Self-tracking and gamification of physical activity: Effects on wellbeing

Elaine Marie Grech [1], Marie Briguglio [1] and Emanuel Said [1]

[1] *University of Malta, Msida, MSD2080, Malta*

Abstract

The use of physical activity trackers and gamification can have wide-ranging benefits, however, their effect on wellbeing has not yet been sufficiently examined in literature. Our study examines whether gamified and non-gamified self-tracking experiences create positive psychological responses that yield enhanced wellbeing. We gathered data on self-reported happiness and life satisfaction before and after a four-week self-tracking experience of physical activity, with and without the use of gamification. We measured the users' emotional and cognitive responses and parsed out the effect of these psychological outcomes on the users' subjective wellbeing. We found that users' perceived usefulness of the experience was associated with an increase in the individuals' life satisfaction, while enjoyment and interest were linked to an increase in the individuals' happiness. Both gamified and non-gamified self-tracking experiences evoked similar positive emotional and cognitive responses, yielding similar gains in wellbeing. Future research could explore long-term health and wellbeing impacts.

Keywords

Self-tracking; gamification; psychological outcomes; life satisfaction; happiness; wellbeing

1. Introduction

In the realm of physical activity, exercise and wellbeing, there is widespread use of wearables, physical activity trackers, mobile fitness applications, and extensive use of gamification to promote and maintain regular physical activity [1]. The aim of these technologies is arguably to provide the motivational enforcement through self-knowledge on one's physical activity, goal setting, social influence, and social support to achieve self-improvement goals [2], [3]. Literature suggests that self-tracking experiences and gamification can have beneficial effects on the users' wellbeing [4], [5]. However, the effect of these behavioral interventions on wellbeing has not been sufficiently examined [4], [6]–[8].

We question whether experiences of self-tracking and gamification create positive emotional and cognitive responses that yield enhanced wellbeing. To answer this question, we gather data on wellbeing measures (*life satisfaction* and *happiness*) before and after an experience of self-tracking alone, and in conjunction with the use of gamification. We measure the users' emotional (*enjoyment and interest*) and cognitive (*perceived usefulness*) responses and parse out the effect of these psychological outcomes on the users' subjective wellbeing. We also examine whether gamification enhances the effects compared to a non-gamified self-tracking experience.

Through the findings of this study, we extend our understanding of the psychological responses that enhance wellbeing and contribute to the literature on gamification and self-tracking.

2. Literature

2.1. Theoretical underpinnings

Self-tracking technologies (also referred to as quantified self) [9] enable people to collect data

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EMAIL: elaine.m.grech@um.edu.mt (A.1)
ORCID: 0000-0002-0856-0374 (A.1); 0000-0003-4018-795X (A.2); 0000-0002-6481-6258 (A.3)

about themselves. Physical activity trackers help people realize their level of physical activity or rather inactivity. The provision of personal informatics data received through the use of activity trackers initiates a process of self-reflection and evaluation [10], [11]. This process brings about behavior change opportunities for self-improvement [12], [13]. The desirable behaviors are facilitated through goal setting, reminders, and goal achievement [13], [14]. Self-tracking experiences facilitate informational feedback and simultaneously also bring about hedonic and affective responses [2], [15]. The informational feedback provided by self-tracking experiences help users realize the utilitarian value and perceived usefulness of the activity, which in turn acts as a motivational tool [2], [16]. When individuals recognize and identify the perceived value of an activity, they internalize and integrate the desired behavior, yielding self-motivation and enhanced subjective wellbeing [17].

Gamification defined as '*the use of game design elements in non-game contexts'* [18, p. 1] is commonly integrated with self-tracking technologies to enhance the intervention's intended effects and promote engagement [4], [5]. Gamification serves a dual-purpose, users can derive both hedonic and utilitarian benefits [19], [20]. The intrinsically motivating positive experience that gamification is intended to provide supports the initiation, reinforcement, and maintenance of healthy behaviors [4]. The hedonic design of gamified systems offers the potential to generate a positive affective experience that enhances the users' perceived benefits and sustain continued usage of self-tracking technologies [4]. The use of gamification is known to evoke affective experiences [2], [3] and satisfy intrinsic needs [21]. The positive experience provided through the use of gamification could potentially have a direct contribution to wellbeing [4].

Wellbeing is defined as '*a person's cognitive and affective evaluations of his or her life*' [22, p. 187]. Extant literature provides evidence that leisure-time physical activity is correlated with positive affect, life satisfaction [23], and happiness [24], [25]. The magnitude of this association is small [23]. The literature has identified that subjective wellbeing is also affected by other factors, including the individual's health (physical and mental), the individual's lifecycle stage, income and employment, education, relationship status, religious participation, socialization, environment quality and cultural participation [26].

Motivational design technologies which promote physical activity can also enhance wellbeing outcomes. The premise is based on the underlying processes that these interventions can bring about. For instance, the self-determination theory [17] suggests that activities which provide an intrinsically motivating experience, or that are well-internalized (due to the perceived value of the activity or congruence with one's values) can lead to enhanced subjective wellbeing. An indicator of intrinsic motivation that is widely used in literature [27], [28] is perceived enjoyment and interest. Enjoyment and interest reflect the users' emotional response to the intervention. On the other hand, perceived usefulness reflects the users' cognitive response to the intervention based on the utilitarian value of the experience. Perceived usefulness facilitates internalization and integration of extrinsically motivated behaviors [17], [29]. The advantages of internalization include more autonomous and volitional commitment towards the desired behavior and enhanced subjective wellbeing [17].

Based on the theoretical underpinnings and literature presented in this section, we postulate that the use of self-tracking technologies and gamification can enhance wellbeing by eliciting positive emotional and cognitive responses based on hedonic and utilitarian benefits respectively. Furthermore, we posit that gamified (relative to a non-gamified) self-tracking experience results in stronger emotional and cognitive responses, and as a result enhanced wellbeing. Specifically, the data gathered through this study tests the following hypotheses:

H1*: The use of gamification enhances the effect on wellbeing (relative to a non-gamified self-tracking experience)*

H2*: The use of gamification results in stronger emotional and cognitive responses (relative to a non-gamified self-tracking experience)*

H3*: Enjoyment and interest enhance wellbeing gain*

H4*: Perceived usefulness of the experience enhances wellbeing gain*

2.2. Empirical evidence

Justifiably, the effectiveness of these motivational technologies needs to be corroborated with a body of empirical evidence supporting the promising beneficial effects [7],

[30], [31]. Notwithstanding the popularity of fitness trackers and gamification in industry practice, empirical evidence supporting the positive claims on wellbeing is scarce [4], [6]–[8].

Extant empirical evidence on the effect of self-tracking of physical activity on wellbeing provides mixed evidence [32]. The use of self-tracking technology was found to be effective in improving the individuals' quality of life and wellbeing in corporate wellness programs [33], amongst older adults [34] and breast cancer survivors [35]. Other literature [8] reports that self-tracking experiences of physical activity had a statistically significant small positive effect on the users' perceived physical health and the sense of goal accomplishment. Albeit positive, the increase reported for overall psychological wellbeing was not significant [8]. Likewise, another randomized controlled study [36] also reported that exercise-related self-tracking and step goals did not substantially influence psychological wellbeing. There is also evidence which suggests that while self-tracking can increase the task performance, it may simultaneously have negative effects on subjective wellbeing, including happiness and satisfaction by undermining the intrinsic motivation and enjoyment of performing such activities [37]. Thus, the effect of self-tracking of physical activity on the users' wellbeing needs to be further investigated.

The majority of existing studies in the field of gamification of physical activity, health and wellbeing [4], [30], [38] report positive effects on user experience, affect, cognition and behavior, which can have a positive impact on wellbeing [4]. However, despite the possibility of having a positive impact on wellbeing, there is scant literature [39], [40] investigating whether gamification of physical activity enhances the individual's quality of life and wellbeing. A gamified community-wide physical activity intervention [41] reported increases in both self-reported physical activity and mental wellbeing. Findings from other empirical studies [39], [40] reveal that whilst gamification led to an increase in physical activity, there was no change on the quality of life or wellbeing measures reported.

3. Materials and method

3.1. Study design

This study involved a two-wave longitudinal survey conducted before and after the implementation of a four-week behavioral intervention of physical activity, namely self-tracking of physical activity, alone and in conjunction with gamification.

3.2. Participants

The study was conducted amongst academic researchers and post-graduate research students at the University of Malta. Participants were recruited using a non-probabilistic convenience sampling method. Following an email invitation and a post on social media, interested participants were invited to review the information about the study (including its objectives, duration, and requirements) and provide informed consent. Participants were eligible for this study if they were over 18 years of age, did not use a fitness tracker or a wearable to monitor their physical activity during the previous year, and had no health issues (such as heart condition, chest pain, bone or joint pain, or dizziness) that they are aware of, which could prevent them from engaging in physical activity. Participants were ineligible if they were currently pregnant or have been told by their doctor not to engage in physical exercise.

3.3. Data collection

Data collection was carried out through self-completed pen-and-paper questionnaires. In total, eighty participants completed both the pre- and post-intervention surveys.

Subjective wellbeing was measured using two validated items identified in literature [42], namely *life satisfaction* and *happiness*. Both items were measured using an eleven-point Likert scale validated in previous empirical work [42]. The emotional response was measured in terms of the users' *enjoyment and interest*, while the cognitive response was measured in terms of the *perceived usefulness* of the activity. The latter two constructs were measured using validated sub-scales of the Intrinsic Motivation Inventory [27] on a seven-point Likert scale. Self-reported data on potential predictors of wellbeing identified in literature [26] was also gathered. This includes demographic and lifestyle data including the self-reported stage of physical activity based on the transtheoretical model [43].

3.4. Procedure and interventions

Following the eligibility screening criteria, a unique reference number was assigned to all participants to ensure anonymity all throughout the study. Using an online random sequence generator (random.org), eligible participants (n = 80) who provided informed consent were randomly assigned to either a non-gamified self-tracking experience (n = 20) or a gamified self-tracking experience (n = 60). Participants were blinded to group allocation and groups were color-coded to hide the identity of each group from participants.

During the intervention period, all participants were given a smartwatch (Xiaomi Mi Band) to track their physical activity. Earlier studies [44], [45] show that these wearable devices are adequately reliable in tracking physical activity, and hence these were preferred against other brands of pedometers due to their cost and battery lifespan. All participants were instructed on how to pair and sync the smartwatch with the corresponding mobile application, and to wear the device at all times.

During the set-up of the wearables and the corresponding application installed on their smartphones, all participants were allowed to choose a personalized daily step target. Goal setting is a commonly used feature in self-tracking motivational technologies [46] that supports users' intrinsic motivation and self-regulation [47]. Participants assigned to the non-gamified self-tracking group monitored whether they achieved their personal daily step goal target set on their smartwatch.

In addition to self-tracking, participants assigned to a gamified experience were randomly assigned to either a group cooperation challenge (cooperative design), an individual competition (competitive design), or an inter-team competition (competitive-cooperative design).[2] The design of these gamified experiences was guided by the classification of gamification features [48] and gamification design frameworks [19], [49] identified in literature. The game elements utilized within these interventions are associated with the motivational constructs of the self-determination theory [17] to afford an appealing and motivating experience for the users [49]. The gamification experiences were designed using a gamified platform (pointagram.com) that was accessible to all participants through an application installed on their smartphone or through a web browser. Visual images of the gamified experiences are presented in the Supplementary Material.

3.5. Statistical data analysis

Statistical analysis was carried out in three phases. First, descriptive statistics were computed for all the variables measured. Wilcoxon signed-rank tests were computed to determine whether *happiness* and *life satisfaction* scores increased post-intervention compared to pre-intervention levels. The effect size *r* was computed using the Z value resulting from Wilcoxon test and the number of observations in the sample [50]. The change for each wellbeing measure (*life satisfaction* and *happiness*) was computed as follows (Equation 1):

$$Gain = post - pre \quad (1)$$

where *pre* and *post* refers to the life satisfaction and happiness measures assessed before and after the intervention.

To test hypothesis H1, Mann-Whitney U tests were carried out to determine whether the use of gamification led to significantly higher gains in wellbeing measures. To increase the robustness of the results, an ANCOVA was carried out to determine whether there is a statistically significant difference in the post-intervention wellbeing scores between the non-gamified self-tracking group and the gamified self-tracking group, after controlling for the pre-intervention wellbeing scores. Furthermore, we also tested for significant differences between the different gamification experiences and non-gamified self-tracking group in terms of wellbeing gains using Kruskal-Wallis test.

Second, the constructs' reliability for *Enjoyment and Interest* and *Perceived Usefulness* were measured using Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE). All convergent validity metrics obtained were checked against the thresholds (Cronbach's $\alpha > 0.7$, $CR > 0.7$ and $AVE > 0.5$) suggested in literature [51]. In order to test hypothesis H2, we conducted Mann-Whitney U tests to determine whether the use of gamification led to significantly higher emotional and

[2] These interventions were part of an experimental study examining the effect of different types of gamification designs on psychological and behavioral outcomes, detailed in a forthcoming publication [54].

cognitive responses (relative to a non-gamified self-tracking experience). Furthermore, we also tested for significant differences between the different gamification experiences and non-gamified self-tracking group in terms of the emotional and cognitive responses using Kruskal-Wallis tests.

Third, pair-wise bivariate correlations were computed to examine whether there is a relationship between wellbeing gains and potential predictors of change including enjoyment and interest, perceived usefulness, gamification and the baseline levels of life satisfaction and happiness. While correlation analysis provides an insight on the strength of positive or negative associations between these wellbeing constructs, and between them and their potential predictors of change, it is not possible to parse out the net effect of the latter variables on the dependent measures. Thus, to test Hypotheses H3 and H4, we carried out a multi-variate regression analysis for each wellbeing measure (*life satisfaction* and *happiness*) to examine the contribution of each potential predictor of change and identify which factors were causing an effect on subjective wellbeing. The model used for this analysis is presented below (Equation 2):

$$WB\_Gain = \beta_0 + \beta_1 BaselineWB + \beta_2 Enjoyment\_Interest + \beta_3 Perceived\_Usefulness + + \beta_4 Gamification \quad (2)$$

where *WB_Gain* is the dependent variable relating to the gain reported in life satisfaction and happiness. The independent variables included are enjoyment and interest, perceived usefulness, a dummy variable for gamification and the baseline scores for life satisfaction and happiness. In order to increase the robustness of our findings, we computed multi-variate regression models on the post-intervention wellbeing measures (as dependent variables), controlling for the demographic and lifestyle variables, in addition to the independent variables listed in Equation 2. Statistical analysis was carried out using STATA™ (version 16.1, StataCorp). Regression models were estimated using a robust estimator of variance.

4. Results

4.1. Sample characteristics

Descriptive statistics were computed for the sample characteristics, including demographic and lifestyle data, and the self-reported stage of physical activity at baseline (pre-intervention). The sample characteristics are set out in Table 1.[3]

Table 1
Sample characteristics

Variables	%
Male	44%
Female	56%
Young adult (20 - 34 years)	52%
Middle aged (35 - 54 years)	45%
Older adult (55+ years)	3%
Full-time employed	65%
Have children under 16 years	22%
Have a steady relationship	72%
Have sufficient income	88%
Do voluntary work	23%
Participate in religious/spiritual activity	31%
Participate in artistic/creative activity	20%
Spend time in nature	61%
Spend time with friends and family	96%
Maintain a balance between work and play	50%
Regular physical exercise	25%

4.2. Change in wellbeing

Table 2
Pre- and post-intervention wellbeing scores

	Pre	Post	Gain
Variables	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Happiness	6.90 (1.769)	7.21 (1.998)	0.31 (1.688)
Life Satisfaction	6.86 (1.941)	7.34 (1.916)	0.48 (1.467)

The findings show that there is a significant increase in *happiness* (z = -2.298, p = 0.022, effect size r = -0.182) and *life satisfaction* (z = -2.911, p = 0.004, effect size r = -0.230) when

[3] The distribution of participants between the gamified and the non-gamified self-tracking groups was relatively well-balanced in terms of all demographic and lifestyle characteristics, with the exception of having less participants in the non-gamified group who had children under the age of sixteen, even though randomization was employed. For sensitivity analysis, 'having children under 16 years of age' was included as a covariate amongst other variables in the multi-variate regression model analyzing the potential predictors of wellbeing change. The results presented as part of the Supplementary Material confirm that having children under the age of sixteen was not a significant predictor to the change reported in wellbeing measures.

comparing post-intervention scores to pre-intervention scores (see Table 2).

Non-gamified and gamified self-tracking groups reported similar increases in wellbeing measures (see Table 3). The findings show that the use of gamification did not produce significantly higher gains in *happiness* (U = 587.5; z = -0.143, p = 0.886) and *life satisfaction* (U = 529.0; z = -0.816, p = 0.414) relative to a non-gamified self-tracking experience, thus **rejecting Hypothesis 1** *(H1: The use of gamification enhances the effect on wellbeing relative to a non-gamified self-tracking experience)*. Kruskal-Wallis tests also confirm that there are no significant differences in the gains reported for *happiness* ($\chi^2(3) = 1.944$, p = 0.584) and *life satisfaction* ($\chi^2(3) = 3.066$, p = 0.381) between the different gamified experiences and non-gamified self-tracking experience. ANCOVA results show that after adjusting for the pre-test wellbeing scores, there are no statistically significant differences in the post-intervention wellbeing scores of the non-gamified self-tracking group and the gamified group for either *happiness* (F(1,77) = 0.029, p = 0.865) or *life satisfaction* (F(1,77) = 0.140, p = 0.709).

Table 3
Wellbeing gain for the non-gamified and gamified self-tracking groups

	Non-Gamified	Gamified
Variables	**Mean (SD)**	**Mean (SD)**
Happiness Gain	0.35 (1.899)	0.30 (1.629)
Life Satisfaction Gain	0.35 (1.872)	0.52 (1.321)

4.3. Emotional and cognitive responses

The subscales used to measure the users' emotional and cognitive responses were found to be reliable, indicating internal consistency among the scale items used to measure each specific construct. *Enjoyment and Interest* sub-scale (α = 0.735; CR = 0.859; AVE = 0.677) resulted in a scale with M = 6.22 and SD = 0.867, and the *Perceived Usefulness* sub-scale (α = 0.808; CR = 0.891; AVE = 0.734) resulted in a scale with M = 5.46 and SD = 1.288.

Both the non-gamified and gamified self-tracking groups reported similar positive psychological outcomes (see Table 4). Results show that there are no significant differences between the groups in terms of reported *enjoyment and interest* (U = 513.50, z = -0.988, p = 0.323) and *perceived usefulness* (U = 509.00, z = -1.017, p = 0.309), thus **rejecting Hypothesis 2** *(H2: The use of gamification results in stronger emotional and cognitive responses relative to a non-gamified self-tracking experience)*.

The analysis also confirms that *enjoyment and interest* ($\chi^2(3) = 1.160$, $p = 0.657$), and *perceived usefulness* ($\chi^2(3) = 1.969$, $p = 0.579$) were not statistically significantly different between the different gamification experiences and the non-gamified self-tracking group.

Table 4
The emotional and cognitive responses for the non-gamified and gamified self-tracking groups

	Non-Gamified	Gamified
Variables	**Mean (SD)**	**Mean (SD)**
Enjoyment & Interest	6.40 (0.746)	6.16 (0.901)
Perceived Usefulness	5.28 (1.186)	5.52 (1.324)

4.4. Predictors of wellbeing change

The intercorrelations between the gains reported in wellbeing outcomes and the variables hypothesized to cause an increase in subjective wellbeing are presented in the Supplementary Material. The correlations indicate a significant positive relationship between happiness gain and life satisfaction gain, a significant negative correlation with baseline happiness and life satisfaction scores, and a significant positive association with the users' enjoyment and interest, and perceived usefulness.

The results of the multi-variate regression analysis (see Table 5) provide evidence to the predictors of the gains reported in happiness and life satisfaction. The emotional psychological response to the intervention measured through the individuals' enjoyment and interest (hedonic benefit) produced a significant positive effect (β = 0.596) that increased the individuals' happiness levels, **supporting Hypothesis 3** *(H3: Enjoyment and interest enhance wellbeing gain)*. The cognitive psychological response to the intervention measured through the perceived usefulness (utilitarian benefit) produced a significant positive effect (β = 0.450) that increased the individuals' life satisfaction levels, **supporting Hypothesis 4** *(H4: Perceived*

usefulness of the experience enhances wellbeing gain). The use of gamification did not produce a significant positive effect, thus providing further evidence to Hypothesis H1. The results also provide evidence that the baseline measure of happiness was a significant predictor to the happiness gain (β = -0.331). The negative coefficient value for baseline happiness indicates that lower happiness levels at baseline contributed to higher happiness gains. Similarly, the baseline measure of life satisfaction was a significant predictor to the gain reported in life satisfaction (β = -0.328), meaning that lower life satisfaction levels at baseline contributed to higher life satisfaction gains. To increase the robustness of our findings, we controlled for the demographic and lifestyle variables. We find that the results remain unchanged (see Supplementary Material).

Table 5
Multi-variate regression on wellbeing gains

Variables	Happiness Gain	Life Satisfaction Gain
Baseline	**-0.331*** **	
Happiness	**(0.113)**	
Baseline Life		**-0.328*** **
Satisfaction		**(0.086)**
Enjoyment &	**0.596** **	0.295
Interest	**(0.281)**	(0.222)
Perceived	0.176	**0.450*** **
Usefulness	(0.174)	**(0.132)**
Gamification	0.029	0.094
	(0.413)	(0.364)
Constant	-2.093	-1.631
	(1.619)	(1.454)
Observations	80	80
R-squared	0.279	0.437
F value	F(4, 75) = 6.29	F(4, 75) = 9.71
P value	p < 0.001	p < 0.001

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Discussion and conclusion

The findings support the theoretical prediction that experiences of self-tracking, alone and in conjunction with gamification elicit positive emotional and cognitive responses that yield enhanced wellbeing. Both gamified and non-gamified self-tracking experiences facilitated similar positive psychological responses, measured as enjoyment and interest (hedonic benefit) and as perceived usefulness (utilitarian benefit). Previous research [2], [20] highlights the importance of both perceived usefulness and enjoyment for continued use of motivational information systems.

Previous empirical studies [39], [40] indicated that physical activity interventions involving activity trackers and gamification did not produce a significant change in wellbeing and quality of life measures. In contrast, our findings suggest that experiences of self-tracking and gamification have statistically significant positive effects on *happiness* (effect size r = -0.182) and *life satisfaction* (effect size r = -0.230). These effects corroborate the standardized effect sizes observed in previous literature following the use of self-tracking technologies [8], [35].

Gamification is commonly integrated with self-tracking technologies to promote engagement and enhance the intervention's intended effects [4], [5]. Nevertheless, the findings from our study show that at the end of the intervention (after four weeks), gamified and non-gamified self-tracking evoked similar positive emotional and cognitive responses, yielding similar wellbeing gains. Literature suggests that enjoyment and perceived usefulness of gamification declines with use [52]. Thus, future work could consider more frequent measurements during the intervention period.

The gains in wellbeing measures were attributed to the users' positive psychological responses resulting from gamified and non-gamified self-tracking experiences of physical activity. Specifically, enjoyment and interest were linked to an increase in the individuals' happiness levels. In turn, the perceived usefulness of the experience was associated with an increase in the individuals' life satisfaction levels. Our findings support existing literature suggesting that intrinsic motivation and autonomous forms of extrinsic motivation enhance wellbeing [17]. In synthesis, the findings suggest that the hedonic benefit of the experience enhances happiness levels (hedonic wellbeing), while the utilitarian benefit of the experience enhances life satisfaction levels (eudaimonic wellbeing) [53].

Our findings provide insights into how subjective wellbeing is influenced by self-tracking technologies and the use of gamification, an area which is underexplored in literature. Yet, despite our contributions, we acknowledge that there are some limitations which could be addressed in future research. First, this study was conducted amongst academic members and post-

graduate students. Future studies should also examine a broader population and a larger sample size with longer timeframes to increase the generalizability and robustness of the findings. Understandably, there are challenges to conduct empirical studies involving wearable physical activity trackers with a large sample size. However, the accumulation of knowledge from rigorous empirical work on the effect of self-tracking and gamification on health-related behaviors and societal wellbeing would have practical relevance. Second, this study compared longitudinal wellbeing data of gamified and non-gamified self-tracking experiences. Future studies could also include an inactive control group, with no access to physical activity trackers. Third, this study examined wellbeing measures pre- and post-intervention. Future studies could consider gathering data on the users' experience and wellbeing more frequently during the intervention, possibly using a diary research approach or through real-time customer experience tracking. This would allow more granular data on the users' interaction with motivational information systems and a more comprehensive view of the effect on the users' experience and wellbeing.

To conclude, results from this study demonstrate that using wearable fitness trackers (with and without the use of gamification) increases subjective wellbeing. The value co-created through such meaningful experiences improves people's quality of life and wellbeing.

6. Declaration of interest

The authors declare that they have no conflict of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

7. References

[1] A. Neupane, D. Hansen, A. Sharma, J. A. Fails, B. Neupane, and J. Beutler, "A Review of Gamified Fitness Tracker Apps and Future Directions," in *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, New York, NY, USA: ACM, Nov. 2020, pp. 522–533. doi: 10.1145/3410404.3414258.

[2] L. Hassan, A. Dias, and J. Hamari, "How motivational feedback increases user's benefits and continued use: A study on gamification, quantified-self and social networking," *Int J Inf Manage*, vol. 46, pp. 151–162, Jun. 2019, doi: 10.1016/j.ijinfomgt.2018.12.004.

[3] J. Hamari, L. Hassan, and A. Dias, "Gamification, quantified-self or social networking? Matching users' goals with motivational technology," *User Model User-adapt Interact*, vol. 28, no. 1, pp. 35–74, Mar. 2018, doi: 10.1007/s11257-018-9200-2.

[4] D. Johnson, S. Deterding, K.-A. Kuhn, A. Staneva, S. Stoyanov, and L. Hides, "Gamification for health and wellbeing: A systematic review of the literature," *Internet Interv*, vol. 6, pp. 89–106, Nov. 2016, doi: 10.1016/j.invent.2016.10.002.

[5] V. W. S. Cheng, T. Davenport, D. Johnson, K. Vella, and I. B. Hickie, "Gamification in apps and technologies for improving mental health and well-being: Systematic review," *J Med Internet Res*, vol. 21, no. 6, pp. 1–15, 2019, doi: 10.2196/13717.

[6] S. Hermsen, J. Frost, R. J. Renes, and P. Kerkhof, "Using feedback through digital technology to disrupt and change habitual behavior: A critical review of current literature," *Comput Human Behav*, vol. 57, pp. 61–74, Apr. 2016, doi: 10.1016/j.chb.2015.12.023.

[7] A. Rapp, F. Hopfgartner, J. Hamari, C. Linehan, and F. Cena, "Strengthening gamification studies: Current trends and future opportunities of gamification research," *International Journal of Human Computer Studies*, vol. 127, no. November 2018, pp. 1–6, 2019, doi: 10.1016/j.ijhcs.2018.11.007.

[8] B. Stiglbauer, S. Weber, and B. Batinic, "Does your health really benefit from using a self-tracking device? Evidence from a longitudinal randomized control trial," *Comput Human Behav*, vol. 94, no. January, pp. 131–139, 2019, doi: 10.1016/j.chb.2019.01.018.

[9] D. Lupton, *The Quantified Self*. John Wiley & Sons., 2016.

[10] I. Li, A. Dey, and J. Forlizzi, "A stage-based model of personal informatics systems," in *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, New York, New York, USA: ACM Press,

2010, p. 557. doi: 10.1145/1753326.1753409.

[11] A. Rapp, A. Marcengo, L. Buriano, G. Ruffo, M. Lai, and F. Cena, "Designing a personal informatics system for users without experience in self-tracking: a case study," *Behaviour & Information Technology*, vol. 37, no. 4, pp. 335–366, Apr. 2018, doi: 10.1080/0144929X.2018.1436592.

[12] A. Bandura, "Social cognitive theory of self-regulation," *Organ Behav Hum Decis Process*, vol. 50, no. 2, pp. 248–287, Dec. 1991, doi: 10.1016/0749-5978(91)90022-L.

[13] E. T. Kersten-van Dijk, J. H. D. M. Westerink, F. Beute, and W. A. IJsselsteijn, "Personal Informatics, Self-Insight, and Behavior Change: A Critical Review of Current Literature," *Hum Comput Interact*, vol. 32, no. 5–6, pp. 268–296, Nov. 2017, doi: 10.1080/07370024.2016.1276456.

[14] S. a Munson and S. Consolvo, "Exploring goal-setting, rewards, self-monitoring, and sharing to m motivate physical activity," *6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, pp. 25–32, 2012.

[15] L. Hassan, N. Xi, B. Gurkan, J. Koivisto, and J. Hamari, "Gameful Self-Regulation: A Study on How Gamified Self-Tracking Features Evoke Gameful Experiences," *Proceedings of the 53rd Hawaii International Conference on System Sciences*, no. January, 2020, doi: 10.24251/hicss.2020.138.

[16] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions," *Contemp Educ Psychol*, vol. 61, no. April, 2020, doi: 10.1016/j.cedpsych.2020.101860.

[17] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being.," *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.

[18] S. Deterding, D. Dixon, R. Khaled, L. Nacke, M. Sicart, and K. O'Hara, "Gamification: Using Game Design Elements in Non-Game Contexts," *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems (CHI 2011)*, pp. 2425–2428, 2011, doi: 10.1145/1979742.1979575.

[19] D. Liu, R. Santhanam, and J. Webster, "Toward Meaningful Engagement: A Framework for Design & Research of Gamified Information Systems," *MIS Quarterly*, vol. 41, no. 4, pp. 1011–1034, 2017.

[20] D. B. Köse, B. Morschheuser, and J. Hamari, "Is it a tool or a toy? How user conceptions of a system's purpose affect their experience and use," *Int J Inf Manage*, vol. 49, no. June, pp. 461–474, 2019, doi: 10.1016/j.ijinfomgt.2019.07.016.

[21] N. Xi and J. Hamari, "Does gamification satisfy needs? A study on the relationship between gamification features and intrinsic need satisfaction," *Int J Inf Manage*, vol. 46, pp. 210–221, Jun. 2019, doi: 10.1016/j.ijinfomgt.2018.12.002.

[22] E. Diener, S. Oishi, and R. E. Lucas, "Subjective Well-Being: The Science of Happiness and Life Satisfaction," in *The Oxford Handbook of Positive Psychology*, S. J. Lopez and C. R. Snyder, Eds., Oxford University Press, 2009, pp. 186–194. doi: 10.1093/oxfordhb/9780195187243.013.0017.

[23] C. W. Wiese, L. Kuykendall, and L. Tay, "Get active? A meta-analysis of leisure-time physical activity and subjective well-being," *J Posit Psychol*, vol. 13, no. 1, pp. 57–66, Jan. 2018, doi: 10.1080/17439760.2017.1374436.

[24] M. Argyle, *The Psychology of Happiness*, 2nd Editio. London: Routledge, 2001. doi: 10.4324/9781315812212.

[25] Z. Zhang and W. Chen, "A Systematic Review of the Relationship Between Physical Activity and Happiness," *J Happiness Stud*, vol. 20, no. 4, pp. 1305–1322, 2019, doi: 10.1007/s10902-018-9976-0.

[26] M. Briguglio, "Perspectives on Wellbeing," Brill | Sense, Mar. 2019. doi: 10.1163/9789004394179.

[27] R. M. Ryan, "Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory.," *J Pers Soc Psychol*, vol. 43, no. 3, pp. 450–461, 1982, doi: 10.1037/0022-3514.43.3.450.

[28] J. Wu and X. Lu, “Effects of extrinsic and intrinsic motivators on using utilitarian, hedonic, and dual-purposed information systems: A meta-analysis,” *J Assoc Inf Syst*, vol. 14, no. 3, pp. 153–191, 2013, doi: 10.17705/1jais.00325.

[29] E. L. Deci, H. Eghrari, B. C. Patrick, and D. R. Leone, “Facilitating Internalization: The Self-Determination Theory Perspective,” *Journal of Personality*, vol. 62, no. 1. pp. 119–142, 1994. doi: 10.1111/j.1467-6494.1994.tb00797.x.

[30] J. Koivisto and J. Hamari, “The rise of motivational information systems: A review of gamification research,” *Int J Inf Manage*, vol. 45, no. October 2018, pp. 191–210, 2019, doi: 10.1016/j.ijinfomgt.2018.10.013.

[31] J. Hamari, J. Koivisto, and H. Sarsa, “Does gamification work? - A literature review of empirical studies on gamification,” in *Proceedings of the Annual Hawaii International Conference on System Sciences*, IEEE Computer Society, 2014, pp. 3025–3034.

[32] D. Jin, H. Halvari, N. Maehle, and A. H. Olafsen, “Self-tracking behaviour in physical activity: a systematic review of drivers and outcomes of fitness tracking,” *Behaviour and Information Technology*, vol. 41, no. 2, pp. 242–261, 2022, doi: 10.1080/0144929X.2020.1801840.

[33] L. Giddens, D. Leidner, and E. Gonzalez, “The role of fitbits in corporate wellness programs: Does step count matter?,” *Proceedings of the Annual Hawaii International Conference on System Sciences*, vol. 2017-Janua, pp. 3627–3635, 2017, doi: 10.24251/hicss.2017.438.

[34] A. Suh and M. Li, “How the use of mobile fitness technology influences older adults’ physical and psychological well-being,” *Comput Human Behav*, vol. 131, no. September 2021, p. 107205, 2022, doi: 10.1016/j.chb.2022.107205.

[35] J. K. H. Vallance, K. S. Courneya, R. C. Plotnikoff, Y. Yasui, and J. R. Mackey, “Randomized Controlled Trial of the Effects of Print Materials and Step Pedometers on Physical Activity and Quality of Life in Breast Cancer Survivors,” *Journal of Clinical Oncology*, vol. 25, no. 17, pp. 2352–2359, Jun. 2007, doi: 10.1200/JCO.2006.07.9988.

[36] L. Busch, T. Utesch, P.-C. Bürkner, and B. Strauss, “The Influence of Fitness-App Usage on Psychological Well-Being and Body Awareness—A Daily Diary Randomized Trial,” *J Sport Exerc Psychol*, vol. 42, no. 3, pp. 249–260, Jun. 2020, doi: 10.1123/jsep.2019-0315.

[37] J. Etkin, “The hidden cost of personal quantification,” *Journal of Consumer Research*, vol. 42, no. 6, pp. 967–984, 2016, doi: 10.1093/jcr/ucv095.

[38] M. Schmidt-Kraepelin, S. Warsinsky, S. Thiebes, and A. Sunyaev, “The role of gamification in health behavior change: A Review of Theory-driven Studies,” *Proceedings of the Annual Hawaii International Conference on System Sciences*, vol. 2020-Janua, no. January, pp. 1256–1265, 2020, doi: 10.24251/hicss.2020.155.

[39] C. Maher *et al.*, “A web-based, social networking physical activity intervention for insufficiently active adults delivered via Facebook app: Randomized controlled trial,” *J Med Internet Res*, vol. 17, no. 7, 2015, doi: 10.2196/jmir.4086.

[40] L. Paul *et al.*, “Increasing physical activity in stroke survivors using STARFISH, an interactive mobile phone application: a pilot study,” *Top Stroke Rehabil*, vol. 23, no. 3, pp. 170–177, Apr. 2016, doi: 10.1080/10749357.2015.1122266.

[41] M. A. Harris, “The relationship between physical inactivity and mental wellbeing: Findings from a gamification-based community-wide physical activity intervention,” *Health Psychol Open*, vol. 5, no. 1, 2018, doi: 10.1177/2055102917753853.

[42] European Social Survey, “Measuring and Reporting on Europeans’ Wellbeing: Findings from the European Social Survey,” 2018. https://www.europeansocialsurvey.org/data/download.html?r=9

[43] J. O. Prochaska and W. F. Velicer, “The Transtheoretical Model of Health Behavior Change,” *American Journal of Health Promotion*, vol. 12, no. 1, pp. 38–48, Sep. 1997, doi: 10.4278/0890-1171-12.1.38.

[44] M. K. Tam and S. Y. Cheung, “Validation of consumer wearable activity tracker as step measurement in free-living conditions,” *Finnish Journal of eHealth*

and eWelfare, vol. 11, no. 1–2, pp. 68–75, 2019, doi: 10.23996/fjhw.76673.

[45] J. Xie, D. Wen, L. Liang, Y. Jia, L. Gao, and J. Lei, "Evaluating the validity of current mainstream wearable devices in fitness tracking under various physical activities: Comparative study," *JMIR Mhealth Uhealth*, vol. 6, no. 4, 2018, doi: 10.2196/mhealth.9754.

[46] N. Aldenaini, F. Alqahtani, R. Orji, and S. Sampalli, "Trends in Persuasive Technologies for Physical Activity and Sedentary Behavior: A Systematic Review," *Front Artif Intell*, vol. 3, no. April, 2020, doi: 10.3389/frai.2020.00007.

[47] G. P. Latham and E. A. Locke, "Self-regulation through goal setting," *Organ Behav Hum Decis Process*, vol. 50, no. 2, pp. 212–247, Dec. 1991, doi: 10.1016/0749-5978(91)90021-K.

[48] B. Morschheuser, A. Maedche, and D. Walter, "Designing Cooperative Gamification: Conceptualization and Prototypical Implementation," in *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*, New York, NY, USA: ACM, Feb. 2017, pp. 2410–2421. doi: 10.1145/2998181.2998272.

[49] J. Buckley, T. DeWille, C. Exton, G. Exton, and L. Murray, "A Gamification–Motivation Design Framework for Educational Software Developers," *Journal of Educational Technology Systems*, vol. 47, no. 1, pp. 101–127, 2018, doi: 10.1177/0047239518783153.

[50] R. Rosenthal, *Meta-Analytic Procedures for Social Research*. 2455 Teller Road, Thousand Oaks California 91320 United States of America: SAGE Publications, Inc., 1991. doi: 10.4135/9781412984997.

[51] J. Hair, W. Black, B. Babin, and R. Anderson, *Multivariate Data Analysis*, Seventh Ed. New Jersey: Pearson Education, 2010.

[52] J. Koivisto and J. Hamari, "Demographic differences in perceived benefits from gamification," *Comput Human Behav*, vol. 35, pp. 179–188, 2014, doi: 10.1016/j.chb.2014.03.007.

[53] R. M. Ryan and E. L. Deci, "On Happiness and Human Potentials: A Review of Research on Hedonic and Eudaimonic Well-Being," *Annu Rev Psychol*, vol. 52, no. 1, pp. 141–166, Feb. 2001, doi: 10.1146/annurev.psych.52.1.141.

[54] E. M. Grech, M. Briguglio, and E. Said, "Can Gamification Help with Physical Inactivity? A Randomised Controlled Field Experiment on the Psychological and Behavioural Effects of Gamification," *[Manuscript submitted for publication]*, 2023.

Supplementary Material

Description of the gamification experiences

Group cooperation challenge

This group had a *quest* to reach a target step count by the end of the week. The map shows a pirate making his way to reach the treasure chest with a countdown timer indicating the time left for the participants to complete the challenge. The progress that the pirate made towards the treasure chest reflected the users' accumulated points based on their step counts.

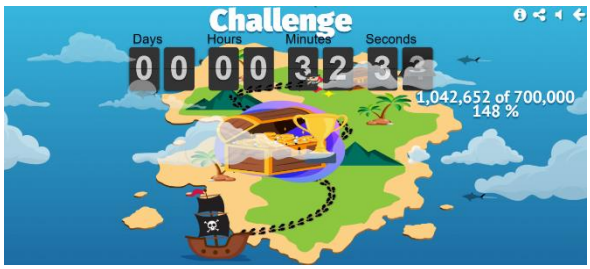

Figure S1
Group cooperation challenge

Individual competition

This group had an individual competition amongst the participants. Points based on their daily step counts were visible on a *leaderboard* which indicated the ranking of all the participants. *Virtual trophies* were awarded to the top three players with the highest step counts.

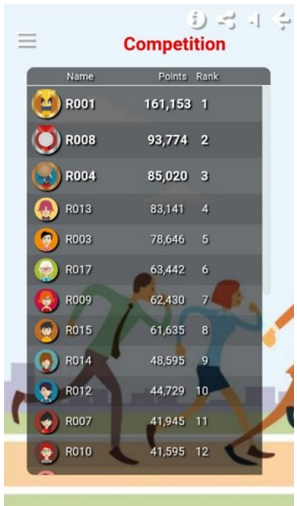

Figure S2
Individual competition

Inter-team competition

This group had a team versus team competition. Participants were randomised to teams of four players each. Accumulated points based on the daily step counts were visible on a *leaderboard* which indicated the ranking of all the teams. *Virtual trophies* were awarded to the top three teams with the highest step counts.

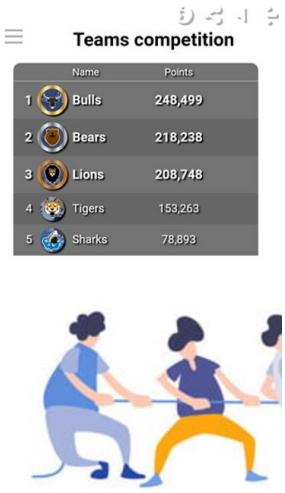

Figure S3
Inter-team competition

Supplementary Tables

Table S1
Correlations for the study variables

Variables	1	2	3	4	5	6	7
1. Happiness gain	--						
2. Life satisfaction gain	**0.691****	--					
3. Baseline happiness	**-0.333****	**-0.323****	--				
4. Baseline life satisfaction	-0.184	**-0.395****	**0.881****	--			
5. Enjoyment & Interest	**0.393****	**0.428****	0.015	0.041	--		
6. Perceived usefulness	**0.321****	**0.482****	0.076	0.083	**0.696****	--	
7. Gamification	-0.013	0.050	-0.016	-0.026	-0.120	0.079	--

*** Correlation is significant at the 0.01 level (2-tailed).*

Table S2
Regression models for post-intervention happiness and life satisfaction including demographic and lifestyle variables

Variables	POST Happiness model	POST Life Satisfaction model
Baseline happiness	**0.669***** (0.159)	
Baseline life satisfaction		**0.743***** (0.096)
Enjoyment & Interest	**0.704**** (0.337)	0.335 (0.214)
Perceived usefulness	0.101 (0.233)	**0.508***** (0.162)
Gamification	0.079 (0.420)	0.123 (0.372)
Male gender	0.160 (0.349)	0.132 (0.316)
Young adult	-0.201 (0.329)	-0.336 (0.298)
Children under 16 years	-0.358 (0.733)	-0.353 (0.432)
Voluntary work	-0.148 (0.364)	0.125 (0.254)
Religious participation	0.208 (0.474)	-0.376 (0.281)
Artistic activity	-0.322 (0.628)	-0.119 (0.364)
Spends time in nature	-0.120 (0.381)	-0.418 (0.312)
Spends time with family & friends	1.208 (1.140)	0.280 (0.567)
Balance work and play	-0.380 (0.332)	**-0.490**** (0.239)
Regular physical exercise	0.074 (0.467)	0.367 (0.351)
Constant	-3.156 (1.981)	-2.263* (1.332)
Observations	80	80
R-squared	0.521	0.718

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1