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MEDIATORS OF PHYSICAL ACTIVITY BEHAVIOR CHANGE:

A MULTIVARIATE APPROACH

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Abstract

Using a multivariate extension of the Baron and Kenny (1986) mediation framework, we examined the simultaneous effect of psychosocial variables hypothesized to mediate the relationship between a motivationally-tailored physical activity intervention, and 6-month physical activity behavior in 239 healthy, under-active adults (mean age=47.5; 82% women). Participants were randomly assigned to 1) Print-based feedback; 2) Telephone-based feedback; or 3) Contact Control. All mediation criteria were satisfied for both intervention arms. In terms of effect size, a moderate indirect effect of Print (0.39, 95% CI=0.21, 0.57) was due to increases in behavioral processes (0.54, 95% CI= 0.29, 0.80) being attenuated by decreases due to cognitive processes (-0.17, 95% CI= -0.31,-.03). A moderate indirect effect was observed for Telephone (0.47, 95% CI=0.28, 0.66), with increases due to behavioral processes (0.61, 95% CI=0.34, 0.87) attenuated by decreases due to cognitive processes (0.15, 95% CI=-0.27, -0.02); self-efficacy and decisional balance mediational paths did not attain statistical significance. These findings highlight the importance of studies that deconstruct the theoretical components of interventions to determine which combination produces the greatest behavior changes at the lowest cost.

Keywords

Mediators; Physical Activity; Intervention studies; Randomized controlled trial; Multivariate analysis

INTRODUCTION

To promote physical activity among sedentary individuals, researchers have examined the efficacy of interventions targeting physical activity adoption and maintenance. Specifically, theory-based face-to-face, telephone, print, and internet interventions have been shown to increase physical activity among sedentary adults (e.g., Dunn et al., 1997; King, Haskell, Young, Oka, & Stefanick, 1995; Marcus, Bock et al., 1998, Marcus, Lewis et al., 2007; Marcus, Napolitano et al., 2007a). Even though these interventions are theory-based, few studies have examined whether the observed effects are due to changes in the theoretical constructs targeted by the intervention or other extraneous factors (Lewis, Marcus, Pate, & Dunn, 2002). If the interventions are efficacious due to changes in the theoretical constructs, then these constructs are “mediators” of the relationship between the intervention and physical activity behavior change (Kraemer, Wilson, Fairburn, & Agras, 2002; Lewis et al., 2002).

The Transtheoretical Model (TTM; Prochaska & DiClemente, 1983) and Social Cognitive Theory (Bandura, 1986; 1997) have been recommended as theoretical models that provide a framework for effective physical activity interventions (U.S. Department of Health and Human Services [USDHHS], 1996). Previous interventions have successfully used the TTM in studies

of health behaviors (e.g., smoking cessation, physical activity; Marcus, Emmons et al., 1998; Adams & White, 2003). The Transtheoretical Model postulates that individuals move through a series of stages as they adopt and maintain physical activity (Marcus, Rossi, Selby, Niaura, & Abrams, 1992; Marcus & Lewis, 2003). In addition to the well-known stages of change (i.e., Precontemplation, Contemplation, Preparation, Action, and Maintenance), TTM includes several processes of change, which are strategies people use as they move through the stages. A second TTM construct is decisional balance, where individuals weigh the pros and cons of becoming physically active as they move through the stages of change (Marcus, Rakowski, & Rossi, 1992). Social Cognitive Theory (SCT) also posits that there are both cognitive and social/behavioral factors that influence behavior. For example, self-efficacy, one's confidence to be physically active, plays a central role in changing behavior (Bandura, 1986; Marcus, Selby, Niaura, & Rossi, 1992). According to SCT (Bandura, 1997), other important factors are self-monitoring and goal setting (Rovniak, Anderson, Winett, & Stephens, 2002), and social support (Bandura, 1997).

A few studies have examined theoretical constructs as mediators of intervention outcomes (e.g., Miller, Trost, & Brown, 2002; Pinto, Lynn, Marcus, DePue, & Goldstein, 2001) using the recommended statistical methods for testing mediation (Kraemer et al., 2002; Lewis et al., 2002). Pinto et al. found that behavioral processes and decisional balance acted as mediators of physical activity at six weeks but not eight months in a study testing a cognitive-behavioral intervention for increasing physical activity levels. One constraint was that the physical activity intervention was delivered in a primary care-based setting, which may not generalize to other community samples or settings. Miller et al. found that among mothers of young children, spousal support and self-efficacy were significant mediators of physical activity behavior change. Although this study provides more information regarding important physical activity mediators among mothers with young children, these findings may not generalize to individuals without young children. Lewis et al. (2006) examined mediators in a theory-based physical activity intervention study among sedentary individuals and found partial support for the importance of behavioral processes and self-efficacy. Another study, which involved the delivery of a school-based physical activity intervention among adolescent girls, found that self-efficacy (Dishman et al., 2004), and enjoyment (Dishman et al., 2005), partially mediated the effect of the intervention on physical activity (Dishman et al., 2004). Haerens et al. (2007) found that changes in physical activity among adolescents who participated in a parental-support based intervention were mediated by self efficacy. Interestingly, a suppressor effect for attitudes towards exercise was found. This study was limited in the mediational analyses because both study arms were active treatment and there was not a 'no treatment' control group. Finally, using four different statistical approaches for examining mediation, Cerin, Taylor, Leslie, and Owen (2007) found social support to be a mediator for active adults for all approaches except for one. Based on these previous studies, behavioral processes and self-efficacy appear to have the most support for mediation in physical activity intervention trials.

These studies provide an important first step in examining mediational relationships between theoretical constructs and physical activity. A question that remains unanswered is how these variables would operate in a multivariate mediational analysis, given that, in practice, they would be operating in concert. That is, it is not known how multiple mediators would perform if tested concurrently within the same model when predicting physical activity behavior. The purpose of this study, therefore, was to test, using a multivariate mediational analysis, whether the theoretical constructs of behavioral processes, cognitive processes, decisional balance, and self-efficacy mediated the relationship between a theory-based physical activity intervention and physical activity behavior change. We predicted that our intervention would successfully change physical activity and the mediator variables (i.e., behavioral processes, cognitive processes, self-efficacy, and decisional balance), that these four sets of variables would mediate

the relationship between study arm (i.e., print and telephone vs. contact control) and physical activity behavior, and that the multivariate analysis would show that the behavioral processes and self-efficacy would be the strongest predictors in the model.

METHOD

Recruitment and Inclusion Criteria

Recruitment methods and full inclusion criteria for the parent trial (Project Stride) are described elsewhere (Marcus, Napolitano, et al., 2007a, 2007b). The primary recruitment strategy was via newspaper advertisements. Inclusion criteria included being healthy, 18-65 years, and under-active based on current national recommendations (Haskell et al., 2007; Pate et al., 1995; i.e., participating in moderate or vigorous physical activity for 90 minutes or less per week). See Figure 1 for more details. Participants had to be willing to be randomly assigned to any of the three intervention arms and endorse 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 were college educated (70.6%), and the majority reported a total household income above \$50,000 (60.8%). Table 1 presents demographic information on the participants.

Intervention Arms

Individuals were randomly assigned to one of three intervention arms: 1) telephone-based, individualized motivationally-tailored feedback; 2) print-based, individualized motivationally-tailored feedback; or 3) contact control. The interventions used in the parent study are described in more detail elsewhere (Marcus, Napolitano, et al., 2007b; Napolitano & Marcus, 2002). They consisted of individually-tailored messages, based primarily on the TTM, with some SCT concepts integrated, as well. Participants received computer-generated expert system reports, stage-targeted booklets, and physical activity-related tip sheets. The expert system reports were more specific, and were individually tailored with specific feedback based on TTM constructs (i.e., stages of motivational readiness, processes of change, self-efficacy, decisional balance), with the extent of focus on each theoretical construct determined by the individual's current stage of change. The five stage targeted booklets included general information on processes of change, self-efficacy, and decisional balances relevant to the particular stage of change, as well as SCT concepts such as goal setting, social support, and self-monitoring. Finally, the tip-sheets provided information about reminders, social support, as well as general physical activity information (e.g., safety, stretching, buying shoes).

The content was held constant between the telephone intervention and the print intervention, with a health educator delivering the content from the stage-matched manuals, expert system feedback report, and tip sheets in the telephone intervention. In the telephone intervention the health educator also helped the participant problem-solve barriers and discussed the content of the intervention materials. The length of the telephone calls was approximately 13.0 minutes ($SD 3.84$), and 90.5% of the scheduled calls were completed. The contact control received wellness materials in the same mailing frequency as the print intervention. The goal for the participants in the treatment arms was to meet or exceed CDC/ACSM recommendations [at least 5 days per week for a total of at least 30 minutes each time] (Pate et al., 1995). Treatment fidelity was implemented for the print and telephone arms of the study, with two Ph.D.-level investigators each separately reviewing audiotapes of the sessions for content and process related variables, as well as an additional investigator reviewing the printed reports to ensure the proper content was produced based on questionnaire responses. For more detailed information, please see Marcus, Napolitano, et al. (2007b).

Primary Assessments

Outcome data were collected at baseline, 6 months, and 12 months (for primary outcomes see Marcus, Napolitano, et al., 2007a). These assessments consisted of an interviewer administered 7-day Physical Activity Recall Interview (PAR), anthropometric assessments, an exercise stress test, stage of motivational readiness for change, and a battery of psychosocial questionnaires. Because the first 6 months of the intervention contained the bulk of the intervention contacts (i.e., 11 out of 14 contacts occurred during this period) and was considered to be the active intervention phase of the study, this study examined mediation effects occurring during this more intensive period. Importantly, there were significant treatment effects for both print and telephone at this time point compared with contact control, thus allowing for a full test of mediation effects for the two different interventions.

MEASURES

Outcome Measures

Physical Activity Recall (PAR)—The primary outcome measure for the main trial was the 7-Day Physical Activity Recall (PAR), which is an interviewer administered procedure (Blair et al., 1985; Sallis et al., 1985). The PAR has been shown to be sensitive to change in trials examining moderate-intensity physical activity (Dunn, Andersen, & Jakicic, 1998; Dunn et al., 1999; King et al., 2007). Numerous studies have demonstrated both the reliability and validity of the PAR (see Pereira et al., 1997, for a review). For example, one study found that the test re-test reliability was 0.86 between two interviewers administering the measure on the same day (Gross, Sallis, Buono, Roby, & Nelson, 1990). Validity has been demonstrated by a study indicating a significant correlation between the PAR and the Caltrac (0.33), which is an objective measure of physical activity (Jacobs, Ainsworth, Hartman, & Leon, 1993). Additionally, the PAR also has been shown to correlate with a four-week physical activity diary (0.36; Jacobs et al.). The time-related PAR intra-class correlation coefficient between the two summary measures (baseline and Month 6) was 0.68.

Proposed Physical Activity Mediators

Processes of change—The 40-item processes of change for physical activity were measured by instruments developed by Marcus, Rossi, et al. (1992). These include both behavioral (i.e., substituting alternatives, enlisting social support, rewarding yourself, committing yourself, and reminding yourself), and cognitive processes (increasing knowledge, warning of risks, caring about consequence to others, comprehending benefits, and increasing healthy opportunities; Marcus & Forsyth, 2003; Marcus, Rossi, et al.). The Processes of Change have been shown to have a high internal consistency of .83 and correlated with the stage of change of physical activity ($p < .001$; Marcus, Rossi, et al.). Within the present study the Cronbach alpha coefficients were .84 for cognitive processes and .78 for behavioral processes.

Exercise self-efficacy—Self-efficacy for exercise was assessed using a questionnaire developed by Marcus and colleagues (Marcus, Selby, et al., 1992). This measure consisted of 5-items, and has demonstrated an internal consistency of 0.76, test-retest reliability of .90 and correlated with the stage of change of physical activity ($p < .001$; Marcus, Selby, et al.); within the present study internal consistency rose to 0.78.

Decision-making—The 16-item Decisional Balance instrument was used to measure decision-making related to exercise (Marcus, Rakowski, et al., 1992). Internal consistency was moderately high (.79 for pros; .95 for cons) and correlated with the stage of change of physical activity ($p < .001$; Marcus, Rakowski, et al.). In the present study, internal consistency reached .82 for the decisional balance total score (Pros-Cons).

ANALYSES

Within the single-mediator framework established by Baron and Kenny (1986) and elaborated further in Judd, Kenny, and McClelland (2001), the overall treatment effect on outcome Y adjusting for confounders Z is given by the coefficient c of the path from X to Y . The model is then elaborated by the introduction of a single mediator M , e.g., behavioral processes. In this instance, it can be shown that the overall treatment effect can be decomposed into the sum of the direct effect of X on Y - denoted by c' - and the indirect effect of X on Y via the mediator M , given by the product ab of the coefficients along the path from X to Y via M . Here, a represents the direct effect of X on M partialling out Z , and b the direct effect of M on Y partialling out both X and Z . Since $c=ab+c'$, complete mediation occurs when $c'=0$, i.e. when the direct effect of treatment in achieving and maintaining improvements in physical activity vanishes when controlling for changes in behavioral processes. In Figure 2 we depict the model extension of the Baron and Kenny (1986) single mediation framework to a multiple mediation framework, in which the indirect effect of X on Y is calculated by adding all four mediator-specific effects given by the product of the coefficients along each path from X to Y via M_i , $i=1,...,4$. Therefore, the overall treatment effect is given by $c=\sum_{i=1}^4 a_i b_i + c'$.

In a comprehensive review of the literature on mediation testing, MacKinnon, Lockwood, Hoffman, West, & Sheets (2002) identified 14 possible tests for single mediation, which they grouped into three broad classes: (i) causal steps along the lines of Baron and Kenny (1986), (ii) tests based on the difference of the total and direct effects of X on Y , and (iii) tests based on the indirect effect of X on Y via the individual mediator, calculated as a product of coefficients along the mediation path. Both theoretical (Collins, Graham, & Flaherty, 1998; Shrout & Bolger, 2002) and practical power considerations suggest testing the indirect effect of X on Y alone, using either Sobel's (1982) variance formula (<http://www.psych.ku.edu/preacher/sobel/sobel.htm>) or methods that take the skewness in the distribution of a product of two standard normal variables into account (MacKinnon et al., 2002). We have decided to use the Baron and Kenny (1986) approach (i.e., p values as markers of statistical significance). However, based on the observation of Kraemer, Stice, Kazdin, Offord, & Kupfer (2001) and Kaemer et al. (2002) that significance levels are a function of sample size, we also will use Cohen's delta (1988) as a guide when analyzing continuous variables. These single mediation approaches can be easily generalized to multiple mediation scenarios, provided that in Step 2 of the Baron and Kenny all four putative mediators are regressed simultaneously on treatment group via a multivariate normal regression model, so as to obtain the variance-covariance matrix of the coefficients of all four a paths (Preacher & Hayes, 2006). Missing data was accounted for using baseline-carry-forward within an Intent-To-Treat (ITT) framework.

RESULTS

Following the Baron & Kenny (1986) recommendations, our analyses were conducted in four steps, despite the fact that the initial step of establishing significance of an overall treatment effect might be redundant in a multiple mediation scenario such as ours, where certain intervening variables may act as bona fide mediators, whereas others may act as "suppressors" (MacKinnon, Kruss, & Lockwood, 2000).

In step 1, we checked whether the intervention was successful in changing overall physical activity outcomes from baseline to 6-month follow-up, controlling for gender, season, baseline values of physical activity as measured by the 7-day PAR, and baseline values of all four putative mediators (self-efficacy, behavioral processes, cognitive processes, decisional balance). Standardized **total treatment effects on outcome**, denoted by c path coefficients,

are 0.43 (95% CI= 0.12, 0.74) for Print, are 0.37 (95% CI= 0.07, 0.67) for Telephone. Since treatment assignment was coded using baseline contrasts (Print versus Contact Control, Telephone versus Contact Control), the c path coefficients estimate the differential change in outcome that can be attributed to being assigned to a particular intervention arm, rather than the control arm, after controlling for all other variables in the model. They can be converted to actual PAR minutes by multiplying them by the standard deviation of the 6-month PAR change scores (SD=126), and show a statistically significant differential treatment benefit of 54 minutes (95% CI= 15, 93) for the Print arm, and of 47 minutes (95% CI= 9, 85) for the Telephone arm for all study participants, over and above the 73-minute increase observed in the Contact Control arm (95% CI= 35, 110) for a “typical” subject with values of physical activity and mediators at baseline set equal to their sample averages. Therefore, both the Print and Telephone arms were able to satisfy the first mediation criterion of Baron and Kenny (1986).

In step 2, we proceeded to check whether the intervention produced statistically significant increases in the putative mediator variables from baseline to 6-month follow-up. To this effect, we estimated a multivariate regression model with the mediator change scores as the dependent variables, and intervention arm as the independent variable of interest. The **treatment effect on the mediators** is represented by the a path coefficients of Figure 2; they are shown in the first column of Table 2 for the Print arm and the first column of Table 3 for the Telephone arm. Although the regression model additionally controlled for the effects of gender, season, baseline values of physical activity, and baseline values of all four mediators, effects summarily captured by the e' path coefficients in Figure 2, these results have been omitted from Tables 3 and 4 due to space considerations. As all these covariates were allowed to have mediator-specific effects, it should be pointed out that the reported a path coefficients are identical to those that would have been obtained from analyzing each mediator separately. However, joint modeling also allowed for the estimation of their correlation matrix, which would not have been available otherwise, and is needed for estimating the standard error of the total indirect treatment effect.

All mediator change scores were standardized to zero mean and unit variance across the entire sample. An inherent advantage of using standardized regression coefficients is that their sign and magnitude is then directly comparable across mediators and treatment arms. From Table 2 it can be seen that the Print intervention had the highest impact on behavioral processes, producing a differential increase relative to the control arm of $a_1=0.82$ standard units (95% CI= 0.54, 1.10), a large effect size according to Cohen's (1988) nomenclature. In contrast, it resulted in only moderate increases in cognitive processes ($a_2=0.59$, 95% CI= 0.31, 0.87) and self-efficacy ($a_3=0.55$, 95% CI=0.27, 0.84), and small-to-moderate increases in decisional balance ($a_4=0.34$, 95% CI=0.05, 0.63). The Telephone intervention produced even larger increases in behavioral processes ($a_1=0.91$, 95% CI=0.64, 1.19), self-efficacy ($a_3=0.64$, 95% CI=0.36, 0.92), and decisional balance ($a_4=0.38$, 95% CI=0.09, 0.66), but slightly smaller increases in cognitive processes ($a_2=0.52$, 95% CI = 0.24, 0.80). Since all four mediators showed statistically significant increases for both Print and Phone interventions, the second Baron and Kenny (1986) mediation criterion was also satisfied for both intervention arms.

In step 3, we sought to check whether increases in the putative mediator variables from baseline to 6-month follow-up produced statistically significant increases in physical activity over the same time frame, controlling for any other effects due to the intervention. Hence, we fit a univariate regression model with changes in physical activity from baseline to 6-month follow-up as the sole outcome, and estimated both the **direct treatment effect on outcome**, denoted by the c' path coefficient of Figure 2, as well as the **direct mediator effects on outcome**, denoted by the b path coefficients in the same figure. Just as in step 2, we additionally controlled for the effect of gender, season, baseline values of the outcome and of all four mediators; these

effects were summarily denoted by a single e' path coefficient in Figure 2, and have been omitted for simplicity from the tables. Since both the mediator and outcome change scores were standardized to zero mean and unit variance, the b path coefficients listed in the second column of Tables 3 and 4 are partial correlation coefficients that can be readily converted back to the original scale of the outcome variable. For example, the standard deviation of the change scores was 0.69 units for behavioral processes, and 126 minutes for the PAR. Hence, a standardized path coefficient for behavioral processes of decisional balance $b_1=0.67$ (95% CI= 0.46, 0.88) translates into a net increase in physical activity of $0.67*126=84$ minutes (95% CI= 58, 111) as a result of increasing behavioral processes by 0.69 units in the original scale, while holding constant all other independent variables in the model, including change in the remaining three mediators. Comparing the b path coefficients of Tables 3 and 4 across mediators, we note that although increases in behavioral processes were associated with moderate-to-large increases in physical activity ($p<0.001$), the mediation chain appears to have broken down with respect to increases in self-efficacy ($b_3=0.01$, 95% CI= -0.15, 0.17) and decisional balance ($b_4=0.02$, 95% CI= -0.14, 0.17), which had no direct effects on PAR change scores, after adjusting for other variables in the model. More surprising was the negative sign of the path coefficient obtained for cognitive processes ($b_2=-0.29$, 95% CI=-0.48, -0.10), which suggested that increases in this mediator from baseline to 6-month follow-up were associated with net decreases in physical activity over the same time period ($p=0.003$). In summary, the third Baron and Kenny (1986) mediation step was statistically significant for both the Print and Telephone interventions in terms of changes in both behavioral and cognitive processes, but failed for changes in self-efficacy and decisional balance. However, change in behavioral processes acted as a mediator in the traditional sense, while change in cognitive processes acted as a “suppressor” variable (MacKinnon et al., 2000).¹

In step 4 we sought to assess whether the treatment effect was attenuated after accounting for its indirect effects via the mediators. Both the **total treatment effect** (c) of step 1 and the **direct treatment effect** (c') of step 3 are reported in the last two rows of Tables 3, 4. The results suggest a complete mediation scenario according to Baron and Kenny (1986), with the direct treatment effect losing its statistical significance for both the Print ($c'=0.04$, 95% CI=-0.26, 0.34) and Telephone arms ($c'=-0.10$, 95% CI=-0.40, 0.20). However, whereas in a single mediation scenario the difference between the total and direct treatment effects equals the indirect treatment effect through the sole mediator, in a multiple mediation scenario one needs to probe further, and establish which paths contribute the most to the mediation phenomenon. The product of each pair of a and b coefficients in Tables 3 and 4 gives the indirect treatment effect on outcome via a particular mediation path, and is expressed in standard units of the outcome variable, i.e., in terms of the standard deviation of the 6-month PAR change-scores (SD=126). Adding these ab products over all four mediator paths, produces the **total indirect treatment effect on outcome**. Table 2 reveals a moderate indirect effect of the Print intervention ($c-c'=0.39$, 95% CI=0.21, 0.57), with increases due to changes in behavioral processes ($a_1 b_1=0.54$, 95% CI=0.29, 0.80) counteracted by decreases due to change cognitive processes ($a_2 b_2=-0.17$, 95% CI= -0.31, -0.03). Similarly, Table 3 shows a moderate indirect effect of the Telephone intervention ($c-c'=0.47$, 95% CI=0.28, 0.66) arms, with increases due to behavioral processes ($a_1 b_1=0.61$, 95% CI=0.34, 0.87 for Telephone) partially cancelled out by decreases due to changes in cognitive processes ($a_2 b_2=-0.15$, 95% CI=-0.27, -0.02 for Telephone). In both cases, the mediation paths through changes in self-efficacy and decisional

¹Although we wanted to further examine this puzzling finding by fitting mediator-specific effects on the coefficients represented by the b paths, the study was not powered to test for treatment by mediator interactions. Hence, a common set of b coefficients is presented for both the Print and Telephone arms in Tables 1, 2. However, an informal investigation of these interactions, revealed that the b coefficients were consistently positive across all three treatment arms for behavioral processes, consistently negative for cognitive processes, and showed small fluctuations on either side of the origin for self-efficacy and decisional balance. In this sense, it does not appear that the sign of the cognitive processes coefficient is an artifact of averaging coefficients with disparate signs across intervention arms.

balance appeared negligible in magnitude, and failed to attain statistical significance. In the original scale of the data, assignment to the Print arm had an indirect effect of increasing physical activity by 49 minutes more than assignment to the control group (95% CI= 26, 72), whereas assignment to the Telephone arm produce an even larger benefit of 59 minutes (95% CI= 35, 83), mainly due to its larger impact on behavioral processes. In summary, for the Print and Telephone interventions, only changes in behavioral processes acted as a mediator in the traditional sense, while cognitive processes acted as a “suppressor”; changes in self-efficacy and decisional balance did not appear to affect outcome in either capacity.

MacKinnon et al. (2000) demonstrated that the product of two independent normal variables is likely to exhibit considerable skewness for sample sizes comparable to those in the present study (N=239), an observation that led them to question the adequacy of the asymptotic confidence intervals described above, which were based on the first-order delta method (Sobel, 1982). Following their suggestion, and recent work by Cerin et al. (2007), we supplemented these with bias-corrected and accelerated bootstrap intervals based on 10,000 iterations (Efron & Tibshirani, 1993), which performs better for small-to-moderate sample sizes, since it does not assume asymptotic normality of products of the path coefficients. Displayed in the rightmost column of Tables 1 and 2, and centered at the bootstrap median, these showed substantial agreement with the asymptotic results, and were not as asymmetric as theoretical considerations might have led one to expect.

DISCUSSION

The results of these mediational analyses suggest a complete mediation scenario according to Baron and Kenny (1986), with moderate indirect effects for both the Print and Telephone interventions and with increases due to changes in behavioral processes counteracted by decreases due to change cognitive processes. In both cases, the mediation paths through changes in self-efficacy and decisional balance were small, and failed to attain statistical significance. In summary, being assigned to the Print arm had an indirect treatment effect of increasing physical activity by 49 minutes more than assignment to the control group, whereas assignment to the Telephone arm produce an even larger benefit of 59 minutes, predominately due to its larger impact on behavioral processes. For the overall treatment effect, however, the ranking of the two arms of the intervention was reversed because there was a negative direct treatment effect (i.e., “suppressor effect”) operating within the telephone arm, which will be discussed in more detail below.

Effects of both the print and telephone arms’ 6-month outcomes were mediated by the theoretical constructs targeted by the interventions. Since results of the mediation analyses were similar for models comparing print and control and telephone and control arms, these findings will be discussed together below unless otherwise indicated. Specifically, while the interventions had positive effects on all four targeted constructs, only behavioral and cognitive processes mediated the effects of the intervention on physical activity outcomes when accounting for the effects of all four variables. As expected and as is consistent with the literature (Pinto et al., 2001; Lewis et al., 2002), behavioral processes had a mediation effect, such that the intervention increased participants’ behavioral processes, which in turn led to increases in physical activity. When controlling for all other variables in the model, an increase of one standard unit in behavioral processes resulted in an increase of 84 minutes of physical activity for the print and telephone intervention arms relative to the control arm.

Change in behavioral processes acted as a mediator in the traditional sense, while unexpectedly, change in cognitive processes acted as a “suppressor” variable (MacKinnon et al., 2000). While the intervention increased participants’ cognitive processes, this, in turn, served to decrease physical activity behavior. This suppressor effect must be understood in the context of the

multiple mediation analysis. It is not increases in cognitive processes per se that had a detrimental effect on physical activity outcomes, but the residual effects of cognitive processes not accounted for by behavioral processes, self-efficacy, and decisional balance in the multivariate analysis. That is, increases in cognitive processes may have been beneficial to the extent that they overlapped conceptually with increases in these other constructs; however, results indicate that unique aspect(s) of cognitive processes had detrimental effects on physical activity outcomes during the 6-month period.

In order to help interpret this finding, we examined which individual processes of change uniquely contribute to the relationship with outcome. We found two cognitive processes that uniquely contribute to a negative relationship with outcome once behavioral processes are controlled for (i.e., *Warning of risks*, *Caring about the consequences to others*) and two behavioral processes (i.e., *Substituting alternatives*, *Rewarding oneself*) that uniquely contribute to the positive relationship with the outcome once cognitive processes are controlled for. Based on normative data collected on the processes of change, a few patterns are noteworthy (Marcus & Forsyth, 2003; Marcus, Rossi, et al., 1992). First, all of the cognitive processes of change tend to decline between the Action and Maintenance stages of change, so it is possible that stage of change and activity level are factors here (Marcus & Forsyth). Data have shown that these two cognitive processes of change (*Warning of risks*, *Caring about the consequences to others*) perform a bit differently from the other cognitive processes (Marcus & Forsyth). For example, *Warning of risks* declines slightly from Contemplation to Preparation, then increases in Action and declines again in the Maintenance stage, similar to the level at Contemplation. *Caring about the consequences to others* tends not to change from Contemplation to Preparation, but then has an increase to Action, but a decline in Maintenance (approximating ratings found in Contemplation). In terms of the behavioral processes of change, both *Substituting alternatives* and *Rewarding oneself* have the highest values of the behavioral processes at maintenance. *Substituting alternatives* shows the most dramatic increase between each combination of stages and the biggest difference between Precontemplation and Maintenance, and shows an increase even into Maintenance. *Rewarding oneself* shows a very large increase from Preparation to Action. Of note, the two cognitive processes of change with unique contributions are related to greater understanding of how inactivity can be unhealthy and/or affect one's family or friends. Also, the two behavioral processes, which are using rewards and substituting activity for other sedentary pursuits, are important strategies for making behavior changes. It will be important to target these individual processes of change in future studies that are adequately powered to examine the processes individually.

The lack of mediation effects found for self-efficacy and decisional balance must be interpreted in the context of the multiple mediation analysis. The lack of direct mediation effects of self-efficacy and decisional balance, in combination with a strong mediational effect of behavioral processes, may reflect the omission of direct effects of self-efficacy and decisional balance on behavioral processes. Unfortunately, a lack of power in the present study precluded testing for additional endogenous mediational pathways. In a study of adolescents, Nigg (2001) found that self-efficacy and decisional balance at time one did not predict exercise behavior at 3-year follow-up, but vice versa (i.e., exercise predicted self-efficacy and pros/cons), with the processes of change showing no relationship to exercise; however, this study did not include all variables within the same model. Another study (Haerens et al., 2007) also found a suppressor effect for attitudes towards physical activity, a construct similar to cognitive processes. Future studies should continue to examine these constructs in both adult and adolescent samples.

The contrast in findings from multiple mediation analyses highlights the importance of the latter approach. While univariate analyses conducted by other researchers suggest that Social

Cognitive Theory (Bandura, 1986, 1997) and Transtheoretical Model (Prochaska & DiClemente, 1983) constructs each work to enhance physical activity, the multivariate analysis reveals a more complex picture in which interrelationships among the targeted theoretical constructs determine how each construct influences physical activity outcomes. The results of the multivariate analyses should not be interpreted as an immediate call for the paring down of interventions to target only behavioral processes of change. Indeed, one might find that in the absence of the additional intervention components, behavioral processes cannot be effectively changed, or that any change in behavioral processes fails to impact intervention outcomes. However, given the present findings, the latter hypothesis should be tested empirically through continued experimental research. Further, as shown in the present paper and in related work by Cerin et al. (2007), the Baron and Kenny mediation framework should be compared and contrasted with the potentially more powerful approaches examined in MacKinnon et al. (2002); especially given that the latter also provide better control of Type I error rate in small-to-moderate-sized samples. More generally, the findings from the multiple mediation analysis highlight the importance of studies that deconstruct the theoretical components of interventions to determine exactly what combination of components produce the greatest physical activity behavior change at the lowest cost in terms of time and resources.

From a practical perspective, the findings highlight the robustness of the intervention content, as nearly identical results were obtained for the two intervention delivery channels. Moreover, the results indicate that nearly all of the positive effects of each intervention were mediated by the targeted theoretical constructs. One difference in the findings for the two treatment approaches, however, involves the residual direct treatment effects on physical activity outcomes. At the risk of over-interpreting small and non-significant effects, it is worth noting that the direct treatment effect c' was positive for the Print arm (Table 2), but negative for the Telephone arm (Table 3), a difference of -0.14 standard units (95% CI= -0.63, 0.30). This indicates that some unmeasured process had a slight negative impact on physical activity outcomes for participants in the Telephone arm. While we can only hypothesize about this negative impact, one possibility is increased burden of planning and being available for a scheduled telephone call. Alternatively, because the study was designed to hold content constant across both intervention arms, while only varying the channel of delivery, it may have failed to take full advantage of the unique aspects of the Telephone communication channel. It is, thus, possible that a tailored Telephone intervention might have outperformed the Print intervention, since, even in its present form, it was found to be about one fifth more effective in producing physical activity increases via its action on the targeted mediators. Future studies should examine mediators among print and telephone interventions not matched on content, which might allow for a less structured, and perhaps less burdensome telephone intervention and more tailored to the goals of the participant.

Some limitations of the study should be noted. First, establishing mediation calls for temporal ordering of the treatment, putative mediator, and outcome, respectively (Baron & Kenny, 1986; Kraemer et al., 2001, 2002). In the present study, changes in the putative mediators and the outcome both were measured over the same 6-month period beginning immediately after the treatment was initiated. Specifically, although we measured change in mediators from baseline to 6 months, we cannot comment on whether there might have been changes at 3 months in self-efficacy and decisional balance that led to changes in the behavioral processes at 6 months. Therefore, changes in physical activity may have led to changes in the proposed mediators. Indeed, such a pattern is likely given the reciprocal interaction inherent in social-cognition-based interventions (Bandura, 1986). Nonetheless, theory also indicates that changes in the targeted constructs must occur before behavioral change can take place (Bandura, 1997). Thus, ordering of the constructs in our statistical model can be justified on theoretical grounds (Pedhazur & Pedhazur-Schmelkin, 1991). However, temporally-based analyses

should be tested in ongoing studies where such mediators are being assessed monthly in all arms.

Additionally, the sample for the present study was predominately Caucasian, female, mostly college educated and the majority reported a total household income above \$50,000. While this may limit the generalizability of the study to other populations, the study findings raise interesting conceptual ideas regarding intervention design and the importance of parsimony of intervention content.

In summary, the unique contribution of this study was to show that, when evaluated simultaneously through multivariate mediation model, behavioral processes were found to mediate the intervention effect, cognitive process actually had a suppressor effect, and that indirect paths via self-efficacy and decisional balance were not significant, after accounting for behavioral and cognitive processes. These findings suggest that interventions should focus on implementing behavioral strategies when attempting to increase physical activity among sedentary adults. For example, reinforcing physical activity, committing yourself to physical activity through goal setting or other strategies, putting reminders around the house about physical activity, and asking other individuals to exercise with you or to support you in exercising are all strategies that are important for physical activity behavior change. Adequately powered studies are needed that examine the specific behavioral and cognitive processes and other potential mediators (e.g., enjoyment, outcome expectations) to better understand the importance of mediators. Future studies are also needed to better understand the suppressor effect we observed in the current study. In summary, our study represents an advance in our knowledge of theoretical mediators, while at the same time suggesting future studies and analyses to test order effects among the mediators.

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Figure 1.
CONSORT Diagram

Figure 2.
Multiple Mediation.
Y = Outcome, X = Treatment, Z = Confounders, M₁,...,M₄ = Mediators.

Table 1

Demographic Information

Variable	Telephone (n= 80)	Print (n=81)	Contact Control (n=78)
Age (years)	45.16 (8.30)	43.44 (10.42)	44.79 (10.08)
Gender (% Female)	85	75.3	85.9
Race (% Caucasian)	95	86.4	87.2
Marital Status (% Married)	68.8	63	59
Employment (% Employed)	91.3	90.1	89.7
Cigarette Use (% Smokers)	13.8	14.8	9
Body Mass Index	27.92 (4.65)	28.24 (5.52)	29.50 (6.78)
Physical Activity (minutes per week)	19.75 (26.56)	20.19 (24.15)	19.36 (24.51)

Note. Standard deviations are in parentheses

TABLE 2
Effects of Print Intervention on 6-Month Standardized 7-Day PAR Changescores *

	Treatment to Mediator (a path)		Mediator to Outcome (b path)		Treatment to Outcome $\hat{\gamma}$ (ab path)		Treatment to Outcome $\hat{\gamma}\hat{\gamma}$ (ab path)	
	PE	95% CI	PE	95% CI	PE	95% CI	PE	95% CI
Mediators								
Self-Efficacy	0.55	0.27, 0.84	0.01	-0.15, 0.17	0.01	-0.08, 0.09	0.00	-0.09, 0.08
Behavioral Processes	0.82	0.54, 1.10	0.67	0.46, 0.88	0.54	0.29, 0.80	0.54	0.32, 0.85
Cognitive Processes	0.59	0.31, 0.87	-0.29	-0.48, -0.10	-0.17	-0.31, -0.03	-0.17	-0.34, -0.04
Decisional Balance	0.34	0.05, 0.63	0.02	-0.14, 0.17	0.01	-0.05, 0.06	0.00	-0.06, 0.07
Total Indirect Effect					0.39	0.20, 0.56	0.37	0.19, 0.63
Direct Effect (c')					0.04	-0.26, 0.34	0.05	-0.23, 0.32
Total Effect (c)					0.42	0.11, 0.73	0.42	0.11, 0.77

* PE=Point Estimate; CI = Confidence Interval

$\hat{\gamma}$ First Order Delta Method (Sobel, 1982)

$\hat{\gamma}\hat{\gamma}$ Bias-corrected and accelerated bootstrap results based on 10,000 iterations (Efron & Tibshirani, 1993).

TABLE 3
Effects of Telephone Intervention on 6-Month Standardized 7-Day PAR Changerscores. *

Mediators	Treatment to Mediator (a path)		Mediator to Outcome (b path)		Treatment to Outcome $\hat{\gamma}$ (ab path)		Treatment to Outcome $\hat{\gamma}\hat{\gamma}$ (ab path)	
	PE	95% CI	PE	95% CI	PE	95% CI	PE	95% CI
Behavioral Processes	0.91	0.64, 1.19	0.67	0.46, 0.88	0.61	0.34, 0.87	0.60	0.38, 0.91
Cognitive Processes	0.52	0.24, 0.80	-0.29	-0.48, -0.10	-0.15	-0.27, -0.02	-0.17	-0.31, -0.03
Self-Efficacy	0.64	0.36, 0.92	0.01	-0.15, 0.17	0.01	-0.10, 0.11	0.01	-0.10, 0.10
Decisional Balance	0.38	0.09, 0.66	0.02	-0.14, 0.17	0.01	-0.05, 0.07	0.01	-0.06, 0.07
Total Indirect Effect					0.47	0.29, 0.66	0.46	0.28, 0.70
Direct Effect (c')					-0.10	-0.40, 0.20	-0.09	-0.41, 0.16
Total Effect (c)					0.37	0.06, 0.67	0.37	0.10, 0.64

* PE=Point Estimate; CI = Confidence Interval

$\hat{\gamma}$ First Order Delta Method (Sobel, 1982)

$\hat{\gamma}\hat{\gamma}$ Bias-corrected and accelerated bootstrap results based on 10,000 iterations (Efron & Tibshirani, 1993)