



# Exploring the working mechanisms of a web-based physical activity intervention, based on self-determination theory and motivational interviewing



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## ABSTRACT

The aim of this study was to compare a web-based computer tailored physical activity intervention based on self-determination theory and motivational interviewing (I Move) to a traditional web-based computer tailored physical activity intervention (Active Plus) with regard to their basic psychological need supporting capabilities. We also aimed to assess the extent to whether self-determination constructs played a stronger mediating role in the effects of I Move than in the effects of Active Plus. A randomized controlled trial was conducted among 3089 participants (age  $44.9 \pm 12.9$ , 69.1% women), comparing 1) I Move, 2) Active Plus, and 3) a waiting list control condition. Physical activity behavior (measured at baseline, and at six months after baseline), potential mediators (intrinsic motivation, identified regulation, perceived competence and perceived choice, measured at baseline, and at three months after baseline) and basic psychological need support (measured six weeks and six months after baseline) were assessed through self-report, using web-based questionnaires. I Move was found to be more effective in supporting participants' basic psychological needs (sessions 1 and 2;  $p = .001$ ; sessions 3 and 4;  $p = .004$ ). The results of the mediation analyses show that the effects of both interventions were (equally) mediated by perceived competence, but not by intrinsic motivation, identified regulation or perceived choice.

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## 1. Introduction

Web-based computer tailored physical activity (PA) interventions are promising for PA promotion (Enwald and Huotari, 2010; Laplante and Peng, 2011; Davies et al., 2012). The content of these interventions is modified according to participants' characteristics, and this makes them more likely to be effective than non-tailored, generic programs (Enwald and Huotari, 2010; Broekhuizen et al., 2012; Lustria et al., 2013). Because the intervention materials are provided via the internet, these programs can be used to reach large numbers of inactive individuals at relatively low costs (Lustria et al., 2013). To date most web-based computer tailored PA interventions have been grounded in traditional health behavior theories such as social cognitive theory (SCT), the trans-theoretical model (TTM) and the theory of planned behavior (TPB) (Davies et al., 2012). Interventions of this type, hereafter referred to as 'traditional interventions', make use of theoretical constructs such as stages of change, modeling, attitude and self-efficacy (Davies et al., 2012). Recent research on PA promotion, however, shows another

theoretical construct to be of major importance: autonomous motivation (Bagoien et al., 2010; Silva et al., 2011; Sweet et al., 2009; Sebire et al., 2011). Substantial evidence suggests that having higher autonomous motivation makes an individual more likely to undertake PA regularly and persist with a PA routine (Teixeira et al., 2012). Although the concept of autonomous motivation does not feature explicitly in SCT, TTM or TPB, it is central to self-determination theory (SDT) and motivational interviewing (MI) (Miller and Rollnick, 2013; Ryan and Deci, 2000). This suggests that web-based computer tailored PA interventions based on SDT and MI could be effective in promoting PA on a large scale.

In order to explore the effectiveness of using SDT and MI as the basis of web-based PA interventions, we developed I Move, a web-based computer tailored PA intervention, based on SDT and MI (Miller and Rollnick, 2013; Ryan and Deci, 2000; Friederichs et al., 2014a). I Move was shown to be effective in increasing PA behavior six months after the baseline assessment (Friederichs et al., submitted for publication). The present study was intended to investigate the processes by which I Move influences PA behavior, specifically whether these are consistent with SDT and whether they are different from those associated with traditional web-based computer tailored PA interventions. We begin with a brief overview of SDT and MI in general, and in the context of PA promotion.

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### 1.1. Self-determination theory and motivational interviewing

SDT is a comprehensive theory of behavioral motivation (Ryan and Deci, 2000; Deci and Ryan, 2008; Ryan et al., 2008) which has proved particularly useful in the context of PA research, both for accounting for patterns of PA behavior and for informing the development of interventions for promoting PA (Teixeira et al., 2012; Patrick et al., 2013). One of the key principles of SDT is that motivation varies in the extent to which it is autonomous or controlled (Ryan and Deci, 2000; Deci and Ryan, 2008). More specifically, SDT proposes several forms of motivation. In ascending order of autonomy these are: external regulation (i.e. execution of a specific behavior is motivated by a desire to avoid punishment or obtain reward); introjected regulation (i.e. execution of a specific behavior is motivated by a desire to avoid negative emotions such as guilt or shame); identified regulation (i.e. execution of the behavior in question produces outcomes which are valued by the individual); integrated regulation (i.e. behavior is executed because it is congruent with personal beliefs and values) and intrinsic motivation (i.e. the individual is motivated to execute a behavior because he or she finds it intrinsically interesting or enjoyable) (Ryan and Deci, 2000; Deci and Ryan, 2008). Both autonomous and controlled motivation are held to influence behavior, but to lead to different outcomes, with autonomous motivation leading to greater commitment and long-standing maintenance of behavior (Ryan and Deci, 2000; Deci and Ryan, 2008; Ryan et al., 2008; Markland and Ingledew, 2007).

SDT posits that individuals are more likely to exhibit autonomous motivation when three basic psychological needs are supported. These basic needs are the need for autonomy (i.e. the need to feel that one can choose one's behaviors), competence (the need to feel competent and confident) and relatedness (the need to feel connected to and understood by others) (Ryan and Deci, 2000; Deci and Ryan, 2008; Ryan et al., 2008). When these three needs are supported, individuals are enabled to develop autonomous motivation based on the feeling of being competent and in control of one's behavior (Vansteenkiste et al., 2007; Coroy et al., 2007). Several researchers have argued that the specific client-centered communication skills used in MI can be used to support client's basic psychological needs (Patrick et al., 2013; Patrick and Williams, 2012; Markland et al., 2005; Vansteenkiste et al., 2012).

Several SDT-based PA counseling interventions focused on supporting the participants' needs for autonomy, competence and relatedness have been developed and evaluated over the recent past years (Silva et al., 2011; Van Hoecke et al., 2013; Van Hoecke et al., 2014; Silva et al., 2008; Silva et al., 2010a; Duda et al., 2014; Jolly et al., 2009; Fortier et al., 2012; Fortier et al., 2007a; Fortier et al., 2011; Silva et al., 2010b). In general these interventions are effective in promoting a sustained increase in PA (Silva et al., 2011; Van Hoecke et al., 2013; Van Hoecke et al., 2014; Silva et al., 2008; Silva et al., 2010a; Silva et al., 2010b). Some studies have used mediation analysis to investigate whether SDT-based PA interventions exert their effects via the pathways specified by SDT (Silva et al., 2011; Sweet et al., 2009; Van Hoecke et al., 2013; Halvari et al., 2009). These studies have shown that the effects of the SDT-based PA intervention on PA behavior are mediated by autonomous motivation and/or perceived competence.

### 1.2. Research questions

Large scale PA promotion may benefit from the development of web-based computer tailored PA interventions, based on SDT and MI. To date, however, no research has investigated whether web-based computer tailored PA interventions based on SDT and MI are able to support participants' basic psychological needs; nor is it known how such interventions exert their effects. In particular there has been no research into whether the pathways specified by SDT are valid in the context of this type of PA intervention and whether the processes underlying the effects of web-based computer tailored interventions based on SDT and MI are different from those underlying traditional

web-based PA interventions. Indeed, web-based computer tailored PA interventions based on traditional theories may also influence SDT constructs such as autonomous motivation or perceived competence. However, the working mechanisms of an intervention that is specifically based on SDT may be more in line with SDT tenets than the working mechanisms of an intervention based on other theoretical frameworks.

The aim of this study was to compare the effectiveness of I Move (a web-based computer tailored PA intervention, based on SDT and MI) and a traditional web-based computer tailored PA intervention in supporting participants' basic psychological needs. We also explored the extent to which the effects I Move on PA behavior were mediated by intrinsic motivation, identified regulation, perceived competence and perceived choice and whether the mediation effects were stronger than for a traditional web-based computer tailored PA intervention. The conceptual mediation model for this study is presented in Fig. 1.

## 2. Methods

We conducted a randomized controlled trial using a protocol approved by the Medical Ethics Committee of Atrium-Orbis-Zuyd. The trial was registered with the Dutch Trial Register (NTR 4129).

### 2.1. Participants and procedure

Individuals were eligible to participate in this study if they were aged between 18 and 70 years old; were not seriously limited in their ability to be physically active, had not taken part in one of the pilot studies (Friederichs et al., 2014b; Friederichs et al., 2013) and were physically active for less than 60 min per day, 5 days per week (Friederichs et al., 2014a). A power calculation ( $ES = .25$ ; power = .80), indicated that data from 600 participants would be needed to investigate the effects of interest. Calculations based on a dropout rate of 40–70%, based on other studies on web-based interventions (Elfeddali et al., 2012; Peels et al., 2013), indicated that an initial sample of at least 2000 participants was required.

During the period September–December 2013 participants were recruited via advertisements placed in national newspapers and social media which contained a link to the study website, and via an online panel. The study website required individuals to indicate that they wanted to participate in the study by clicking on an 'I want to participate' button. After responding to the questions designed to establish that they met the inclusion criteria and giving informed consent participants were randomly assigned to one of the three research conditions by an automatic randomizer that was built into the website. After that, they were asked to fill in the baseline questionnaire. The three research conditions were 1) the I Move condition: participants in this condition received I Move, a web-based computer tailored PA intervention based on SDT and MI (Friederichs et al., 2014a); 2) the Active Plus condition: participants in this condition received Active Plus, a traditional web-based computer tailored PA intervention, based on TPB, SCT and TTM (Peels et al., 2012; van Stralen et al., 2008) and 3) the control condition: participants in this condition were placed on a waiting list (after completion of the RCT, these participants were routed to the I Move intervention). During the period September–December 2013, over 3000 participants were enrolled in the study.

Variables of interest were assessed at baseline, and three and six months later. All assessments were web-based questionnaires administered via the study website. Participants in the two intervention conditions were also asked to fill in a questionnaire six weeks after the baseline assessment. The responses to this questionnaire were used to tailor the content of the intervention; the questionnaire also elicited feedback about participants' experience of the intervention. To reduce attrition the participants who completed each separate questionnaire were entered into a prize draw offering ten €50 prizes (Robroek et al., 2009).

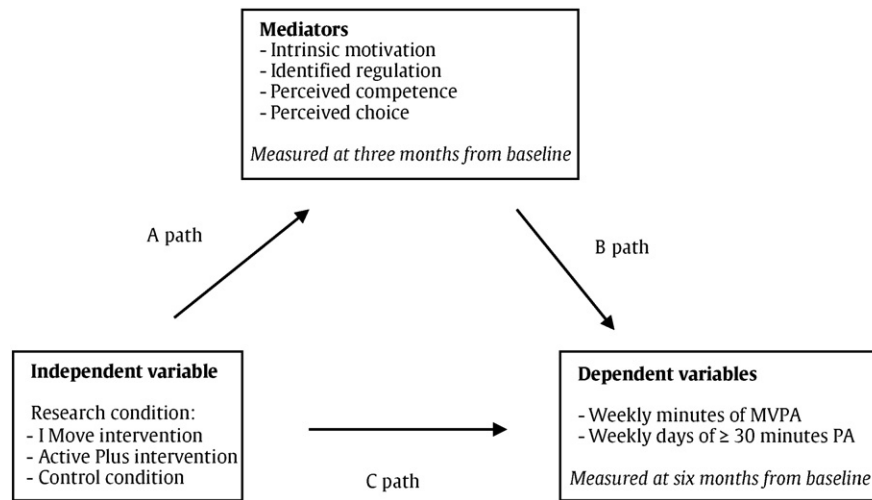


Fig. 1. Conceptual mediation model.

## 2.2. Interventions

I Move is a systematically developed, web-based computer tailored PA intervention, based on SDT and MI (Friederichs et al., 2014a; Bartholomew et al., 2011). Before developing the final I Move intervention, two pilot studies were conducted (Friederichs et al., 2014b; Friederichs et al., 2013). The outcomes of these pilot studies were used to inform the optimal question-feedback mechanism and the optimal appearance of a web-based computer tailored PA intervention, based on SDT and MI. The skills, processes and spirit of MI were adapted for use in a web-based computer tailored intervention (Miller and Rollnick, 2013). Throughout the development of the intervention we were guided by the principles of SDT (Markland et al., 2005). I Move comprises four automated, text-based sessions in which the participants enters into a motivational dialogue with the intervention software. The text-based segments of an intervention session are interspersed with opportunities to watch short videos featuring a coach, a PA expert and four actors playing the role of a former intervention participant. The first session takes about 20 min to complete; the subsequent sessions take about 10 to 15 min. Table 1 provides an overview of the content of each of the intervention sessions. For more detailed information on I Move, readers are referred to our previously published report on the design and development of the intervention (Friederichs et al., 2014a).

Active Plus is a systematically developed web-based computer tailored PA intervention which has been shown to be effective in increasing PA among older adults (Peels et al., 2013; Peels et al., 2014). This intervention is based predominantly on traditional health behavior change theories such as TPB, SCT and TTM (Peels et al., 2012; van Stralen et al., 2008). It comprises three web-based tailored advice sessions; sessions are text-based and supplemented by pictures and short videos (Peels et al., 2012; van Stralen et al., 2008). Since Active Plus was originally designed for individuals over 50 years, we adapted the intervention in such a way that it is appropriate for the general adult population; messages that were clearly aimed at older individuals were adapted or removed. We also added an extra session to the original Active Plus (only three sessions) to make it more comparable to I Move. All four advice sessions of Active Plus take about ten minutes to go through.

Although I Move and Active Plus are both systematically developed, web-based computer tailored PA interventions consisting of four intervention moments, there are important differences in content between them. I Move is designed to be interactive, taking the form of a simulated conversation about PA, whereas Active Plus simply delivers the advice in a unidirectional format. The interventions also have different

theoretical foundations. I Move is based on SDT and MI and is therefore intended to support participants' basic psychological needs for autonomy, competence and relatedness (Friederichs et al., 2014a). In contrast Active Plus, which is based on traditional health behavioral constructs, uses materials which are intended to provide participants with advice and guidance on why and how to become more physically active (Peels et al., 2012; van Stralen et al., 2008). It should be noted that both Active Plus and I Move focus on strengthening participants' behavior-specific self-esteem (termed self-efficacy in TPB, perceived competence in SDT) (Haerens et al., 2008; Fortier et al., 2007b; Edmunds et al., 2006).

## 2.3. Questionnaire

### 2.3.1. Demographics

At baseline, age, gender, weight, height, relational status and highest completed educational level were assessed by self-report. Educational level was categorized into high (higher vocational school or university level) and low (elementary education, medium general secondary education, preparatory vocational school, lower vocational school, higher general secondary education, preparatory academic education, medium vocational school), according to the Dutch educational system.

### 2.3.2. PA intention

At baseline, intention to become sufficiently active was measured, since this can be an important predictor of dropout in web-based PA interventions (Peels et al., 2013). Intention to become sufficiently active was measured with three items (e.g. 'Are you planning to be sufficiently physically active?' Definitely not (1)–Yes, definitely (10)).

### 2.3.3. Perceived basic psychological need support

Perceived support for the basic psychological needs for autonomy, competence and relatedness was measured using nine especially developed items – three per basic psychological need – based partly on items from the Health Care Climate Questionnaire, (see Table 2 for an overview of these items). These items were presented to participants in the two intervention conditions six weeks after baseline (after sessions 1 and 2) and six months after baseline (after sessions 3 and 4), participants in the control condition did not receive these items. Participants indicated their agreement with each item using a seven-point scale (1: totally disagree–7: totally agree). Principal component analysis revealed a 1-factor scale, both for the items on sessions 1 and 2 (Cronbach's alpha 0.92) and for the items on sessions 3 and 4 (Cronbach's alpha 0.93). Further analyses were conducted using these scales.

**Table 1**  
Integration of SDT and MI in I Move.

SDT	MI	Integration in I Move
Autonomy support	Skills: asking open questions and reflective listening Skills: summarizing	A combination of open and multiple choice questions was used. Unique feedback messages were developed for specific combinations of multiple choice answers. At regular times during the intervention, participants receive feedback messages that summarize the before going. One day after each of the four sessions, they receive a summary by email.
	Processes: focusing	Throughout the intervention, participants are encouraged to come up with their own themes and ideas (within the context of PA).
	Processes: evoking (I)	Throughout the intervention, several methods are used to elicit the participants' self-determined motivation. These are, for example, the importance ruler and value clarification.
	Processes: planning	Participants are offered the opportunity to create a specific action and coping plans that suit well to their needs and wishes.
Competence support	Spirit: evocation Skills: affirming	The intervention contains many evocative elements (see processes: evoking I & II) Feedback messages specifically address and comment on the participants' strengths and efforts. Messages were written in an empathetic style.
	Skills: informing and advising	Participants are offered information through several short expert videos. They can choose themselves which videos they want to see.
	Processes: evoking (II)	Throughout the intervention, several methods are used to help the participants increase their perceived confidence. These are, for example, the confidence ruler and reviewing past successes.
Relatedness support	Processes: engaging	At the start of the intervention it is stated that participants are experts about themselves. Each of the four sessions contains a video-coach; a series of video messages in which a coach welcomes the participant, and briefly introduces new questions and exercises. Furthermore, at several moments throughout all four sessions, participants can watch short videos with narratives of four allegedly former participants of I Move. These narratives provide the opportunity for the participants to feel connected with other people who go through similar experiences as themselves.
	Spirit: partnership	The intervention uses the participants' input as the starting point for each session, in order to create a collaborative conversation.
	Spirit: acceptance and compassion	We developed highly specific feedback messages, that suit well to the participants' needs and wishes. All messages were written in an empathetic style, without coercion or blame.

#### 2.3.4. Outcome measures: PA behavior

At baseline and at six months later, total weekly days of at least 30 min PA and minutes of moderate to vigorous PA (MVPA) were measured using the validated self-administered Dutch Short Questionnaire to Assess Health Enhancing Physical Activity (SQUASH) (Wendel-Vos et al., 2003).

Total weekly minutes of MVPA was calculated by multiplying the frequency (how many days per week), and duration (how many hours and minutes per day) of leisure and transport walking, leisure and transport cycling, sports, gardening, household chores and odd jobs performed with moderate or vigorous intensity. The relative validity ( $r_{\text{Spearman}} = 0.45$ ; 95% CI = 0.17–0.66) and reproducibility ( $r_{\text{Spearman}} = 0.58$ ; 95% CI = 0.36–0.74) of the SQUASH are reasonable for the general adult population (Wendel-Vos et al., 2003).

Total weekly days with at least 30 min PA was measured by a single item: 'How many days per week are you, in total, moderately physically active by undertaking, for example, brisk walking, cycling, chores, gardening, sports, or other physical activities for at least 30 min?'. Prior research provided support for the validity and reliability of single-item self-reports of PA (Milton et al., 2011; Milton et al., 2013) and several

studies found the single item PA measure to be among the most accurate PA questionnaires, when compared to accelerometer output (Wanner et al., 2013; van Poppel et al., 2010).

#### 2.3.5. Mediator measures

At baseline and three months later, intrinsic motivation and identified regulation for PA were assessed using the Exercise Self-Regulation Questionnaire. Perceived competence and perceived choice were also measured at baseline and three months later, using the Intrinsic Motivation Inventory. These measures and their Cronbach's alphas (derived from the data from this study) are described in Table 3.

#### 2.4. Statistical analyses

All analyses were conducted using SPSS for Windows (Version 22). In line with the instruction manual for the SQUASH, participants who reported over 6720 min PA per week were excluded from all analyses as it was assumed that being physically active for over 16 h per day for 7 days per week was impossible (Wendel-Vos et al., 2003). One-way analyses of variance (ANOVAs) and Chi-square tests were performed to identify baseline differences among the research conditions. Logistic regression analyses were conducted to assess predictors of dropout at the six-month assessment. Pearson's correlations were calculated between all key variables (PA at baseline and six months from baseline, mediator variables at baseline and three months from baseline, basic psychological need support at six weeks and six months from baseline).

##### 2.4.1. Evaluation of basic psychological need support

Potential group differences in basic psychological need support (for sessions 1 and 2, and for sessions 3 and 4) were assessed using independent samples t-tests.

##### 2.4.2. Mediation analyses

Fig. 1 shows the conceptual mediation model for this study. Mediation was evaluated using the MacKinnon's product-of-coefficients test (MacKinnon, 2008). The outcome variables in the mediation model were weekly days with  $\geq 30$  min PA and weekly minutes of MVPA; data for both variables were taken from the six-month assessment.

**Table 2**  
Overview of the assessed items on basic psychological need support.

SDT need	Item description
Autonomy	During (session/advice) (1&2/3&4) I could explore my own options During (session/advice) (1&2/3&4) it was assumed that I am the one who knows the most about myself
Competence	(Session/Advice) (1&2/3&4) were based on what I think is important During (session/advice) (1&2/3&4) I received useful information about physical activity (Session/Advice) (1&2/3&4) have helped me in making plans (Session/Advice) (1&2/3&4) have helped me in becoming more confident
Relatedness	I felt comfortable with the way I was spoken to during (session/advice) (1&2/3&4) I felt that my situation was taken into account during (session/advice) (1&2/3&4) I was able to recognize myself in the experiences of others in (session/advice) (1&2/3&4)

**Table 3**  
Description of the mediation variables.

Concept	Questionnaire	# items	Example question	$\alpha$
Intrinsic motivation	Exercise Self-Regulation Questionnaire (SRQ-E)	4	I try to be sufficiently physically active because it's fun. <i>Totally disagree (1)–Totally agree (7)</i>	.88
Identified regulation	Exercise Self-Regulation Questionnaire (SRQ-E)	4	I try to be sufficiently physically active because I believe exercise helps me feel better. <i>Totally disagree (1)–Totally agree (7)</i>	.87
Perceived competence	Intrinsic Motivation Inventory (IMI)	6	I think I am pretty good at physical activities. <i>Totally disagree (1)–Totally agree (7)</i>	.88
Perceived choice	Intrinsic Motivation Inventory (IMI)	7	I believe I have some choice about being physically active. <i>Totally disagree (1)–Totally agree (7)</i>	.82

The mediating variables were intrinsic motivation, identified regulation, perceived competence and perceived choice; data for these variables were taken from the three-month assessment. The independent variable was research condition; this was recoded using two contrast dummy variables, as recommended in Hayes and Preacher's guidelines for mediation analysis with a multi-categorical independent variable (Hayes and Preacher, 2014). Contrast dummy 1 was coded 0.25 for both intervention conditions and  $-0.5$  for control condition; contrast dummy 2 was coded 0.5 for the I Move condition,  $-0.5$  for the Active Plus condition and 0 for the control condition. The following variables were included as covariates: gender, age, educational level, relational status, BMI, intention to be sufficiently physically active, baseline values for PA (minutes and days), and baseline values for intrinsic motivation, identified regulation, perceived competence and perceived choice. Including the baseline values of the mediator and outcome variables allows for correction of individual baseline differences, and thus enables assessment of change from baseline.

Mediation models were evaluated using Hayes' PROCESS macro for SPSS (Hayes, 2013). Mediation was evaluated according to the following steps. First, PA was regressed onto treatment condition (C path). Second, potential mediators were regressed onto research condition (A path). Third, PA was regressed onto treatment condition (C' path) and onto the potential mediators (B path). Fourth, the significance of the mediated effect was evaluated by calculating the bias-corrected bootstrap 95% confidence intervals (CI). If the 95%-CI did not include zero, criteria for mediation were met. In the case of significant indirect effects the proportion of the total effect that was mediated was computed using the following formula,  $[(a * b)/(c' + (a * b))]$ . The PROCESS macro was run twice for both dependent variables; once using contrast dummy 1 as the independent variable and contrast dummy 2 as a covariate to compare both intervention conditions with the control condition, and once using contrast dummy 2 as the independent variable and contrast dummy 1 as covariate to compare I Move with Active Plus (Hayes

and Preacher, 2014). In addition, univariate mediation analyses were conducted, to assess the influence of each of the mediation variables on the PA outcomes separately.

### 3. Results

The six-month assessment (primary endpoint) was completed by 1646 of the 3165 participants who had completed the baseline assessment. Data from 76 participants were excluded because they reported PA levels over 6720 min per week in at least one assessment. The 3089 included participants who completed the baseline questionnaire had an average age of 44.9 years ( $SD = 12.9$ ), 69.1% were women, 52.4% had a BMI of 25 or more and 38.3% were lowly educated. As shown in Table 4, no baseline differences on key characteristics were found between the three study conditions. As shown in Table 5, all correlations between PA and SDT variables were significant. In addition, several significant correlations were found between basic psychological need support and PA- and SDT-variables.

#### 3.1. Dropout analysis

Dropout analysis revealed that lower age ( $B = 0.019 \pm 0.003$ ;  $p < .001$ ), higher BMI ( $B = 0.023 \pm 0.008$ ;  $p = 0.005$ ) and lower intention to be sufficiently physically active ( $B = 0.076 \pm 0.022$ ;  $p < .001$ ) were associated with a higher probability of dropping out before completing the six-month PA assessment. Participants were also more likely to drop out before the six-month assessment if they reported more weekly minutes of MVPA at baseline ( $B < 0.001 \pm 0.000$ ;  $p < .001$ ) and fewer weekly days with  $\geq 30$  min PA at baseline ( $B = 0.090 \pm 0.024$ ;  $p < .001$ ). Finally, participants were less likely to complete the six-month assessment if they were lowly educated ( $OR = 1.34$ ; 95% CI = 1.15–1.57;  $p < .001$ ), were married or living together ( $OR = 1.19$ ; 95% CI = 1.00–1.42) or had been assigned to one of the intervention conditions

**Table 4**  
Demographic values, motivational variables and physical activity.

	I Move	Active Plus	No intervention	$F/\chi^2$ (df = 2)
Gender: % male	30.0%	31.5%	31.2%	0.59
Age	44.99 $\pm$ 13.11	45.28 $\pm$ 12.70	44.49 $\pm$ 12.98	1.00
Education: % high education	63.1%	61.3%	61.0%	1.06
BMI	26.16 $\pm$ 4.80	26.07 $\pm$ 5.23	25.80 $\pm$ 4.47	1.50
PA minutes at baseline	511.92 $\pm$ 576.51	482.38 $\pm$ 547.87	501.51 $\pm$ 555.34	0.75
PA minutes at 6 months	640.31 $\pm$ 649.89	636.49 $\pm$ 661.39	561.61 $\pm$ 582.69	3.03*
PA days at baseline	3.09 $\pm$ 1.70	3.09 $\pm$ 1.65	3.13 $\pm$ 1.70	0.16
PA days at 6 months	4.07 $\pm$ 1.87	4.34 $\pm$ 1.81	3.75 $\pm$ 1.90	17.29***
Intrinsic motivation at baseline	4.56 $\pm$ 1.52	4.60 $\pm$ 1.49	4.57 $\pm$ 1.49	0.17
Intrinsic motivation at 3 months	4.92 $\pm$ 1.39	4.92 $\pm$ 1.34	4.64 $\pm$ 1.51	8.30***
Identified regulation at baseline	5.10 $\pm$ 1.37	5.17 $\pm$ 1.33	5.20 $\pm$ 1.33	1.50
Identified regulation at 3 months	5.42 $\pm$ 1.21	5.42 $\pm$ 1.17	5.21 $\pm$ 1.34	5.71**
Perceived competence at baseline	4.35 $\pm$ 1.25	4.38 $\pm$ 1.22	4.35 $\pm$ 1.23	0.26
Perceived competence at 3 months	4.65 $\pm$ 1.18	4.62 $\pm$ 1.17	4.44 $\pm$ 1.21	5.40**
Perceived choice at baseline	5.40 $\pm$ 1.15	5.49 $\pm$ 1.12	5.47 $\pm$ 1.12	1.70
Perceived choice at 3 months	5.59 $\pm$ 1.12	5.62 $\pm$ 1.05	5.55 $\pm$ 1.12	0.66

\*  $p < .05$ .

\*\*  $p < .01$ .

\*\*\*  $p < .001$ .

**Table 5**  
Correlation matrix.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Intrinsic motivation at baseline	1	.790***	.587***	.528***	.200**	.228**	.717**	.563***	.551***	.471***	.247***	.187***	.103**	.099**
2. Identified regulation at baseline		1	.392***	.312***	.127***	.210***	.557***	.624***	.367***	.269***	.172***	.156***	.118***	.094**
3. Perceived competence at baseline			1	.519***	.208***	.187***	.495***	.318***	.781***	.467***	.222***	.161***	.030	.087*
4. Perceived choice at baseline				1	.143***	.167***	.428***	.247***	.457***	.697***	.139***	.125***	.027	.004
5. PA minutes at baseline					1	.217***	.162***	.090	.171***	.116	.489***	.130***	.025	.084*
6. PA days at baseline						1	.178***	.144***	.158***	.143***	.143***	.392***	-.041	-.035
7. Intrinsic motivation at 3 months							1	.794***	.615***	.530***	.250***	.206***	.232***	.286***
8. Identified regulation at 3 months								1	.433***	.320***	.184***	.166***	.227**	.278***
9. Perceived competence at 3 months									1	.540***	.238***	.193***	.088*	.136***
10. Perceived choice at 3 months										1	.142***	.124***	.093*	.082*
11. PA minutes at 6 months											1	.299***	.117**	.187***
12. PA days at 6 months												1	.069	.116***
13. Need support sessions 1 and 2													1	.666***
14. Need support sessions 3 and 4														1

\*  $p < .05$ .  
\*\*  $p < .01$ .  
\*\*\*  $p < .001$ .

( $OR_{I Move} = 3.49$ , 95% CI = 2.89–4.22,  $p < .001$ ;  $OR_{ActivePlus} = 3.17$ , 95% CI = 2.64–3.81,  $p < .001$ ). These predictors of dropout were included in the mediation analysis as covariates.

**3.2. Evaluation of basic psychological need support**

Independent samples t-tests showed that, compared to Active Plus participants, I Move participants experienced more basic psychological need support, both during sessions 1 and 2 (I Move  $4.64 \pm 1.20$ ; Active Plus  $4.39 \pm 1.12$ ;  $p = .001$ ), and during sessions 3 and 4 (I Move  $4.60 \pm 1.19$ ; Active Plus  $4.35 \pm 1.19$ ;  $p = .004$ ).

**3.3. Mediation analyses**

Tables 6 and 7 show the results of the mediation analyses. These results will be discussed below.

**3.3.1. Intervention effects on physical activity (C path)**

Six months after baseline there were differences between the combined intervention condition (I Move and Active Plus) and the control condition in terms of weekly minutes of MVPA ( $B = 108.83$ ;  $p = .005$ ) and weekly days with  $\geq 30$  min PA ( $B = 0.50$ ;  $p < .001$ ). There were no differences in weekly minutes of MVPA between I Move and Active Plus ( $B = -4.46$ ;  $p = .911$ ) at the six-month assessment, but

Active Plus was more effective than I Move in increasing weekly days with  $\geq 30$  min PA ( $B = -0.28$ ;  $p = .018$ ).

**3.3.2. Intervention effects on potential mediators (A path)**

The combined intervention condition generated significant increases in intrinsic motivation ( $B = 0.28$ ;  $p < .001$ ), identified regulation ( $B = 0.20$ ;  $p < .004$ ) and perceived competence ( $B = 0.22$ ;  $p < .001$ ). There was no difference between the two intervention conditions in terms of effects on these variables. The combined intervention condition had no significant effect on perceived choice.

**3.3.3. Effects of potential mediators on physical activity (B path)**

Increased perceived competence ( $B = 0.14$ ;  $p = .028$ ) was associated with an increase in weekly days with  $\geq 30$  min PA. Neither increases in intrinsic motivation ( $B = 0.11$ ;  $p = .092$ ), identified regulation ( $B = -0.02$ ;  $p = .715$ ) nor perceived choice ( $B = -0.03$ ;  $p = .573$ ) were significantly associated with an increase in weekly days with  $\geq 30$  min PA. Similarly, neither increases in intrinsic motivation ( $B = 34.59$ ;  $p = .129$ ), identified regulation ( $B = 3.06$ ;  $p = .890$ ), perceived competence ( $B = 37.46$ ;  $p = .089$ ) nor perceived choice ( $B = -22.89$ ;  $p = .260$ ) were associated with an increase in weekly minutes of MVPA.

Univariate mediation analyses showed that, when tested separately, intrinsic motivation ( $B = 0.13$ ;  $p = .026$ ), identified regulation ( $B = 0.09$ ;  $p = .033$ ) and perceived competence ( $B = 0.18$ ;  $p = .002$ ) were

**Table 6**  
A path, B path and significance of the mediated effect on weekly minutes of MVPA (n = 1415).

Independent variable	Mediators	A path		B path		Total effect		Mediated effect	95% CI	Proportion (%)
		A (SE)	p-Value	B (SE)	p-Value	C' + AB (SE)	p-Value			
Interventions vs. control	Intrinsic motivation	0.28 (0.07)	<.001	34.59 (22.79)	.129	108.83 (38.55)	.005	9.85 (7.21)	-2.03 to 27.34	16%
	Identified regulation	0.20 (0.07)	.004	3.06 (22.09)	.890			0.61 (4.86)	-9.28 to 10.53	
	Perceived competence	0.22 (0.05)	<.001	37.46 (22.00)	.089			8.17 (5.28)	-0.41 to 20.82	
	Perceived choice	0.07 (0.05)	.188	-22.89 (20.30)	.260			-1.64 (2.15)	-8.90 to 0.73	
	Multi-mediation (all)							16.98 (6.53)	6.54 to 33.11	
I Move vs. Active Plus	Intrinsic motivation	0.07 (0.07)	.365	34.59 (22.79)	.129			2.26 (3.28)	-1.77 to 13.19	
	Identified regulation	0.05 (0.07)	.474	3.06 (22.09)	.890			0.15 (2.01)	-2.98 to 5.97	
	Perceived competence	0.04 (0.05)	.426	37.46 (22.00)	.089			1.59 (2.60)	-1.80 to 9.18	
	Perceived choice	-0.03 (0.06)	.604	-22.89 (20.30)	.260			0.67 (1.71)	-1.24 to 7.21	
	Multi-mediation (all)					-4.46 (39.75)	.911	4.67 (4.33)	-3.30 to 13.96	

Covariates: gender, age, educational level, relational status, BMI, intention to be sufficiently physically active, baseline values for PA (minutes and days), and baseline values for intrinsic motivation, identified regulation, perceived competence and perceived choice.

**Table 7**  
A path, B path and significance of the mediated effect on weekly days of  $\geq 30$  min PA (n = 1485).

Independent variable	Mediators	A path		B path		Total effect		Mediated effect	95% CI	Proportion (%) AB/(C' + AB)
		A (SE)	p-Value	B (SE)	p-Value	C' + AB (SE)	p-Value	AB (SE)		
Interventions vs. control	Intrinsic motivation	0.27 (0.07)	<.001	0.11 (0.07)	.092			0.03 (0.02)	−0.00 to 0.08	
	Identified regulation	0.20 (0.07)	.004	−0.02 (0.06)	.715			−0.00 (0.01)	−0.04 to 0.02	
	Perceived competence	0.21 (0.05)	<.001	0.14 (0.07)	.028			0.03 (0.02)	0.01 to 0.07	6%
	Perceived choice	0.07 (0.05)	.214	−0.03 (0.06)	.573			−0.00 (0.01)	−0.02 to 0.00	
	Multi-mediation (all)					0.50 (0.12)	<.001	<b>0.05 (0.02)</b>	<b>0.02 to 0.10</b>	<b>10%</b>
I Move vs. Active Plus	Intrinsic motivation	0.05 (0.07)	.519	0.11 (0.07)	.092			0.01 (0.01)	−0.01 to 0.03	
	Identified regulation	0.04 (0.07)	.614	−0.02 (0.06)	.889			−0.00 (0.01)	−0.02 to 0.01	
	Perceived competence	0.05 (0.05)	.329	0.14 (0.07)	.028			0.01 (0.01)	−0.01 to 0.03	
	Perceived choice	−0.00 (0.05)	.990	−0.03 (0.06)	.573			0.00 (0.00)	−0.01 to 0.01	
	Multi-mediation (all)					−0.28	.018	0.01 (0.01)	−0.01 to 0.04	

Covariates: gender, age, educational level, relational status, BMI, intention to be sufficiently physically active, baseline values for PA (minutes and days), and baseline values for intrinsic motivation, identified regulation, perceived competence and perceived choice.

significantly associated with an increase in weekly days with  $\geq 30$  min PA, while intrinsic motivation ( $B = 43.28$ ;  $p = .003$ ) and perceived competence ( $B = 60.15$ ;  $p = .002$ ) were associated with an increase in weekly minutes of MVPA.

### 3.3.4. Mediated effects (AB)

Multiple mediator analysis with weekly days with  $\geq 30$  min PA as the dependent variable showed that 10% of the total effect of the combined intervention condition on this outcome was mediated ( $B = 0.05$ ; 95% CI = 0.02 to 0.10). Separate single mediator analyses showed that 6% of the intervention effect on weekly days with  $\geq 30$  min PA was mediated by perceived competence ( $B = 0.03$ ; 95% CI = 0.01 to 0.07). None of the other potential mediators were significant mediators of the intervention effect on weekly days with  $\geq 30$  min PA. The two interventions did not differ in terms of the mediation of their effect on weekly days with  $\geq 30$  min PA.

Multiple mediator analysis with weekly minutes of MVPA as the dependent variable showed that 16% of the total effect of the combined intervention condition on this outcome was mediated ( $B = 16.98$ ; 95% CI = 6.54 to 33.11). Separate single mediator analyses failed to detect any significant mediators of the intervention effect, although perceived competence almost significantly mediated the intervention effect on weekly minutes of MVPA ( $B = 8.17$ ; 95% CI = −0.41 to 20.82). The two interventions did not differ in terms of the mediation of their effect on weekly minutes of MVPA.

## 4. Discussion

This study compared how effective a web-based computer tailored PA intervention based on SDT and MI (I Move) and a traditional web-based computer tailored PA intervention (Active Plus) were in supporting participants' basic psychological needs. It also assessed the extent to whether intrinsic motivation, identified regulation, perceived competence and perceived choice played a stronger mediating role in the effects of I Move than in the effects of Active Plus. The answers to these questions provide insight into the practical value of using SDT and MI in web-based PA interventions.

### 4.1. Evaluation of basic psychological need support

In this study we found that the MI- and SDT-based I Move was more effective in supporting participants' basic psychological needs than the more traditional Active Plus. I Move was designed specifically to support participants' basic psychological needs (Friederichs et al., 2014a) so these results were in line with our expectations, and provide support for the theoretically driven development process that produced the intervention. Furthermore, these findings have demonstrated that it is possible to design web-based PA interventions which target participants' needs more successfully than traditional web-based PA interventions.

### 4.2. Intervention effects on potential mediators (A path)

This study showed that both interventions were equally effective in increasing participants' intrinsic motivation, identified regulation and perceived competence with respect to PA. Both interventions were similarly unsuccessful in increasing participants' perceived choice with respect to PA. I Move did not have a greater impact on SDT-related psychosocial constructs than Active Plus. This is an unexpected finding, since (1) I Move better supported participants' basic psychological needs and (2) significant correlations were found between basic psychological need support scores and autonomous motivation at three months (see Table 5). One possible explanation is that participant's autonomous motivation scores already were rather high at baseline resulting in a ceiling effect. In addition, while autonomous motivation is not a central feature in traditional health behavioral theories, web-based computer tailored PA interventions based on these theories might actually be capable of increasing autonomous motivation. The finding that both interventions were equally successful in increasing perceived competence can be explained by the fact that one of the targets of Active Plus is self-efficacy (Peels et al., 2012; van Stralen et al., 2008), which is conceptually similar to perceived competence (Haerens et al., 2008; Fortier et al., 2007b; Edmunds et al., 2006).

### 4.3. Effect of potential mediators on physical activity (B path)

The results showed that changes in perceived competence three months after baseline were significantly associated with changes in weekly days with  $\geq 30$  min PA six months after baseline. The association between changes in perceived competence and changes in weekly minutes of MVPA approached significance ( $p = 0.089$ ). Changes in intrinsic motivation, identified regulation or perceived choice, however, were not associated with changes in the PA outcome variables. In view of the strong evidence on the association between autonomous motivation and PA behavior (Teixeira et al., 2012) these are unexpected results. Therefore, additional mediation analyses were conducted, each with just one of the four mediators. In these analyses changes in intrinsic motivation, identified regulation and perceived competence at three months were significantly associated with changes in PA at six months. These findings indicate that the different mediators in the multiple mediation analyses may have been repressing the significance of each other's B paths. In the multiple mediation analysis, perceived competence was the only mediating variable significantly associated to PA. This finding is in line with other studies (Armitage, 2005; Armitage and Conner, 2001; Wasserkampf et al., 2014a) suggesting that perceived competence (or the related concept of self-efficacy) is an important predictor of initial PA adoption. Autonomous motivation may be especially important for sustained changes in PA behavior (Teixeira et al., 2012; Wasserkampf et al., 2014b; Thøgersen-Ntoumani and Ntoumanis, 2006). Therefore, an increase in autonomous motivation three months after baseline might be associated with long-term

increases in PA following both interventions. An alternative explanation, however, is that the PA questionnaire used in this study measures very varied kinds of PA, many of which are essentially utilitarian (e.g. active transport and daily chores). The fact that these forms of PA are conducted mainly for practical reasons may affect the extent to which they are enjoyed or valued. Therefore, it could well be that autonomous motivation plays a relevant role in only a part of the reported PA. This may explain the rather moderate association between self-reported PA and autonomous motivation in this study. This line of thought is supported by the fact that perceived competence, which is more likely to be associated with a broader range of behaviors, is stronger related to self-reported PA in our study.

#### 4.4. Mediated effects

In both interventions the effect on weekly days with  $\geq 30$  min PA was significantly mediated by perceived competence. The mediating effect of perceived competence on the effect of both interventions on weekly minutes of MVPA was very close to significance (95% CI =  $-0.41$  to  $20.82$ ). Mediation of the effects was similar in both intervention conditions. These results indicate that perceived competence is the most important driver of change in I Move. Indeed, perceived competence or self-efficacy seem critical to the early adoption of structured PA behaviors (Koring, 2012). Other studies of PA interventions (Van Hoecke et al., 2013; Haerens et al., 2008; van Stralen et al., 2011; Koring, 2012) have also found perceived competence or self-efficacy to be an important mediator of long-term effects.

This study suggested that the mechanisms underpinning the effects of the SDT- and MI-based I Move and the traditional Active Plus are very similar; the effects of both interventions were driven by increases in perceived competence. Nevertheless the mechanisms underpinning the long-term effects of the interventions may be different. In this study the effects of I Move were not mediated by intrinsic motivation or identified regulation; however, as discussed above, autonomous motivation may be especially important in maintenance of changes in PA behavior, in which case intrinsic motivation and identified regulation may be more important mediators of the long-term effects of PA interventions (Teixeira et al., 2012; Wasserkampf et al., 2014b; Thøgersen-Ntoumani and Ntoumanis, 2006). Indeed, several studies found that autonomous motivation was a significant mediator of the long-term effects of SDT-based PA interventions (Silva et al., 2011; Van Hoecke et al., 2013; Silva et al., 2010a; Chatzisarantis and Hagger, 2009). Alternatively, it could be that in the I Move condition, SDT-mechanisms have been operative for a while, but that the intervention had little room to further increase values of PA and autonomous motivation that were quite high at baseline already.

#### 4.5. Strengths and limitations

This study is the first to evaluate the mediation of the effects of a web-based computer tailored PA intervention based on SDT and MI. The study also has several methodological strengths, such as the prospective design and the large sample size. Some limitations of the study should also be acknowledged. First, the attrition was considerable. All the predictors of dropout were included in the analyses as covariates to control for differences between completers and non-completers; nevertheless caution should be exercised in generalizing these findings to the adult population as a whole, partly because women and highly educated individuals were over-represented in our sample. Second, PA behavior was assessed using self-report questionnaires and although the SQUASH has reasonable reproducibility and relative validity (Wendel-Vos et al., 2003) there is still a risk that the data were subject to biases, for example over-estimation of PA or socially desirable responding (Prince et al., 2008). This could be related to the fact that baseline self-reported PA was very high (among all three study conditions). As social desirability was not assessed, it is not possible to

determine the influence of socially desirable responding on the results. It is recommended that more objective measures of PA behaviors are used in future studies of web-based PA interventions (Lyons et al., 2014; Trost and O'Neil, 2014). Third, it should be acknowledged that high correlations were found between identified regulation and intrinsic motivation, which could lead to difficulties when interpreting the results of this paper. Indeed, high correlations between identified regulation and intrinsic motivation are common in SDT-based studies on PA (Teixeira et al., 2012) which indicates that these two subcomponents of autonomous motivation often coexist. However, since identified regulation and intrinsic motivation represent substantively different (highly correlating but yet distinct) constructs, we chose not to use a merged autonomous motivation measure. Lastly, in the absence of a validated questionnaire on basic psychological need support in digital interventions we used especially developed items to assess perceived basic psychological need support.

#### 4.6. Conclusions and implications for future research

The results indicate that the web-based computer tailored PA intervention based on SDT and MI was able to better support the participants' basic psychological needs, when compared to the more traditional intervention. The working mechanisms of the SDT/MI based intervention and the traditional intervention seemed to be very similar, as both interventions produced their effects through increasing perceived competence but not through intrinsic motivation, identified regulation or perceived choice. More research is needed, however, to confirm these findings.

As proposed by Norman et al. (2007), the domain of eHealth can be advanced by conducting studies that examine whether web-based interventions work through hypothesized theoretical constructs. Therefore, more research should be done on mediators of effects of web-based PA interventions, based on SDT and MI. In the current study, a data analysis protocol from two of the experts in the field of mediation (Hayes and Preacher) was followed (Hayes and Preacher, 2014). However, future studies might consider to use structural equation modeling (SEM) as an alternative data analysis method since this method is helpful in disentangling specific effects of different variables and in avoiding suppression effects. In studies on the effects of web-based PA interventions, based on SDT and MI, special attention should be paid to the mechanisms underpinning the long-term effects of interventions; autonomous motivation may become more important over time. In summary, a better understanding of the effects of web-based PA interventions would support the development of more effective interventions, capable of targeting constructs central to the various theoretical frameworks currently used in this field.

#### List of abbreviations

ANOVA	analysis of variance
ES	effect size
MI	motivational interviewing
MVPA	moderate to vigorous physical activity
OR	odds ratio
PA	physical activity
SCT	social cognitive theory
SDT	self-determination theory
SQUASH	Dutch Short Questionnaire to Assess Health Enhancing Physical Activity
TPB	theory of planned behavior
TTM	trans theoretical model

#### Authors' contributions

AO, CB and LL designed and wrote the original proposal. SF, AO, CB and LL developed the intervention. SF significantly contributed to writing this article. PV provided assistance with the statistical analysis of the



data. AO, CB, PV and LL were involved in revising the manuscript critically. All authors read and approved the final manuscript.

## Competing interests

The authors declare that they have no competing interests.

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