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Zooming in on the Effects: a Controlled Trial on Motivation and Exercise Behaviour in a Digital Context

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Abstract This study is a description of a short-term digital exercise intervention based on the theoretical framework self-determination theory and tested in a controlled trial. The sample consisted of 318 adult women (n = 279) and men (n = 40) aged 23–67 years (M = 46.7; SD = 9.4) participating in a digital step contest provided by their employer. All participants completed study baseline measures via validated web-based versions of the following instruments: Basic Psychological Needs in Exercise Scale, Behavioural Regulations in Exercise Questionnaire-2, and Leisure Time Exercise Questionnaire. These measures were repeated twice, 3 weeks (post-intervention) and 6 weeks (follow-up) after study baseline. The experimental group had access to the intervention platform for three weeks. Data were analysed by analyses of covariance and mediation variable analysis. Results showed the intervention to affect exercise level and intensity as well as basic psychological need satisfaction and behavioural regulations. Intervention effects on amotivation post-intervention were found to mediate total exercise behaviour at follow-up. Moderation analyses showed intervention effects on light exercise to be stronger for those participants engaging in moderate or high levels of light activities at study baseline. Also, the effect on identified regulation was stronger for those with low levels of identified regulation at study baseline. This study adds to the knowledge on exercise motivation based on short-term intervention effects on level and intensity of exercise and physical activity. The use of mediating and moderating analyses uncover processes underlying the main intervention effects. Findings are discussed in relation to self-determination theory and previous research.

Keywords Exercise · Intervention · Mediation · Moderation · Self-determination

Several diseases causing early mortality are related to lifestyle factors, and stimulating adherence to health recommendations for physical activity (PA) and exercise might have a considerable protective effect on mortality risk (Petersen et al. 2015). Moreover, the World Health Organization (2009) has stated the importance of sustainable and cost-effective PA-promoting interventions. The use of technology in health care carries potential to lessen costs for clinical contact and to reach more people than traditional care (Williams et al. 2014), to facilitate standardization and evaluations of potential effects (Patrick and Canavello 2011), and to develop decision tools facilitating access to and empowering choices about treatment for users (Marsch and Gustafson 2013). Technology could also fuel significant innovation in public health care models by putting the consumer in a central role, enabling customized care and services based on personal needs (Marsch and Gustafson 2013). In this paper we will examine the effects of a digital intervention aimed at promoting exercise motivation and behaviour. We will also investigate mediating and moderating effects of the intervention.

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Reviews studying the effects of such interventions have shown digital interventions for PA and exercise to have positive effects (Davies et al. 2012; Norman et al. 2007), at least in the short term. Encouraging health behaviour change via Internet has, nevertheless, proven to be quite a challenging task (Davies et al. 2012) and there is a need to deepen the understanding of the psychological and social processes behind effective intervention design (Baranowski et al. 1998; Pingree et al. 2010). Interventions should be firmly based in theory (Cerin et al. 2009; Pingree et al. 2010), which is particularly relevant in digital interventions because e-health involves dynamic interactions between users, providers and digital systems (Epstein and Street 2007). Theory provides a framework where the assumed theoretical constructs will mediate behaviour (Baranowski et al. 1998; MacKinnon et al. 2007), a process where the independent variable (i.e., intervention) will cause an effect on the dependent variable (i.e., behaviour) via postulated mediators (Cerin and Mackinnon 2009). The use of mediation analyses could limit future intervention costs (e.g., in terms of time commitments and participant recruitments) by aiming to change mediators instead of actual behaviours (Cerin et al. 2006) and thereby facilitating cost-effective and successful behaviour change programs (Baranowski et al. 1998; Cerin and Mackinnon 2009). In the construction of e-health intervention programs, the most straightforward approach would be to tailor the intervention backwards, targeting predicted mechanisms of change (i.e., the mediators) to attain the desired outcome (Pingree et al. 2010). Due to multiple mediator paths, which could be concurrently active and working differently for different people, this approach is easier said than done.

Tailoring and understanding e-health systems requires comprehensive theoretical frameworks, and contemporary research studies (Friederichs et al. 2015; Hesse 2008; Patrick and Canavello 2011; Pingree et al. 2010; Williams et al. 2014) suggest that self-determination theory (SDT; Deci and Ryan 1985; Deci and Ryan 2000) could be such a framework. SDT is a macro theory of motivation with relevance for intervention design through the emphasis on the mechanisms and processes of motivation and well-being in the areas of PA and exercise (Duda et al. 2014; Silva et al. 2011, 2010). The main focus in SDT is how behavioural outcomes are affected by autonomous and controlled motivation (i.e., motivation quality) and how the social context could facilitate or thwart optimal motivation by its ability to satisfy three basic psychological needs. The psychological need for *autonomy* refers to feelings of choice and volition; the need for *competence* involves feelings of effectiveness and confidence, and the need for *relatedness* signifies feelings of belonging and care (Deci and Ryan 1985, 2000). Within SDT, higher psychological need satisfaction is associated with more autonomous (or self-determined) motivation and psychological well-being, whereas thwarting of the psychological needs will lead to more controlled motivation, a finding supported in review studies and meta-analyses (Ng et al. 2012; Teixeira et al. 2012). Autonomous motivation includes intrinsic motivation (when engagement is motivated by enjoyment and interest) and identified regulation (when engagement is motivated by personal values and important goals; (Deci and Ryan 2000). Controlled motivation, on the other hand, contains introjected regulation (engagement is due to avoidance of negative feelings or enhancement of self-esteem) and external regulation (engagement is driven by pursuit of rewards or avoidance of punishments). Finally, the concept of amotivation represents a lack of self-determination and does not contain any motivation for behaviour (Deci and Ryan 2000). Internalization is the process whereby people embrace behaviours they previously engaged in as a response to their social environment. The process model (see Fig. 1) of how psychological need satisfaction and motivation quality relates to behavioural outcomes (see Fortier et al. 2012; Williams et al. 2006) allow for the study of these mechanisms in interventions via mediation analyses (Fortier et al. 2011), which is also applicable in e-health interventions (Pingree et al. 2010) and might help bridge the gap between theory and practice.

Cerin et al. (2009) highlighted that mediated effects constitute a simultaneous test of action theory links (if the intervention had any effect on the mediator) and conceptual theory links (whether changes in the dependent variable were influenced by the mediator). When examining the mediation capacity of a theory, one must also consider action and conceptual theory links because they constitute important foundations of mediation (Cerin and Mackinnon 2009). Rhodes and Pfaeffli (2010), in their review, found that action theory links were more often reported than conceptual theory links, but they also found that many of the interventions studied in their review failed to bring about the desired outcome (PA behaviour) as well as the mediators according to action theory links. Reviewing a few robust intervention trials (e.g. Duda et al. 2014; Silva et al. 2011; Silva et al. 2010; Fortier et al. 2012), support for the suggested mediational links in the SDT process model are commonly reported, but conceptual or action theory links are not explicitly discussed. It seems evident that in-depth studies of mechanisms in SDT-related phenomena are still limited and previous suggestions for further examination of these links (Rhodes & Pfaeffli, 2010; Cerin et al. 2009) remain pertinent.

It is valuable to examine potential moderators, because both indirect and main effects can be affected by these third variables (Hayes 2009) and moderator analysis could help clarify which features in an intervention yield the largest effects and reveal for whom the effects are larger or smaller. Moderator analysis could aid the tailoring of effective interventions adapted to certain subgroups (van Stralen et al. 2010). One reason many interventions show only small overall effects in terms of behaviour change could actually be an

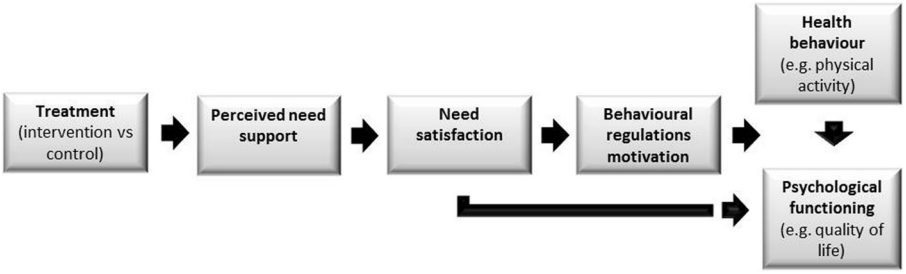

Fig. 1 (SDT process model) figure text: "From Fortier et al. 2012, p 3"

absence of moderation analyses that could reveal where and for whom the intervention was most effective (Hardcastle and Hagger 2016). In this way target groups might be reached through targeted messages and tailored intervention content, for example, based on moderators such as patterns and segmentation of psychographic profiles (Hardcastle and Hagger 2016) aiming to understand values, interests and lifestyle factors influencing needs and motives of participants (Walker et al. 2014) by adding knowledge about what will work and for whom (i.e., the "what" and "why"; French et al. 2011).

It has been questioned whether internet-based interventions are capable of stimulating sustainable behaviour change (Davies et al. 2012), but results from a recent computer-tailored intervention in PA (Friederichs et al. 2015) is one of the first to show long-term effects and maintenance of PA levels after 12 months follow-up. The Friederichs et al. study holds great promise for the application of SDT in computer-tailored interventions. Several rigorous trials on PA and exercise have demonstrated SDT-based interventions have long-term effects on behaviour, ranging from one up to three years documented maintenance in face-to-face programs (Duda et al. 2014; Fortier et al. 2012; Silva et al. 2011). Given the belief that SDT can be adequately applied in a digital context (Hesse 2008; Pingree et al. 2010), the results from Friederichs and colleagues (Friederichs et al. 2015) might be considered promising also for digital interventions having potential to stimulate sustainable behaviour change and to promote well-being. Bearing in mind the need for adequate and effective theory-driven interventions in PA and exercise (Baranowski et al. 1998; World Health Organization 2009; Patrick and Canavello 2011), the purpose of this study is to examine the motivational processes regulating exercise behaviors through a digital intervention program, building on the different steps of the SDT process model.

Aims

The main focus of this intervention study was to examine different paths in the SDT process model and the effects of a digital intervention on exercise and PA through a controlled trial over 6 weeks. More specifically, we tested: (a) if the intervention would affect exercise level and intensity, (b) if the intervention would affect psychological need satisfaction and motivation quality, and (c) if potential intervention effects would be mediated according to the SDT process model.

Methods

Participants

Participants were 318 working adults participating in a digital step contest provided by their employer(s). Of these 318 adults, 187 participated in all three measurement points. The sample consisted of adult women (n = 278) and men (n = 40) aged 23–67 years (M_{age} = 46.7; SD = 9.4) recruited from different companies. The sample was expected to vary in both demographic (e.g., type of profession, gender, age) variables and geographic location. Participants were stratified by age and gender and assigned to either control (n = 152) or experimental (n = 166) group (see Online resource 1). Eighty-five of the 166 individuals assigned to the experimental group logged in to the digital intervention platform at least once, and they were considered "treated as intended" (TAI), hence 81 participants from the experimental group were unexposed to the intervention. Consequently, the main analyses will be conducted comparing three groups (TAI, unexposed experimental group and control group). Dropout analyses (t-tests) showed that participants with high amotivation levels at Time 2 were more likely to drop out from the study.

Measures

Psychological Need Satisfaction The Basic Psychological Needs in Exercise Scale (BPNES; Vlachopoulos and Michailidou 2006) measured psychological need satisfaction in autonomy, competence and relatedness using 12 items and a 5-point Likert scale ranging from 1 (*I don't agree at all*) to 5 (*I completely agree*). Cronbach's alpha for the BPNES subscales ranged from .84 to .93. Validation studies have shown that the BPNES reflects the constructs of SDT (Vlachopoulos and Michailidou 2006) as well as gender invariance (Vlachopoulos 2008) and cross-cultural validity (Weman-Josefsson et al. 2015a; Vlachopoulos et al. 2010). The BPNES results in a total score as well as separate subscale scores.

Behavioural Regulations Behavioural Regulations in Exercise Questionnaire-2 (BREQ-2; Markland and Tobin 2004) has been validated in several translated versions (Moustaka et al. 2010; Murcia et al. 2007; Palmeira et al. 2007; Weman-Josefsson et al. 2015a). This scale measures amotivation and external, introjected, identified and intrinsic regulations via 19 items on a 5-point Likert scale ranging from 0 = (*not true for me*) to 4 (*very true for me*). The external and introjected regulation subscales were summed and averaged for the new factor "controlled motivation," and the identified and intrinsic regulation subscales were summed and averaged for the new factor "autonomous motivation" as recommended by previous research (Vansteenkiste et al. 2008).

Self-Reported Exercise The Leisure Time Exercise Questionnaire (LTEQ; Godin and Shephard 1985, 1997) measured self-reported exercise for weekly rates of: (a) strenuous, (b) moderate and (c) light exercise. Strenuous exercise scores were then multiplied by 9, the scores of moderate exercise by 5, and the scores of light exercise by 3 before adding them collectively into a total exercise score of metabolic equivalent of exercise (MET). These score adjustments are standard procedures with this instrument to obtain a composite score of exercise energy expenditure. The LTEQ has been tested for test-retest reliability (Godin and Shephard 1985; Jacobs et al. 1993) and for construct validity (Wilson et al. 2010) and has been confirmed to relate to objective (accelerometer) measures (e.g., Jacobs et al. 1993).

Procedure

Methodological characteristics of the intervention trial are presented in Tables 1–2 (see Online resource 2). The translation and validation of the instruments is documented in a previously published paper (Weman-Josefsson et al. 2015a). Participants were invited to the study via the web company's regular information systems (e-mail, notification and web site bulletin boards). They were provided with study information (aim, ethical concerns and practicalities) and a web link to an informed consent check, containing the same information package, a tick-in-the-box and e-mail registration procedure. After informed consent, they were informed that they would be contacted a week later with a link to the web survey. The registered e-mail addresses of the voluntarily enrolled participants was then, via customized software, transformed into anonymous ID numbers, enabling cross-reference for the three measure points to each individual participant without personal identification and also allowing longitudinal reference for each case. The list connecting e-mail addresses to the ID numbers was stored separate from the collected data in accordance with local university ethical and IT regulations and accessible only by the chief researcher. No personal data except e-mail addresses was requested. After this procedure, the participants were stratified by age and gender and randomly assigned to experimental or control groups using software algorithms specifically designed for this study's purpose.

Intervention timeline is presented in Fig. 2. All participants received three automatically generated e-mails (based on the registered e-mail addresses provided) with a link to the web survey and the information package at 3-week intervals over 6 weeks (T1: study baseline, T2: post intervention and T3: follow-up). Each time they signed in with the same e-mail address as user name and a freely selected password. The e-mail service system was connected to the web survey system, and 1 week after each of the three measurement points it automatically dispatched a reminder to those who had not filled out the web form. In addition to these e-mails, the experimental group received an e-mail with a web link to the intervention application, with weekly reminders and "teasers" with intervention article contents. Due to the system synchronization, access to the intervention application for the experimental group was granted first after completion of T1. The control group received weekly e-mails with general health information and relevant web links. The ten participants (from experimental and control group collectively) first completing all three measure points (time was logged by the system) received an activity bracelet (worth approximately €50). The total process spanned 9 weeks in total, from February to April 2015 (see Fig. 2). The intervention trial was approved by the regional ethics board (Dnr. Etik 2014/336) and guided by the CONSORT and TIDiER checklists (See Online resources 3–4).

Intervention Content The intervention took place in relation to a workplace step contest. Because no participants could be invited before they had registered for the step contest, study baseline measures took place approximately 1 week after the contest had started. The step contest finished 2 weeks after T2 (i.e., post-intervention). In addition to the regular web service available for all step contestants, the experimental group also had access to the intervention (a digital platform adaptable to tablet/smartphone) for 3 weeks. From a SDT perspective, the underlying intention was to influence participants' exercise behaviours by manipulating the suggested causal mechanisms described in the process model, that is, through facilitating internalization by providing digital autonomy support, structure and involvement. The manipulation was done by constructing a digital intervention package using approaches for web based interventions recommended in previous research such as goal-setting support (Abraham and Michie 2008; Pingree et al. 2010) represented by information articles and opportunity to write down goals inside the tool, regular contact with the participants using e-mail (Brouwer et al. 2011; Plotnikoff et al. 2005), prompts and

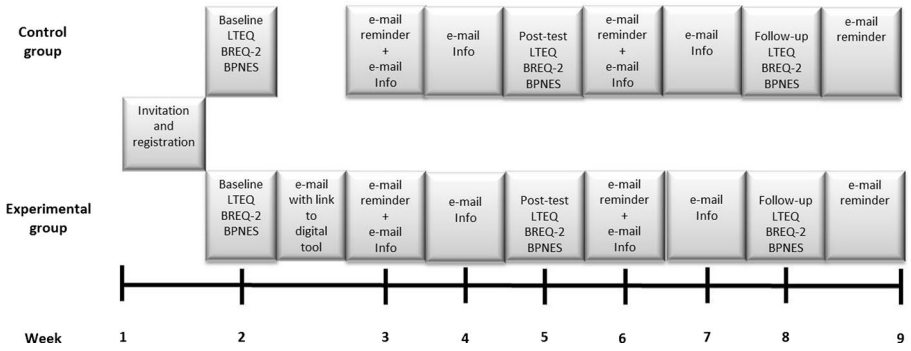

Fig. 2 Intervention timeline

social functions (Abraham and Michie 2008), e.g. possibility to anonymously share type, duration and appreciation (using a smiley) of exercise with other participants and health literacy (Pingree et al. 2010). See also Vandelanotte et al. (2014). Because no single theory may suffice for explaining complex behaviour, SDT was complemented by other behavioural models (see also Weman-Josefsson et al. 2015a). At the initial login occasion, the participants answered four questions to determine their current stage of change according to TTM and then automatically got a number of articles with exercise and PA-related information tailored to this stage prompted on the welcome page. Intervention delivery was not sequenced. The prototype did not include possibilities for interaction with professionals (e.g. tailored feedback or advice), but autonomy- and competence-need support was provided in terms of exercise and health literacy articles organized in four categories (health, lifestyle changes, inspiration and tips & facts). The aim was to provide instructions to meaningful rationale while also acknowledging negative feelings, and using non-controlling language, offering choice and encouraging inner motivational resources as recommended for face-to-face interventions (Fortier et al. 2011; Su and Reeve 2011), translated into written instructions and information. Another ambition was to provide motivational readiness/stage-based support for appropriate goal setting/modification, exercise-barrier identification, relapse prevention and health-related exercise rationale (see Kahn et al. 2002; Larimer et al. 1999; Ogilvie et al. 2007; Stetson et al. 2005). The potential significance of identified regulation found in previous research (e.g., Teixeira et al. 2012; Weman-Josefsson et al. 2015b; Weman-Josefsson et al. 2015a) was considered when tailoring the intervention content. The need for relatedness was mainly tapped by failure normalization, the possibility to share and view posts (logged activities) from other participants and real life role model stories written and shared for this purpose (inspiration category). In sum, the lion part of the intervention consisted of written instructions and information. The digital intervention was developed within a larger interdisciplinary project described in Weman-Josefsson and colleagues (Weman-Josefsson et al. 2014), and the current study constitutes a test of the prototype tool.

Data Analysis

One-way ANOVAs were performed using the LTEQ (MET, strenuous, moderate, and light exercise), the BREQ-2 (amotivation, external, introjected, identified and intrinsic regulation along with controlled and autonomous motivation computations) and the three subscales of the BPNES (i.e., autonomy, competence, relatedness) to detect differences between the TAI-group, unexposed experimental group and control groups at the study baseline measurements. Instrument reliability was tested using Cronbach's alpha. According to recommendations (Cole and Maxwell 2003; Senn 2006), intervention effects were tested through analyses of covariance (ANCOVA), whereby the post-intervention and follow-up scores on exercise, psychological need satisfaction and motivational quality were compared in the control and two experimental groups, controlling for study baseline scores. The significance level for all tests was set to $p < .05$. To test indirect effects, multiple mediator and moderator models with a bootstrapping resampling approach was performed to calculate product-of-coefficients and an asymmetric 95 % confidence interval based on 5000 resamples (Preacher and Hayes 2004 ; Preacher and Hayes 2008). All mediation and moderation analyses were performed through the SPSS macro PROCESS, as recommended by Hayes (2013).

Results

No statistical differences between the three groups were found in the BPNES, BREQ-2 or LTEQ at study baseline.

Post-Intervention Differences

In terms of exercise behavior, participants in the TAI group displayed significantly higher total exercise $F(2245) = 3.29$, $p = .039$ (η^2 partial = .03), than the unexposed members of the experimental group and the control group did post-intervention (see Table 1). There were no significant effects on exercise at

Table 1 Means (M) and standard deviations (SD) of study variables at study baseline, post-intervention and follow up and between-group differences post-intervention and follow up

	Control group	Unexposed experimental group	Treated as intended	Between-group differences post-intervention and follow up		Effect size
	M (SD)	*M (SD)*	*M (SD)*	*F*	*p*	η^2
BPNES – Autonomy	(*n* = 100)	(*n* = 34)	(*n* = 59)			
Study baseline	3.38 (0.91)	3.43 (1.11)	3.40 (0.94)	0.86	.424	-
Post-intervention	3.45 (0.91)	3.33 (1.04)	3.57 (0.85)	0.30	.741	.57
Follow up	3.24 (0.81)	3.00 (0.91)	3.88 (0.74)	16.80	.000	.15
BPNES – Competence	(*n* = 100)	(*n* = 34)	(*n* = 59)			
Study baseline	3.14 (0.93)	3.14 (0.97)	3.03 (0.92)	0.38	.683	-
Post-intervention	3.19 (0.84)	3.00 (0.97)	3.26 (0.86)	1.09	.336	.01
Follow up	3.26 (0.88)	3.01 (0.95)	3.27 (0.89)	1.41	.248	.02
BPNES – Relatedness	(*n* = 100)	(*n* = 34)	(*n* = 59)			
Study baseline	3.31 (1.01)	3.21(1.03)	3.31 (1.12)	0.23	.796	-
Post-intervention	3.43 (0.96)	3.08 (1.10)	3.45 (1.03)	2.15	.119	.02
Follow up	3.42 (1.11)	3.08 (1.13)	3.50 (1.09)	0.40	.672	.00
BPNES Global Need	(*n* = 100)	(*n* = 34)	(*n* = 59)			
Study baseline	9.82 (2.50)	9.78 (2.79)	9.75 (2.51)			
Post-intervention	10.08 (2.33)	9.43 (2.83)	10.3 (2.25)	0.02	.980	-
Follow up	9.92 (2.35)	9.09 (2.60)	10.82 (2.11)	1.48	.230	.01
				4.48	.013	.06
BREQ2 – Amotivation	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	0.12 (0.31)	0.09 (0.31)	0.12 (0.31)			
Post-intervention	0.55 (0.35)	0.14 (0.49)	0.08 (0.19)	0.29	.796	-
Follow up	0.35 (0.52)	0.14 (0.31)	0.08 (0.52)	1.33	.267	.01
				5.87	.003	.06
BREQ2– Extern.Reg.	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	0.26 (0.51)	0.31 (0.52)	0.29 (0.52)			
Post-intervention	0.52 (0.61)	0.64 (0.71)	0.29 (0.56)	0.69	.505	-
Follow up	0.31 (0.57)	0.26 (0.48)	0.27 (0.52)	9.10	.000	.09
				0.85	.429	.01
BREQ2 – Introj. Reg.	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	1.77 (0.88)	1.83 (0.92)	1.80 (0.92)			
Post-intervention	1.88 (0.90)	1.89 (0.86)	1.71 (1.00)	0.87	.831	-
Follow up	1.94 (0.96)	1.63 (1.02)	1.63 (0.98)	1.62	.198	.02
				2.54	.081	.03
BREQ2 – Ident.Reg.	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	2.99 (0.70)	2.87 (0.89)	2.83 (0.82)			
Post-intervention	3.07 (0.69)	2.93 (0.59)	3.01 (0.90)	1.16	.315	-
Follow up	3.10 (0.71)	2.71 (1.04)	3.04 (0.76)	0.15	.985	.00
				1.52	.221	.02
BREQ2 – Intrin.Reg.	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	3.00 (0.80)	2.99 (0.98)	2.96 (0.87)			
Post-intervention	3.04 (0.73)	3.04 (0.84)	3.04 (0.92)	0.70	.500	-
Follow up	3.05 (0.81)	2.88 (1.24)	3.17 (0.67)	1.10	.896	.00
				1.44	.239	.02
BREQ2 – Cont-Mot.	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	1.01 (0.56)	1.07 (0.59)	1.09 (0.59)			
Post-intervention	1.20 (0.56)	1.26 (0.65)	1.00 (0.65)	0.50	.609	-

Table 1 (continued)

	Control group	Unexposed experimental group	Treated as intended	Between-group differences post-intervention and follow up		Effect size
	M (SD)	*M (SD)*	*M (SD)*	*F*	*p*	η^2
Follow up	1.13 (0.55)	1.04 (0.61)	0.96 (0.61)	6.56	.002	.06
				3.31	.039	.03
BREQ2 – Aut-Mot.	(*n* = 98)	(*n* = 38)	(*n* = 57)			
Study baseline	5.99 (1.43)	5.87 (1.79)	5.70 (1.55)			
Post-intervention	6.10 (1.31)	6.0 (1.34)	6.05 (1.76)	0.99	.373	-
Follow up	6.16 (1.40)	5.59 (2.22)	6.06 (1.53)	0,21	.979	.00
				1.30	.274	.01
LTEQ –MET	(*n* = 102)	(*n* = 42)	(*n* = 64)			
Study baseline	51.38 (23.93)	53.00 (26.32)	48.02 (22.51)			
Post-intervention	55.30 (30.33)	53.96 (34.96)	65.27 (37.66)	0.86	.424	-
Follow up	49.30 (23.73)	48.26 (26.09)	50.94 (23.62)	3.29	.039	.03
				0.97	.381	.01
LTEQ –Stren.Exrc.	(*n* = 102)	(*n* = 42)	(*n* = 64)			
Study baseline	20.63 (15.89)	19.71 (16.23)	19.75 (15.71)			
Post-intervention	25.17 (18.81)	22.50 (22.78)	30.49 (21.11)	0.77	.465	-
Follow up	22.06 (16.69)	16.50 (15.13)	19.97 (16.21)	2.37	.095	.02
				1.42	.244	.01
LTEQ –Mod.Exrc.	(*n* = 102)	(*n* = 42)	(*n* = 64)			
Study baseline	17.67 (13.18)	18.57 (14.90)	18.19 (13.92)			
Post-intervention	19.42 (13.10)	18.82 (12.54)	22.01 (13.93)	0.27	.767	-
Follow up	16.60 (11.74)	18.69 (11.27)	19.30 (16.01)	0.99	.370	.01
				0.36	.699	.00
LTEQ –Light Exrc.	(*n* = 102)	(*n* = 42)	(*n* = 64)			
Study baseline	13.19 (11.47)	14.71 (11.98)	11.05 (10.57)			
Post-intervention	10.83 (9.30)	12.27 (8.86)	12.76 (11.05)	1.95	.144	-
Follow up	10.82 (8.88)	13.07 (11.99)	11.67 (11.64)	2.66	.072	.02
				1.30	.276	.01

Study baseline = One-way ANOVA. Betweeen-group differences = *ANCOVA*, controlling for T1. *Reg.* Regulation. *Cont-Mot.* Controlled Motivation, *Aut-Mot.* Autonomous Motivation, *Exrc.* Exercise, *MET* metabolic equivalent of exercise (total exercise), a weighted score, *n* number of participants included in all three analyses of this variable

follow-up $F(2204) = 0.97$, $p = .381$. Furthermore, the TAI group showed significantly higher autonomy need satisfaction $F(2, 189) = 16.80$, $p = .000$ (η^2 partial = .15) and global need satisfaction $F(2, 189) = 4.48$, $p = .013$ (η^2 partial = .06), but lower amotivation $F(2, 189) = 5.87$, $p = .003$ (η^2 partial = .06) at T3 (follow-up measures) than the two other groups. The TAI group reported significantly lower levels of external regulation $F(2, 189) = 9.10$, $p = .000$ (η^2 partial = .09) post-intervention and significantly lower controlled motivation both post-intervention $F(2, 189) = 6.56$, $p < .002$ (η^2 partial = .06) and at follow up $F(2, 189) = 3.31$, $p < .039$ (η^2 partial = .03) than the participants in the two other groups. Except for the large effect size for autonomy need satisfaction (.15), the partial eta-squared were medium sized (.03–.09) for ANCOVA analyses (Cohen 1988).

Mediation (Indirect) Effects

Because no differences were found between the two control groups (the original control group and the unexposed experimental group) in the main analyses, we grouped them together (comparing them against the TAI-group), resulting in two levels for the independent variables rather than three, when examining mediation effects of regulations and psychological needs on exercise. Only one mediation effect was found (see Fig. 3). There was an indirect effect of amotivation post-intervention ($\alpha\beta$ 1.40; 95 % *CI* = 0.37–2.94) in the effect of the intervention on total exercise (MET) at follow-up. Both the *a*-path ($\beta - 0.11$; 95 % *CI* = −0.21- -0.01) as well as the *b*-path ($\beta - 12.55$; 95 % *CI* = −22.86- -2.25) were significant. The TAI group reported lower amotivation level post-

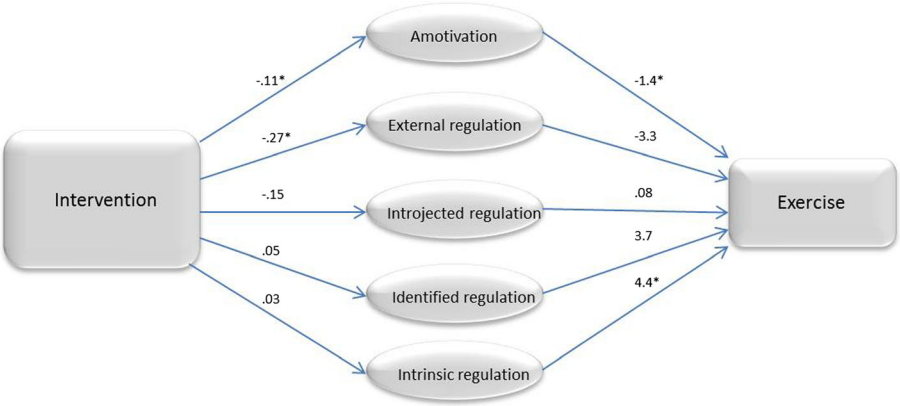

Fig. 3 Mediation model for amotivation, depicting a-paths and b-paths

intervention, which in turn predicted higher exercise score at follow-up. For the other examined variables, there were significant *a*-paths between post-intervention measures and follow-up for external regulation (β − 0.27; 95 % *CI* = −0.44- -0.09) and controlled motivation (β − 0.21; 95 % *CI* = −0.39- -0.03) and significant *b*-paths in intrinsic motivation (β 4.35; 95 % *CI* = 0.38–8.23), and autonomous motivation (β 2.29; 95 % *CI* = 0.08–4.51).

Testing a model using psychological need satisfaction as mediating variables between intervention and exercise, *a*-paths were found between autonomy need satisfaction (β 6.67; 95 % *CI* = −3.19- -10.16), competence need satisfaction (β 7.03; 95 % *CI* = 2.27–10.69), relatedness need satisfaction (β 3.53; 95 % CI = 0.39–6.67) and global need satisfaction (β 2.53; 95 % *CI* = 1.21–3.85) between post-intervention and exercise at follow-up.

Moderating Effects of the Intervention

Moderation analyses showed that the effects of the intervention on light exercise post-intervention were stronger for those with moderate (β = 3.31, $p < .01$), or high levels (β = 8.81, $p < .01$), of light exercise at study baseline. The effects of the intervention on identified regulation at follow-up were stronger for those with low levels of identified regulation (β = 0.39, $p < .05$) at study baseline. Explained variance ranged between r^2 .33 to .58.

Discussion

The purpose of this intervention study was to design and test a digital intervention in a controlled trial, focusing on different steps in the SDT process model. The main questions were if the intervention would have an effect on exercise level and intensity, and if the intervention would influence psychological need satisfaction and behavioural regulations. We also examined potential mediating effects of the intervention. The most important findings were related to the main effects of the intervention and the mediating effect of amotivation in the intervention effect on total exercise.

The intervention was found to have positive effects on total exercise (MET), which is in line with previous studies showing digital interventions to have positive short-term effects on behaviour (Davies et al. 2012; Norman et al. 2007; Van den Berg et al. 2007). These results support the application of SDT in interventions aimed at increasing PA (Fortier et al. 2007) and exercise (Duda et al. 2014; Silva et al. 2011) and when using computer tailored programs (Friederichs et al. 2015; Hesse 2008; Patrick and Canavello 2011; Pingree et al. 2010; Webber et al. 2010; Williams et al. 2014). The results also add to a growing body of literature advocating the benefits of theoretical foundations in applied work (e.g., Cerin and Mackinnon 2009; Lubans et al. 2008; Pingree et al. 2010). The participants exposed to the digital tool (the TAI group) reported lower scores on external regulation and controlled motivation post-intervention and also had lower levels of amotivation, but higher autonomy need satisfaction and global need satisfaction at follow up measures. These findings indicate that the intervention might be able to influence motivational regulations and psychological need satisfaction in line with previous studies showing SDT based interventions to have positive effects on targeted behaviours, psychological need satisfaction and motivational quality (Duda et al. 2014; Edmunds et al. 2008; Fortier et al. 2012; Silva et al. 2011). The decrease in controlled motivation and amotivation is interesting because the previous studies referred to above have not demonstrated significant decreases in controlled regulations and amotivation. Furthermore, the link between exercise and PA behaviour and controlled motivation or amotivation has been elusive in other studies (see e.g., the review by Teixeira et al. 2012).

Although the effect sizes and explained variances were generally moderate to small in size, the main results could be of practical importance (Ivarsson et al. 2013). As an example, even small effect sizes could be interpreted as meaningful when it comes to costs and benefits for a given population (Ivarsson et al. 2013), also called clinical significance

(Thompson 2002). Due to the ample amount of exercise correlates influencing behaviour (Bauman et al. 2012); also a small percentage of variance explained in exercise level and intensity might be of importance for health related costs/benefits on a population level. For example, a small difference between groups in energy expenditure (MET) might spawn weight loss that has positive health effects (i.e. lower risk of diabetes, colon cancer and so on, see e.g. Petersen et al. (2015). When it comes to improvements in motivation quality (e.g. decrease in amotivation and controlled motivation) this could be considered highly valuable if sustained, not only for potential influence on future behaviour, but according to SDT stipulates also for increased quality of life. Furthermore, the significance of finding out how to motivate the unmotivated has also been stressed (Hardcastle and Hagger 2016) and adding adherence to physical activity behaviours would have considerable protective effects on mortality risk (Petersen et al. 2015).

Moving into the process model, only one indirect effect was found when mediation effects were tested across time. The participants exposed to the intervention tool reported lower amotivation level post-intervention, which in turn predicted higher total exercise score at follow-up. This specific path has not been observed in the abovementioned trials and is of particular interest in several ways. First, as many as 30 % of individuals lack the intention to exercise (Rhodes and deBruijn 2013) and Thøgersen-Ntoumani and Ntoumanis (2006) found that amotivated individuals could not find reasons to act and had both low intentions and adherence to health behaviours. Second, to "motivate the unmotivated" is acknowledged as a significant challenge in the promotion of health behaviours (Hardcastle et al. 2015; Miller and Rollnick 2013; Peters et al. 2013). The additional display of a significant (negative) *a*-path, seems to further strengthen the intervention's proposed ability to affect amotivation in a desired direction by verifying an action theory link (Cerin et al. 2009). Moreover, the significant (negative) *b*-path support conceptual theory links by indicating that different amotivation levels predicts different levels in exercise behaviour (Cerin et al. 2009). These analyses might be an indication the intervention possibly could be more helpful for those who could be considered to need it the most, although additional trials will be needed to support such an assumption.

Although lacking indirect effects, looking more closely at the different paths in the model as recommended by previous research (e.g. Rhodes and Pfaeffli 2010; Cerin et al. 2009), we also found action theory links (i.e., the effect of the intervention on potential mediators) for the intervention effect on external regulation and controlled motivation. These results reveal that the intervention did seem to generate positive effects in line with theoretical expectations on changes in regulations of lower motivation quality. Regarding conceptual theory links (i.e. the effect of the mediator on outcome), these were found for autonomy, competence and relatedness need satisfactions, as well as for intrinsic motivation and the autonomous motivation factor. These links are in expected directions as well and confirm SDT tenets of how these constructs relate to behavioural outcomes (Deci and Ryan 2000; Fortier et al. 2012; Ryan and Deci 2002; Williams et al. 2006) also applied in a digital context (Pingree et al. 2010).

To better understand intervention effects and the mechanisms of intervention efficacy, moderation analyses have been strongly advocated (Hardcastle and Hagger 2016; Hayes 2009; Weman-Josefsson et al. 2015a). Overall, the general trend in the current analyses was that most effects did not differ between sub-groups. For example, moderation analyses showed that no intervention effects were moderated by participant characteristics such as gender or age. On the other hand, moderation analyses showed that the effects of the intervention on light exercise post-intervention were stronger for those with moderate or high levels of light exercise at study baseline, which means that the intervention seemed to have had most effect on exercise behaviors in those who were already engaging in light activities to a certain degree. Conceivably, those mainly partaking in more vigorous activities already had a solid foundation for their engagement, a possible explanation supported by findings in previous studies (Weman-Josefsson et al. 2015b; Weman-Josefsson et al. 2015a) where strenuous exercise was related both exercise behavior and SDT variables. The current intervention was mainly designed to support exercise initiation and maintenance via autonomy need support, internalization and relapse prevention, but not so much adapted to experienced and/or committed exercisers who might have well established desires and preferences. Looking at specific regulations, the effects of the intervention on identified regulation at follow-up was stronger for those with low levels of identified regulation at study baseline. This indicates that the efforts to facilitate identified regulation in tailoring the intervention might have been successful. Altogether, the current results follow core postulations of motivation quality (Deci and Ryan 2000) and the related parts of the SDT process model (Fortier et al. 2012; Pingree et al. 2010; Williams et al. 2006).

The tailoring of this particular intervention show some promise from an SDT perspective and especially interesting potential in "motivating the unmotivated," which plausibly was supported by the inclusion of relapse prevention strategies and the intervention articles tailored for the different stages of change (e.g. the texts regarding relapse prevention strategies could have helped participants to understand and overcome potential obstacles). The general decrease in levels of many of the variables examined between post-intervention and follow-up could be logically explained by the step contest setting and that the competition

ended between these two measurement points. In spite of this decline, we found significant intervention effects and mechanisms in some paths of the process model, supporting intervention tool utility in this particular context, perhaps buffering potential adverse (need thwarting) effects of competitive settings. The analyses of moderation and mediation also enable deeper scrutiny of the psychological processes tapped in the intervention (Baranowski et al. 1998; Hardcastle and Hagger 2016; Pingree et al. 2010) and their relationships with the improvements in exercise levels.

Strengths and Limitations

The main strengths of this study were the controlled design with three measurements points, the use of recommended mediation analyses with documentation of action and conceptual theory links in the relation between the intervention and targeted variables and the moderation analyses. No unexpected disparities were found in the drop-out analysis, and high drop-out is quite common in this type of study (Elfeddali et al. 2012; Eysenbach 2005; Friederichs et al. 2015; Peels et al. 2013), but because only half of the original experimental group actually logged on to the intervention tool, drop-out might have influenced power and analysis precision. Also, despite using a well-documented instrument (Jacobs et al. 1993; Wilson et al. 2010), self-report measures are subject to biases and the use of objective measures would be highly beneficial for future studies (Fortier et al. 2012; Teixeira et al. 2012). Being a small-scale and short-term trial, some interpretations could be more practically or clinically important in the real world of exercise and PA than statistically significant (Ivarsson et al. 2013). It is important to note that the intervention was a prototype platform, and interacting features for communication and feedback were not included, hence representing a substantial divergence from more interactive digital tools or from face-to-face interventions with personal counselling.

Conclusions

This study adds to the knowledge on how digital tools based on SDT might affect motivation quality towards more self-determined forms of motivation and to influence positive behavioural change (i.e., increased level and intensity of exercise and PA) over the course of 6 weeks. Through the use of mediating and moderating variables, we could also test the ability of SDT to shed light on the process underlying the main intervention effects. Notably, the intervention had the strongest effects on those participants who were engaging mainly in light activities, and with low levels of identified regulation at study baseline. The most interesting discoveries were related to amotivation, which was involved in significant main (time) effects, as well as in mediating the intervention effects. One future avenue for better understanding of the mechanisms found in this study would be to study how social contexts might differ in autonomy support or opportunities of barrier management.

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Author's Contributions KWJ participated in the study design, data collection, drafting and finalizing the manuscript and was responsible for the statistical analyses. ML supervised and participated in the writing process, and UJ participated in study design and manuscript writing. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Competing Interests The authors declare that they have no competing interests.

Ethics, Consent and Permissions The intervention trial was approved by the regional ethics board (Dnr. Etik 2014/336) and guided by the CONSORT checklist. Participation was voluntary and all respondents completed informed consent.

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