Investigating whether engagement with the specific components of a financial incentive based eHealth intervention predicts physical activity outcomes and mediators: process analysis of the Physical Activity Loyalty (PAL) scheme.

Abstract

Background: Investigating participant engagement and levels of non-usage attrition can help researchers identify which are the likely ‘active ingredients’ operating in eHealth interventions. Research on engagement can identify which intervention components predict health outcomes. Research on non-usage attrition is important to make recommendations for retaining participants in future studies.

Objective: To investigate engagement and non-usage attrition in the Physical Activity Loyalty (PAL) scheme, a six month complex physical activity (PA) intervention implemented in workplaces in Northern Ireland (NI). The intervention included financial incentives with reward redemption, and self-regulation techniques. Specific objectives included: (1) To determine whether engagement in specific intervention components predicted PA at six months; (2) To determine whether engagement in specific intervention components predicted mediators targeted by the intervention at six months; (3) To investigate rates, and predictors, of non-usage attrition for participants recording daily activity via the PAL scheme PA monitoring system and logging onto the PAL scheme website.

Methods: PA was assessed at baseline and six months using pedometers (Yamax Digiwalker CW-701, Japan). Markers of engagement and website use, PA monitoring system use and reward redemption were collected throughout the scheme. Random-effects generalised least squares (GLS) regressions determined whether engagement with specific intervention components predicted six month PA and mediator variables (mediators). Cox proportional hazards regressions were used to investigate predictors of non-usage attrition (i.e. days until first two week lapse).

Results: A multivariable GLS regression model showed frequency of hits on the monitoring and feedback component of the website ($b=50.2$, SE=24.5, $P=0.04$) and percentage of earned points redeemed ($b=9.1$, SE=3.3, $P<0.01$) were positively related to six month pedometer steps/day. Frequency of hits on the discussion forum component ($b=-69.3$, SE=26.6, $P<0.01$) was negatively related to six month pedometer steps/day. Reward redemption rates were not related to levels of more internal forms of motivation. Median time to first
Relapse in usage was 26 days for use of the PA monitoring system to record daily activity and 13 days for website use. Multivariable Cox proportional hazards regression models identified several baseline predictors which were associated with a reduced the risk of non-usage attrition.

Conclusion: Our results provide evidence in opposition to one of the main hypotheses of Self-Determination Theory by showing financial rewards are not necessarily associated with decreases in more internal forms of motivation when offered as part of a complex multi-component intervention. Several baseline predictors of non-usage attrition were identified (i.e. identified regulation, recovery self-efficacy, financial motivation, perceptions of workplace environment, participant health status). Strategies should be incorporated into study design to ensure maximum adherence to interventions in their intended form.

Keywords: Physical activity, Workplace, Intervention, Cluster randomised controlled trial, Behaviour change, Maintenance, Financial incentives, Engagement, Non-usage attrition.

Trial registration: ISRCTN17975376 (Registered 19/09/2014).
Introduction

The worldwide ‘pandemic’ of physical inactivity [1] requires innovative approaches to increasing population physical activity (PA) levels with a view to achieving long-term maintenance [2]. PA interventions are needed which can be delivered through less costly channels (e.g. internet, telephone or post) than those requiring direct contact in the interest of reaching as many participants as possible [3].

One example of an internet-delivered intervention was the Physical Activity Loyalty (PAL) scheme, implemented in workplaces in Northern Ireland (NI). The PAL scheme was a complex PA intervention which offered financial incentives and other behaviour change techniques (BCTs) delivered via the study website to increase workplace PA (recorded by outdoor sensors located within 2 km of the workplace). Paradoxically, results showed there was a small but significant decline in pedometer steps/day at six months relative to baseline, for the intervention group compared to controls, which dissipated at 12 months [4]. Mediation and moderation analyses showed that decreases in PA were partially mitigated by positive indirect effects through the constructs of integrated regulation, intrinsic motivation and habit measured at six months whilst the negative intervention effect was moderated by participants’ perceptions of availability of PA opportunities in the workplace environment [5]. The current report aims to further investigate mechanisms of behaviour change for participants in the PAL scheme by examining usage rates for specific intervention components, predictors of usage rates, and whether usage was related to study outcomes. As such, it reflects guidance provided by the Medical Research Council (MRC) on conducting process evaluations, which promotes the understanding of ‘cause’ as a key feature [6].

The concept of ‘engagement’ may be defined in terms of the level of exposure to and use of an intervention, and the amount of skills practice involved (i.e. completing activities or exercises to acquire knowledge or learn behaviour relevant to the target outcome) [7]. A participant’s level of engagement determines the extent to which they receive the intended intervention, and research on engagement is useful for identifying which intervention components are associated with health outcomes [8,9]. Investigating engagement in the different components of the intervention separately may help uncover which aspects of the intervention were beneficial (or detrimental) for increasing PA behaviour. Thomson and colleagues, for example, examined intervention engagement indicators (both singly and combined) in relation to several health behaviours in a broad lifestyle
intervention, and recommended the use of single engagement indicators, relevant to each intervention component, for predicting health outcomes [9]. Examining engagement in this way may help identify the key ‘active ingredients’ [10,11] for refinement in future studies.

One issue observed to impact web-based interventions is the tendency for a substantial proportion of participants to discontinue use of the intervention prior to intervention-end [12]. Non-usage attrition refers to the phenomenon of participants ceasing intervention-use before the end of the intervention period, which seems particularly to affect web-based interventions [12]. For example, previous web-based PA interventions targeting healthy, sedentary adults define non-usage attrition as occurring when the participant has a two week lapse from using the intervention [13,14]. In determining how successful web-based interventions are for achieving health behaviour change, it is important to understand participants’ non-usage patterns and what affects them. We might thus be able to make recommendations for participant retention in future intervention studies. This is important considering the fact that lack of participant engagement and high levels of non-usage attrition are factors which can impede researchers’ ability to appropriately test hypotheses in intervention studies [9,15].

The objectives of this report are: (1) To determine whether levels of engagement in different components of the intervention predicted PA measured six months post-baseline for participants assigned to the intervention group; (2) To determine whether levels of engagement in different components of the intervention predicted psychosocial variables (i.e. mediators) targeted by the intervention at six months post-baseline; (3) To investigate rates of non-usage attrition for participants recording daily activity via the PAL scheme PA monitoring system and logging onto the PAL scheme website, and baseline predictors of non-usage attrition (i.e. socio-demographic, mediator, environmental, and PA variables) for participants in the intervention group.

Methods

Overview

The PAL scheme was a cluster randomised controlled trial (RCT) of a complex, six month multi-component workplace PA intervention targeting inactive employees in workplaces in Belfast and Lisburn city centres in NI to increase their PA during working hours [16]. The underpinning theoretical framework was based on Learning
Theory [17], self-regulation control theory [18], Social Cognitive Theory (SCT) [19] and Self-Determination Theory (SDT) [20]. The scheme included a novel PA tracking system (with sensors in outdoor locations within 2 km of the workplace) and web-based monitoring (i.e. self-monitoring, prompts/cues, habit formation, adding objects to the environment). The main intervention component was the provision of financial incentives with ‘points’ accumulated depending on participants’ minutes of walking (i.e. one ‘point’ for one minute of PA) with a notional monetary value of £0.03 for a maximum of 30 minutes/day and could be redeemed for rewards at local businesses. Maps of walking routes and examples of PA opportunities were provided on the website (i.e. instruction on how to perform the behaviour). Sensors were operational during working hours (i.e. 7am-7pm, Monday-Friday). Other BCTs included regular tailored motivational emails (i.e. prompts), tailored feedback and links to other resources (e.g. PA and healthy eating advice) [22]. Discussion forums on the website provided a platform for participants to contact researchers and other participants (i.e. social support).

Participants randomly assigned (in clusters) to the control arm received no intervention during the six month intervention period but were placed on a waiting list to participate in the scheme at the end of the study period (i.e. 12 months).

Data collection

Outcome data were collected at baseline (socio-demographic, mediator, environmental, and PA variables) and six months (mediator and PA variables). Data on daily PA captured via the PAL scheme PA monitoring system (i.e. dates and minutes), website usage (i.e. dates, number of hits and minutes), and reward redemption (i.e. number of earned points and proportion redeemed) were collected throughout the six month intervention period.

Outcome measurements

Engagement variables

Three markers of overall intervention engagement (i.e. daily PA captured via the PAL scheme PA monitoring system, use of the PAL website, reward redemption) were tracked throughout the six month intervention period and the following variables were derived:
Percentage of intervention days during which participants walked for at least ten minutes captured via the PAL scheme PA monitoring system over the six month intervention period. This captured participants' engagement with the PA monitoring system component of the intervention (i.e. their willingness to practice PA behaviour in the workplace and earn points to incentivise their PA). Government recommendations suggest adults (aged 18-65 years) should accumulate 150 mins/week moderate-intensity PA, or 75 mins/week vigorous-intensity PA, or an equivalent combination of both, in blocks of at least ten minutes duration [23]. Recommendations from the Chief Medical Office emphasise the importance of daily PA and suggest the accumulation of 30 minutes of at least moderate-intensity PA on most, preferably all, days of the week [24]. Therefore engagement was measured in terms of days and only days with at least ten minutes of recorded activity were counted;

Percentage of intervention weeks during which participants logged onto the PAL website at least once over the six month intervention period. Whilst there was no specific guidance for ‘intended use’ of the PAL website (i.e. there was no recommendation for how often participants should log on), research shows that the typical web-based intervention is meant to be used once a week [25] and previous studies have categorised a log-in frequency of once/week as being high [26]. Therefore engagement was measured in terms of weeks and only weeks during which participants logged in at least once were counted;

Percentage of earned points redeemed over the six month intervention period. Aside from earning points by recording activity via the PA monitoring system, this indicator captured whether participants were interested in redeeming their earned points for financial rewards to incentivise their PA behaviour.

Engagement with the different aspects of the PAL website was assessed as the frequency of hits on each intervention component for every ten days the participant accessed the website and the total number of intervention components accessed on the website at least once (range 0-6). Research shows that measures of time spent online may not accurately capture engagement with the intervention. For example, whilst web-based interventions with unstructured access facilitate tailoring and flexibility, they enable users to multitask by opening multiple webpages or undertaking other activities, complicating the measurement of intervention engagement [27]. As participants in the PAL scheme had complete freedom to choose how they used the website, a higher frequency of hits on a particular website component across the days on which the participant
chose to log on was expected to reflect a higher level of interest (and willingness to engage) in that aspect of the intervention. This was also in line with previous studies of engagement in web-based interventions using log-in frequency as a measure of engagement [26,28–32].

The six intervention components participants could access on the website were as follows:

1. **Monitoring and feedback:** Data and visual representation (i.e. graphics) of the participant’s activity over the intervention period for self-monitoring purposes (i.e. self-monitoring and feedback, goal setting);
2. **Rewards:** Platform for participants to view their earned and bonus points, information on available rewards, and how to redeem points (i.e. immediate reward contingent on behaviour change);
3. **Maps:** Maps of sensor locations and example walking routes for planning of PA (i.e. information on when/where to perform PA, action planning);
4. **Health information (PA):** PA facts and information, health benefits, safety tips and tips for a physically active lifestyle (i.e. provision of information about health benefits of PA);
5. **Health information (Other):** Information related to healthy eating, smoking, alcohol consumption and stress reduction (i.e. provision of information about health benefits of other health behaviours);
6. **Discussion forums:** Platform for participants to contact researchers and other participants to ask questions, make enquiries, raise concerns and respond to comments (i.e. social support).

**Non-usage attrition: recording activity via the physical activity monitoring system and website use**

Non-usage attrition was considered to occur if a participant had at least a two week lapse from use [13,14]. Non-usage attrition for recording activity via the PA monitoring system was measured as the number of days until the first two week lapse from recording activity. Website non-usage attrition was measured as the number of days until the first two week lapse from logging onto the website.

**Physical activity**

The primary outcome was steps/day objectively measured over seven days using sealed pedometers (Yamax Digiwalker CW-701, Japan) [33–35] and considered valid if the participant provided ≥250 steps/day for three or more days. This was collected at baseline and six months.
Mediator outcomes

Mediator outcomes collected at baseline and six months included planning [36], self-determined motivation (i.e. identified regulation, integrated regulation, intrinsic motivation) [37,38], habit [39], recovery and maintenance self-efficacy [40], outcome satisfaction [41,42], social norms and workplace norms [43].

Predictors of non-usage attrition

Predictors of non-usage attrition were socio-demographic, mediator and environmental variables (assessed by questionnaire) and PA measures (pedometer steps/day) collected at baseline. Socio-demographic variables included age, gender, highest educational level, income, marital status, and self-report height and weight (used to compute BMI). Measures of health included Short Form-8 (SF-8) physical and mental health component scores [44], the Quality of Life (EQ-5D-5 L) health state utility measure and the weighted health index [45] and the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) [46,47]. Mediator variables included outcome expectations [41], PA self-efficacy [48], intention [49], planning [36], financial motivation [50,51], self-determined motivation (i.e. identified regulation, integrated regulation, intrinsic motivation) [37,38], habit [39], recovery and maintenance self-efficacy [40], outcome satisfaction [41,42], social support and workplace norms [43]. Perceptions of workplace environment (attractiveness, safety, accessibility, availability) were also collected at baseline [52]. Descriptions of assessed variables are provided in supplement 1 (table 1.1).

Statistical analysis

These analyses are exploratory and should be interpreted with caution on account of multiple testing. The level of significance was $P<0.05$ for all analyses. Analyses were carried out using Stata 13 [53]. All questionnaire items were coded so that higher numerical variables equalled higher values of the construct.

Objective 1: To determine whether levels of engagement in different components of the intervention predicted PA measured six months post-baseline for participants assigned to the intervention group

Random-effects generalised least squares (GLS) regressions were run with six month PA (i.e. pedometer steps/day) as the dependent variable, and engagement variables (i.e. % intervention days in which participants undertook at least ten minutes of PA captured using the PAL scheme PA monitoring system, % intervention weeks participants logged onto the PAL website, % earned points redeemed, frequency of hits on each of the...
six website intervention components for every ten days the participant accessed the website, total number of website sections accessed at least once) as the independent variables. The model was adjusted for randomisation stratum (Large >50, Medium 20-50, Small <20 or Schools/Colleges), season (December 2015-April 2016, July-August 2016) and baseline pedometer steps/day with standard errors (SEs) and p-values adjusted for clustering (three clusters based on size and one cluster for educational establishments). Random-effects models explicitly modelled the dependence between observations within the same cluster by including the random-effect. This represented the amount by which the intercept for a given cluster differed from the overall mean intercept value [54]. These analyses were conducted using Stata’s ‘xtreg’ command with the ’vce(cluster)’ option specified. Engagement variables showing a significant relationship with six month PA in univariable analyses ($P<0.05$) were included in a multivariable model with backwards elimination of the predictor with the highest p-value until all included predictors had $P<0.05$. This determined the combined effects of all relevant predictors on six month PA. The distributions of residuals for each regression were plotted to check for normality. Partial regression plots were used to identify influential points and homogeneity of variances was checked by graphing residual versus fitted values.

**Objective 2: To determine whether levels of engagement in different components of the intervention predicted psychosocial variables (i.e. mediators) targeted by the intervention at six months post-baseline**

Random-effects GLS regressions were run with six month mediators as the dependent variable, and engagement variables (i.e. % intervention days in which participants undertook at least ten minutes of PA captured using the PAL scheme PA monitoring system, % intervention weeks participants logged onto the PAL website, % earned points redeemed, frequency of hits on each of the six website intervention components for every ten days the participant accessed the website, total number of website sections accessed at least once) as the independent variables. These analyses used the same procedures outlined under objective 1 and additionally included baseline values of the relevant mediator as a covariate.
Objective 3: To investigate rates of non-usage attrition for participants recording daily activity via the PAL scheme physical activity monitoring system and logging onto the PAL scheme website, and baseline predictors (i.e. socio-demographic, mediator, environmental, and physical activity variables) of non-usage attrition for participants in the intervention group.

Survival curves for time to non-usage attrition were plotted separately for participants’ use of the PA monitoring system to record daily activity and website use. The median usage (i.e. the time by which 50% of participants’ usage had lapsed) was then calculated. Baseline measures of socio-demographic variables, mediator variables, environmental variables, and PA were investigated as predictors of non-usage attrition of the PA monitoring system to record daily activity and the website using Cox proportional hazards regression analyses. In the first analysis, the time variable was the number of days until the first two week lapse from using the PA monitoring system to record daily activity. In the second analysis, the time variable was the number of days until the first two week lapse from logging onto the website. For each model, the event variable was coded 1 if non-usage attrition occurred or 0 if non-usage attrition did not occur. Univariable analyses were conducted on all predictor variables and those with $P<0.05$ were included in a multivariable model with backwards elimination of the predictor with the highest $p$-value until all included predictors had $P<0.05$. All analyses included SEs and $p$-values corrected for clustering, with the Efron procedure used for handling ties as it is advocated over the Breslow method [55] and can be implemented with models adjusting SEs and $p$-values for clustering. The proportional hazards assumption was tested for each model formally using the Schoenfeld residuals ($P<0.05$ provided evidence to reject the proportional hazards assumption), and by visual inspection of scaled Schoenfeld residual plots [56]. Plots of $-\log(-\log(survival))$ versus $\log(time)$ were created for categorical predictors with non-parallelism indicating violation of the proportional hazards assumption.

Results

Baseline characteristics

A total of 457 participants from 19 clusters were randomised to the intervention group. Baseline characteristics are reported in supplement 1 (table 1.2).
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Six months</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td><strong>Engagement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% intervention days participants walked for at least 10 mins captured via</td>
<td>422</td>
<td>24.7 (21.8)</td>
</tr>
<tr>
<td>the PA monitoring system (^a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% intervention weeks participants logged onto the website (^b)</td>
<td>418</td>
<td>37.8 (32.5)</td>
</tr>
<tr>
<td>% earned points redeemed (^c)</td>
<td>422</td>
<td>39.3 (42.5)</td>
</tr>
<tr>
<td>Frequency: Monitoring and feedback (^d)</td>
<td>418</td>
<td>13.7 (3.5)</td>
</tr>
<tr>
<td>Frequency: Rewards (^d)</td>
<td>418</td>
<td>5.7 (4.5)</td>
</tr>
<tr>
<td>Frequency: Maps (^d)</td>
<td>418</td>
<td>3.4 (4.0)</td>
</tr>
<tr>
<td>Frequency: Health info. (PA) (^d)</td>
<td>418</td>
<td>0.5 (1.7)</td>
</tr>
<tr>
<td>Frequency: Health info. (Other) (^d)</td>
<td>418</td>
<td>1.2 (3.2)</td>
</tr>
<tr>
<td>Frequency: Discussion forums (^d)</td>
<td>418</td>
<td>1.9 (4.2)</td>
</tr>
<tr>
<td>Total no. sections (website) (^d)</td>
<td>418</td>
<td>3.9 (1.5)</td>
</tr>
<tr>
<td>Total minutes (recording daily activity via PA monitoring system)</td>
<td>422</td>
<td>1,000 (987)</td>
</tr>
<tr>
<td>Total minutes (PAL website)</td>
<td>418</td>
<td>1,171 (2,048)</td>
</tr>
<tr>
<td><strong>Non-usage attrition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days to non-usage attrition (recording daily activity via PA monitoring</td>
<td>422</td>
<td>53.7 (61.2)</td>
</tr>
<tr>
<td>system) (^f)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days to non-usage attrition (PAL website) (^g)</td>
<td>418</td>
<td>31.7 (43.4)</td>
</tr>
<tr>
<td>No. participants with non-usage attrition for recording daily activity</td>
<td>375</td>
<td>89%</td>
</tr>
<tr>
<td>via PA monitoring system (%)</td>
<td>403</td>
<td>96%</td>
</tr>
<tr>
<td>No. participants with PAL website non-usage attrition (%)</td>
<td>403</td>
<td>96%</td>
</tr>
</tbody>
</table>

\(^{250}\)Percentage of days participants were recorded walking for at least 10 mins captured via the PA monitoring system.

\(^{252}\)Percentage of weeks participants logged onto the website at least once.

\(^{253}\)Percentage of total accumulated points which the participant had redeemed by six months.

\(^{254}\)Frequency of hits (i.e. total number of hits for every ten days the participant accessed the website).

\(^{255}\)Number of sections accessed on website at least once (0-6).

\(^{256}\)Number of days until first two week lapse from recording daily activity via PA monitoring system.

\(^{257}\)Number of days until first two week lapse from logging onto the website.

\(^{258}\)NB. Numbers are Mean (SD) unless otherwise stated.
Table 1 shows six month engagement and non-usage attrition measures. The mean percentage of intervention days during which participants were recorded being active via the PA monitoring system was 24.7% (SD 21.8%), and the mean number of intervention weeks that participants logged onto the study website was 37.8% (SD 32.5%). Participants redeemed 39.3% (SD 42.5%) of their earned points on average. Participants clicked on four of the six website components at least once on average and the component accessed with the highest frequency was monitoring and feedback. Six month PA and mediator outcomes are reported in table 2.

### Table 2. Baseline and six month physical activity outcomes and scores on mediator variables

<table>
<thead>
<tr>
<th>VARIABLES (scale range)</th>
<th>Baseline</th>
<th>Six months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>PA self-efficacy (1-5)</td>
<td>439</td>
<td>2.91 (0.97)</td>
</tr>
<tr>
<td>Intentions (1-7)</td>
<td>435</td>
<td>5.38 (1.68)</td>
</tr>
<tr>
<td>Outcome expectations (1-5)</td>
<td>418</td>
<td>3.37 (0.62)</td>
</tr>
<tr>
<td>Financial motivation (1-7)</td>
<td>439</td>
<td>1.71 (1.16)</td>
</tr>
<tr>
<td>Planning (1-4)</td>
<td>414</td>
<td>2.37 (0.69)</td>
</tr>
<tr>
<td>Social norms (1-7)</td>
<td>414</td>
<td>3.87 (1.20)</td>
</tr>
<tr>
<td>Identified regulation (1-5)</td>
<td>438</td>
<td>3.81 (0.87)</td>
</tr>
<tr>
<td>Integrated regulation (1-5)</td>
<td>439</td>
<td>3.12 (1.13)</td>
</tr>
<tr>
<td>Intrinsic motivation (1-5)</td>
<td>438</td>
<td>3.52 (0.99)</td>
</tr>
<tr>
<td>Habit (1-5)</td>
<td>437</td>
<td>2.89 (1.32)</td>
</tr>
<tr>
<td>Workplace norms (1-5)</td>
<td>439</td>
<td>3.20 (0.82)</td>
</tr>
<tr>
<td>Recovery self-efficacy (1-4)</td>
<td>438</td>
<td>2.36 (0.82)</td>
</tr>
<tr>
<td>Maintenance self-efficacy (1-4)</td>
<td>438</td>
<td>2.79 (0.86)</td>
</tr>
<tr>
<td>Outcome satisfaction (1-5)</td>
<td>404</td>
<td>3.85 (0.68)</td>
</tr>
<tr>
<td>Pedometer steps/day</td>
<td>414</td>
<td>7,977 (3,602)</td>
</tr>
</tbody>
</table>

GPAQ: General Physical Activity Questionnaire; PA: physical activity.
Table 3 shows the results of random-effects regressions with pedometer steps/day at six months as the dependent variable, and use of specific intervention components as the independent variable, controlling for baseline pedometer steps/day, stratum and season, with cluster-adjusted SEs and p-values. Engagement variables which were significant predictors of six month pedometer steps/day in univariable analyses were included in a multivariable model which showed that frequency of hits on the monitoring and feedback component of the website across the six month intervention period ($b=50.2, \ SE=24.5, P=0.04$) and percentage of earned points redeemed across the six month intervention period ($b=9.1, \ SE=3.3, P<0.01$) were positively related to six month pedometer steps/day whilst frequency of hits on the discussion forum component of the website across the six month intervention period ($b=-69.3, \ SE=26.6, P<0.01$) was negatively related to six month pedometer steps/day. None of the other variables were significant predictors of six month pedometer steps/day in univariable analyses.
Table 3. Results of random-effects regressions with six month pedometer steps/day as the dependent variable and engagement indicators as independent variables among intervention group participants providing six month pedometer readings

<table>
<thead>
<tr>
<th>ENGAGEMENT VARIABLES</th>
<th>Univariable models</th>
<th>Multivariable modela</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>b (SE)</td>
</tr>
<tr>
<td>Engagement indicators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% intervention days participants walked for at least 10 mins captured via the PA monitoring systema</td>
<td>231</td>
<td>4.21 (8.54)</td>
</tr>
<tr>
<td>% intervention weeks participants logged onto the websiteb</td>
<td>234</td>
<td>4.39 (6.01)</td>
</tr>
<tr>
<td>% earned points redeemedc</td>
<td>231</td>
<td>8.26 (4.07)</td>
</tr>
<tr>
<td>Website sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring and feedbackd</td>
<td>234</td>
<td>66 (18)</td>
</tr>
<tr>
<td>Rewardsd</td>
<td>234</td>
<td>14 (36)</td>
</tr>
<tr>
<td>Mapsd</td>
<td>234</td>
<td>-47 (44)</td>
</tr>
<tr>
<td>Health information: Paod</td>
<td>234</td>
<td>35 (160)</td>
</tr>
<tr>
<td>Health information: Otherd</td>
<td>234</td>
<td>26 (66)</td>
</tr>
<tr>
<td>Discussion forumsd</td>
<td>234</td>
<td>-77 (27)</td>
</tr>
<tr>
<td>Number of sectionsd</td>
<td>234</td>
<td>-32 (117)</td>
</tr>
</tbody>
</table>

aR-squared=0.54 for multivariable model. R-squared=0.51 for model including covariates only (i.e. stratum, season, baseline pedometer steps/day).
bPercentage of days participants were recorded walking for at least 10 mins captured via the PA monitoring system.
cPercentage of weeks participants logged onto the website at least once.
dFrequency of hits (i.e. total number of hits for every ten days the participant accessed the website).
eNumber of sections accessed on website at least once (0-6).
fPercentage of total accumulated points which the participant had redeemed by six months.

NB. Results are adjusted for stratum, season, baseline pedometer steps/day with cluster-adjusted standard errors and p-values.
Objective 2

The only mediator variable for which more than one independent variable was retained in the multivariable analysis was integrated regulation (table 4). Engagement variables which were significant predictors of six month integrated regulation were included in a multivariable model which showed that the percentage of intervention days during which participants walked for at least ten minutes captured via the PAL scheme PA monitoring system over the six month intervention period ($b=0.008$, SE=0.002, $P<0.01$) and frequency of hits on the monitoring and feedback component of the website across the six month intervention period ($b=0.03$, SE=0.01, $P=0.02$) were positively related to six month pedometer steps/day whilst frequency of hits on the discussion forum component of the website across the six month intervention period ($b=-0.02$, SE=0.01, $P=0.02$) was negatively related to six month pedometer steps/day. The results of all univariable analyses are presented in supplement 2.
Table 4. Results of multivariable random-effects regressions with six month integrated regulation as the dependent variable and engagement indicators as independent variables among intervention group participants providing six month data

<table>
<thead>
<tr>
<th>ENGAGEMENT VARIABLES</th>
<th>Univariable models</th>
<th>Multivariable models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>b (SE)</td>
</tr>
<tr>
<td>% intervention days participants walked for at least 10 mins captured via the PA monitoring system</td>
<td>238</td>
<td>0.007 (0.002)</td>
</tr>
<tr>
<td>% intervention weeks participants logged onto the website</td>
<td>240</td>
<td>0.004 (0.002)</td>
</tr>
<tr>
<td>% earned points redeemed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Website sections**

| Monitoring and feedback | 240 | 0.03 (0.01) | 0.02 | 236 | 0.03 (0.01) | 0.02 |
| Rewards | |
| Maps | |
| Health information: PA | 240 | 0.11 (0.05) | 0.03 | |
| Health information: Other | |
| Discussion forums | 240 | -0.02 (0.01) | 0.03 | 236 | -0.02 (0.01) | 0.02 |
| Number of sections | 240 | 0.09 (0.03) | 0.01 | |

- Percentage of days participants were recorded walking for at least 10 mins captured via the PA monitoring system.
- Percentage of weeks participants logged onto the website at least once.
- Frequency of hits (i.e. total number of hits for every ten days the participant accessed the website).
- Number of sections accessed on website at least once (0-6).
- R-squared=0.59 for multivariable model. R-squared=0.50 for model including covariates only (i.e. stratum, season, baseline pedometer steps/day and baseline integrated regulation).
- NB. Results are adjusted for stratum, season, baseline pedometer steps/day and integrated regulation with cluster-adjusted standard errors and p-values.
Objective 3

The median usage (i.e. the time by which 50% of participants’ usage had lapsed) was 26 days for use of the PA monitoring system to record daily activity (figure 1) and 13 days for use of the website (figure 2). Non-usage attrition of the PA monitoring system to record daily activity occurred for 89% of participants (n=375), and website non-usage attrition occurred for 96% of participants (n=403).
Figure 1. Survival curve for time to non-usage attrition for recording daily activity via the PA monitoring system (n=422)

This figure shows the percentage of intervention participants still using the PA monitoring system to record PA as time elapsed over the six month intervention period. The estimated median usage (i.e. after which 50% of participants had lapsed from use) was 26 days for use of the PA monitoring system to record daily activity. Non-usage attrition occurred for 89% of participants (n=375). The vertical section of the curve indicates that there were a proportion of participants who did not use the PA monitoring system to record daily PA within the first two weeks of the intervention period (approximately equal to 25% of the intervention group).
This figure shows the percentage of intervention participants still using website as time elapsed over the six month intervention period. The estimated median usage (i.e. after which 50% of participants had lapsed from use) was 13 days for use of the website. Non-usage attrition occurred for 96% of participants (n=403). The vertical section of the curve indicates that there were a proportion of participants who did not log onto the website within the first two weeks of the intervention period (approximately equal to 20% of the intervention group).
Univariable and multivariable Cox regression analyses are presented in supplement 3. The multivariable analysis for use of the PA monitoring system to record daily activity showed that having higher levels of identified regulation at baseline (hazard ratio [HR]=0.88, 95% CI: 0.81, 0.97), having higher levels of recovery self-efficacy at baseline (HR=0.88, 95% CI: 0.80, 0.98) reduced the risk of attrition. In contrast, having a higher perception of the safety of the workplace environment for PA at baseline (HR=1.07, 95% CI: 1.02, 1.11) was associated with a higher risk of attrition. The multivariable analysis for website use showed that having higher values on the EuroQol (EQ5D) weighted health index (HR=0.33, 95% CI: 0.12, 0.91), having higher levels of financial motivation at baseline (HR=0.93, 95% CI: 0.87, 0.99), or having a higher perception of the availability of PA opportunities in the workplace environment at baseline (HR=0.96, 95% CI: 0.93, 0.99) reduced the risk of attrition. Formal tests and visual inspection of plots showed no evidence for violation of the proportional-hazards assumption for the multivariable models.

Discussion

The present study examined whether overall engagement (i.e. using the PA monitoring system to record PA, accessing the study website, redeeming earned points for financial rewards) in a six month workplace PA intervention (i.e. the PAL scheme), and engagement with specific intervention components (i.e. specific sections of the website) was associated with PA and mediator outcomes at six months. Time to non-usage attrition for different intervention components and predictors of non-usage attrition (i.e. socio-demographic, mediator, environmental and PA variables) were also investigated. Due to the nature of the wait-list control, there is no available data on intervention engagement and non-usage attrition for the control group. Therefore we are cautious not to over-interpret the results and draw causal conclusions from these analyses.

Principal findings

This study found that overall levels of engagement with the intervention (i.e. using the PA monitoring system to record PA, accessing the study website) were not related to PA at six months in contrast to the findings of several previous studies [9,57]. One plausible explanation is that our indicators may not have sufficiently captured participants’ true levels of engagement. Time spent on the website was not included as a measure of...
engagement due to the unstructured nature of website access which meant that participants may have been engaging in other activities when logged on. Previous web-based intervention studies investigating engagement include the website as the main intervention component and require participants to spend a significant period of time online [13,14,27,30,31]. Furthermore, the website was a mode of intervention delivery for the PAL study (the main intervention components were the financial incentive; placing sensors in outdoor environment; self-monitoring). Therefore, time spent online is less relevant as an indicator of intervention engagement in the present study than for these previous studies. Instead, we assumed that a higher frequency of hits on a particular section of the website for every ten days of website use indicated higher levels of interest (and willingness to engage) in that aspect of the intervention. However, Baltierra and colleagues noted that even this may be problematic since it gives no indication of whether participants are reading and comprehending information, or merely clicking on the various sections [27]. Although the authors recommend general knowledge quizzes and assessments to determine the knowledge acquired by participants and their intervention exposure, they acknowledge that even these measures are subject to limitations. This illustrates the complexity inherent in measuring engagement in behaviour change interventions and the need for a standardised approach [58].

Examining intervention engagement as a whole may not be sufficient to explain PA behaviour change for this intervention, given the observed decline in PA for intervention participants. In particular, the use of multiple or multicomponent engagement measurements are recommended to track participant engagement in all the components of complex interventions [9]. Therefore, we also examined whether engagement with different intervention components was related to PA. The self-monitoring and feedback component was the most frequently accessed aspect of the website and a higher frequency of accessing it was associated with a significant increase in PA at six months. This finding may indicate that when participants focused more on the scheme’s self-monitoring and feedback aspects, this was associated with less of a decline in PA and is in line with the results of the study’s mediation analyses which found planning and habit formation are important mediators [5]. Previous research also shows that self-regulation techniques and self-monitoring are useful strategies for PA behaviour change [34,59–63] and one previous systematic review of web-based interventions also highlights that web-based self-monitoring is a potentially effective technique [64]. Redeeming a higher proportion of earned points for rewards was associated with slightly higher PA levels at six months. This finding
397expands upon the results of the study’s mediation analyses which found that financial motivation was not
398related to PA behaviour at six months, and proposed that it is possible that the participants did not find the
399financial incentives attractive enough to trigger behaviour change in the first place [5]. Specifically, it appears
400that when participants found the financial incentives desirable and redeemed their accumulated points, this
401was associated with less of a decline in PA. Previous studies have also shown that in order for financial
402incentives to be successful in inducing behaviour change, the reward on offer must be deemed worthwhile to
403the individual participant. For example, monetary value [65] or type (e.g. individual versus group-based) [66] of
404reward can impact its effectiveness for behaviour change.

405A higher frequency of accessing the discussion forum component of the website was associated with a
406significant decline in PA at six months. Discussion forums were included on the PAL website as means of
407providing social support for behaviour change. For example, it was expected that participants would use these
408forums to contact researchers and interact with other participants to support behaviour change. However, one
409potential reason for this result is that participants mainly used this component to make queries and report
410technological issues. This finding may indicate that participant frustration with some perceived limitations of
411the intervention, which were highlighted in a separate qualitative process evaluation [67], contributed to the
412overall negative impact on PA. One previous study finding negative intervention effects on PA behaviour
413concluded that reduced support for the intervention over time was a contributing factor and cited similar
414reasons (e.g. lack of variety in activities resulting in participant boredom, and restrictions on the availability of
415time or space) [68]. Interpreting our results in the context of what was learned in the study’s qualitative work is
416essential to tease out aspects of intervention engagement which cannot be captured by quantitative usage
417data [69].

Intervention engagement and mediator outcomes

419A higher frequency of accessing the website’s feedback and monitoring component was also associated with
420increases in integrated regulation (in addition to PA behaviour), further highlighting the importance of this
421particular intervention component. For example, there is evidence in the theoretical literature on SDT that
422more intrinsically motivated behaviour is more likely to be maintained since it fulfils basic psychological needs
423for competence, autonomy and relatedness to others [11]. In comparison, engagement with the financial
incentive component of the intervention (i.e. redeeming a higher proportion of earned incentives for rewards or a higher frequency of accessing the website’s rewards component) was not found to be related to levels of identified regulation, integrated regulation and intrinsic motivation. Thus this study contributes unique evidence to contravene one of the main criticisms of financial incentives which is highlighted in the SDT literature (i.e. that the use of financial incentives should have a ‘crowding out’ effect on intrinsic motivation for behaviours which are already internalised [70]). The present report provides further and supporting evidence for the findings of the study’s mediation analysis to suggest financial incentives do not necessarily diminish more internal forms of motivation when delivered as part of a complex multi-component behaviour change intervention [5].

**Non-usage attrition**

Non-usage attrition for use of the PA monitoring system and use of the website was high as most participants lapsed from using one, or both, features. High levels of attrition are commonly observed for use of web-based interventions, however program usage is generally expected to be higher for controlled trials compared to freely accessible programs as participants are more likely to be motivated and committed to taking part in the study [12]. Furthermore, a 2012 systematic review of web-based interventions [25] found an adherence rate of approximately 50% of participants. The definition of non-usage attrition (i.e. occurring at the time of the first two week lapse from intervention use) adopted in the present study may have contributed to the high levels of attrition observed. Whilst other studies of web-based PA interventions have adopted this definition, it may be less applicable to analysis of non-usage attrition in workplace interventions for which a two week lapse from intervention use may occur if a participant is on annual leave, or is absent from work for two weeks or more. Therefore, every two week lapse from intervention use may not indicate that the participant had intentionally ceased intervention use.

The results of the present analysis are consistent with findings in previous intervention studies showing that participants with higher reported health status at baseline (versus lower health status) [71] have decreased risk for non-usage. It has previously been observed that web-based interventions are frequently not successful in reaching individuals for whom health behaviour change is needed most (e.g. those with lower health status) [72]. Participants who were more financially motivated, had higher levels of identified regulation, or who had
higher levels of recovery self-efficacy at baseline, were at lower risk for non-usage in this study. Individuals with higher levels of financial motivation may have been encouraged to continue participation in the scheme over time in order to continue benefitting from financial rewards. There is evidence that identified regulation and recovery self-efficacy are constructs which are important for long-term behavioural maintenance [73–77]. Identified regulation refers to behaviour that is freely enacted based on the perceived value of its outcomes to the individual [78]. Individuals with higher levels of identified regulation may have been encouraged to engage in more continuous use of the intervention (i.e. recording daily activity via the PA monitoring system) to achieve these valued outcomes (e.g. improved health). Recovery self-efficacy refers to the individual's beliefs about their capability to return to PA following a lapse. Therefore, someone with higher levels of recovery self-efficacy has faith in their competence to regain control following a setback (i.e. period of inactivity) [79]. It makes sense that individuals with higher recovery self-efficacy would experience a longer period of intervention usage before encountering their first two week lull because they are quicker to recover from a lapse.

Finally, perceptions of the workplace environment were shown to be related to non-usage risk in this study. Since the intervention required participants to engage in PA in the outdoor environment of the workplace, it is plausible that their perceptions of the workplace environment with respect to PA may have influenced the use they made of the scheme. Certainly, the results of the study's moderation analysis would indicate that intervention effectiveness depended on participants’ perceptions of the workplace environment [5]. One important component of the PAL scheme was the provision of information on opportunities for PA in the workplace environment, and intervention participants had access to maps on the study website marking out suggested walking routes. There is evidence that supportive social and physical environments facilitate behaviour change maintenance by lowering the opportunity cost of behaviour [80]. Taken together, these results indicate it may be possible at baseline to identify those participants who are at the highest risk for non-usage attrition and to design-in strategies for retention.

Strengths and limitations

A strength of this study is the examination of engagement as separate individual indicators related to the different components (i.e. BCTs) of the intervention. Furthermore, previous studies have investigated whether
Engagement (or adherence) is predictive of behavioural outcomes [29,31,57,81] without consideration of how they may relate to psychosocial outcomes (i.e. mediators) targeted by the intervention and thought to lead to behaviour change. Non-usage attrition was assessed in relation to use of more than one intervention component (i.e. use of the PA monitoring system and the website) and this improves upon previous studies which typically assess non-usage attrition in relation to website use only [71,82–86].

Whilst previous research on engagement in intervention studies has compared engagement between an intervention arm and a comparison arm [14], we were unable to include comparable engagement (e.g. recording of daily activity and web usage) data from our control group due to the nature of the wait-list control. Our analysis is also limited to responders at six months (i.e. those who provided pedometer steps/day and mediator measurements). Furthermore, whilst measures of the frequency of hits on different sections of the website may indicate the participant’s level of interest in a specific intervention component, they do not capture how well the participant processed the information. However, although Yardley and colleagues highlight the limitations of reporting raw usage data as outcomes in a process evaluation, they highlight the utility to be gained from experimentally testing mediation of study outcomes by engagement with particular intervention components [69]. Another potential limitation is that only baseline variables were investigated as predictors of non-usage attrition. However, our goals were broadly similar to previous studies of predictors of non-usage attrition [85], the aim being to better describe the groups who will continue engaging in an intervention at enrolment. Finally, as previously discussed, our definition of non-usage attrition (i.e. occurring at the time of the first two week lapse from intervention use) may have contributed to the high levels of non-usage attrition observed due to participants potentially taking a two week period of annual leave or other absence from work. In general, there is difficulty in defining non-usage attrition in workplace interventions as any period of non-use may not be indicative of an intentional lapse from using the intervention. However, provided such unintentional lapses did not occur differentially between groups, it can be reasonably assumed that the results of the survival analyses, indicating groups of participants who were at higher risk for non-use, will not have been spuriously impacted.
Implications for future research

Lack of participant engagement and high levels of non-usage attrition are phenomena which restrict researchers' ability to assess the effectiveness of interventions. Therefore, future intervention studies should measure levels of engagement and non-usage with a view to making recommendations for retaining groups of participants who are at the highest risk for non-usage and lack of intervention engagement. This is particularly important for studies of web-based interventions which are known to be particularly susceptible to these phenomena [12]. Better guidelines on how to measure intervention engagement are needed. For example, whilst commonly used markers of engagement (e.g. the number of hits on certain website pages, time spent online) may indicate greater interest in different intervention components, they do not capture how much information is absorbed and processed. Regular knowledge quizzes may be helpful in this regard, but even these measures are problematic (e.g. it is unclear whether the results can be attributed to intervention delivery, the participant’s engagement, or another factor) [27]. The Medical Research Council guidance on developing and evaluating complex interventions currently makes no reference to intervention engagement and non-usage attrition [87] and their process evaluation guidelines refer to engagement in a general way [6]. How to measure and analyse engagement and non-usage in complex public health interventions is a key gap in the literature. Furthermore, researchers should consider developing engagement and retention strategies, tailored towards specific groups of participants identified as being at risk for low engagement and high levels of non-usage attrition. Such endeavours should make use of behaviour change theory and BCTs within intervention trials, using similar approaches to how interventions are currently designed for changing behaviour.

Survival analyses indicated that participant age, marital status and health status were associated with the risk of non-usage attrition in the present study. This finding accords with previous intervention studies. Future research should determine how to keep younger participants, and those with family commitments or in worse health engaged with interventions for their entire duration. For the present study, survival analyses also indicated that baseline levels of financial motivation, identified regulation, recovery self-efficacy and perceptions of the workplace environment were associated with non-usage. Future research should consider how to ensure that specific groups of participants keep engaged with the intervention. For example, researchers could make use of baseline data to identify participants who are at risk of non-engagement and
Interventionists should consider how to retain participants who are initially less financially motivated in studies whose main component is the offer of financial rewards. For studies of PA interventions requiring behavioural practice in the outdoor environment (as was the case for the current study), participants' perceptions of the environment with respect to PA are important influencing factors which should be considered for engagement and non-usage.

**Conclusion**

This analysis showed that more frequent use of the self-monitoring and feedback components of the intervention website (i.e. self-monitoring and feedback, goal setting), and the redemption of a higher proportion of earned points for financial rewards (i.e. immediate reward contingent on behaviour change) were associated with increases in PA at six months for intervention group participants in the PAL study. Conversely, more frequent use of website discussion forums (i.e. social support) was associated with decreases in PA at six months. One possible explanation for the negative association of discussion forum use with six month PA was that rather than making use of these forums to build social support for PA, participants generally used them as platforms to make queries or raise concerns. Therefore, it appears that the decline in PA behaviour at six months for intervention group participants was due, at least in part, to participant dissatisfaction with some perceived study limitations (e.g. technical glitches, limited financial rewards and PA opportunities for which rewards could be earned) which emerged in a separate qualitative process evaluation.[67]. Levels of intrinsic motivation were not associated with the percentage of rewards redeemed or with the frequency of accessing the reward component of the website. Therefore, in contrast to the hypothesis of SDT that offering financial rewards may ‘crowd out’ intrinsic motivation, our results support that intrinsic motivation is not necessarily diminished when rewards are offered as part of a complex multi-component intervention (e.g. a higher frequency of accessing some of the website’s other components was actually associated with higher intrinsic motivation). Rates of non-usage attrition were high and survival analysis showed that participants who were younger, married, or in worse health at baseline were at higher risk for non-use. This was supported by previous research finding that younger individuals, those facing greater time-presures (e.g. married participants with greater family commitments) or hard to reach groups (e.g. individuals in worse health) are more likely to stop engaging in interventions. Financial motivation, identified regulation, recovery self-efficacy, and perceptions of the environment were also risk factors for non-usage. Guidelines to
improve and measure engagement, and improve non-usage attrition, should be established and strategies incorporated into study design to ensure that participants adhere to the intervention in its intended form.
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Conflicts of interest

None declared.

Abbreviations

BCT: Behaviour change technique
DfE: Department for the Economy
EQ5D: EuroQol
GLS: Generalised least squares
MRC: Medical Research Council
MVPA: Moderate-vigorous intensity physical activity

NI: Northern Ireland

NIHR: National Institute for Health Research

PA: Physical activity

PAL: Physical Activity Loyalty

RCT: Randomised controlled trial

SCT: Social Cognitive Theory

SD: Standard deviation

SDT: Self-Determination Theory

SE: Standard error

SF-8: Short Form-8

WEMWBS: Warwick-Edinburgh Mental Wellbeing Scale
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