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Mediators of Physical Activity Behavior Change: Findings From a 12-Month Randomized Controlled Trial

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Abstract

Objective—To examine putative mediators of a 12-month motivationally tailored physical activity (PA) promotion intervention.

Design—We randomly assigned 239 healthy, underactive adults (moderate–vigorous physical activity <90 min/week; mean age = 47.5 years; 82% women) to receive (a) print-based feedback, (b) phone-based feedback, or (c) contact control.

Primary Outcome—PA at baseline, 6, and 12 months, as measured by the 7-Day Physical Activity Recall interview.

Mediators—Four TransTheoretical Model constructs explicitly targeted by the intervention (i.e., self-efficacy, decisional balance, cognitive and behavioral processes of change), as well as four additional constructs linked to PA behavior change (i.e., social support, outcome expectancy, PA enjoyment, exercise-induced feelings).

Results—Multivariate mediation analyses were used to analyze longitudinal PA outcomes. Changes in behavioral processes and one aspect of exercise-induced feelings (revitalization) satisfied both Action Theory (i.e., treatment effects on mediators) and Conceptual Theory (i.e., mediator effects on PA) tests at 6 and 12 months and emerged as statistically significant mediators of treatment effects on PA across delivery channels ($ps < .014$). Cognitive processes, self-efficacy, decisional balance, and social support for PA participation satisfied Action Theory tests at both 6 and 12 months, but failed Conceptual Theory tests. Delayed intervention effects were observed on other aspects of exercise-induced feelings, PA enjoyment, and outcome expectancies, but these variables failed mediation testing at 12 months.

Conclusion—Findings are consistent with previous research illustrating the importance of behavioral processes of change, but also indicate that affective response to PA may warrant more attention as a potential target of behavior change programs.

Keywords

physical activity; behavior change; multivariate mediation

Increasing rates of regular physical activity (PA) is a public health priority given the combination of substantial health benefits of regular PA and the low prevalence of PA among the general population (Garber et al., 2008). To this end, a growing number of studies have tested theory-based PA-promotion interventions. To help inform the design of more effective behavior-change interventions, analyses focused solely on intervention effects on PA outcomes should be supplemented by mediational analyses that can help researchers and practitioners understand the underlying mechanism of action contributing to success of the intervention. Cerin and MacKinnon (2009) highlight the importance of determining whether (a) the intervention successfully acted on the putative mediators (i.e., “Action Theory test”), (b) changes in the mediators were indeed predictive of changes in the target behavior suggested by the conceptual framework underpinning the intervention (i.e., “Conceptual Theory test”) over and above any direct treatment effects, and (c) these conditions held simultaneously for each mediator, indicating that the corresponding mediational pathways accounted for at least part of the relationship between the intervention and the target behavior (i.e., “Mediation test”).

Previous reviews of PA interventions have generally found few studies in which putative mediators were adequately evaluated (Baranowski, Anderson, & Carmack, 1998; Lewis, Marcus, Pate, & Dunn, 2002). In a recent review of mediation analyses in studies of PA outcomes conducted since 1998, Rhodes and Pfaeffli (2010) identified 22 studies they deemed of moderate or high quality. Eleven of these failed to show intervention effects on PA outcomes, despite the fact that four passed Action Theory tests for at least one of the targeted constructs. Of the studies that did demonstrate significant intervention effects on PA outcomes, all passed Action Theory tests for at least one construct, but only five passed Conceptual Theory tests as well. However, one of the latter five studies failed to show significant intervention effects through any of the putative mediator paths, leaving only four of the original 22 studies for which mediation could be established statistically. For example, self-regulation strategies, the behavioral processes of change construct from the

TransTheoretical Model (TTM), received the most support as mediators of physical activity interventions (see also Lewis, Marcus, Pate, & Dunn, 2002).

Project STRIDE

One of the four studies demonstrating significant mediation in the review by Rhodes and Pfaeffli (2010) was Project STRIDE (Marcus et al., 2007a), a 12-month randomized clinical trial that is analyzed further in this article. Project STRIDE used a print-based contact-control arm (Control), in which participants received standard educational materials on health and wellness. In addition, the study had two intervention arms that were equated for individually tailored content, but used different delivery channels: print-based materials (Print) versus telephone counseling (Phone). Intervention content was based on four targeted TTM constructs, that is, feedback on performance (self-efficacy), tailored information on relevant advantages of physical activity (decisional balance), discussion of how PA behavior has an impact on important others (cognitive processes of change), and planning and self-monitoring (behavioral processes of change). A full classification of the Project STRIDE intervention content has been provided by Abraham and Michie (2008) and Michie, Abraham, Whittington, McAteer, and Gupta (2009).

Both Print and Phone showed significant PA increases at 6 months relative to Control. However, PA continued to increase in Print between 6 and 12 months and was significantly greater than both Control and Phone at study end. In contrast, PA leveled off in Phone and was no longer significantly different from Control at 12 months (Marcus et al., 2007b). A multiple mediation analysis focused on 6-month outcomes alone showed that change in behavioral processes successfully mediated the effects of both Print and Phone on changes in PA behavior from baseline, whereas change in cognitive processes acted as a suppressor (i.e., increases in cognitive processes led to decreases in PA behavior). Neither self-efficacy nor decisional balance was found to be a significant mediator in the full model (Napolitano et al., 2008).

The Present Study

Mediators of 12-month outcomes of Project STRIDE have not been previously reported. Thus, one goal of the present study is to extend prior mediator analyses of the targeted TTM constructs (i.e., self-efficacy, decisional balance, cognitive and behavioral processes of change) to cover the entire 12-month study period. A second goal is to include in the mediator analysis four additional constructs (i.e., PA enjoyment, exercise-induced feelings, social support, and outcome expectancy) that cover conceptual domains untapped by the TTM constructs that were the focus of the STRIDE intervention. Specifically, Social Cognitive Theory (SCT) posits that both affect, as measured by PA enjoyment and exercise-induced feelings, and social support influence behavior via their effects on more proximal cognitive variables (Bandura, 1997). Additionally, although decisional balance measures the perceived importance of potential behavioral outcomes (e.g., Marcus, Rakowski, & Rossi, 1992), outcome expectancies involve the perceived likelihood of potential outcomes and form a distinct, and quite central, determinant of behavior according to SCT (Bandura, 1997). Furthermore, all four of these SCT constructs have been previously shown to be

predictive of PA behavior change (Sallis, Grossman, Pinski, Patterson, & Nader, 1987; Rovniak, Anderson, Winett, & Stephens, 2002; Williams, Anderson, & Winett, 2005; Williams et al., 2006; Williams et al., 2008). Thus, though not explicitly targeted by the STRIDE intervention, these four SCT constructs may have acted as mediators in showing both differential change across study arms and association with change in PA outcomes.

We hypothesize that the original four TTM constructs, as well as the additional four SCT constructs, will jointly mediate the effects of the STRIDE intervention at both 6 and 12 months. In conducting our analyses, we distinguish between Action Theory and Conceptual Theory tests, in order to draw distinct conclusions regarding the effects of our specific intervention on the selected putative mediators versus the effects of the putative mediators on PA outcomes. In this way, the present analysis aims to build on the accumulating literature (e.g., Rhodes & Pfaeffli, 2010) delineating theoretical constructs that are either malleable (i.e., as demonstrated by the Action Theory test) and/or potentially important mechanisms of PA behavior change if successfully modified by an intervention (i.e., as demonstrated by the Conceptual Theory test).

Method

Recruitment and Inclusion Criteria

Recruitment methods and full inclusion criteria have been described elsewhere (Marcus et al., 2007a). The primary recruitment strategy was via advertisements in the local newspaper. Participants were required to be healthy, aged 18–65 years, and underactive based on national recommendations (Pate et al., 1995) (i.e., participating in moderate or vigorous physical activity 90 min/ week or less). Additionally, they had to be willing to be randomly assigned to any study arm and to read and sign an institutionally approved consent form.

Sample Description

The final sample of the parent study consisted of 239 previously sedentary, healthy men and women. The sample was mostly Caucasian (90.3%), female (82.0%), and middle-aged ($M=44.5$ years). Most participants were college educated (70.6%) with annual household income above \$50,000 (60.8%). Detailed demographic and descriptive information on the sample appears elsewhere (Marcus et al., 2007a).

Intervention Arms

The interventions in Project STRIDE are described in more detail elsewhere (Marcus et al., 2007b). Participants randomized to either Print or Phone received a total of 14 contacts over the two phases of the intervention: the more intensive PA Adoption Phase (months 0–6) that contained the bulk of the intervention contacts (i.e., 11 of 14 contacts occurred during this period) and the less intensive PA Maintenance Phase (months 7–12). The contacts were guided by TTM recommendations and consisted of individually tailored messages, including computer-generated expert system reports, stage-targeted booklets, and physical activity-related tip sheets. The content was held constant between the intervention arms, with a health educator delivering the content from the stage-matched manuals, expert system feedback report, and tip sheets. In the Phone arm alone, the health educator also helped the

participant problem-solve PA barriers and discussed the content of the intervention materials. The goal for participants on both intervention arms was to meet or exceed CDC/American College of Sports Medicine (ACSM) recommendations: at least 5 days per week for a total of at least 30 min each time (Pate et al., 1995).

Primary Assessments

Outcome data were collected at baseline, 6 months, and 12 months. Assessments consisted of an interviewer-administered 7-Day Physical Activity Recall (PAR) interview, anthropometric measures, an exercise stress test, stage of motivational readiness for change, and a battery of psychosocial questionnaires. In this article, we will focus exclusively on the 7-Day PAR and psycho-social measures.

Measures

Primary outcome—The Stanford 7-Day PAR is an interviewer-administered measure of demonstrated validity and reliability (Blair et al., 1985; Sallis et al., 1985) that has shown sensitivity to change in trials examining moderate-intensity PA (Dunn, Andersen, & Jakicic, 1998; Dunn et al., 1999; King et al., 2007).

PA intervention constructs—For our purposes, a mediator is defined as a variable on the causal pathway between the intervention and PA behavior change (Baron & Kenny, 1986). In other words, it is assumed that the effectiveness of the intervention is due at least in part to self-reported changes on particular mediating variables. The following summarizes the set of measures we hypothesized would mediate the relationship between our intervention and PA behavior change, as guided by the TTM and SCT. Their internal consistency reliability (Cronbach's alpha) was evaluated across time (baseline, 6, and 12 months) among all available study participants.

Processes of change—Individuals appear to use a variety of strategies as they progress through the stages of motivational readiness to change a behavior (Prochaska & DiClemente, 1983). In this study, the processes of PA behavior change were measured by instruments developed by Marcus, Rossi, Selby, Niaura, and Abrams (1992). Internal consistency across time ranged from 0.78 to 0.91 for behavioral processes and from 0.84 to 0.85 for cognitive processes.

Exercise self-efficacy—Self-efficacy for exercise was assessed using a 5-item questionnaire developed by Marcus, Selby, Niaura, and Rossi (1992). Internal consistency across time ranged from 0.78 to 0.86 in this study.

Decision making—The 16-item Decisional Balance instrument (Marcus et al., 1992) was used to measure the perceived importance of potential benefits from PA adoption (e.g., "stress reduction"), as well as of potential costs (e.g., "less time with family and friends"). Following convention, the difference of the two total scores (Pros–Cons) was used to derive an overall measure of perceived net benefit from PA adoption that showed quite high internal consistency across time (Cronbach's alpha = 0.82–0.85).

Social support for exercise participation—The original scale measures the extent to which an individual has sources of support specific to PA participation and has been shown to correlate well with PA behavior (Sallis et al., 1987). In this study, we used the first 10 items of the scale with the strongest factor loadings and combined social support from family and friends (Cronbach's $\alpha = 0.85\text{--}0.94$). The companion 3-item subscale measuring the frequency of rewards and punishments provided by the respondent's social network did not have adequate internal consistency at any time point and was dropped from further consideration (Cronbach's $\alpha = .34\text{--}0.51$).

Exercise-Induced Feeling Inventory—A measure of feeling states that occur in conjunction with acute bouts of PA (Gauvin & Rejeski, 1993), the **Exercise-Induced Feeling Inventory (EFI)** scale consists of 12 items that assess four distinct states: (a) revitalization, (b) positive engagement, (c) tranquility, and (d) physical exhaustion. Internal consistency across time ranged from 0.85 to 0.88, 0.88 to 0.90, 0.85 to 0.91, and 0.89 to 0.92, respectively.

Physical Activity Enjoyment Scale—The Physical Activity Enjoyment Scale (PACES) scale (Kendzierski & DeCarlo, 1991) is an 18-item measure that examines perceived PA attributes (e.g., “It's very pleasant,” “It's no fun at all”) and has been predictive of PA behavior (Williams et al., 2006). It showed high internal consistency across time (Cronbach's $\alpha = 0.94\text{--}0.96$).

Outcome expectancies for exercise—Although Decisional Balance assesses the perceived importance of potential costs and benefits resulting from PA adoption, this 9-item measure (Resnick, Zimmerman, Orwig, Furstenberg, & Magaziner, 2000) was designed to measure participants' subjective assessment of the likelihood of occurrence of certain beneficial outcomes as a result of regular PA uptake (e.g., “How likely is it that exercise will make me feel better physically?”). This scale demonstrated high internal consistency across time (Cronbach's $\alpha = 0.90\text{--}0.91$).

Statistical Analyses

Longitudinal trajectories for our primary PA outcome (7-Day PAR) and all putative mediators were estimated by jointly analyzing the 6- and 12-month follow-ups, with random subject-specific intercepts used to accommodate within-subject correlation across time. The corresponding linear mixed-effects models were estimated via restricted maximum likelihood using Splus 8.2 (Insightful Corp., 2007). Likelihood-based estimation uses all available data to produce consistent estimates of the regression coefficients, as long as missingness is related only to previously observed outcomes as well as model covariates (Daniels & Hogan, 2008; Little & Rubin, 2002). Although still sensitive to dropout patterns that depend on the missing outcome itself (an assumption that cannot be tested empirically), it makes fewer assumptions than the intent-to-treat (ITT) approach of assigning a prespecified score to the missing data (e.g., baseline observation carried forward).

Continuous variables were standardized by across all time points subtracting off their baseline mean and dividing by their baseline standard deviation. Hence, regression

coefficients have an effect size interpretation, and their magnitude can be meaningfully compared both within and across regression models. Results can be converted back into the original measurement scale using sample means and standard deviations reported in Table 1. The only categorical covariate was study group, coded using Control as the reference category.

According to the mediational framework outlined in the Introduction and depicted graphically for a single follow-up in Figure 1 of Napolitano et al. (2008), we initially conducted Action Theory tests that sought to determine whether the intervention produced statistically significant changes in each of the putative mediator variables from baseline to follow-up. To this effect, 6- and 12-month measures of each variable of interest were jointly regressed on their own baseline, study group, time, and group-by-time interaction. Adjusted group means at follow-up were then calculated for “typical” subjects, with baseline values of the outcome of interest equal to the overall sample means listed in Table 1. Results are presented in Table 2 in terms of (a) contact control trajectories and (b) differences between the trajectories of each intervention group and that of the contact control group. Inclusion of contact control trajectories was deemed important, because it helped identify variables that showed changes from baseline, even in the absence of the intervention. Because of the standardization process, all these trajectories are anchored at a common baseline value of zero, which has been omitted from Table 2. Adjusted means in the original measurement scale can be obtained by multiplying the standardized regression coefficients in Table 2 by the baseline standard deviations in Table 1 and then adding back the corresponding baseline means.

Table 3 focuses on multivariate regression models for our primary PA outcome. In these models, putative mediators were subjected to Conceptual Theory tests that sought to evaluate whether their observed changes from baseline were associated with statistically significant increases in PA over the same time frame, controlling for any effects due to the intervention itself. Because we did not expect mediator changes from baseline to affect concurrent change in PA differentially by follow-up time, a common regression slope was assumed for mediator change scores at both 6 and 12 months (no change score by time interaction). These Conceptual Theory tests formed the basis of a forward selection procedure used to identify additional SCT constructs associated with change in PA over and above that which could be attributed to the four TTM variables alone. Because mediator–outcome correlations at baseline can confound the mediator–outcome relationship at follow-up, PA changes were adjusted for baseline values of all mediators of interest as well as for baseline PA levels (Shrout & Bolger, 2010).

Finally, in Table 4 we tested within a multiple mediation framework whether each of the pathways included in the most comprehensive regression model shown in Table 3 accounted for at least part of the relationship between the intervention and the target behavior using the “product of coefficients” method (MacKinnon, 2008), with standard errors based on a first-order delta method (Sobel, 1982). Despite the widespread acceptance of linear structural equation modeling techniques for conducting mediation analyses, we note that our estimates may differ from the stronger causal mediation effect one would have obtained using a

potential outcomes framework (Sobel, 2008). Sufficient conditions for this more stringent causal interpretation to hold are provided by Imai, Keele, and Tingley (2010).

Results

Baseline means and standard deviations are presented in Table 1 for both the 7-Day PAR ($M = 19.64$, $SD = 25.00$) and all putative mediators. They can be used to convert standardized treatment effects listed in Tables 3 and 4 to the original measurement scale. Examination of correlations between mediator change scores revealed a strong association between change in behavioral and cognitive processes ($\rho = 0.73$ – 0.74 across follow-ups).

Action Theory tests for both the 6- and 12-month follow-ups are shown in Table 2. Standardized between-groups differences suggest the presence of statistically significant intervention effects at 6 months for both Print and Phone on all four TTM variables, social support for exercise participation, and the revitalization component of the EFI scale. In addition, Print showed increases in the magnitude of the intervention effects on all putative mediators between 6 and 12 months. As a result, changes from baseline in the three remaining components of the EFI scale (positive engagement, tranquility, physical exhaustion), PA enjoyment, and outcome expectancies attained statistical significance within the Print arm at 12 months, despite null effects at 6 months. In contrast, Phone had a more mixed record, with the attainment of statistical significance by two additional EFI subscales (tranquility, physical exhaustion) counterbalanced by a loss of significance with respect to decisional balance. As a result, Action Theory tests at 12-month follow-up were uniformly stronger in terms of both effect size and statistical significance for Print than for Phone, with respect to all intermediate TTM and SCT variables considered likely to have been affected by the PA intervention.

Conceptual Theory tests are shown in Table 3, which summarizes the output of three distinct longitudinal outcome models, shown in increasing order of complexity. PA at both 6 and 12 months was initially regressed on its own baseline as well as baseline values of putative mediators, but not on mediator change scores themselves. Therefore, differences in adjusted means between each of the two active interventions and the control arm in this “Base” model capture the *total treatment effects* on PA for a “typical” subject with baseline PA and mediator values equal to the overall sample mean. In accordance with the cross-sectional analyses of Marcus et al. (2007b), which used an ITT approach to deal with missing data, increases in PA during the initial 6 months of the study were significantly larger in the two active interventions than in the control arm and were stronger in magnitude for Print than for Phone. Further, Print effects increased by an additional 0.90 baseline SD units over the last 6 months of the study, from 2.68 units at 6 months ($p = .005$) to 3.58 units at 12 months ($p < .001$). In contrast, Phone effects were deflated by 0.61 baseline SD units over the same time period, dropping from 2.22 units at 6 months ($p = .02$) to 1.61 units at 12 months ($p = .204$).

The effect of expanding this Base model for PA outcomes to also account for changes from baseline in the TTM constructs explicitly targeted by the intervention is shown by the “Base + TTM” results. Although inclusion of these change scores did attenuate all previously significant intervention effects observed in the Base model, Conceptual Theory tests were

satisfied for only three of four TTM constructs. In particular, only changes in behavioral processes ($p < .001$), cognitive processes ($p = .014$), and self-efficacy ($p = .007$) appeared predictive of PA change from baseline, whereas changes in decisional balance did not ($p = .735$). Further, increases in cognitive processes were associated with decreases in PA in this multiple-mediator setting, in contrast to the positive association observed in a single-mediator setting (results not shown). It can be shown that the difference in the sign of the partial and bivariate correlations between change in cognitive processes and change in PA is due to the addition of change in behavioral processes as a covariate in the Base + TTM model, a variable whose correlation with changes in cognitive processes was both large and positive ($\rho = 0.61$ after adjustment for baseline values of both mediators).

The rightmost part of Table 3 shows how Conceptual Theory tests for the four TTM constructs were themselves affected by the inclusion in the model of change scores of additional SCT variables deemed likely to have been affected by the intervention. A forward selection procedure concluded that only changes in revitalization contributed significantly to the prediction of PA outcomes, once changes in the four TTM mediators were controlled for. Controlling for changes in revitalization from baseline resulted in attenuation of the effects on PA outcome of change in both cognitive processes ($p = .084$) and self-efficacy ($p = .086$). As a result, only change in behavioral processes ($p = .007$) and revitalization ($p < .001$) passed the Conceptual Theory test in this enlarged model, denoted as “Base + TTM + EFI.”

Mediation tests for the theoretical constructs included in the Base + TTM + EFI multivariate regression model are shown in Table 4, with *indirect treatment effects* calculated for both the Print and Phone interventions by multiplying intervention effects on individual mediators shown in Table 2, with mediator effects on PA outcome from the Base + TTM + EFI multivariate mediation model shown in the Table 3. However, before this product of path coefficients could yield valid Mediation tests, the models in Table 2 had to be adjusted post hoc to control for the same set of baseline covariates used in the Base + TTM + EFI model (i.e., PA measured using the 7-Day PAR, all four TTM constructs, and revitalization) rather than the baseline value of each mediator alone (updated Table 2 results not shown). In line with our Conceptual Theory tests, Mediation tests at both 6 and 12 months confirmed the importance of increasing behavioral processes and revitalization in both intervention arms as a means of increasing PA ($p < .014$). Despite successfully passing the Action Theory tests, cognitive processes and self-efficacy did not pass the corresponding Mediation Tests, presumably due to the weak Conceptual Theory links previously identified in Table 3.

Of note, one would typically expect the sum of the *indirect treatment effects* calculated in this manner to equal the difference between the *total treatment effect* (adjusted mean differences of our Base model) and the *direct treatment effect* (adjusted mean differences of our Base + TTM + EFI model). However, even after using a common set of baseline covariates to adjust the outcomes examined in Tables 2 and 3, the sum of the direct and indirect treatment effects continued to underestimate the total treatment effect by 1%-6%, in line with previous observations about mediation in longitudinal model settings by Krull and MacKinnon (1999).

Discussion

This study examined potential mediators of a 12-month PA promotion intervention based on TTM recommendations. When considering only TTM constructs explicitly targeted by the intervention (behavioral and cognitive processes, self-efficacy, decisional balance), we found behavioral processes to have the strongest effect for both intervention delivery channels, consistent with previous research (Lewis et al., 2002; Rhodes & Pfaeffli, 2010). Possibly because of collinearity with change in behavioral processes, change in cognitive processes appeared to act as a significant suppressor, such that, when accounting for other variables in the model, increases in cognitive processes resulted in decreases in PA. Despite differences in the approach for dealing with missing data and in variable standardization procedures, results were consistent with 6-month cross-sectional TTM mediator analyses (Napolitano et al., 2008) and were found to hold at 12 months as well. However, after adjusting for changes in nontargeted putative mediators (i.e., exercise-induced revitalization), change in cognitive processes no longer met mediation criteria at either time point.

In interpreting the findings of our multiple mediation analysis it is important distinguish Action Theory tests (effects of the intervention on the putative mediators) from Conceptual Theory tests (effects of the putative mediators on behavioral outcomes), as the results of these two subanalyses have differing implications (Cerin & MacKinnon, 2009).

In our Action Theory tests, both Print and Phone interventions generally had significant effects at months 6 and 12 on each of the targeted TTM constructs. These treatment effects are consistent with our intervention goals and thus amount to a successful manipulation check. However, we also observed treatment effects on the additional nontargeted SCT constructs of social support and one aspect of exercise-induced feelings (i.e., revitalization) at months 6 and 12, as well as delayed treatment effects (i.e., at month 12, but not month 6) on the remaining nontargeted constructs (other aspects of exercise-induced feelings: positive engagement, tranquility, and physical exhaustion; physical activity enjoyment; and outcome expectancies). There are a number of possible explanations for the effects of treatment on these nontargeted constructs. First, intervention materials intended to target TTM constructs may have also directly influenced the nontargeted constructs. For example, in intervening on *helping relationships*—one of the behavioral processes of change (Prochaska & DiClemente, 1983)—we may have also influenced the similar construct of social support. This explanation, however, does not easily account for the *delayed change* in some of the nontargeted SCT constructs (e.g., outcome expectancies). Thus, a second explanation is that initial changes in the targeted TTM constructs may have led to subsequent changes in the nontargeted SCT constructs. For example, consistent with SCT (Bandura, 1997), initial changes in self-efficacy may have led to subsequent changes in outcome expectancies, a temporal ordering that we cannot establish without monthly data on mediator change across all three study arms. A third possibility is that initial changes in the targeted TTM constructs may have led to increases in PA, which in turn led to subsequent changes in the nontargeted SCT constructs. Further research is needed to disentangle these alternative explanations. Nonetheless, from a practical perspective, our Action Theory tests demonstrated that the intervention was robust in its effects and that each of the variables under consideration is malleable.

In the Conceptual Theory test, changes in behavioral and cognitive processes as well as in self-efficacy were all predictive of changes in PA, thus supporting the TTM. However, this interpretation must be qualified by the fact that the mediation paths via cognitive processes and self-efficacy were attenuated to nonsignificance when affective variables—most prominently, exercise-induced revitalization—were included in the model. These findings are potentially consistent with traditional accounts of affective variables as distal sources of more temporally proximal cognitive mechanisms of behavior (Bandura, 1997, pp. 106–107; Fishbein, 2008). However, given the strong effects of exercise-induced revitalization on physical activity behavior and the attenuation of the cognitive variables, the findings are also consistent with recent conceptual models emphasizing affect as a determinant of health behavior (Bryan, Hutchison, Seals, & Allen, 2007; Ekkekakis & Lind, 2006; Kiviniemi, Voss-Humke, & Seifert, 2007; Williams, 2008). Again, further research that allows for more fine-grained analysis of the temporal sequence of change in putative mediators and behavioral outcomes is needed. The present findings, nonetheless, clearly point to the need for greater attention to affective determinants of behavior in health-behavior theory and practice.

Taken together, both the Action Theory and Conceptual Theory tests are limited by the concurrent assessment of changes in putative mediators. More generally, the external validity of the findings is limited by the large proportion of highly educated, Caucasian women in our study sample. Thus, future research should assess putative mediators and behavior at more time points and among more diverse participant samples.

In summary, the findings suggest that TTM constructs, social support, exercise-induced feelings, enjoyment of PA, and outcome expectancies are all malleable; however, changes in behavioral processes and in exercise-induced feelings—particularly revitalization—appear to be most important in determining behavior change. The findings add to the accumulating body of research illustrating the importance of behavioral processes of change (Lewis et al., 2002; Rhodes & Pfaeffli, 2010). Moreover, consistent with the recent update of the American College of Sports Medicine's (Garber et al., 2011) guidelines for exercise prescription, the present findings indicate that exercise-induced feelings warrant more attention as a potential target of PA promotion programs. Specifically, the ACSM's guidelines (Garber et al., 2011) suggest that varying the intensity of exercise and/or exposure to music, TV, and pleasant scenery may enhance affective response to PA, and, in turn, increase adherence. However, as noted by the ACSM (Garber et al., 2011), more research is needed on the potential link between affect and PA.

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References

- Abraham C, Michie S. A taxonomy of behavior change techniques used in interventions. *Health Psychology*. 2008; 27:379–387. [PubMed: 18624603]
- Bandura, A. *Self-Efficacy: The Exercise of Control*. New York, NY: Freeman; 1997.

- Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions How are we doing? How might we do better? *American Journal of Preventive Medicine*. 1998; 15:266–297. [PubMed: 9838973]
- Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*. 1986; 51:1173–1182. [PubMed: 3806354]
- Blair SN, Haskell WL, Ho P, Paffenbarger RS Jr, Vranizan KM, Farquhar JW, Wood PD. Assessment of habitual physical activity by seven-day recall in a community survey and controlled experiments. *American Journal of Epidemiology*. 1985; 122:794–804. Retrieved from <http://aje.oxfordjournals.org/>. [PubMed: 3876763]
- Bryan A, Hutchison KE, Seals DR, Allen DL. A transdisciplinary model integrating genetic, physiological, and psychological correlates of voluntary exercise. *Health Psychology*. 2007; 26:30–39. [PubMed: 17209695]
- Cerin E, MacKinnon DP. A commentary on current practice in mediating variable analyses in behavioural nutrition and physical activity. *Public Health Nutrition*. 2009; 12:1182–1188. [PubMed: 18778534]
- Daniels, MJ., Hogan, JW. Missing data in longitudinal studies. Boca Raton, FL: Chapman & Hall/CRC; 2008.
- Dunn AL, Andersen RE, Jakicic JM. Lifestyle physical activity interventions: History, short- and long-term effects, and recommendations. *American Journal of Preventive Medicine*. 1998; 15:398–412. [PubMed: 9838980]
- Dunn AL, Marcus BH, Kampert JB, Garcia ME, Kohl HW III, Blair SN. Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: A randomized trial. *Journal of the American Medical Association*. 1999; 281:327–334. [PubMed: 9929085]
- Ekkekakis P, Lind E. Exercise does not feel the same when you are overweight: The impact of self-selected and imposed intensity on affect and exertion. *International Journal of Obesity*. 2006; 30:652–660. [PubMed: 16130028]
- Fishbein M. A reasoned action approach to health promotion. *Medical Decision Making*. 2008; 28:834–844. [PubMed: 19015289]
- Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM. American College of Sports Medicine Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults Guidance for prescribing exercise. *Medicine and Science in Sports and Exercise*. 2011; 43:1334–1359. Retrieved from <http://journals.lww.com/acsm-msse/pages/default.aspx>. [PubMed: 21694556]
- Gauvin L, Rejeski WJ. The Exercise-induced Feeling Inventory: Development and initial validation. *Journal of Sport & Exercise Psychology*. 1993; 15:403–423.
- Imai K, Keele L, Tingley D. A General Approach to Causal Mediation Analysis. *Psychological Methods*. 2010; 15:309–334. [PubMed: 20954780]
- Insightful Corp. S-Plus 8 for Unix user's guide. Seattle, WA: Insightful Corp; 2007.
- Kendzierski D, DeCarlo KJ. Physical Activity Enjoyment Scale: Two validation studies. *Journal of Sport & Exercise Psychology*. 1991; 13:50–64. Retrieved from <http://journals.humankinetics.com/jsep>.
- King AC, Friedman R, Marcus B, Castro C, Napolitano M, Ahn D, Baker L. Ongoing physical activity advice by humans versus computers: The Community Health Advice by Telephone (CHAT) trial. *Health Psychology*. 2007; 26:718–727. [PubMed: 18020844]
- Kiviniemi MT, Voss-Humke AM, Seifert AL. How do I feel about the behavior? The interplay of affective associations with behaviors and cognitive beliefs as influences on physical activity behavior. *Health Psychology*. 2007; 26:152–158. [PubMed: 17385966]
- Krull JL, MacKinnon DP. Multilevel mediation modeling in group-based intervention studies. *Evaluation Review*. 1999; 23:418–44. [PubMed: 10558394]
- Lewis BA, Marcus BH, Pate RR, Dunn AL. Psycho-social mediators of physical activity behavior among adults and children. *American Journal of Preventive Medicine*. 2002; 23(2 Suppl):26–35. [PubMed: 12133735]

- Little, RJA., Rubin, DB. Statistical analysis with missing data. 2. New York, NY: J. Wiley & Sons; 2002.
- MacKinnon, DP. Introduction to statistical mediation analysis. New York, NY: Lawrence Erlbaum Associates; 2008.
- Marcus BH, Napolitano MA, King AC, Lewis BA, Whiteley JA, Albrecht AE, Papandonatos GD. Examination of print and telephone channels for physical activity promotion: Rationale, design, and baseline data from Project STRIDE. *Contemporary Clinical Trials*. 2007a; 28:90–104. [PubMed: 16839823]
- Marcus BH, Napolitano MA, King AC, Lewis BA, Whiteley JA, Albrecht A, Papandonatos GD. Telephone versus print delivery of an individualized motivationally tailored physical activity intervention: Project STRIDE. *Health Psychology*. 2007b; 26:401–409. [PubMed: 17605559]
- Marcus BH, Rakowski W, Rossi RS. Assessing motivational readiness and decision-making for exercise. *Health Psychology*. 1992; 11:257–261. [PubMed: 1396494]
- Marcus BH, Rossi JS, Selby VC, Niaura RS, Abrams DB. The stages and processes of exercise adoption and maintenance in a worksite sample. *Health Psychology*. 1992; 11:386–395. [PubMed: 1286658]
- Marcus BH, Selby VC, Niaura RS, Rossi JS. Self-efficacy and the stages of exercise behavior change. *Research Quarterly for Exercise and Sport*. 1992; 63:60–66. [PubMed: 1574662]
- Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: A meta-regression. *Health Psychology*. 2009; 28:690–701. [PubMed: 19916637]
- Napolitano MA, Papandonatos GD, Lewis BA, Whiteley JA, Williams DM, King AC, Marcus BH. Mediators of physical activity behavior change: A multivariate approach. *Health Psychology*. 2008; 27:409–418. [PubMed: 18642998]
- Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Wilmore JH. Physical activity and public health: A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Association*. 1995; 273:402–407. [PubMed: 7823386]
- Prochaska JO, DiClemente CC. The stages and processes of self-change in smoking: Towards an integrative model of change. *Journal of Consulting and Clinical Psychology*. 1983; 51:390–395. [PubMed: 6863699]
- Resnick B, Zimmerman SI, Orwig D, Furstenberg AL, Magaziner J. Outcome expectations for exercise scale: Utility and psychometrics. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*. 2000; 55:S352–S356.
- Rhodes RE, Pfaeffli LA. Mediators of physical activity behaviour change among adult non-clinical populations: A review update. *International Journal of Behavioral Nutrition and Physical Activity*. 2010; 7:37. [PubMed: 20459781]
- Rovniak LS, Anderson ES, Winett RA, Stephens RS. Social cognitive determinants of physical activity in young adults: A prospective structural equation analysis. *Annals of Behavioral Medicine*. 2002; 24:149–156. [PubMed: 12054320]
- Sallis JF, Grossman RM, Pinski RB, Patterson TL, Nader PR. The development of scales to measure social support for diet and exercise behaviors. *Preventive Medicine*. 1987; 16:825–836. [PubMed: 3432232]
- Sallis JF, Haskell WL, Wood PD, Fortmann SP, Rogers T, Blair SN, Paffenbarger RS Jr. Physical activity assessment methodology in the Five-City Project. *American Journal of Epidemiology*. 1985; 121:91–106. Retrieved from <http://aje.oxfordjournals.org/>. [PubMed: 3964995]
- Shrout, PE., Bolger, N. Refining inferences about mediated effects in studies of personality and social psychology processes. Paper presented at the 11th Annual Meeting of the Society for Personality and Social Psychology; Las Vegas, NV. 2010.
- Sobel, ME. Asymptotic confidence intervals for indirect effects in structural equation models. In: Leinhardt, S., editor. *Sociological Methodology*. Washington DC: American Sociological Association; 1982. p. 290–312.
- Sobel ME. Identification of causal parameters in randomized studies with mediating variables. *Journal of Educational and Behavioral Statistics*. 2008; 33:230–251.

- U.S. Department of Health and Human Services. Physical activity guidelines advisory committee report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008.
- Williams DM. Exercise, affect, and adherence: An integrated model and a case for self-paced exercise. *Journal of Sport and Exercise Psychology*. 2008; 30:471–496. Retrieved from <http://journals.humankinetics.com/jsep>. [PubMed: 18971508]
- Williams DM, Anderson ES, Winett RA. A review of the outcome expectancy construct in physical activity research. *Annals of Behavioral Medicine*. 2005; 29:70–79. Retrieved from <http://www.springer.com/medicine/journal/12160>. [PubMed: 15677303]
- Williams DM, Dunsiger S, Ciccolo JT, Lewis BA, Albrecht AE, Marcus BH. Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychology of Sport and Exercise*. 2008; 9:231–245. [PubMed: 18496608]
- Williams DM, Papandonatos GD, Napolitano MA, Lewis BA, Whiteley JA, Marcus BH. Perceived enjoyment moderates the efficacy of an individually tailored physical activity intervention. *Journal of Sport and Exercise Psychology*. 2006; 28:300–309. Retrieved from <http://journals.humankinetics.com/jsep>.

Table 1

Sample Characteristics at Baseline

Variable	Mean	SD
7-day PAR (min/week)	19.64	25.02
Behavioral processes	2.39	0.58
Cognitive processes	2.90	0.71
Self-efficacy	2.64	0.76
Decisional balance	−0.22	13.76
Social support: exercise participation	6.77	6.44
EFI		
Revitalization	1.97	0.95
Positive engagement	2.90	1.01
Tranquility	2.57	0.95
Physical exhaustion	2.47	1.07
PACES: enjoyment	4.52	1.09
Outcome expectancies for exercise	4.05	0.65

Note. PAR = Physical Activity Recall; EFI = Exercise-Induced Feeling Inventory; PACES = Physical Activity Enjoyment Scale.

^a *N* = 239.

Table 2
Action Theory Tests Based on Treatment Effects on Putative Mediators at 6 and 12 Months

Variable	Group	6 months			12 months		
		Coefficient	SE	p	Coefficient	SE	p
Behavioral processes	Con	0.10	0.13	.451	0.04	0.13	.741
	Print-Con	1.09	0.19	<.001	1.25	0.19	<.001
	Phone-Con	1.29	0.19	<.001	1.07	0.20	<.001
Cognitive processes	Con	-0.14	0.11	.179	-0.30	0.11	.005
	Print-Con	0.43	0.15	.005	0.66	0.15	<.001
	Phone-Con	0.45	0.15	.003	0.54	0.16	.001
Self-efficacy	Con	-0.28	0.13	.035	-0.46	0.56	<.001
	Print-Con	0.75	0.19	<.001	1.10	0.19	<.001
	Phone-Con	0.83	0.19	<.001	0.80	0.19	<.001
Decisional balance	Con	-0.17	0.10	.097	-0.17	0.10	.096
	Print-Con	0.30	0.15	.040	0.39	0.15	.009
	Phone-Con	0.36	0.15	.014	0.27	0.15	.080
SS: exercise participation	Con	0.05	0.16	.737	0.18	0.16	.270
	Print-Con	0.67	0.22	.005	0.69	0.22	.002
	Phone-Con	0.91	0.22	<.001	0.50	0.22	.026
EFI	Con	0.10	0.10	.339	-0.04	0.11	.724
	Print-Con	0.38	0.15	.010	0.60	0.15	<.001
	Phone-Con	0.43	0.15	.004	0.58	0.15	<.001
Positive engagement	Con	0.07	0.09	.469	-0.11	0.09	.210
	Print-Con	0.06	0.13	.649	0.28	0.13	.039
	Phone-Con	0.11	0.13	.381	0.16	0.13	.222
Tranquility	Con	-0.04	0.10	.762	-0.18	0.10	.081
	Print-Con	0.26	0.14	.075	0.58	0.15	<.001
	Phone-Con	0.16	0.14	.250	0.45	0.15	.002
Physical exhaustion	Con	-0.18	0.10	.084	-0.14	0.10	.190
	Print-Con	-0.15	0.14	.314	-0.35	0.15	.018
	Phone-Con	-0.15	0.14	.291	-0.32	0.15	.032

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Variable	Group	6 months			12 months		
		Coefficient	SE	p	Coefficient	SE	p
PACES: enjoyment	Con	0.07	0.11	.552	0.01	0.84	.933
	Print-Con	0.27	0.16	.092	0.44	0.16	.007
	Phone-Con	0.16	0.16	.311	0.25	0.16	.118
Outcome expectancies	Con	0.02	0.10	.868	−0.12	0.10	.234
	Print-Con	0.08	0.14	.571	0.35	0.14	.015
	Phone-Con	0.07	0.14	.590	0.22	0.14	.113

Note. Putative mediators have been standardized by subtracting off their baseline mean and dividing by their baseline standard deviation, using values listed in Table 1. Study group has been coded with Control (Con) as the referent. Treatment contrasts have been adjusted for between-group differences in mediator values at baseline. Con = control; Print = print-based materials; Phone = telephone counseling; SS = Social Support; EFI = Exercise-Induced Feeling Inventory; PACES = Physical Activity Enjoyment Scale.

Table 3
Conceptual Theory Tests Based on Putative Mediator Effects on 7-Day PAR at 6 and 12 Months

	Base model			Base + TTM			Base + TTM + EFI		
	Coefficient	SE	p	Coefficient	SE	p	Coefficient	SE	p
Adjusted group means									
Con (6 M)	2.59	0.66	<.001	2.56	0.65	<.001	2.33	0.63	<.001
Print vs. Con (6 M)	2.68	0.94	.005	0.55	0.93	.555	0.43	0.90	.638
Phone vs. Con (6 M)	2.22	0.94	.020	−0.31	0.96	.749	−0.27	0.92	.767
Con (12 M)	3.18	0.68	<.001	3.17	0.68	<.001	3.28	0.66	<.001
Print vs. Con (12 M)	3.58	0.99	<.001	1.08	0.99	.276	0.49	0.96	.613
Phone vs. Con (12 M)	1.61	1.00	.109	−0.33	0.98	.740	−0.88	0.95	.358
Baseline covariates									
7-Day PAR	−0.60	0.31	.055	−0.28	0.28	.319	−0.23	0.27	.389
Behavioral processes	0.00	0.48	.996	−1.14	0.46	.015	−0.99	0.45	.029
Cognitive processes	0.31	0.47	.506	0.81	0.48	.095	0.60	0.47	.202
Self-efficacy	0.42	0.36	.243	−0.29	0.34	.386	−0.28	0.33	.396
Decisional balance	0.06	0.35	.871	0.02	0.35	.964	0.09	0.34	.789
EFI: revitalization	0.37	0.32	.243	0.07	0.28	.804	−0.56	0.30	.064
Mediator change scores									
Behavioral processes				1.68	0.46	<.001	1.25	0.45	.007
Cognitive processes				−1.26	0.51	.014	−0.86	0.50	.084
Self-efficacy				0.96	0.35	.007	0.60	0.35	.086
Decisional balance				0.14	0.41	.735	−0.02	0.40	.956
EFI: revitalization							1.70	0.34	<.001

Note. Continuous variables have been standardized by subtracting off their baseline mean and dividing by their baseline standard deviation, using values listed in Table 1. Study group has been coded with Control (Con) as the referent. PAR = PAR = Physical Activity Recall; Base = baseline; TTM = Trans Theoretical Model; EFI = Exercise-Induced Feeling Inventory; Con = control; Print = print-based materials; Phone = telephone counseling.

Table 4

Indirect Treatment Effects on 7-Day PAR at 6 and 12 Months via Putative Meditational Pathways Included in the Base + TTM + EFI Multiple Mediation Model

Variable	Group	6 months			12 months		
		Coefficient	SE	p	Coefficient	SE	p
Behavioral processes	Print-Con	1.38	0.55	.013	1.58	0.62	.011
	Phone-Con	1.57	0.62	.011	1.31	0.53	.014
Cognitive processes	Print-Con	−0.38	0.26	.135	−0.61	0.37	.104
	Phone-Con	−0.38	0.25	.136	−0.46	0.30	.121
Self-efficacy	Print-Con	0.44	0.28	.113	0.65	0.39	.098
	Phone-Con	0.52	0.32	.104	0.51	0.32	.106
Decisional balance	Print-Con	−0.01	0.12	.956	−0.01	0.17	.956
	Phone-Con	−0.01	0.15	.956	−0.01	0.11	.956
EFI: revitalization	Print-Con	0.77	0.30	.010	1.27	0.37	<.001
	Phone-Con	0.74	0.30	.012	1.12	0.35	.001

Note. Continuous variables have been standardized by subtracting off their baseline mean and dividing by their baseline standard deviation, using values listed in Table 1. Study group has been coded with Control (Con) as the referent. PAR = PAR = Physical Activity Recall; Base = baseline; TTM = Trans Theoretical Model; EFI = Exercise-Induced Feeling Inventory; Con = control; Print = print-based materials; Phone = telephone counseling.