induce a strong personal identification with one's own team, mainly as a sense of collectivism where individuals recognize that they are part of a larger picture (Wit and Wilke 1992). The motivation for action in this context is assumed to derive from an interest to "act right" since there is no winner from the comparative feedback. Furthermore, the goal for this team is defined by the experimenters, which may imply that this is a good and meaningful target to reach. The winners in this case, one could argue, are the society and the environment, since there is no winner among the participating households: either they all win or they all lose. However, the individual is driven by injunctive and descriptive social norms from their identification with their team (Ohnmacht et al. 2017). This context may create more pressure for people to act in a "right" way, which is described by the activities in the gamified app, as compared to the competitive structure, where right action is also partially driven by how the other team is performing. Still, Deci et al. (1999) report that a reward environment that strongly dictates desired behavior will reduce intrinsic motivation, as compared to an environment that allows for deciding on one's own.

Participants in the competitive structure are instead provided with both an *individual-to-group* and a *group-to-group* comparison, to enhance social identity (Brewer and Weber 1994). They are split in two groups (i.e., teams), each of whom is given the goal to save as much electricity as possible compared to the other team. As such, a social comparison, that is, the assessment of one's ability compared to others (Festinger 1954), is expected not only to result in a more communal behavior within the team but additionally to generate more competitive feelings and a striving for better performance against the other team (Schultz et al. 2015; Siero et al. 1996). An *inter-team* competition explicitly delimits a winner and a loser in the gamified experience: in the Social Power competitive structure, one of the teams will ultimately be the winner. While there are no tangible prizes for the winning team, the sense of pride, positive self-esteem, and "bragging rights" resulting from the hedonic goal framing are assumed to drive the individual (Lindenberg and Steg 2007). Hence, the competitive structure can trigger both competition (against the other team) as well as collaboration (within the team). It is assumed that this goal framing dominates over other motivations, though empirical results are lacking (Frederiks et al. 2015b).

In this framework, the following null-hypotheses are explicitly tested:

- A 3-month intervention, providing electricity use feedback, learning elements, and social comparison feedback in a gamified structure, produces neither electricity savings nor improved reported behavior with respect to before the intervention.
- After a 3-month intervention, there is no difference between a collaborative and a competitive gamified structure with respect to electricity savings or reported behavior compared to before the intervention.

To test such hypotheses, we analyze electricity consumption data provided by smart-metering systems and perform online surveys before and after the intervention, measuring attitudes and reported behavior.

Methodology: real-life intervention

The Social Power intervention took place from February until May 2016 in two cities in Switzerland, Massagno (from here on referred to as city 1) and Winterthur (city 2).

Participants

Overall, 108 ($n = 54$ in city 1 and $n = 54$ in city 2) voluntary household participants were recruited using advertising flyers sent by the local utility, public events, school visits, and telephone campaigns. The recruited households were stratified according to their household composition and building type (i.e., single people vs. families, apartments vs. detached houses) and then randomly assigned to one of the two gamified structures. The participants were made aware of the research project in advance and, through signing up, agreed to playing honestly and participating fully in the intervention, as well as in the surveys.

Despite the prior commitments made, some participants did not complete the intervention. Due to dropouts and non-active participants, only 46 ($n = 23$ in city 1, $n = 23$ in city 2) fully completed the intervention period for statistical testing; see Table 1 for the participant overview. Control groups ($n = 30$ per city at the outset, but later adjusted to reflect the active household participants), provided anonymously by the utility, were included to control for external non-intervention impacts on electricity consumption. The control groups were built with a stratified sampling approach, to create a similar proportion of household (adults only vs. families) and building types (apartments vs. houses) as the overall intervention groups, and no further criteria was used. See Table 2 for the household characteristics per group. Households in the control group were not aware of being monitored, which avoids biases by the Hawthorne effect (Tiefenbeck 2016).

Comparing historical electricity consumption by strata of all groups (participants and control) shows no significant differences, fortunately also even after accounting for attrition. Thus, even though recruitment was voluntary, a selection bias for electricity affinity does not appear to be prevalent in those that remained active. Further, participating and control group households remain anonymous throughout the intervention and thus likely have little influence on one another. Biases that may arise due to comparing the gamified structures with neighbors in the other structure are minimal, as while participating households on the same team are encouraged to communicate with one another, the two structures are independent and the comparison of the two approaches is not explicitly stated to the participants. All selected households have no electrical heating (no heat pumps, no boilers for hot water, and no other electricity-based heating systems). Therefore, all

Table 1 Number of active household participants out of the total recruited during the entire intervention period, and number of households in the control group observed

Groups	Intervention			Control
	Competitive	Collaborative	Total	
City 1	13 / 26	10 / 27	23/53	23
City 2	11 / 28	12 / 27	23/55	22
Total	24 / 54	22 / 54	46/108	45

Table 2 Percentage of household types in each intervention setting (active participants only) and control group (single people vs. families, apartments vs. houses)

	Single adults	Families	Apartments	Houses
Competition ($n = 24$)	63%	37%	71%	29%
Collaboration ($n = 22$)	64%	36%	73%	27%
Control group ($n = 45$)	59%	41%	72%	28%

electricity consumption is due to electrical appliances and lightings.

Finally, based on a baseline survey investigating energy-related behavior, the motivations and technical affinity of the two participant groups (competitive and collaborative) prior to the intervention are compared, in order to avoid a bias during the intervention. An independent sample *t* test shows no significant differences between the means (presented in Table 3) of the two groups, so it is assumed that the groups are homogenous in terms of technical appliance use skills and interest in participating.

Data collection timeline

To analyze the electricity-saving progress made by the participating households depending on the gamified context, electricity consumption patterns were tracked before and during the intervention period, as shown in Fig. 1.

Tracking period A (3 months, October–December 2015) represents the "before intervention" phase, when an average weekly electricity consumption was compiled from historical data already collected by the electricity utilities from previously installed smart meters. The pre-intervention self-reported energy-related behavior of the participating household members was characterized through a baseline survey in order to compare to a follow-up survey after the intervention.

In period B (the intervention phase, 3 months between February and May 2016), the treatment groups were provided with the Social Power mobile app, offering individual electricity feedback from their smart meters, tips, individual energy-saving activities, and the social comparison feedback, showing how their team was performing. Depending on whether they were assigned to a competitive or collaborative group, participants were provided with the competitive or

Table 3 Means of the motivations and technical affinity of the active participants in the intervention settings

Variables[a]	Collaborative ($n = 24$)		Competitive ($n = 20$)		Difference	
	M	*SD*	*M*	*SD*	*t*	*p*
I want to reduce my negative impact on the environment	6.20	1.15	5.83	2.12	− .69	.49
I want to reduce my electricity costs	5.20	1.85	5.83	1.74	1.17	.25
I participate because it is free and/or the prizes are attractive	3.50	1.93	3.04	2.12	− .74	.46
I want to contribute to a relevant scientific project	6.05	1.40	6.33	1.24	.71	.48
I like trying out new mobile phone/tablet apps	4.55	2.01	3.83	2.10	− 1.15	.26
I like the idea of playing in a game	5.20	1.58	4.92	2.02	− .51	.61
I like to support community initiatives	5.80	1.36	5.58	1.91	− .43	.67
Technical affinity[b]	6.13	0.86	5.82	0.89	− 1.18	.25

[a] All variables are measured on a seven-point Likert scale, where 1 is low or do not agree and 7 is high or fully agree

[b] Technical affinity is reported as an average of the ratings (1—do not agree, 7—fully agree) on the following statements:

- I like using new gadgets and apps.
- I have a difficult time understanding how to use apps. (recoded).
- I use office electronic devices (computer, printer, etc.) for my work or at home on a daily basis.
- I know how to use all the appliances that I own.
- I regularly maintain my appliances.

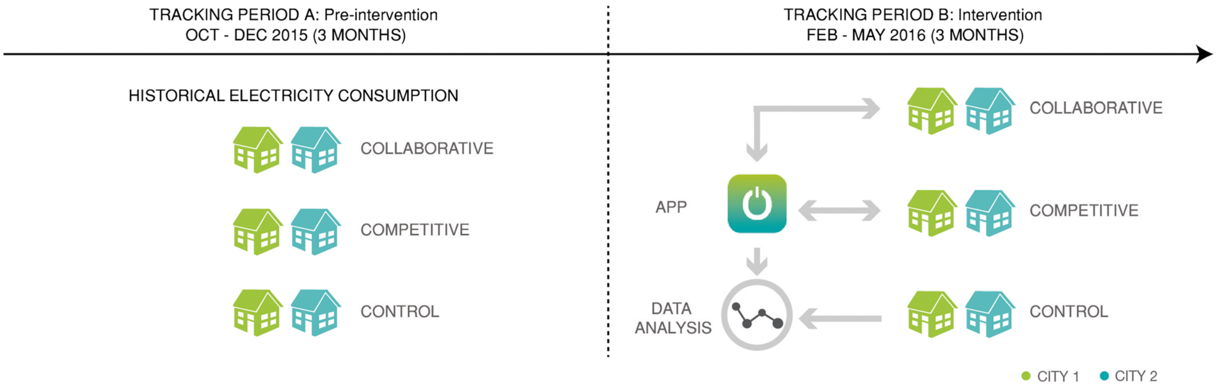

Fig. 1 Tracking periods of the Social Power project for the three groups

collaborative interface of the Social Power app, which differ regarding the social interaction feedback.

At the end of period B, a second wave of the survey was performed, to determine perceived behavior change. The choice of the timing for tracking period A and B guaranteed comparability between electricity consumption, as length of the day is similar between autumn and spring. The effect of different outdoor temperatures, which might influence remaining at home, has not been considered in this analysis.

After the period B intervention phase, the play session was closed and the treatment groups ceased to receive tips, challenges, and feedback on team achievements.

The Social Power app

The Social Power app was designed and realized for the Social Power intervention study. It uses electricity consumption data of the participating households which is automatically imported through a direct connection with the utility companies' smart meter networks.

In the app, both gamified structures show the *learning elements* ("activities" and "energy tips"), *individual energy feedback* (the "energy diary"), *social comparison feedback* (either collaborative or competitive screens), and links to the *communication channels* to interact with the other members of their team (the interaction is external: a project weblog and the Facebook page). Participants gain points by performing real-life activities guided by the app, which simultaneously increases their knowledge on sustainable electricity use behavior and progresses them towards the collective goal.

Since the collaborative and competitive gamified structures differ in the *social interaction feedback* component, two interfaces of the Social Power app exist:

- The competitive interface provides descriptive feedback about team and individual performance against the team's opponent. The competing groups created in city 1 and in city 2 compete against one another for the most electricity savings (Fig. 2a).
- Whereas, the collaborative interface shows progress in a non-competitive way towards the collective electricity-savings target of 10% at the

Fig. 2 Comparative contexts of the two gamified structures. **a** Competitive. **b** Collaborative

team level. Two collaborative teams are created, one in city 1 and one in city 2 independent of each other, and they are given the same collective goal of 10% electricity saving (Fig. 2b).

Otherwise, the design of the app interface and the game-like elements (points, activities, rewards, achievements) provided for the two structures are identical, in order to test for differences due to the intervention. Figure 3 provides an overview of the app interface, by showing screenshots of the main app components; a step in a typical activity (a), the individual energy consumption feedback (b), and the social gamified structures (c and d) where the group-to-group and individual-to-group comparisons are shown.

Individual feedback

The Social Power app displays the participant's progress in earning points, as well as the individual electricity use in the energy diary (Fig. 3b), which shows the hourly and daily electricity consumption and a weekly comparison with one's own historical consumption (i.e., the weekly average during tracking period A; see Fig. 1). The household also receives injunctive norm feedback since evaluation of personal consumption and performance are simplified in the energy diary through the use of an unhappy, neutral, or smiling face graphic, for whether the participant used more, the same, or less electricity, respectively, as compared to the personal historical average.

This kind of feedback, that is personal and with a high temporal resolution, is often new for households who previously never had smart meter data available on a mobile device. While this direct feedback is essential for self-regulated learning, it supports the contextualization of the intervention and hopefully new habits, into daily life. As it has been seen that information feedback alone tends to be ignored after a time when one's own electricity use patterns are known (Hargreaves et al. 2013), the disruption in one's awareness of own habits can be used as an opportunity to embed new habits before the novelty is lost (Verplanken et al. 2008).

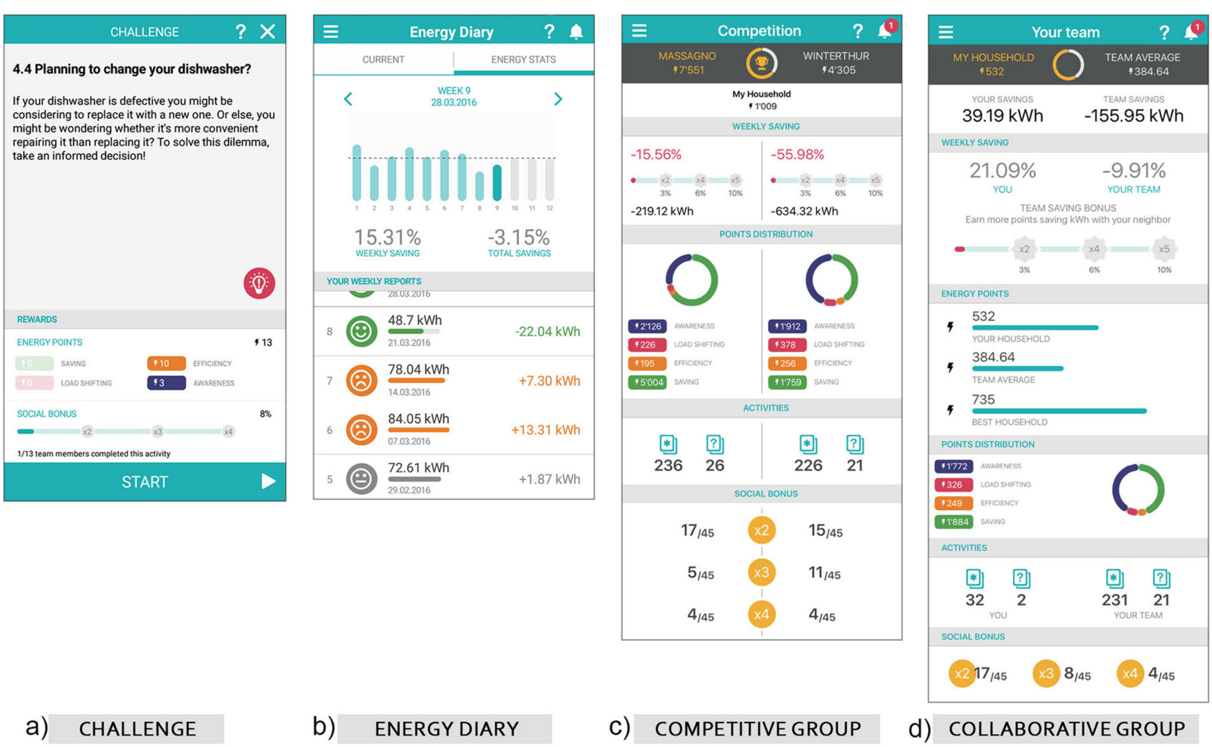

Fig. 3 Screenshots of the Social Power app. **a** First step of an activity. **b** Energy Diary with weekly consumption reports. **c** Competition feedback. **d** Collaboration feedback

Action oriented, gamified learning elements

A series of 50 electricity-saving activities (example shown in Fig. 3a) and energy-saving tips covering 12 weekly energy-related topics (e.g., cooking, washing, home office and appliances, lighting etc.) are proposed within the app to foster new energy consumption habits. Completing activities earns the participant points, and thus the activities are stimuli to guide step-by-step improvement in electricity consumption in different home topics. Activities contextualize learning by asking participants to take actions in their real-world environment which relates to the use of electrical appliances (e.g., dishwasher) or household activities (e.g., cooking) which can be more energy efficient, energy saving (that is, sufficient), realize peak-shifting, or increase consumption awareness. Points are rewarded in these four categories (efficiency, saving, load shifting, and awareness) and are clearly displayed with different colors on the comparison feedback screen. Each time an activity is completed, attention is brought to the sustainable behavior and through the positive reinforcement in the intervention, increase the potential intention of adopting a new habit (Kurz et al. 2015).

While the point system and gamified structures are there to encourage engagement, the completion of activities sometime during the week is self-regulated, as the intervention encourages participants to complete new challenges within the week that they are released. Thus, when the participant has the overview of the new challenges, they must choose the time and context in which to complete the activity which best fits their lifestyle. Ideally, this means that the activities are embedded in personal and social settings that are optimized for the participant. Additionally, along with the weekly thematic activities, related tips support self-driven learning and problem solving (for example, one tip may describe the actual energy savings from de-icing a refrigerator, and another tip may provide a suggestion on how to manage the melting ice during the activity). Ultimately, the Social Power app provides a model of learning that occurs simply by "doing" sustainable activities, which in the long term may create a "capitalization" of positive events (Langston 1994).

Finally, every 4 weeks, quizzes with real prizes serve as a self-assessment tool for the participants, as well as an extrinsic motivation to keep participants engaged throughout the whole intervention period. The quizzes are specifically related to the weekly themes of the previous week. The results of the quizzes are provided after the closing of the contest, and winners are announced, in a semi-anonymous form using only first names, on the intervention weblog.

Social comparison feedback

In both gamified structures, collaborative and competitive, an overview of the team performance (examples in Fig. 3c, d) aims to trigger inter- and intra-team comparison and enhance social group identity by grounding individual performance evaluation on the basis of group performance (Brewer and Weber 1994). Therefore, the message is that "playing with your team pays off".

Consequently, in the Social Power app, specific gamification elements are provided to reward for (1) collective *electricity-saving efforts*—when weekly saving goals are attained by the team, then the so-called savings bonus is activated, which awards additional points for each team member—and (2) collective *action*—when the percentage of team members that have completed an activity attains a set level, then the so-called social bonus is activated, which doubles or triples the points earned for that activity.

Thereafter, researchers expect the different forms of social comparison and incentive underlying the two distinctive gamified structures to highlight possible differences in their efficacy of triggering transformational behavior change at the individual level, wherein

- Individual-to-group comparison with a set goal is used in the collaboration, versus
- Group-to-group comparison in the competition

As such, even though the two game structures use the same metrics to measure team performance, i.e., the (i) number of completed challenges, (ii) sum of team points attributed, and (iii) percentage of team energy savings achieved, the competitive team section compares the progress in savings, points earned, and number of activities completed between the teams in the two cities. The collaborative team section, instead, compares the individual household savings progress to their team's, how close they are to the milestone target of 10% electricity saving, and the points earned and challenges completed. Ultimately, this comparison, based on a set of single performances (savings, points etc.) is what Grevet et al. (2010) describe as "explicit" or "unidimensional" social comparison. It potentially leads to assimilation with others, where the person being compared wishes to be similar to others (Feldman 1984), thus, again, encouraging people to increase individual action to attain a more significant collective impact for change.

Communication channels

Due to privacy concerns, the app displays only aggregate social feedback and participants remain anonymous throughout the intervention. During the intervention, the app did not allow for direct communication between team members. To support intra-team communication, an external weblog and Facebook page were the platforms created to allow household members to interact with each other, as well as with the research team. While a virtual community differs from real-life relationships, the sense of belonging to a group, as well as social influence, can readily develop over virtual networks, as it is seen within social media and online gaming communities, for example (Castronova 2007).

Results

The impacts of the intervention directly after period B are presented here and are based on only those participants that completed both surveys and stayed active during the entire intervention. Thus, attrition bias is explicitly avoided.

Electricity savings

Comparing effects of the two gamified structures against each other, neither of the household teams reached the 10% goal altogether; however, they all had substantial savings.

Figure 4 shows the weekly progress of changes in consumption with respect to historical weekly average

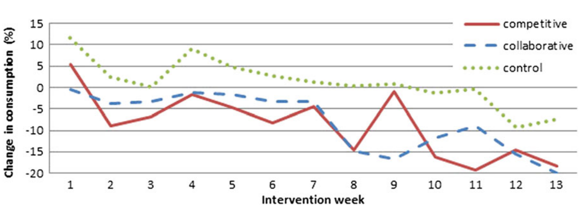

Fig. 4 Average weekly change in electricity consumption over time for groups in the two gamified structures vs. the control groups

values of the teams in the two gamified structures. Note that a data point below zero means less consumption and therefore savings. The control groups had a similar drop in consumption over time but on average remained consuming more than their historical average.

Table 4 presents the mean savings in the cities and for the overall gamified structures. This information is additionally visualized in Fig. 5. While the analysis concerns the change in consumption, thus the absolute historical baseline values are not used for calculation, a randomization check showed that intervention groups and control groups did not differ significantly in their historical electricity consumption measured over Oct–Dec 2015; thus, a selection bias does not appear to exist. The mean change in consumption of electricity in the competitive groups ($M = -8.73\%$, $SD = 8.20\%$) was very similar to the collaborative groups' average ($M = -8.07\%$, $SD = 15.46\%$). On the other hand, the control group of both cities combined consumed slightly more electricity ($M = 1.13\%$, $SD = 18.05\%$) compared to their baseline consumption period from Oct to Dec 2015.

From Fig. 5, it appears that location may have an effect on the change in consumption. Thus, a 2 (location: city 1 vs. city 2) × 3 (gamified structure: competitive vs. collaborative vs. control) ANOVA was performed, taking the mean change in electricity consumption as the dependant variable.

The analysis reveals that the location where the household is located also has a significant effect on whether electricity was saved, $F(1,85) = 4.96$, $p = .029$. On average, in fact, households in city 1 saved more electricity compared to households in city 2. The interaction between gamified structure and location on electricity savings is however not significant, $F(2,85) = 1.30$, $p = .279$, meaning that which gamified structure is used does not result in a statistically significant difference in the savings in teams located in different cities.

Post hoc tests (using Bonferroni correction) indicate no significant difference between the collaborative and the competitive context $M_{diff} = -0.01$, $p = 1$; thus, neither the collaborative nor the competitive gamified structure provides better electricity savings results. Thus, the second null hypothesis remains true, that there is no difference between the two approaches. However, compared to the control group, households in the competitive context saved significantly more electricity $M_{diff} = -0.10$, $p = .03$. Also, households in the collaborative structure saved electricity compared to the

Table 4 Change in team electricity consumption (active household participants only) after the intervention

Groups/teams		Number	Team consumption		Group consumption	
			Mean (%)	SD (%)	Mean (%)	SD (%)
Competitive	City 1	13	− 8.54	7.51	− 8.73	8.20
	City 2	11	− 8.96	9.32		
Collaborative	City 1	10	− 15.00	17.45	− 8.07	15.46
	City 2	12	− 2.29	11.25		
Control	City 1	23	− 3.64	16.62	1.13	18.05
	City 2	22	6.13	18.5		

Note: Negative consumption means savings. Comparison made between weekly electricity consumption during intervention (period B) as compared to historical weekly average (period A)

control group, although this difference is only marginally significant, $M_{diff} = -0.09$, $p = .06$. The marginal significance of the collaborative structure may result from the large variance in the savings between teams in the two cities, whereas the variance is smaller for the competitive structure. This shows that the first null hypothesis is false, and there are significant electricity savings due to this intervention approach.

Furthermore, the ANOVA shows a significant main effect of engagement in a gamified structure on whether a participating household saved electricity, $F(2, 85) = 5.02$, $p = .009$, with respect to the control group.

Thus, overall, the intervention does produce electricity savings compared to a control group; however, the gamified structure is not a deciding variable on savings.

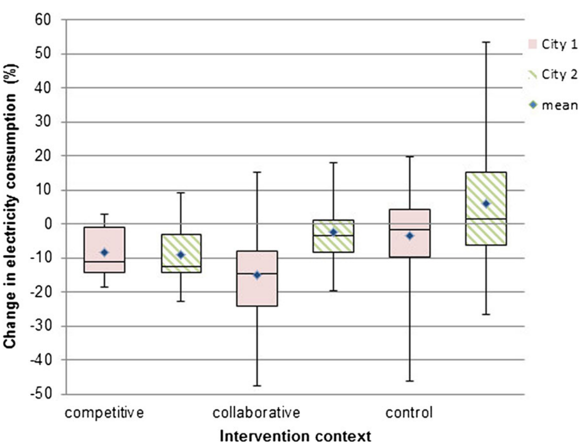

Fig. 5 Boxplots of change in electricity consumption in each group by gamified structure, including median (midline), mean (blue diamond), maximum (top whisker), and minimum (bottom whisker) values

Reported behavior

Behavioral changes occurring during the intervention period are determined through the responses to two surveys, pre- and post-intervention. Reported electricity use in the collaborative group improved, i.e., became more sufficient, from before the intervention ($M = 5.31$, $SD = 0.68$) to after the intervention ($M = 5.81$, $SD = 0.68$), $t(18) = 6.39$, $p < .001$, $d_{rm} = 1.01$. Reported electricity use also improved significantly in the competitive groups, from before the intervention ($M = 5.13$, $SD = 0.83$) to after ($M = 5.95$, $SD = 0.58$), $t(23) = 5.71$, $p < .001$, $d_{rm} = 1.17$. Both gamified structures are perceived to have a positive impact on behavior. Additionally, both gamified structures could significantly change the intention to save energy and reported behavior over the intervention period, proving the first hypothesis to be false.

However, as shown in Table 5, where the changes of the competitive and collaborative groups are compared to each other and the exact survey items are listed below the table, no significant differences between the two gamified structures could be detected. Even though the game mechanics are designed with a focus on community engagement, the sense of community within the Social Power households is relatively low (mean values of 3.33 and 4.06 for the two gamified structures on a scale out of 7). The difference between the means of the two groups is tested using an independent two-tailed t test.

It is important here to address the potential selection bias due to the significant number of participants that dropped out during the study (see Table 1). A high drop-out rate might lead to the hypothesis that only participants who were already motivated to save electricity

Table 5 Comparison of reported behavior, savings intentions, and social process between the collaborative and competitive groups

Category	Collaborative ($n = 20$)[a]		Competitive ($n = 24$)		Difference		Effect size (Cohen)[b]
	M	*SD*	*M*	*SD*	*t*	*p*	d_s
Impact and reported behavior							
Reported impact of the intervention[c]	4.53	1.77	5.43	1.56	1.80	0.08	0.54
Reported electricity use post-intervention[d]	5.81	0.68	5.95	0.58	0.73	0.47	0.22
Change in reported electricity use behavior (behavior pre-behavior post)	0.64	0.44	0.82	0.70	0.96	0.34	0.30
Savings intentions							
Intention to save energy in the future[e]	5.14	0.99	5.47	0.96	1.12	0.27	0.34
Social processes							
Sense of community in the team post intervention[f]	3.33	1.56	4.06	1.72	1.48	0.15	0.44

Note: Independent two-tailed t test for significant difference of means; positive difference implies more sustainable behavior; $p < .01$ = significant difference

[a] $N = 22$ participants in total for the collaborative teams, but not all participants filled out both surveys

[b] Lakens (2013)

[c] Impact of the intervention (Cronbach's alpha = 0.92) is reported as an average of the ratings (1—do not agree, 7—fully agree) on the following statements:

- I learned something new about electricity reduction in the social power game
- I learned something new about energy efficiency in the social power game
- I learned something new about electricity load shifting in the social power game
- I feel that the social power game had an impact on my electricity consumption

[d] Reported electricity use (Cronbach's alpha = 0.72) is reported as an average of items asking about the frequency of behaviors (1—never do this, 7—always do this) in the prior 3 months, specifically:

- Fill washing machine to capacity
- Turn down/off heating before leaving for holidays
- Defrost freezer/freezing compartment
- Wash laundry at lower temperatures (e.g., hot wash at 40 °C, lightly soiled laundry at 30 °C)
- Turn off standby on appliances
- Ventilate only briefly, but intensively during winter
- Adjust room temperature according to room's usage, e.g., turn down temperature in unused rooms
- Cook with pots covered
- Let the water run while brushing teeth (recode)
- Take a long shower (recode)
- TV is on and no one is watching (recode)
- Turning off the light when leaving a room
- When buying electrical appliances, consciously pay attention to their energy consumption
- Use appliances during low tariff times

[e] Future intention to save electricity (Cronbach's alpha = 0.85) is reported as an average of the response (1—I intend to use more energy, 4—I intend to maintain my current behaviour, 7—I intend to reduce my energy use) to the statement "how do you intend to behave with regard to electricity use in the following areas," in the following areas:

- Cooking (stove, oven, fridge)
- Cleaning (washing machine, dish washer, vacuum)
- Daily electronic appliance use (computer, stereo, TV)
- Lighting (indoor and outdoor)

[f] Sense of community in the team post intervention (Cronbach's alpha = 0.73) is reported as an average of the ratings (1—do not agree, 7—fully agree) on the statements: I feel attached to the members of my Social Power team and I am happy to be part of my Social Power team

remained active during the intervention. If so, it could mean that social engagement with the app was not the primary driver of behavior change. However, Wemyss et al. (2016) showed that electricity savings, as well as the "sense of community in the team" tested after the intervention, are significantly improved for the active participating household members compared to the inactive ones. Thus, we conclude that the active engagement in the intervention had a positive impact on the participants, increasing their motivation to save electricity, as well as their sense of community.

Discussion

The results after historical and control group comparison indicate that the Social Power intervention succeeded in changing electricity consumption behavior. Both gamified structures (competitive and collaborative) showed significant positive impacts compared to the control group, both in terms of electricity savings and reported electricity use, proving the first null hypothesis to be false. However, no significant differences between the two groups could be detected, showing the second null hypothesis to be true. While it was hypothesized that the gamified structure would influence the effectiveness of the intervention, the result of no significant difference has been seen in other studies, where only a weak difference is seen between a collaborative and competitive approach; however, these studies have even smaller sample sizes and look at different behaviors, that is, physical activity ($n < 20$) and computer game playing ($n < 65$) (Lin et al. 2006; Malone and Lepper 1987). Thus, we conclude here that both approaches are suitable to engage people and produce effective energy savings in the short term. However, it has to be kept in mind that the study of gaming interventions addressing energy efficiency behavior is an emerging field of research, which still needs to be further enhanced methodologically and numerically (Morganti et al. 2017) to correctly evaluate its effectiveness, as well as to uncover motivations for change and sustained change (Kjeldskov et al. 2012). To achieve longer-lasting effects, repeated interventions are probably suitable as proven in the case of Opower (Allcott and Rogers 2014).

Preconditions for social comparisons

Yet, if we analyze the results from the psychological and contextual perspective, and not in terms of overall energy consumption rates, the present intervention does not seem to have reached the expected effect at the level of team engagement and interaction: in fact, the sense of community in the team was rated low (as reported in Table 5). However, it is precisely this element that was intended to create the pre-condition for a strong social identity and subsequent emergence of potential motivational differences between the two gamified structures, according to the different comparison contexts (*individual-to-group* in collaboration towards a set savings goal versus *group-to-group* and *individual-to-group* in a competition). Thus, without a strong sense of community, we cannot conclude on the different impacts of the gamified structures. In addition, we do not know what motivational effects the two structures had for the individual. In the collaborative structure, one could have felt social identity and peer pressure to achieve the 10% target, but through the comparison with the team, one might have been motivated to outcompete the other team members. Or a free-riding effect may have resulted wherein the individual could reach the team goal without making any effort due to strong peers. On the other hand, the participants in the competitive structure might have had an even stronger sense of team affiliation and collaboration, through the competition against another team ("we against the other"). However, realistically reflecting on the participants' low sense of community in the team, most of the motivational effects described above are likely of lower importance. More likely, the entire gameplay experience which was intrinsic to both gamified structures (novelty of an app and smart meter individual feedback, rewards for achievements, learning elements such as activities, energy tips, and quizzes, etc.) was more effective for behavioral change in electricity consumption, leading to participants' active engagement in electricity-saving practices, while the social comparison feedback played a role as component of the intervention.

We cannot exclude that among the motivations to keep active engagement throughout the intervention, also the fact that it was framed as a research project played a role. In particular, knowing they were observed might have enhanced participants' behavior change (Hawthorne effect, cf. Tiefenbeck 2016). With the present experimental design, however, it is not possible to differentiate between the effect of individual consumption feedback, learning elements, and social comparison feedback provided by the app nor the effect of the participants' awareness of being part of a research project. However, while the motivations to participate were multiple, as shown in Table 3, it appears that we can exclude that electricity-saving behavior was driven purely by monetary rewards due to its lower evaluation. Monetary rewards have been shown as ineffective in the long term or sometimes even counterproductive (Dolan and Metcalfe 2013; Frederiks et al. 2015a).

Design limitations

Besides depending on the personal interests and environmental attitudes of the participating households, reduced effectiveness of the social comparison feedback might also be related to shortcomings in the design of the visualization in the app (Fig. 3c, d) with respect to use of space and graphics. The use of kWh as a unit to define electricity is not necessarily intuitive (Baird and Brier 1981; Kempton and Montgomery 1982) and thus other metrics could be used to better represent electricity consumption with proxies or graphical representations. The social and saving bonuses may have been unintuitive to a less active participant, and thus may have led to comprehension problems, even though the app was pre-tested with a comparable set of users as the participating households. Moreover, due to a high level of privacy set in advance of implementation and without consultation with the participants whether this level could be lowered, the Social Power app only displayed aggregate social feedback and no identification, not even by an avatar or nickname, of single members within the same team was possible. This implies that the experiment bases exclusively on investigating *anonymous* social comparison effects. Engagement outside of the app was tracked through activity on the social media platforms (blog and Facebook page). These channels were not used for communication between players and were rather used to communicate with the research team about the challenges or functioning of the app. The fact that participants rated the team's sense of community low indicates that in real life participants did not experience the motivational drivers of competing against, or acting with, others and that anonymous community feedback on its own is not sufficient to build a real sense of community. While anonymity does not exclude the possibility for forming communities, for example in online gaming communities, the ability for the Social Power participants to interact with each other was very limited due to the app design.

Integrating in the Social Power app an interface for social interaction would have been technically feasible, thus giving the opportunity to cheer on one's own team, share advice between the team members, coordinate activities, and build a community feeling virtually. Additionally, co-creation, that is, to also use the knowledge of the participants, could have been integrated by offering means of developing their own activities, initiating team challenges, or solving challenges together. Ultimately, in a process where people need to work in a team to achieve a common goal, communication and social interaction are essential. However, although mobile applications offer communication flexibility in the sense that users no longer need to be physically co-located in order to interact, the need for creating a virtual social presence is necessary (Rourke et al. 2007). Many basic cues of identity, personality, and social roles are absent or less explicit in the online world (Donath 1999, 2007), making it harder for people to understand each other and work collectively. Furthermore, people, who do not know each other, may not have the same motivation to communicate or even feel inhibited to start a dialog when their period of interaction is short and/or limited. Studies report that teams that are set-up of individuals who actually have positive pre-existing relationships are more cohesive than teams with individuals that have no pre-existing relationships (Evans and Dion 1991; Parise and Rollag 2010; Ravaja et al. 2006), which results in communication, engagement, and consequent team goal advancement. Thus, here, gamification contrasts to playing games, as we observe online gamers who can choose their game and put themselves into a certain role-playing position, subsequently forming strong alliances within the gaming community.

Building on pre-existing relationships, providing households with co-creation and in-person meeting opportunities, would also help limit drop-out rates, which for Social Power was particularly significant, since approximately 57% drop-out rate was experienced. This is not untypical for new game apps, where average drop-out rates are around 20% after first opening and 90% after 3 months (O'Connell 2016), nor for intervention studies (Georges et al. 2016). However, this remains a challenge to scale the positive effects of the Social Power intervention to larger target audiences, if the efficiency of retaining active participants is so low. For real-life interventions, so called Living Labs, intrinsic motivation to stay engaged is necessary to have a successful intervention (Ståhlbröst and Bergvall-Kåreborn 2011). Thus, co-designing with participants helps capture their interests, desires, and motives to participate (Schuurman and De Marez 2012). Furthermore, to address app use, opportunities for boosting retention exist during recruitment, on-boarding, and in regular app use, such as using multiple channels for recruitment; sending push notifications to specifically address inactive users, which was an effective measure in a similar study (Kjeldskov et al. 2012); or rewarding participants for loyalty and consistent engagement.

Conclusions and future directions

While no electricity use-related studies have examined the impact of a competitive or collaborative approach on behavior change, this study provides some first insights into the impact of these approaches. Overall, this paper reports short-term results of a 3-month field intervention which gamified household electricity consumption to promote electricity savings. The intervention is set in authentic real-life contexts, which means there are social and environmental factors that impact electricity consumption. In this framework, the challenge is to bridge the fact that electricity use is socially embedded but also a very abstract and intangible issue for most individuals. To make electricity visible and engage people in a fun and interactive way on a topic that is typically only indirectly considered through the electricity bill, two different gamified structures are implemented and compared: competitive and collaborative.

While both gamified structures are found to be effective in reducing electricity consumption, neither outperforms the other in terms of electricity savings or engagement.

The strength of the analysis, as well as the real-world impact, should be critically assessed with consideration of the high rate of participant attrition, which led to a very small sample of participants. As the feedback in the app was designed to motivate a participant's sustainable behavior based on the active engagement of others, the intervention design could not mitigate a negative effect on performance due to participants with low levels of engagement, and these participants had to be removed. In consideration of this, the resulting electricity savings are encouraging. However, combining findings on electricity savings with the surveys that measure psychological variables in order to attain more accurate information on the social dynamics, consumption behaviors, and psychological effects, it emerges that participants rated the team's sense of community as low, and this may have led to not fully realizing the potential of the gamified structures.

This is probably mainly due to design limitations in the app interface and in intra-team communication system provided to team members, relegating the motivational approaches of competing against, or acting with, others to a purely theoretical, not practical, experience of participants. For future interventions, short-term results of the Social Power intervention show positive impacts from a multi-faceted approach, as Breukers et al. (2013) argue, but there is potential to give a stronger focus on the impacts of interpersonal relations of the participants, as opposed to differentiating the gamified approach. As the active participants were motivated by gamification and interested to learn good energy-use practices, we recommend developing traditional interventions further to incorporate a more prominent interpersonal and socially embedded context.

Finally, we highlight the importance of addressing behavior as a socially embedded attribute, particularly for sustainability topics where the impact of use is invisible or indirect, such as heating, water, or mobility.

Acknowledgments We would like to thank our partners Stadtwerk Winterthur, Azienda Elettrica di Massagno SA, QBT and SparklingLabs for their support in this work. Special thanks to the households of the cities of Massagno and Winterthur who participated in the Social Power project. We thank the reviewers for their constructive inputs.

The authors wish to thank the invaluable support of their colleagues: Emilia Ciardi, Pasquale Granato, Corinne Moser, Vivian Frick, Christian Hertach, Tobias Kuehn, and Pamela Bianchi. The research has been supported by the Gebert Rüf Foundation under the BREF program Social Innovation, as well as carried out thanks to the Swiss utilities AEM in Massagno and Stadtwerk Winterthur in Winterthur. We also thank the reviewers for their constructive comments.

Funding information Funding of the Social Power project was provided by the Gebert Rüf Foundation.Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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