# The Long-Term Efficacy of Two Computer-Tailored Physical Activity Interventions for Older Adults: Main Effects and Mediators

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Objective: Low-cost (e.g., computer-tailored) interventions with sustained effects are needed to increase and maintain physical activity in older adults. This study examined the long-term efficacy of 2 computer-tailored physical activity interventions for older adults and its psychosocial and environmental mediators. Methods: A clustered randomized controlled trial (N = 1,971) was conducted that included 3 research arms: (a) basic computer-tailored print intervention, targeting psychosocial mediators; (b) environmentally computer-tailored print intervention, targeting psychosocial and environmental mediators; and (c) no-intervention control group. Interventions were developed using the intervention mapping approach and consisted of 3 computer-tailored letters delivered over 4 months. Questionnaires assessed the study outcomes (i.e., total weekly days and total weekly minutes of physical activity) at baseline and 12 months. Potential mediators (i.e., awareness, attitude, self-efficacy, intention, social influence, intrinsic motivation, self-regulation, and perceived environment) were assessed at baseline and at 3 or 6 months. Results: Multilevel regression analyses revealed that both interventions significantly changed total weekly days of physical activity compared with the control group, but only the environmentally computer-tailored print intervention significantly changed weekly minutes of physical activity. Multiple mediation models showed that the effects of both interventions on weekly days of physical activity were mediated by changes in awareness and intention. Conclusions: Computer-tailored interventions were effective in inducing long-term behavioral changes in physical activity behavior of older adults. Awareness and intention were found to be important mediators of changing daily physical activity and should be included in future computer-tailored intervention studies.

Keywords: physical activity, intervention, older adults, mediating, randomized controlled trial

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The high prevalence of inactivity in older adults worldwide requires immediate action to stimulate regular physical activity (PA) in this age group (Centers for Disease Control and Prevention, 2005). *Physical inactivity*, defined as not meeting the international recommendation of 30 min of moderate PA a day on at least 5 days of the week (Physical Activity Guidelines Advisory

5 days of the week (Physical Activity Guidelines Advisory effectively changed through PA Burks, Rantz, & Pomeroy, 2003; K

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Committee, 2008), increases the risks of health problems (Department of Health, 2004). Therefore, important health benefits can be achieved with low-cost (e.g., computer-tailored) interventions promoting PA in older adults that demonstrate sustained effects.

Research has shown that PA behavior of older adults can be effectively changed through PA interventions (Conn, Minor, Burks, Rantz, & Pomeroy, 2003; King, Rejeski, & Buchner, 1998; Van der Bij, Laurant, & Wensing, 2002). Computer-tailored interventions, in which computer technology facilitates the broad implementation and fine-tuning of program materials to the individual characteristics and interests (De Vries & Brug, 1999; Kreuter, Farrell, Olevitch, & Brennan, 2000), is a low-cost strategy that has the potential to reach a large population. Computer-tailoring has shown promising effects in different health promotion programs (Kroeze, Werkman, & Brug, 2006; Noar, Benac, & Harris, 2007) and in PA promotion in older adults (Jancey et al., 2008; King et al., 2007; Walker et al., 2009). However, evidence on long-term effects of computer-tailored PA interventions for older adults is still lacking. In addition, most PA interventions have focused solely on intervention effects and failed to analyze the working mechanisms of the intervention (i.e., mediators). Analyzing mediators of intervention effects can evaluate whether the intervention is working as expected (Mackinnon, 2008) and can prompt future intervention developers to add effective intervention components and remove ineffective strategies, resulting in more cost-efficacious interventions (Hafeman & Schwartz, 2009).

In one study, two computer-tailored PA interventions targeted at the adults over 50 years of age were developed (van Stralen et al., 2008). Both interventions consisted of personalized feedback letters for changing PA behavior by targeting potential psychosocial mediators. One such intervention (the intervention-plus condition) additionally targeted potential environmental mediators by providing tailored environmental feedback (e.g., presenting detailed information about PA possibilities at home and in the neighborhood and providing access to a website including a forum and e-buddy system). In the short term, both interventions were effective in changing PA behavior compared with the control conditions, with medium effect sizes (ESs) at 6 months  $ES_{Ibasic} = 0.30$  and  $ES_{Iplus} = 0.35$  (van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009a, 2009b). No differences in intervention effects on total PA behavior between the two interventions were found at 6 months.

The aim of the current study was twofold. First, we aimed to examine the long-term efficacy of two computer-tailored print interventions (one including and one excluding environmental information) aimed at promoting PA in older adults. We hypothesized that the interventions would be effective in changing PA over 12 months compared with the control condition. Second, we aimed to examine the mediated effects of changes in potential psychosocial and environmental mediators on changes in PA behavior over 12 months. As both interventions targeted all underlying psychosocial mediators, we hypothesized that changes in these concepts would mediate changes in PA. We further hypothesized that the working mechanisms of the two interventions would differ. Because only the intervention with environmental information was developed to change underlying environmental mediators, we expected that the mediated effect of social and physical environment factors (i.e., perceived environment, social influence) would be more explicit in the environmental intervention.

#### Method

The study was registered at the Dutch Trial Register (NTR920) and approved by the Medical Ethics Committee of Maastricht University and the University Hospital Maastricht.

# Participants and Procedure

The procedure of the study, including the selection and enrollment of participants and the distribution of the questionnaires and interventions, is shown in Figure 1. Participants were eligible to participate when they were 50 years of age or older, were citizens of one of the selected municipalities, and when their general practitioner did not advise against participating in PA behavior. A clustered randomized controlled trial was conducted that included three research arms: (a) basic computer-tailored print intervention, a motivational focused computer-tailored intervention targeting potential psychosocial mediators; (b) intervention plus, a motivationally and environmentally computer-tailored print intervention

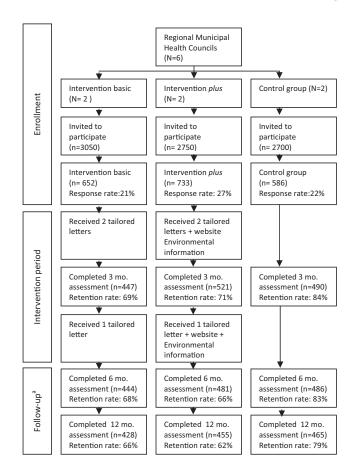


Figure 1. Flow diagram of the selection and enrolment of the participants and the distribution of the tailored letters. <sup>a</sup>Reasons for nonresponse or discontinued participation are unknown.

targeting potential environmental mediators in addition to the motivational focused computer-tailored feedback of the basic intervention; or (3) waitlist control, receiving no intervention. In 2007, all Dutch Regional Municipal Health Councils (MHCs; N =39) were invited to participate in the program. Nine MHCs agreed to participate, after which six MHCs were randomly assigned to one of the three research arms. Randomization was stratified by urbanization level. Per MHC, depending on the size of the invited municipalities, one or two municipalities were invited to participate, resulting in two municipalities per research condition. Only municipalities with a minimum of 20,000 inhabitants and who did not (plan to) participate in another Dutch PA promotion program were eligible for participation. All invited municipalities were willing to participate. In total, a random sample of 8,500 adults 50 years of age and over was selected and invited to participate so as to include 2,000 participants. Based on a significance level of .05 and a power of .90, the minimum sample size for each research condition at 12 months should be 450 subjects to detect a relative increase of 5% in PA behavior. Given that 30% of dropout is expected between baseline and 12 months, 2,000 participants need to be included at baseline. Participants were invited to participate by an invitation letter, signed by the project leader and a representative of the MHC or municipality (e.g., mayor), accompanied by a baseline questionnaire and informed consent form. To encourage returning of the questionnaires, participants were eligible to win city trips or gift vouchers. Baseline measurement lasted from March to June 2007.

## Intervention and Design

The content of the computer-tailored interventions has been described in more detail elsewhere (van Stralen et al., 2008) but is briefly described below. The intervention programs were developed according to the intervention mapping protocol (van Stralen et al., 2008), which is a six-step protocol that facilitates a stepwise process for theory- and evidence-based development of health promotion interventions: (1) conduct a needs assessment and define program objectives, (2) define performance objectives and create matrices of change objectives, (3) select theory-based intervention methods and practical strategies, (4) produce program components and materials, (5) plan a program adoption and implementation, and (6) plan a process and effect evaluation.

The intervention development was based on the theoretical underpinned assumption that an intervention effect can be achieved by changing certain underlying mediators. The selection of mediators was based on a Delphi study (van Stralen, Lechner, Mudde, De Vries, & Bolman, 2010) and a literature review on determinants of PA behavior change in older adults (van Stralen, Lechner, Mudde, Bolman, & De Vries, 2009). Theoretical methods and practical strategies were selected on the basis of focus groups with the target group (van Stralen et al., 2008) and theoretical models such as the I-Change model (De Vries, Mesters, Van 't Riet, Willems, & Reubsaet, 2006), the social cognitive model (Bandura, 1986), the transtheoretical model (Prochaska & DiClemente, 1983), the health action process approach (Schwarzer, 2009), the precaution adoption process model (Weinstein, 1988), self-regulation theory (Baumeister & Vohs, 2004), and self-determination theory (Hagger & Chatzisarantis, 2007). Supplemental material files 1a and 1b (available online) show the potential mediators, theoretical methods, theories related to the theoretical methods, practical strategies, and tools used in the interventions. Because computer-tailored print interventions were found to be more effective in changing PA maintenance than telephone-tailored interventions (Marcus et al., 2007), especially in older adults (Castro, King, & Brassington, 2001), we developed two computer-tailored print interventions.

Basic computer-tailored intervention participants (n = 654) received three computer-tailored letters with personalized PA advice. The first and second tailored letters were based on personal data gathered at baseline and were sent 2 weeks and 2 months after baseline, respectively. The third letter was sent 2 weeks after receiving the 3-month questionnaire and was based on the data gathered at baseline and 3 months; it addressed any changes each adult had undertaken during these 3 months. By targeting potential mediators that underlie each specific phase of behavior change, the intervention tried to influence awareness of own PA level (e.g., by targeting psychosocial mediators such as knowledge and awareness), initiation of PA (e.g., by targeting psychosocial mediators such as attitude, social influence, action planning), and maintenance of PA (e.g., by targeting psychosocial mediators such as coping planning and commitment). The letters comprised between the three and 11 pages depending on (changes in) PA level and mediator scores.

Intervention-plus participants (n = 737) received the same motivationally focused computer-tailored information as the basic

intervention participants but additionally received environmentally focused computer-tailored information about PA opportunities in their neighborhood combined with access to a forum and e-buddy system on a website. The tailored environmental information included handouts with walking and cycling routes in their own neighborhoods, examples of exercises to do at home, contact information of neighborhood sports clubs that matched their interests and abilities, and a map of their close neighborhood on which walking and cycling possibilities were highlighted (see Supplemental file 1b, available online). This tailored environmental information was gathered via GIS, municipality and regional guides, walking and cycling guides of the Dutch transport association, and the Internet.

Waitlist control participants (n = 586) received nothing during the intervention period. They did receive one computer-tailored letter, which was a combination of the three computer-tailored letters from the basic computer-tailored print intervention, after completion of the research period.

### **Data Collection**

All participants were asked to fill in a questionnaire at baseline, 3, 6, and 12 months assessing demographics, the potential mediators, and the outcome variables.

**Demographics.** At baseline, weight, height, age, gender, highest completed educational level, employment status, and having a partner were assessed using a questionnaire. Educational level was categorized into low, middle, and high, according to the Dutch educational system. Body mass index (BMI) was calculated from weight and height.

Mediators. At baseline, all potential mediators were measured. Based on the content of the intervention, we measured different potential mediators at different posttests. For example, if the potential mediator was targeted in the first two letters of the intervention (e.g., attitude and self-efficacy), the potential mediator was measured at the 3-month posttest. If the intervention targeted the potential mediator (also) in the third letter (e.g., awareness, intention, self-regulation concepts), the potential mediator was also measured at the 6-month posttest. As a result, at the 3-month posttest, awareness, attitude, social influences (i.e., social support, social modeling, and having a sports partner), intrinsic motivation, and self-efficacy were assessed. At the 6-month posttest, awareness, intention, perceived environment, commitment, strategic planning, action planning, and coping planning were measured. Because awareness was targeted in all three letters and additional changes were expected after the 3-month posttest, we decided to measure awareness also at 6 months. Awareness was classified by combining self-rated PA level with compliance with the PA norm. Compliance with the PA norm (yes/no) was derived from the total weekly days of PA measure. Based on the combination of the two measures, we then divided the participants into participants unaware of their personal PA level, including overestimators (do not comply with PA norm but rate their PA as [highly] sufficient) and underestimators (do comply with PA norm but rate their PA as [highly] insufficient), scored as 0; and participants aware of their personal PA level, including high realists (do comply with PA norm and rate their PA as [highly] sufficient) and low realists (do not comply with PA norm and rate their PA as [highly] insufficient), scored as 1 (Lechner, Bolman, & Van Dijke, 2006). Table 1 shows answering options and Cronbach's alphas.

The primary outcome measures were Outcome variables. total weekly days of PA and total weekly minutes of PA, assessed with the self-administrated Dutch Short Questionnaire to Asess Health-Enhancing PA (SQUASH) at baseline and 12 months. The overall reliability ( $r_{\text{Spearman}} = .57$ ) and relative validity of the SQUASH in relation to actigraph activity monitors ( $r_{\text{Spearman}}$  = .67) were reasonable in older patients (Wagenmakers et al., 2008). Weekly days of PA was measured using a single item question, "On how many days per week are you, in total, moderately physically active, such as heavy walking, cycling, chores, gardening, sports or other physical activities for at least 30 minutes?" Weekly minutes of PA was measured using 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 including both organized exercises (e.g., gymnastics) and activities done on one's own (e.g., running), gardening, and doing odd jobs. For each activity category, examples were provided.

## **Statistical Analyses**

One-way analyses of variance (ANOVAs) were conducted to test for baseline differences in participant characteristics among the three conditions. Logistic regression analyses were conducted to examine whether dropout was associated with baseline characteristics. Analyses were performed using SPSS for Windows (Version 15.0).

Participants were nested in neighborhoods within their municipality using the probability of interdependence between them. To account for this interdependence, we completed multilevel linear regression analyses with a random intercept for two levels (neighborhood [2], individual [1]) to analyze the efficacy and mediation effects using MLWin (Version 2.02). The research condition variable was recoded into two dummy variables (control group as reference). Assumptions of regression analyses were tested (normal distribution of outcome variables, nonzero variance, multicollinearity, homoscedasticity, independent errors, and normally distributed errors). Because the outcome variables were not normally distributed, we used normally distributed residual change scores of the outcome variables and potential mediators. Residual change

Table 1
Description of the Assessed Variables

Concept	Items (n)	Example question item and answering option	α	Reference
Self-rated PA	1	My level of PA is highly insufficient/insufficient (0) to sufficient/highly sufficient (1)	_	Lechner et al., 2006
Attitude—pros/cons	9/7	I find being regularly physically active very enjoyable/very time consuming. <i>Totally disagree</i> (-2) to <i>totally agree</i> (+2)	.86/.77	Lechner & De Vries, 1995; van Stralen et al., 2008
Social support	1	To what degree do people in your direct environment support you to be physically active? <i>No support</i> (1) to <i>much support</i> (2)	_	Lechner & De Vries, 1995
Social modeling	1	How many people in your direct environment are sufficiently physically active? <i>None</i> (-2) to <i>all</i> (+2)	_	Lechner & De Vries, 1995
Sports partner	1	Do you have one or more regular exercise partners? <i>No</i> (0) or <i>yes</i> (1)	_	Lechner & De Vries, 1995
Intrinsic motivation	6	I engage in physical activity because it's fun. <i>Totally disagree</i> (-2) to <i>totally agree</i> (+2)	.89	Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997
Self-efficacy	10	Do you find yourself able to be physically active for at least 30 min per day when you are tired?  Definitely not able (-2) to definitely able (+2)	.93	Resnick & Jenkins, 2000; van Stralen et al., 2008
Perceived environment	8	Please indicate which of the following facilities are situated in your direct environment? For example, sport or community fitness center, walking tracks. <i>No</i> (0) or <i>yes</i> (1)	a	De Bourdeaudhuij, Sallis, & Saelens, 2003
Intention	3	Are you planning to be sufficiently physically active? Very certainly not (1) to very certainly yes (10)	.76	Sheeran & Orbell, 1999
Commitment	3	How committed are you to being physically active regularly? <i>Totally not committed</i> (-2) to <i>totally committed</i> (+2)	.84	Webb & Sheeran, 2005
Strategic planning	10	I plan my physical activity actions each week. <i>Totally disagree</i> (-2) to <i>totally agree</i> (+2)	.65	Rovniak, Anderson, Winett, & Stephens, 2002
Action planning	6	I have made a detailed plan regarding when to do my physical exercise. <i>Totally not true</i> (-2) to <i>totally true</i> (+2)	.93	Lippke, Ziegelmann, & Schwarzer, 2004
Coping planning	5	I have made a detailed plan regarding how to cope with possible setbacks. <i>Totally not true</i> (-2) to <i>totally true</i> (+2)	.93	Sniehotta, Schwarzer, Sholz, & Schülz, 2005

Note.  $\alpha$  = Cronbach's alpha; PA = physical activity.

<sup>&</sup>lt;sup>a</sup> Cronbach's alpha was not calculated for the perceived environment index.

scores represent the amount of change in the variable independent of its baseline value and can be calculated by regressing the follow-up values of the variable onto their baseline values. Residual change scores are preferred above absolute change scores. This is because, if possible baseline differences are not taken into account, groups with lower levels are more likely to increase their levels by chance alone than groups with higher levels (Twisk, 2003). To analyze intervention effects ( $c_{\text{Ibasic}}$  and  $c_{\text{Iplus}}$ ), the residual PA change scores were regressed onto the two intervention dummies and covariates and confounders (i.e., age, BMI, gender, educational level, having physical limitations, and marital status). Covariates and confounders were selected on the basis of their association with PA or their confounding influence on the intervention effect as found in earlier analyses (van Stralen, De Vries, Mudde, Bolman, & Lechner, 2010). For improved interpretation and comparison, we calculated Cohen's ESs by dividing the difference between two means at follow-up by the pooled baseline standard deviation (Cohen, 1988).

## **Mediation Analyses**

Given that the interventions targeted multiple mediators simultaneously, we conducted multiple mediator models informed by the product-of-coefficients test (Mackinnon, 2008) to be able to evaluate the independent contribution of each mediator. First, the intervention effects on the theoretical mediators were calculated (a path). Second, the effects of the theoretical mediators on the outcome were calculated when controlling for the research condition (b path). Third, by multiplying the a and b values to provide ab coefficients, we estimated the specific/individual-mediated effects  $(a_{1-15}b_{1-15})$ , the total mediated effect  $(\sum a_{1-15}b_{1-15})$ , and the proportion mediation to the total intervention effect  $(\sum a_{1-15}b_{1-15})$  $(c' + \sum a_{1-15}b_{1-15})$ ). The total intervention effect is the sum of the total mediated/indirect effect ( $\sum a_{1-15}b_{1-15}$ ) and the direct intervention effect when accounted for the total mediated effect (c'). The statistical significance of the mediated effect is estimated by dividing the ab coefficients by their standard error. The standard error of the specific mediated effect was calculated with the Sobel test ( $SEab = \sqrt{(a^2 * SEb^2 + b^2 * SEa^2)}$ ), whereas the standard error of the total mediated effect was calculated with the multivariate delta method  $\sqrt{({a_1}^2 * SEb_1^2 + b_1^2 * SEa_1^2 + a_2^2 + a_2^2 * SEa_1^2 + a_2^2 + a_$  $SEb_2^2 + b_2^2 * SEa_2^2 + \ldots + 2 * a_1a_2COVb_1b_2$ ; Bollen, 1987). All analyses were performed according to the intention-to-treat principle (Hollis & Campbell, 1999).

### **Missing Data**

Logistic regression analyses, using SPSS (Version 15.0), were conducted to examine whether the drop-out rate was associated with baseline characteristics of the participants (i.e., age, gender, BMI, marital status, employment status, education level, baseline PA level, and research condition). Participants who did not have a partner (odds ratio [OR] = 1.32, 95% CI [1.16, 1.51]) or participants who were randomly assigned to one of the intervention conditions (OR<sub>Ibasic</sub> = 2.09, 95% CI [1.81, 2.40]; OR<sub>Iplus</sub> = 2.48, 95% CI [2.17, 2.83]) were more likely to drop out at 12 months. Subsequent analyses were corrected for marital status. With regard to the selectiveness on research condition, Carpenter, Kenward, and White (2007) stated that no objection for further analyses can

be raised when dropout is missing at random. Dropout is missing at random when within each research condition the data are missing completely at random. Subsequent analyses found no significant predictors of dropout within each research condition, raising less concern that the selectiveness on research condition undermined the results.

Missing values were not imputed. In a study examining ways to handle missing data, it was found that multilevel analysis is very flexible in handling missing data, leaving no need to impute the data. Moreover, applying multilevel analyses to an incomplete data set gave more accurate estimations than applying imputation methods (Twisk, 2003; Twisk & de Vente, 2002). Data were therefore analyzed using the incomplete data set including missing data (total data analyses).

#### Results

## **Baseline Characteristics**

In total, 1,971 older adults (response rate 23%) completed the baseline questionnaire. The selection and enrollment trends of participants are shown in Figure 1. At 12 months, 1,348 completed the questionnaire (T3 = 68% retention rate). Participants were on average 64 years old (SD = 8.6) and had an average BMI of 25.5 (SD = 3.8), 81% had a partner, 48% had a low level of education (primary, lower vocational, preparatory vocational, or medium general secondary school), and 47% were employed. Significant baseline differences were found for the level of education, in which significantly fewer participants in the intervention-plus condition had a low level of education (42%) compared with the basic computer-tailored print intervention (51%) and control conditions (50%), F(2, 1928) = 5.0, p < .01. Baseline and posttest scores of the total PA behaviors and mediators are shown in Table 2.

## **Intervention Effects on PA Behavior (c path)**

As shown in Table 2, at 12 months, participants in the basic computer-tailored print intervention condition and interventionplus condition had increased their total weekly days of sufficient PA from 4.3 (SD = 2.2) to 4.7 (SD = 2.0) days per week. Participants in the control condition had increased their total weekly days of PA from 4.0 (SD = 2.2) to 4.3 (SD = 2.0) days per week. Significant intervention effects for both the basic computertailored print intervention condition ( $c_{\text{Ibasic}} = 0.39$ , SE = 0.12, p < .01) and intervention-plus condition ( $c_{\text{Iplus}} = 0.28$ , SE = 0.12, p < .01) were found when compared with the control condition, with small effect sizes (ES<sub>Ibasic</sub> = 0.18, ES<sub>Iplus</sub> = 0.18). No significant differences were found between the two intervention conditions in total weekly days of PA (results not shown). Regarding the other PA outcome variable, only the intervention-plus condition was effective in significantly changing total minutes of PA per week. On average, participants in the intervention-plus condition increased their weekly PA behavior by more than 1 hr per week (ES<sub>Iplus</sub> = 0.19,  $c_{Iplus}$  = 61.8, SE = 27.8) compared with the control condition. No significant intervention effect of the basic intervention condition was found on weekly minutes of PA when compared with the control condition.

Table 2
Baseline, Posttest Scores, and Intervention Effect on PA (c Coefficient) and Potential Mediators (a Coefficient)

	Baselin	ne score: Mean	(SD)	Postte	est score: Mean	(SD)	Intervention	n effect (SE)
Measure	С	$I_{basic}$	$I_{plus}$	С	$I_{basic}$	$I_{plus}$	$I_{basic}$	$I_{plus}$
PA behavior							$c_{\mathrm{Ibasic}}$	$c_{ m Iplus}$
Total days/week PA	4.0 (2.2)	4.2 (2.2)	4.2 (2.2)	4.3 (2.0)	4.7 (2.1)	4.7 (2.0)	0.39 (0.12)**	0.28 (0.12)**
Total min/week PA	610 (438)	663 (475)	629 (440)	619 (448)	671 (436)	703 (443)	13.0 (28.4)	61.8 (27.8)*
Mediators 3 months							$a_{\mathrm{Ibasic}}$	$a_{\mathrm{Iplus}}$
Awareness	0.61 (0.49)	0.58 (0.49)	0.63 (0.48)	0.64 (0.48)	0.68 (0.47)	0.68 (0.47)	0.05 (0.04)	0.05 (0.03)
Pros	1.0 (0.519)	1.0 (0.54)	1.0 (0.53)	1.0 (0.51)	1.0 (0.49)	0.97 (0.48)	-0.01(0.03)	-0.03(0.03)
Cons	-0.97(0.59)	-1.0(0.55)	-0.99(0.60)	-0.98(0.55)	-0.98(0.56)	-1.0(0.58)	0.02 (0.03)	0.01 (0.03)
Social support	2.1 (1.1)	2.2(1.1)	2.1 (1.1)	2.1 (1.1)	2.2(1.1)	2.1 (1.1)	-0.05(0.06)	-0.05(0.06)
Social modeling	0.14 (1.12)	0.32 (1.16)	0.21 (1.14)	0.12(1.1)	0.35(1.1)	0.26 (1.12)	$0.20 (0.08)^*$	$0.17 (0.08)^*$
Sports partner	0.62 (0.49)	0.61 (9.49)	0.62 (0.48)	0.61 (0.49)	0.62 (0.49)	0.59 (0.49)	0.02 (0.03)	-0.02(0.03)
Intrinsic motivation	0.57 (0.79)	0.57 (0.82)	0.49 (0.83)	0.57 (0.77)	0.55 (0.74)	0.53 (0.76)	-0.02(0.04)	0.01 (0.04)
Self-efficacy	0.51 (0.67)	0.62 (0.71)	0.56 (0.67)	0.52 (0.66)	0.66 (0.59)	0.59 (0.61)	$0.08 (0.04)^*$	0.00 (0.04)
Mediators 6 months								
Awareness	0.61 (0.49)	0.58 (0.49)	0.63 (0.48)	0.60 (0.49)	0.69 (0.46)	0.70 (0.46)	0.09 (0.03)**	$0.08 (0.03)^{**}$
Perceived environment	4.2 (2.2)	4.3 (2.2)	4.9 (2.3)	4.1 (2.2)	4.6 (2.3)	5.3 (2.2)	0.06 (0.16)	$0.48 (0.16)^{***}$
Intention	7.6 (1.81)	7.7 (1.88)	7.8 (1.76)	7.1 (1.8)	7.5 (1.7)	7.6 (1.7)	0.39 (0.12)***	$0.40 (0.12)^{***}$
Commitment	0.94 (0.62)	0.95 (0.63)	0.92 (0.65)	0.98 (0.60)	1.0 (0.60)	1.1 (0.57)	-0.00(0.03)	$0.06(0.03)^*$
Strategic planning	0.03 (0.49)	-0.02(0.51)	0.00 (0.53)	0.04 (0.53)	0.04 (0.53)	0.04 (0.55)	0.02 (0.03)	0.01 (0.03)
Action planning	0.20 (0.87)	-0.00(0.93)	0.21 (0.90)	-0.04(0.99)	-0.00(1.0)	-0.09(0.98)	$0.13 (0.07)^{\ddagger}$	-0.01(0.07)
Coping planning	0.08 (0.90)	-0.09 (0.94)	0.03 (0.93)	-0.07 (0.96)	-0.12(1.0)	-0.18 (0.99)	0.03 (0.07)	-0.10 (0.07)

Note. Regression models were adjusted for age, gender, educational level, marital status, having physical limitations, body mass index, and within-district clustering effects. Means represent means of the available data.  $a_{\rm Ibasic}=$  effect basic intervention on potential mediator compared to control;  $a_{\rm Iplus}=$  effect environmental intervention on potential mediator compared to control; C= Control group;  $c_{\rm Ibasic}=$  effect basic intervention on PA behavior compared to control;  $c_{\rm Iplus}=$  effect environmental intervention on PA behavior compared to control;  $c_{\rm Iplus}=$  basic computer-tailored intervention;  $c_{\rm Iplus}=$  environmentally environmentally

## Intervention Effects on Mediators (a path)

The first step of the mediation analysis was to estimate the effect of the interventions on changes in the potential mediators (a path). The final two columns of Table 2 show the intervention effects on each mediator for the intervention basic  $(a_{\text{Ibasic}})$  and interventionplus  $(a_{Iplus})$  conditions, respectively, compared with the control group. The basic computer-tailored print intervention increased the participants' perception of social modeling ( $a_{\text{Ibasic}} = 0.20$ , SE =0.08, p < .05) and self-efficacy ( $a_{\rm Ibasic} = 0.08$ , SE = 0.04, p < .05.05) over 3 months, and the participants' awareness ( $a_{\text{Ibasic}} = 0.09$ , SE = 0.03, p < .01), participants' intention to be sufficiently physically active ( $a_{\text{Ibasic}} = 0.39$ , SE = 0.12, p < .001), and participants' action planning skills over 6 months ( $a_{\text{Ibasic}} = 0.13$ , SE = 0.07, p = .06) compared with the control condition, although the latter association was borderline significant. The interventionplus condition was found to have positively changed the participants' perception of social modeling ( $a_{Iplus} = 0.17$ , SE = 0.08, p < .05), participants' awareness ( $a_{\rm Iplus} = 0.08$ , SE = 0.03, p < .01), environmental perceptions ( $a_{\rm Iplus} = 0.48$ , SE = 0.16, p < .001), intention ( $a_{\text{Iplus}} = 0.40$ , SE = 0.12, p < .001), and commitment to PA behavior ( $a_{\text{Iplus}} = 0.06$ , SE = 0.03, p < .05) compared with the control condition.

## Mediator Effect on PA Behavior (b path)

The second step of the mediation analysis was to estimate whether the changes in the mediator were associated with changes in weekly days and weekly minutes of PA behavior over 12 months (b coefficient). Table 3 shows the results of the multiple regression model. Changes in total weekly days of PA were predicted by changes in participants' awareness (b=0.57, SE=0.14, p<.001), sports partner (b=-0.41, SE=0.16, p<.01), and self-efficacy (b=0.28, SE=0.14, p<.01) over 3 months and by changes in participants' awareness (b=0.44, SE=0.14, p<.001), strategic planning behavior (b=0.39, SE=0.15, p<.01), and intention (b=0.19, SE=0.05, p<.001) over 6 months. Changes in total weekly minutes of PA over 12 months were predicted by changes in self-efficacy (b=67.5, SE=30.8, p<.05) and changes in strategic planning (b=79.3, SE=32.8, p<.05).

#### Mediated Effects (ab coefficient)

The last step of the mediation analysis estimated whether the potential mediators significantly mediated the intervention effect and what proportion of the intervention effect could be explained by the total mediated effect. Table 3 presents the specific mediated effects (ab coefficient), which are the independent mediated effect of each individual potential mediator and the proportion of each specific mediated effect on the total intervention effect (% ME). In both intervention conditions, the intervention effects on total weekly days of PA were mediated by changes in awareness ( $ab_{\text{Iba}}$  sic = 0.04, SE = 0.02, p < .05, % ME = 15.9%;  $ab_{\text{Iplus}} = 0.04$ , SE = 0.02, p < .05, % ME = 12.6%) and intention ( $ab_{\text{Ibasic}} = 0.07$ , SE = 0.03, p < .01, % ME = 25.3%;  $ab_{\text{Iplus}} = 0.08$ , SE = 0.03, p < .01, % ME = 22.7%).

For the basic computer-tailored print intervention, the direct intervention effect ( $c'_{\text{Ibasic}}$ ) on weekly days of PA had decreased to

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Multiple Mediator Models Including the Effect of the Mediator on Outcome (b Coefficient) and Mediated Effect (ab Coefficient)

	Effect mediator	Effect mediator on outcome b (SE)			Me	diated ef	Mediated effect ab (SE)			
			Tol	tal weekl	Total weekly days PA		Tota	Fotal weekly minutes PA	tes PA	
Measure	Total weekly days PA	Total weekly days PA Total weekly minutes PA	Intervention basic % ME Intervention plus % ME	% ME	Intervention plus	% ME	Intervention basic	% ME Intervention plus		% ME
Mediators 3 month										
Awareness	$0.57 (0.14)^{***}$	16.8 (30.5)	0.03 (0.02)		0.03 (0.02)		0.8(1.5)		0.8 (1.6)	
Pros	-0.03(0.19)	17.0 (41.4)	0.00 (0.00)		0.00 (0.01)		-0.1(0.6)	'	-0.4 (1.1)	
Cons	-0.26(0.15)	-12.2(31.6)	-0.01(0.01)		-0.00(0.01)		-0.2(0.7)	'	-0.1(0.4)	
Social support	-0.05(0.06)	-12.34(15.2)	-0.00(0.01)		-0.00(0.01)		0.5(1.1)		0.6 (1.0)	
Social modeling	-0.05(0.06)	-26.8(13.9)	-0.01(0.01)		-0.01 (0.01).		-05.3(3.4)	'	-4.4(3.0)	
Sports partner	$-0.41 (0.16)^*$	-41.2(33.8)	-0.01(0.01)		0.01 (0.01)		-0.9(1.4)		0.9 (1.4)	
Intrinsic motivation	0.14 (0.12)	0.63 (26.1)	-0.00(0.01)		0.00 (0.01)		-0.0(0.0)		0.0 (0.2)	
Self-efficacy	$0.28 (0.14)^*$	$67.5 (30.8)^*$	0.02 (0.02)		0.00 (0.01)		5.6 (3.8)		0.2 (2.7)	
Mediators 6 months										
Awareness	$0.44 (0.14)^{**}$	2.3 (30.1)	$0.04 (0.02)^*$	15.9	$0.04 (0.02)^*$	12.6	0.2 (2.8)	'	-0.2(2.5)	
Perceived environment	0.05 (0.03)	8.6 (7.6)	0.00 (0.01)		0.03 (0.02)		0.5(1.5)		4.1 (3.9)	
Intention	$0.19 (0.05)^{**}$	12.7 (10.4)	$0.07 (0.03)^{**}$	25.3	$0.08 (0.03)^{**}$	22.7	5.0 (4.4)		5.1 (4.4)	
Commitment	-0.10(0.15)	-32.1(32.9)	0.00 (0.00)		-0.01(0.01)		0.0(1.0)	'	-1.9(2.2)	
Strategic planning	$0.39 (0.15)^{**}$	79.3 (32.8)*	0.01 (0.01)		0.00 (0.01)		1.7 (2.6)		0.9 (2.4)	
Action planning	0.02 (0.07)	24.1 (16.7)	0.00 (0.01)		-0.00(0.01)		3.0 (2.6)		-1.2(1.7)	
Coping planning	0.09 (0.07)	-10.4(16.2)	0.00 (0.01)		-0.01(0.01)		-0.3(0.9)		1.0 (1.7)	

Note. Regression models were adjusted for age, gender, educational level, marital status, having physical limitations, body mass index, and within-district clustering effects. Means represent means of the available data. PA = physical activity; % ME = proportion mediated.

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

0.22~(SE=0.15) when all mediators were included and was no longer significant. The total mediated effect, including all mediators, was significant ( $\Sigma ab_{\mathrm{Ibasic}}=0.15, SE=0.05, p<.01$ ) and explained 41% of the total intervention effect on weekly days of PA behavior. The direct intervention effect of intervention-plus condition ( $c'_{\mathrm{Iplus}}$ ) on weekly days of PA had decreased to 0.26 (SE=0.14) when all mediators were included and was no longer significant, indicating a partial mediated effect. The total mediated effect on the effect of the intervention-plus condition on weekly days of PA, including all mediators, was significant ( $\Sigma ab_{\mathrm{Iplus}}=0.15, SE=0.05, p<.01$ ) and explained 37% of the total intervention effect. As shown in Table 3, in the multiple mediation models of the intervention effects on total weekly minutes of PA, no significant mediators were found.

### **Discussion**

We aimed to examine the efficacy of two computer-tailored PA intervention studies in changing PA behavior in older adults in the long term (1 year after the start of the intervention) and to identify the mediating mechanisms through which the interventions induced their effect on PA behavior. Based on the results, we could draw three conclusions.

First, the two computer-tailored PA interventions had significant positive effects on the total weekly days of PA of older adults in the longer term. Small effect sizes (ES = 0.18) were found for both interventions. These findings are important considering the need for effective long-term PA promotion interventions for this age group. Although several studies found short-term effects of print computer-tailored PA interventions for older adults (Jancey et al., 2008; Walker et al., 2009), to our knowledge, only one study has assessed the long-term efficacy of a print computer-tailored intervention in this specific age group (Greaney et al., 2008). Contrary to our study, Greaney et al. (2008) found no significant long-term effects. Our results are consistent with the findings of studies analyzing the long-term efficacy of (tailored) PA telephone counseling interventions in older adults (Kolt, Schofield, Kerse, Garrett, & Oliver, 2007; Pinto, Goldstein, Ashba, Sciamanna, & Jette, 2005).

Although both interventions were effective in changing total weekly days of PA, only the environmental intervention was effective in changing total weekly minutes of PA. In-depth analyses (unpublished data) showed that this increase in weekly minutes of PA in environmental intervention participants was due to an increase in both days of PA per week and a nonsignificant increase in minutes of PA on days they were active. Participants of the basic intervention, on the other hand, only increased weekly days of PA and (nonsignificantly) decreased minutes of PA per day. Although the basic intervention was able to increase the number of PA days, it did not significantly increase the total amount of PA. This can be explained by the provided environmental information in the environmental condition. The cycling/ walking routes could have initiated cycling/walking on a day participants were already active, thereby increasing both weekly days and daily minutes of PA. The results indicate that the two PA measures are different, and both outcomes should be presented in the future.

Second, awareness of personal PA level and intention to be sufficiently active were mediators of the intervention effect on

weekly days of PA. The results confirm that awareness of personal PA level is important in changing PA behavior and support theoretical models such as the precaution adoption process model (Weinstein, 1988), the health action process approach (Schwarzer, 2009), and I-Change model (De Vries et al., 2006). Studies have shown that people have a tendency to overestimate their PA behavior, in which they incorrectly think their PA behavior is sufficient (Lechner et al., 2006; Ronda, Van Assema, & Brug, 2001). Consequently, people unaware of their personal insufficient PA level do not perceive a need to change. In our study, the two interventions focused explicitly on increasing awareness of people's own PA level by providing personalized and normative feedback of participants' own PA level compared with the PA guidelines and PA level of others. The effectiveness of these intervention strategies can be confirmed by two computer-tailored interventions targeting nutrition behavior using similar strategies (Kroeze, Oenema, Dagnelie, & Brug, 2008; Oenema & Brug, 2003). Intention was targeted directly by providing computertailored feedback about participants' intention and indirectly by targeting participants' attitude, self-efficacy, and social influence. This multicomponent nature of the intervention makes it hard to draw definite conclusions on the pathway that caused the increase in intention. No other significant mediators were identified, which is in contrast to some other PA interventions for older adults that found mediating effects of self-efficacy (Brassington, Atienza, Perczek, DiLorenzo, & King, 2002; Michael & Carlson, 2009), attitude (Brassington et al., 2002; Pinto, Lynn, Marcus, DePue, & Goldstein, 2001), and social influences (Barrera, Toobert, Angell, Glasgow, & Mackinnon, 2006), although some studies could not, as in our study, confirm these results (Brassington et al., 2002; McAuley, Courneya, Rudolph, & Lox, 1994; Michael & Carlson, 2009; Pinto et al., 2001).

In contrast to our expectations, we found no differences in working mechanisms between the two interventions. Although the environmental intervention yielded changes in perceived environment, its intervention effect on PA behavior was not mediated by these changes in the multiple mediation models. In a single mediation model, on the other hand, we found that environmental perceptions mediated the effect of the environmental intervention on weekly days of PA (results not presented in this study). This suggests that the association between perceived environment and weekly days of PA is mediated by a more proximal variable (e.g., awareness or intention). This confirms theoretical models such as the I-Change model (De Vries et al., 2006) or the environmental research framework for weight gain prevention framework (Kremers et al., 2006), which assume that environmental concepts indirectly influence health behaviors via more proximal awareness or motivational factors. Although the environmental intervention targeted social environmental mediators (e.g., providing access to a website with a forum and e-buddy system to stimulate social influences), the intervention did not additionally affect the social environmental mediators. This could be explained by the low number of intervention-plus participants (i.e., 11%) who had actually visited the website (van Stralen et al., 2009b).

Third, based our mediation analyses, recommendations for future interventions aimed at changing PA in older adults can be made. Intervention developers should add the significant intervention strategies that increased awareness and intention to their intervention. In our cases, a mediating effect was not confirmed, but future research can be informed in two ways. First, if a change in a concept did not affect the outcome (i.e., social modeling), this concept may be irrelevant in changing the behavior and should be removed from the intervention. Other explanations are that our study lacked power, the mediator's indirect influence of behavior via other mediators (Ajzen, 1991; De Vries et al., 2006), insensitivity of our measures, or a low variability in the mediators (Hafeman & Schwartz, 2009). Second, in case the interventions did not affect the mediator (i.e., self-regulation and self-efficacy), the strategies targeting these mediators could have been ineffective, the study lacked power, the measures were insensitive (Hafeman & Schwartz, 2009), or the intervention was ineffective in subgroups (e.g., unmotivated participants). In-depth analysis (not presented in this study) showed that some strategies (e.g., fill in an action plan) were effective in changing a targeted mediator among the participants who applied the strategy. However, because only a few participants applied this strategy (e.g., 49 vs. 640 who did not; van Stralen et al., 2009a), no overall intervention effect was detected. Therefore, before adapting or deleting the intervention components, in-depth analyses are needed to study the effectiveness of the intervention strategies in participants who adequately

Our study was subject to some limitations. First, the measurements of mediators and outcomes relied on self-report. The results could therefore be biased by social desirability and overreporting. Furthermore, given that we measured changes in mediators at 3 and 6 months, it is very likely that, because of changes in PA, several mediators have continued to improve over time (e.g., self-efficacy, intention, awareness). Therefore, if the mediators would have been measured at 12 instead of 3 or 6 months, their association with PA might have been stronger, resulting in stronger mediated effects. Third, generalizing the results might be biased by the initial response and selective dropout. Intervention participants were about twice as likely to drop out as control participants. A possible reason for this higher dropout is that intervention participants, who had made fewer PA changes, had fewer reasons to continue. Furthermore, because intervention participants received their advice at the start, they could have been less reluctant to remain in the study and return additional questionnaires. Waitlist control participants, on the other hand, had the prospect of receiving computer-tailored advice at the end and could have been more motivated to stay in the study. Higher dropout rates among intervention participants have also been reported in other computertailored intervention studies (Oenema, Tan, & Brug, 2005; Spittaels, De Bourdeaudhuij, & Vandelanotte, 2007). By analyzing the total data set, including the missing data using multilevel analyses, we tried to account for selective dropout (Twisk & de Vente, 2002). Fourth, the measures might not have been sensitive enough to detect changes in the mediators. Most of our mediator measures were translated and adapted from existing validated questionnaires because validated Dutch measures are not available. Although the questionnaire was tested for indicators of construct validity (van Bree, 2006), it was not tested for internal validity or sensitivity.

To conclude, the two interventions were effective in changing weekly days of sufficient PA in older adults. In addition, the environmental intervention was effective in changing weekly minutes of PA. Awareness of personal PA level and intention to be sufficiently active were found to be significant mediators of the intervention effect on weekly days of PA. In total, 41% and 37%

of the total intervention effects on weekly days of PA of the basic computer-tailored intervention and environmental intervention, respectively, could be explained by changes in the targeted mediators. This indicates that the interventions were effective in changing some of the mediators, and that the changes in some of the mediators induced by the interventions were causally associated with PA behavior change.

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