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Original Research

Examining the moderating effects of executive function on transtheoretical model utilization to predict physical activity

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ABSTRACT

Introduction: The purpose of this study was to examine the association of each of the transtheoretical model (TTM) constructs on physical activity, with considerations by executive function levels, which has yet to be evaluated in the literature. This is a noteworthy investigation as this may help determine whether the utility of the TTM is contingent upon an individual's level of executive function. **Methods:** Data were collected from 200 University students (mean age: 21.6 years; 63% female). TTM constructs were assessed via a validated TTM survey. To assess executive function, the Parametric Go/No-Go computer task was utilized. **Results:** Physical activity was assessed using the international physical activity questionnaire. The only TTM construct associated with meeting activity guidelines was behavioral processes (odds ratio: 1.13; 95% confidence interval: 1.06-1.20; $P < 0.001$). Further, there were no interaction effects of executive function and any of the TTM constructs on moderate-to-vigorous physical activity (all $P > 0.05$). **Conclusion:** Greater use of behavioral processes of change was associated with higher levels of activity, and executive function did not moderate this association. Utilization of the TTM framework may have utility among young adults irrespective of their executive function level.

KEY WORDS: Behavioral process of change, executive function, moderate-to-vigorous physical activity, transtheoretical model

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INTRODUCTION

The transtheoretical model (TTM) consists of a framework of five discrete stages adopted to study health-promoting behavior. These stages include precontemplation, contemplation, preparation, action, and maintenance [1]. Behavioral and cognitive processes of change, decisional balance which incorporates pros and cons, and self-efficacy are core constructs of TTM. A vast amount of research suggests that TTM is useful in promoting physical activity behavior change [2].

The utility of the TTM in promoting physical activity behavior across varying executive function levels has not been fully investigated. Although the TTM has been shown to be effective in promoting physical activity across various populations including children/adolescents [3], adults in the general population [4], and adults with chronic disease [5], it is plausible that executive function may moderate the utility of the TTM in predicting physical activity. This plausibility stems from the fact that the previous research demonstrates that executive function improvement is associated with increased physical activity [6] and decreased sedentary behavior [7]. Executive functioning (EF) is defined as managing cognitive processes including working memory, cognitive flexibility, response selection, planning, and execution of tasks [8]. For illustrative purposes, EF may moderate the effects of TTM on physical activity. For example, those with worse cognitive function may be less inclined and able to set physical activity goals and enlist social support (behavioral processes of change), and further, those with lower levels of EF may have reduced self-efficacy to overcome physical activity barriers [9]. Despite this plausibility, no study, to our knowledge, has indeed evaluated whether EF plays a moderating role on the relationship between the TTM constructs and physical activity behavior. Thus, the purpose of this study was to examine the association of each of the TTM strategies on physical activity, with considerations by EF level. We hypothesize that EF will moderate the association between the TTM constructs and physical activity.

METHODS

Design and Participants

Participants (undergraduate/graduate students) were recruited via a convenience-based sampling approach at the authors' institution, which is located in the Southeastern part of the

United States. Participants were recruited in various classes at the University as well as at the University's recreational center. Participant recruitment ended when data were collected on 200 participants. Thus, our analyzed sample included 200 participants. All data collection took place in the authors' laboratory. Students were sampled across a variety of different academic majors. Participants, on average, were 21.6 years, 63% were female, 69% were non-Hispanic white, and the majority (86%) were undergraduate students.

Data collection began in October 2015 and continued through June of 2016. Participants completed an assessment of the TTM model constructs and physical activity which were all assessed via questionnaire. This questionnaire took approximately 15 min to complete. Body mass index (included as a covariate) was directly measured using a seca scale and stadiometer. Notably, among the 200 participants, there were no missing data. A random sample of 10% of the 200 participants completed the questionnaires again 1-week later for test–retest reliability purposes. In addition, these participants also wore a pedometer (SW 200 Digi-Walker) on their right hip for 1-week in an effort to assess the possible convergent validity of the self-reported physical activity assessment. Participants wore the pedometer (to assess daily steps) for 7 days, wearing it for at least 10 h a day.

Measurement of TTM Constructs

All TTM constructs were measured from a validated questionnaire, as described in a previous study [10].

Stage of change

To be consistent with stages of change in the TTM, regular participation in exercise was defined as "equal to five or more days per week of at least 30 min at a moderate intensity." As used in previous studies, participants were asked to choose one of five statements to describe their readiness to change their exercise behavior [11,12]. The five different stages of change include precontemplation, contemplation, preparation, action, and maintenance. For example, participants who reported, "No, I do not plan to start in the next 6 months" were classified in the precontemplation stage. The stage of change algorithm has demonstrated evidence of reliability and validity in adults of the general population and those with chronic diseases [11,12]. In this sample, the 1-week test–retest reliability was ICC: 0.64.

Processes of change

To examine the strategies individuals use to change their exercise behaviors, a 30 items measure were used to assess both behavioral and cognitive processes of change. 15 items assessed behavioral process of change (BPC) (i.e., reinforcement management, counterconditioning, helping relationships, self-liberation, and stimulus control), whereas the other 15 items assessed cognitive processes of change (i.e., consciousness-raising, dramatic relief, environmental reevaluation, self-reevaluation, and social liberation). Participants were asked to respond to each question using a Likert scale, with end points ranging from 1 (never) to 5 (repeatedly). A sample BPC item is "Instead of relaxing by watching television or eating, I take a walk or do physical activity." A sample cognitive process of change question is "I believe that regular physical activity will make me a healthier, happier person." Reliability and validity of both behavioral and cognitive process of change have been previously established [13]. Behavioral and cognitive processes of change were calculated by summing the items for each process of change separately. Higher scores indicate higher use of behavioral processes or cognitive processes of change. In this sample, the 1-week test–retest reliability for BPC and CPC, respectively, was ICC: 0.90 and ICC: 0.91. Further, internal consistency, as measured by Cronbach's alpha, for BPC and CPC, respectively, was $\alpha = 0.89$ and $\alpha = 0.83$.

Self-efficacy

To assess self-efficacy, or an individual's confidence in ability to overcome barriers, an 18 items measure, which has demonstrated evidence of reliability and validity, was used [14,15]. For each question, participants responded using a Likert scale, with end points ranging from 1 (not at all confident) to 5 (very confident). A sample item is "I feel confident that I can participate in physical activity when I don't feel like it." Items were summed, with higher scores indicating higher self-efficacy. In this sample, the 1-week test–retest reliability for self-efficacy was ICC: 0.82. Further, internal consistency, as measured by Cronbach's alpha, was $\alpha = 0.92$.

Decisional balance

An individual's reflection of the pros and cons in engaging in regular PA, referred to as decisional balance, was evaluated using a 10 items measure. 5 items assessed pros of regular exercise, whereas the other 5 items evaluated the cons of engaging in regular exercise. Using a Likert scale anchored by 1 (not at all) and 5 (very much), participants were asked to rate their degree of agreement with each perceived positive and negative consequence of exercise involvement. A sample item of pros for exercise is "Physical activity would help me reduce tension or manage stress." A sample item of cons for exercise is "Physical activity would take too much of my time." This measure has previously demonstrated evidence of reliability and validity [16]. Pros and cons were scored separately by summing the respective items, with a higher pros score indicating more perceived pros of exercise and a lower cons score indicating fewer perceived cons of exercise. In this sample, the 1-week test–retest reliability for pros and cons, respectively, was ICC: 0.93 and ICC: 0.63. Further, internal consistency, as measured by Cronbach's alpha, for pros and cons, respectively, was $\alpha = 0.85$ and $\alpha = 0.72$.

Measurement of Executive Function

The Parametric Go/No-Go (PGNG) computer task was used to measure individual differences in executive function [17]. This assessment takes approximately 30 min and requires individuals to actively regulate responses to presented stimuli and either initiate response quickly or inhibit their response.

The EF construct is multidimensional [18], and PGNG measures predominantly tap one facet of EF that may be particularly pertinent to behavioral self-regulation: The ability to suspend proponent responses to external cues. Functional imaging studies have documented associations between PGNG performance and activation in the prefrontal and anterior cingulate regions of the brain [19,20]; both structures have been implicated in behavioral self-regulation in humans [21]. Detailed discussion of the factor structure and construct validity of the PGNG test is published elsewhere [17,22].

Utilizing computerized software, participants are presented with a series of flashing letter targets (e.g., "r," "s," and "t") intermixed with other letters (e.g., "a," "c,"), with each presented letter occurring at a rate of 500 ms. There are two primary outcome parameters including the simple rule and repeating rule. For the simple rule, participants are asked to press the space bar every time the target letter (e.g., "r," "s," or "t") appears, with our evaluated outcome of this rule being the percent of correct target detection and mean reaction time. For the repeating rule, participants are asked to press the space bar every time they see the target letter (e.g., "r," "s," or "t"), but only if the target letter is not repeating the previous target; our evaluated outcome for this rule was the percent of correct (nonrepeating) target detection and mean reaction time. For example, if the following letter sequence occurred, they would not press the space bar for the second "r" (a, t, r, p, d, and r), but they would press the space bar twice (at "r" and "s") during this sequence (a, t, r, p, d, and s). The first EF parameter will be referred to as the Simple Rule and the second EF parameter will be referred to as the repeating rule.

Measurement of Physical Activity

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ). The IPAQ form asks participants about the time they spend being physically active in the last 7 days. For example, a question on the form is "How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?" Participants reported their answer in hours per day or minutes. Participants were classified as meeting physical activity guidelines (vs. not) if they self-reported at least 150 min/weeks of moderate-to-vigorous physical activity (MVPA). Previous research shows the IPAQ to be reliable and valid [23]. Among the 10% random sample of this study, the correlation between IPAQ-determined MVPA and pedometer-determined steps was, r: 0.43 ($P < 0.001$). The 1-week test–retest reliability of the 10% random sample was ICC: 0.79.

Data Analysis

All analyses will be performed in Stata (v. 12). A multivariable logistic regression analysis was used to evaluate the association between the TTM constructs and meeting MVPA guidelines (outcome variable). In this singular analysis, all TTM constructs were included in the same model. Notably, there was no evidence of multicollinearity in the model; highest individual variance inflation factor was 2.46, with a mean variance inflation of 1.57. Multiplicative interaction was assessed by creating a cross product term of the TTM construct and the executive function level, and including this cross product term along with their main effects and the covariates, in the model. In the regression models, covariates included age (years; continuous), gender, race-ethnicity (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and others), education level (undergraduate and graduate), self-reported health status (excellent, very good, good, fair, and poor), and measured body mass index (kg/m^2; continuous). Statistical significance was established as $P < 0.05$.

RESULTS

In Table 1, study variable characteristics are displayed. The mean age for the sample was 21.6 years (standard deviation: 2.2), ranging from 18 to 33 years. Participants included 86% undergraduate students and the remaining 14% were graduate students. Mean minutes/week of MVPA was 375.5. Health status distribution was as follows, 15.5% rated their health as excellent, 46% very good, 32.5% good, and 6% as fair.

In the multivariable logistic regression analysis, only behavioral processes of change were associated with meeting MVPA guidelines (odds ratio [OR]: 1.13; 95% confidence interval [CI]: 1.06-1.20; $P < 0.001$). Further, there did not appear to be any multiplicative interaction effect of TTM and EF on meeting MVPA guidelines. Self-efficacy and the first EF simple rule parameter showed no interaction effect on MVPA, OR: 1.00, 95% CI: 0.99-1.00, $P = 0.69$; for the second EF repeating rule parameter and self-efficacy on MVPA, OR: 1.00, 95% CI:

Table 1: Study variable characteristics (*n*=200)

Variable	Point estimate	Standard deviation
Age, mean years	21.6	2.2
% Female	63	
BMI, mean kg/m^2	25.9	6.9
Ethnicity, % non-Hispanic white	69	
Education, % undergraduate student	86	
Health status (%)		
Excellent	15.5	
Very good	46	
Good	32.5	
Fair	6	
Physical activity		
MVPA, mean min/week	375.5	324
% meets guidelines[a]	75	
TTM constructs		
Stage of change, % precontemplation	0.5	
Stage of change, % contemplation	2.5	
Stage of change, % preparation	19.5	
Stage of change, % action	17.5	
Stage of change, % maintenance	60	
Self-efficacy, mean	64.8	13.2
Decisional balance, cons, mean	8.4	3.1
Decisional balance, pros, mean	21.9	3.1
Processes of change, behavioral, mean	54.8	10.3
Processes of change, cognitive, mean	56.3	8.6

TTM: Transtheoretical model, BMI: Body mass index, MVPA: Moderate-to-vigorous physical activity. [a]MVPA for at least 150 min/weeks

0.99-1.00, $P = 0.23$. In regards to the TTM construct of pros, the simple rule and repeating rule EF parameter demonstrated no interaction effect on MVPA, OR: 1.00, 95% CI: 0.99-1.01, $P = 0.24$ and OR: 0.99, 95% CI: 0.99-1.01, $P = 0.68$, respectively. The TTM construct of cons, the simple rule and repeating rule EF parameter demonstrated no interaction effect on MVPA, OR: 0.99, 95% CI: 0.99-1.01, $P = 0.24$ and OR: 0.99, 95% CI: 0.99-1.01, $P = 0.79$, respectively. The behavioral processes TTM construct and the simple rule and repeating rule EF parameter demonstrated no interaction effect on MVPA, OR: 1.00, 95% CI: 0.99-1.00, $P = 0.79$ and OR: 1.00, 95% CI: 0.99-1.00, $P = 0.39$, respectively. The cognitive processes TTM construct and the simple and repeating rule EF parameter demonstrated no interaction effect on MVPA, OR: 1.00, 95% CI: 0.99-1.00, $P = 0.87$ and OR: 0.99, 95% CI: 0.99-1.00, $P = 0.85$, respectively.

DISCUSSION

It has been accepted that physical activity is associated with improved physical functioning and cognitive performance [24], across varying populations, including children [25], young [26] adults, and older [27] adults. Accumulating studies have examined the role physical activity has on EF. For example, Stillman *et al*. [24] studied this relationship of physical activity and executive function in a young adult population (similar to our evaluated population). Further, studies across varying populations have demonstrated utility for the TTM in influencing physical activity behavior. However, studies examining the potential moderation role of EF on the use of the TTM in promoting physical activity are nonexistent.

While this study is novel, which is considered a strength, there are limited data on the potential moderation effects of EF on promoting physical activity via TTM constructs; thus, this precludes our ability to make direct comparisons to other studies. Consistent with this study, Loprinzi *et al*. [10] demonstrated that BPC, in particular, is a strong correlate of future MVPA among a sample of older adults. The evidence that BPC plays an important role in exercise participation can elicit numerous positive health outcomes by maintaining regular physical activity.

Executive function has been observed as a moderator of treatment effects in regards to implementation intentions for physical activity behavior among older adult women. Implementation intentions are defined by Hall *et al*. [28] as "if-then" plans that provide the when and where an individual will enact a behavior to achieve a goal. It may be plausible to suggest implementation intentions to be similar to behavioral processes of change, as they are thought to facilitate achieving a goal by invoking a behavioral response. A growing body of literature has suggested to use this type of intervention to promote physical activity [28]. Findings from the Hall *et al*. [28] study indicate a significant treatment effect for EF interaction as a moderator. Participants with relatively stronger executive function were more likely to turn their intention into a behavioral enactment.

From this study, it has been suggested that the TTM construct behavioral processes of change is associated with the higher physical activity. The nonsignificant EF interactions may be explained by the reliance on one EF test. Future prospective work employing multiple EF and cognitive function assessments are warranted to confirm or refute our observations. Another limitation of this study is the potential limited generalizability. Our evaluated population consisted of strictly college students, in a Southern part of the United States. Further, the health behavior physical activity and TTM constructs were assessed via self-report and are therefore subject to limitations such as recall and social desirability bias. Notably, however, our physical activity measure was validated against an objective measure, and there is no objective measure available for any of the TTM constructs.

CONCLUSION

Examining the association of TTM constructs on MVPA while considering EF serves importance as it may provide insight on the utility of the TTM in predicting physical activity across various EF levels, ultimately helping to increase adherence to MVPA guidelines. In this study, we did not observe evidence of a moderation effect of TTM and EF on physical activity. Our present study suggests BPC to be associated with higher levels of physical activity and EF did not moderate this association. Therefore, it is plausible to suggest that utilization of the TTM framework may have utility among young adults irrespective of their EF level, which is encouraging from a health promotion standpoint.

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