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Testing the predictive power of the transtheoretical model of behavior change applied to dietary fat intake

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Abstract

This study evaluated how well predictions from the transtheoretical model (TTM) generalized from smoking to diet. Longitudinal data were used from a randomized control trial on reducing dietary fat consumption in adults ($n = 1207$) recruited from primary care practices. Predictive power was evaluated by making *a priori* predictions of the magnitude of change expected in the TTM constructs of temptation, pros and cons, and 10 processes of change when an individual transitions between the stages of change. Generalizability was evaluated by testing predictions based on smoking data. Three sets of predictions were made for each stage: Precontemplation (PC), Contemplation (C) and Preparation (PR) based on stage transition categories of no progress, progress and regression determined by stage at baseline versus stage at the 12-month follow-up. Univariate analysis of variance between stage transition groups was used to calculate the effect size [omega squared (ω^2)]. For diet predictions based on diet data, there was a high degree of confirmation: 92%, 95% and 92% for PC, C and PR, respectively. For diet predictions based on smoking data, 77%, 79% and 85% were confirmed, respectively, suggesting a moderate degree of generalizability. This study revised effect size estimates for future theory testing on the TTM applied to dietary fat.

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More than a half million deaths per year are attributed to diseases that have modifiable risk factors that can be prevented or managed with healthful behaviors [1]. The leading causes of death in the year 2000 were attributed to the modifiable behaviors of tobacco, poor diet and physical activity [2, 3]. Yet prevalence rates for engaging in healthful behaviors such as healthy eating are low [4]. Current data suggest that behavior change interventions result in modest effects on dietary components such as fruits, vegetables and fat intake [5, 6]. There is some evidence that interventions tailored on theoretical concepts result in larger effects than interventions tailored on behavior only [7]. Improved effectiveness will require both innovation and state-of-the-art research methodology that allows replication and extension of findings. Using theory to guide intervention research may help the science of dietary behavior change achieve this goal.

Scientific progress depends in part on the continuous testing and evaluation of theories. One of the most important aspects of theory evaluation is testing the predictive power of a theory [8–11]. A prediction is essentially a statement that under certain conditions a change in variable *A* will be followed by a change in variable *B* [12]. A theory's ability to make accurate predictions provides evidence that the theory is explaining behavior change. The purpose of this study is to evaluate the predictive power of a commonly used theory in health behavior research, the transtheoretical model (TTM) of behavior change [13–16].

The TTM is conceptualized as a framework whose purpose is to guide the content and timing

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of interventions designed to promote and facilitate healthful behaviors (15). The model comprised 15 constructs: (a) stages of change [17], (b) two-decisional balance constructs [18, 19], (c) two self-efficacy constructs [20], (d) five experiential processes of change and (e) five behavioral processes [14, 21, 22].

The stage construct provides the integrating framework and represents the temporal dimension [13]. There are five stages: 1) Precontemplation (PC), 2) Contemplation (C), 3) Preparation (PR), 4) Action (A) and 5) Maintenance (M). Individuals can progress through the stages of change in a linear or cyclical fashion, often making many attempts to change, relapsing back to earlier stages before progressing to the M stage. Within a stage of change, an individual uses the other 14 constructs to a greater or lesser extent. Process use is how an individual progresses from one stage to the next [21, 23]. In general, process use tends to increase when one moves from PC to A [24]. The use of experiential and behavioral processes increases from PC to A where they peak [24]. In M, experiential processes decrease in use while behavioral processes remain stable. However, data suggest that specific process use varies to some extent by behavior [25, 26].

Critics of the TTM have proposed that the majority of studies using the TTM are descriptive while few have addressed its ability to predict behavior change [27]. A robust test of a theory's predictive power is stating prior to doing analyses what is expected to happen (i.e. *a priori*), and testing predictions using statistical methods suited for theory testing [28]. Most studies have relied on exploratory statistical significance testing such as regression techniques to find predictors instead of testing *a priori* predictions [29–33]. Velicer, Cumming *et al.* [34] posit that traditional null hypothesis testing is poorly adapted to theory testing given its focus on testing a prediction that was not made by the theory, that is, the null hypothesis, rather than the actual prediction. Low power, psychometrically weak measures and a poorly operationalized theory can lead to failure to reject the null. An alternative approach is to use the theory to generate explicit effect size predictions that are compared with the observed effect size estimates and the related CIs to test the theoretical predictions [28, 34]. Three studies have used these methods with cross-sectional data from smoking cessation trials and found strong evidence for the TTM's predictive power [34, 35, 36].

While previous studies have led to a better understanding of the predictive power of the TTM, they have tested predictions mainly on smoking cessation trials only. The primary purpose of this study was to evaluate predictions based on the TTM when applied to reducing dietary fat consumption. The TTM has been applied to nearly 50 behaviors [37], yet not enough is known about how well the model generalizes to other behaviors [27]. Generalizability can be evaluated by understanding the scope of a theory, that is, does the theory apply to a variety of situations, times and places [10]. Given that the TTM was first developed on smoking cessation, a good test of the model's generalizability is how well it generalizes to another health behavior.

Method

Participants

Institutional Review Board approval was obtained for secondary data analysis of participant data from two large-scale, randomized control trials on cancer prevention. One sample comprised patients from a study done in adult primary care (Patient Sample) [38]. The second sample comprised parents of adolescents who were participating in a school-based randomized control trial (Parent Sample) [39]. Detailed descriptions of both samples have been previously published [38, 39]. For both trials, a no-treatment control was used. The intervention groups received materials that included a stage-matched manual and tailored feedback reports consisting of strategies and suggestions for making progress toward reducing cancer risk-related behaviors. The reports were mailed to the home at baseline, 6 and 12 months.

Patient sample

The original study sample included 3790 patients randomized to one of two study arms. Eligibility

criteria included being 'at risk' for either smoking, high-fat diet or sun exposure or lack of mammography screening in women over age 50 years. At risk was considered being in the pre-action stages of change (i.e. PC, C or PR), that is, not meeting the current public health consensus for those behaviors. The total number of patients contacted by phone was 8539 and 63% (N = 5382) were eligible for the study. A total of 3790 were at risk for dietary fat intake. The present study examined only those at risk for diet and randomized to the intervention group (N = 1207). The control group was not included because they did not complete the full battery of measures necessary to test the predictions. The sample was 69.7% female, 96.7% Caucasian, 1.3% Hispanic, 1.1% African-American and 71.4% married or living with a partner. The sample had a mean age of 44.7 [standard deviation (SD) ± 12.7] years, mean body mass index (BMI) of 25.7 (SD ± 4.9) and mean level of education of 14.5 years. The stage distribution for dietary fat intake for those in the diet intervention group was 52.6% PC, 13.9% C and 33.6% PR.

Parent sample

As in the patient sample, participants 'at risk' for smoking, unprotected sun exposure or high-fat diet were eligible for the original study. Approximately 1816 parents were at risk for sun exposure, 1820 were at risk for diet and 707 were smokers. Only those at risk for diet were examined in the present study. The sample was 75% female, 92% Caucasian, 3% Hispanic and 77% married. Average age was 42.5 (SD ± 5.5) years, mean BMI was 25.2 (SD ± 4.7) and mean level of education was 14 years. The stage distribution for dietary fat intake was 54.5% PC, 14.4% C and 31.1% PR.

Measures

Only TTM measures for dietary fat reduction were used. Participants were classified into one of the five stages of change for consistently avoiding high-fat foods using a validated staging algorithm [40, 41]. The construct of self-efficacy was assessed using a nine-item Likert scale of the temptation to eat high-fat foods across a variety of challenging situations [42]. The two constructs of decisional balance were measured with a six-item, five-point Likert scale that assessed the relative importance given to the pros and cons when making a decision whether to reduce dietary fat consumption [43]. The processes of change were quantified using 20 items that assessed the frequency of process use [25, 44]. This scale included 10 constructs: (i) consciousness raising (CR) about unhealthful dietary behavior, (ii) dramatic relief (DR), using feelings to help motivate dietary fat reduction; (iii) environmental reevaluation (ER), assessing the impact changing fat intake has on others; (iv) self-reevaluation (SR), reassessing thoughts and feelings about oneself as a person with unhealthful dietary behavior; (v) social-liberation (SO), becoming aware of changes in the environment that influence dietary behavior patterns; (vi) self-liberation (SL), recognizing choices and making a commitment to reduce fat; (vii) helping relationships (HR), seeking and accepting support from others to reduce dietary fat intake; (viii) reinforcement management (RM), rewarding oneself or being rewarded for healthful dietary behaviors; (ix) counter conditioning (CC), substituting other thoughts and healthful dietary behaviors in place of unhealthful ones, and (x) stimulus control (SC), avoiding situations, places or things that trigger excess consumption of high-fat foods [25].

The scales were developed using sequential measurement procedures [45, 46]. All scales had very good to excellent psychometric properties. Temptation and decisional balance had confirmatory factor index of 0.96 and coefficient alphas ranging from 0.82 to 0.96. Processes of change had alphas ranging from 0.59 to 0.86.

This study made predictions based on the premise that the TTM provides an understanding of how to facilitate behavior change. The theory can be used to understand how people move through the stages of change toward a desired criterion. This knowledge is then used for intervention purposes to promote forward stage movement.

There are four critical stage transitions: (i) PC to C, (ii) C to PR, (iii) PR to A and (iv) A to M [35].

Movement may not always be forward-only. Individuals often relapse back to an earlier stage (regression) or remain in the same stage (stable) during the course of an intervention. For interventions, it is important to predict which constructs facilitate forward movement and which constructs predict relapse. This study examined progression and regression for those in the pre-action stages at baseline. Only transitions from the baseline stages of PC, C and PR were examined because those in A or M at baseline were not eligible for the diet intervention. Three types of transitions were examined: progress to a higher stage, regress to a lower stage and no stage change (stable). Predictions of effect size were made for stage transition comparisons for 13 TTM constructs: pros, cons, temptation and processes.

Setting a priori predictions

Longitudinal data from the patient sample were used to test quantitative *a priori* predictions. Two sets of predictions were made for diet: (i) one set was based on effect sizes found in cross-sectional [36, 47] and longitudinal 'smoking data' [22, 30, 35] and (ii) one set was generated from cross-sectional 'diet data' from the parent sample described above and from previous studies [25, 26]. After predictions were made, quantitative analyses determined whether the predictions were corroborated. New hypotheses were generated for the next step of theory testing only after *a priori* analyses were completed, that is, a deductive approach was taken and exploration was minimized.

Diet predictions based on smoking data

The first set of predictions for diet was based on effect size estimates from smoking studies [35, 36, 47]. Graphs of the TTM constructs plotted across the stages of change [22, 29] were also used to make predictions for smoking. The curves from these graphs provided an estimate of the magnitude of change between stages. For example, 1 SD of change was interpreted as a medium effect for cross-sectional studies and as a large effect for prospective studies.

Diet predictions based on diet data

Given that no studies had proposed *a priori* predictions for dietary fat intake, cross-sectional data from the parent sample were used to guide effect size predictions for dietary fat intake. Graphs of the TTM constructs were plotted across the stages of change. The curves provided an estimate of the magnitude of change between stages. Because cross-sectional data describe differences between individuals while longitudinal describes changes within an individual, it was assumed that cross-sectional data produce larger effect sizes. Therefore, 1 SD of change between stages was interpreted as a medium effect. Graphs from previous diet studies were also used to make predictions for temptation, pros and cons and processes [25, 26].

Analysis

The analysis was divided into three studies: (i) Study 1 examined those participants in the PC stage at baseline, (ii) Study 2 examined those in C stage at baseline and (iii) Study 3 examined those in the PR stage at baseline. Table I displays the comparisons made between stage transition categories. For each study, the magnitude of change for 13 TTM constructs was predicted for comparisons between stage transition categories. For example, those who remained in PC compared with those who progressed from PC to C at the 12-month assessment. The magnitude was predicted as small, medium and large [48]. A total of 26 predictions (13 based on smoking studies and 13 based on diet studies) were made for each of the three studies (see Tables II–IV for predictions). The predictor variables were the TTM scale scores for pros, cons, temptation and processes at Time 1 (baseline). The grouping variables were the stage transition categories based on stage at baseline and stage 12 months later. Only those participants who completed the TTM measures (stage of change, temptation, pros and cons and processes) were included in the analyses.

Effect size calculations

The effect size indicator omega squared (ω^2) was used as an estimate of the proportion of variance in

Table I. *Comparisons made between stage transition categories in the three studies*

Study 1, PC	Study 2, C	Study 3, PR
	C to C versus C to PC	PR to PR versus PR to PC
PC to PC versus PC to C		PR to PR versus PR to C
PC to PC versus PC to PR	C to C versus C to PR	
PC to PC versus PC to A/M	C to C versus C to A/M	PR to PR versus PR to A/M

Stage transition category is based on stage at baseline and stage at 12 months, total $N = 1207$.

the dependent variable associated with the independent variable [49]. In this study, ω^2 represents the percentage of variance accounted for in the TTM construct that is predictable from knowledge of stage membership, that is, the strength of association between the construct and stage transition category. Advantages of using ω^2 include that it is an unbiased or corrected effect size that has sampling error influences removed, that is, it estimates the effects in the population, and it provides useful information when the *F*-test is not significant because it is not dependent on sample size or power [50], allowing comparisons to be made with a small number in some stage transition categories, for example, C to PR.

Omega squared was calculated using analysis of variance between stage transition groups. The effect size estimate, ω^2, was interpreted using Cohen's [48] classification of small (0.01), medium (0.059) and large (0.138). If the ω^2 was 0, the effect size was considered trivial or 'none'.

Confidence interval

The American Psychological Association Task Force on Statistical Inference [51] recommends reporting actual *p* value, effect size and confidence intervals (CIs). Smithson suggests that the use of CIs can be linked to null hypothesis testing because the range includes all the hypothetical values of the statistic that cannot be rejected. CIs are useful for theory testing because the true population parameter will eventually be estimated across studies. CIs can also be used to integrate findings and determine how stable the results are across studies [49]. Using CIs around the size of the effect provides more information that can be used for future theory testing and comparisons across studies. For this study, 95% CIs were calculated about the ω^2 using SPSS syntax written by Smithson [52] and adapted by Fiddler and Thompson [49]. Predictions were compared with 95% CI about ω^2. Any effect size prediction that fell within the 95% CI was considered corroborated.

Conclusions were drawn using informed judgments based on population effect size, CI, sample size [53], previous research and theory.

Results

At the 12-month follow-up, 46% of those in PC at baseline remained in PC, while 54% progressed. Approximately, 22% of those in C at baseline remained in C at the 12-month follow-up while 26% regressed, and 52% progressed. About 28% of those in PR at baseline remained in PR at the 12-month follow-up while 40% regressed and 32% progressed. A and M stages at 12-month time point were combined for all analyses.

The data were examined for normality. All variables had a skew and kurtosis of <1.5. Tests for multivariate outliers were run. Ten cases were eliminated based on a Mahalanobis distance greater than chi-square (13) = 34.53, $P < 0.001$.

Study 1: Precontemplation

Table II summarizes the number of corroborated predictions and proposes revised predictions for future studies. Of the 39 smoking-based predictions, 30 (77%) were in agreement. Of the 39 diet-based predictions, 36 (92%) were in agreement. For the smoking-based predictions, the fewest number in agreement was in the comparison between the

Table II. *Diet stage transition comparisons for PC on 13 TTM constructs: Study 1*

Construct	Observed ES (ω^2)	95% CI about ω^2		Predicted ES from Smoking	Agreement with smoking predictions	Predicted ES from diet	Agreement with diet prediction	Revised prediction for diet
		Lower	Upper					
Part I. Comparing stable PC (PC to PC; N = 208) versus progressing one stage (PC to C; N = 93)								
Temptation	0.017	0	0.053	None	✓	Small	✓	*
Pros	0.001	0	0.024	Small	✓	Small	✓	None
Cons	0.024	0.001	0.064	None	✓	Small	✓	*
CR	0.011	0	0.043	None	✓	Small	✓	*
DR	0.009	0	0.040	None	✓	Small	✓	*
ER	0	0	0.016	None	✓	None	✓	*
SO	0.004	0	0.029	Small	✓	None	✓	*
SR	0.023	0.001	0.063	Small	✓	Small	✓	*
CC	0.021	0	0.059	None	✓	Small	✓	*
HR	0.002	0	0.025	None	✓	None	✓	*
RM	0.025	0.002	0.065	None	✓	None	✓	Small
SC	0.005	0	0.033	None	✓	None	✓	*
SL	0.003	0	0.027	None	✓	None	✓	*
Confirmed					13		13	
Part II. Comparing stable PC (PC to PC; N = 208) versus progressing two stages (PC to PR; N = 89)								
Temptations	0.025	0.001	0.065	None	✓	Small	✓	*
Pros	0.007	0	0.036	Small	✓	Small	✓	*
Cons	0	0	0.013	None	✓	None	✓	*
CR	0.015	0	0.050	Medium		Medium		Small
DR	0.013	0	0.047	Medium		Medium		Small
ER	0.003	0	0.028	Medium		Small	✓	*
SO	0.003	0	0.028	Small	✓	Small	✓	*
SR	0.035	0.006	0.080	Medium	✓	Medium	✓	*
CC	0.023	0.001	0.062	Small	✓	Medium	✓	Small
HR	0.003	0	0.027	Small	✓	Small	✓	None
RM	0.017	0	0.053	Small	✓	Medium		Small
SC	0.001	0	0.023	Small	✓	Small	✓	None
SL	0.028	0.003	0.070	Medium	✓	Medium	✓	Small
Confirmed					10		10	
Part III. Comparing stable PC (PC to PC; N = 208) versus progressing three or more stages (PC to A/M; N = 144)								
Temptations	0.008	0	0.036	Large		None	✓	*
Pros	0	0	0	Small		None	✓	*
Cons	0.003	0	0.026	Medium		None	✓	*
CR	0.103	0.054	0.160	None		Medium	✓	*
DR	0.050	0.016	0.096	None		Small	✓	*
ER	0.026	0.003	0.065	None	✓	Small	✓	*
SO	0.064	0.025	0.113	None		Medium	✓	*
SR	0.099	0.051	0.155	Small	✓	Medium	✓	*
CC	0.079	0.036	0.132	Small	✓	Medium	✓	*
HR	0.011	0	0.041	None	✓	Small	✓	*
RM	0.019	0.000	0.053	Small	✓	Small	✓	*
SC	0.066	0.027	0.117	Small	✓	Medium	✓	*
SL	0.125	0.072	0.185	Medium	✓	Medium	✓	*
Confirmed					7		13	

Consciousness raising (CR), dramatic relief (DR), environmental reevaluation (ER), social-liberation (SO), self-reevaluation (SR), counter conditioning (CC), helping relationships (HR), reinforcement management (RM), stimulus control (SC) and self-liberation (SL). $\omega^2 < 0$ were set to 0; effect size (ES): small ES 0.01; medium ES 0.059; large ES 0.139; ✓ indicates agreement with initial prediction. *No revisions made to ES diet-based prediction. Proposed revised predictions are based on results as well as cross-sectional data from a separate sample.

Table III. *Diet stage transition comparisons for C on 13 TTM constructs: Study 2*

Construct	Observed ES (ω^2)	95% CI, about ω^2		Predicted ES from smoking	Agreement with smoking predictions	Predicted ES from diet	Agreement with diet prediction	Revised prediction for diet
		Lower	Upper					
Part I. Comparing stable C (C to C; N = 38) versus progressing one stage (C to PR; N = 41)								
Temptations	0	0	0	None	✓	None	✓	*
Pros	0	0	0	None	✓	None	✓	*
Cons	0	0	0.053	None	✓	None	✓	*
CR	0.000	0	0.087	None	✓	Small	✓	*
DR	0	0	0	None	✓	None	✓	*
ER	0	0	0.057	None	✓	None	✓	*
SO	0.009	0	0.107	None	✓	Small	✓	*
SR	0.013	0	0.115	None	✓	Small	✓	*
CC	0.003	0	0.095	None	✓	Small	✓	*
HR	0	0	0	None	✓	None	✓	*
RM	0	0	0.067	None	✓	Small	✓	*
SC	0	0	0.045	Small	✓	Small	✓	None
SL	0	0	0.025	Small	✓	Small	✓	None
Confirmed					13		13	
Part II. Comparing stable C (C to C; N = 38) versus progressing two or more stages (C to PR; N = 51)								
Temptations	0.018	0	0.115	Large		Small	✓	*
Pros	0	0	0.056	Medium		Small	✓	*
Cons	0.008	0	0.096	Large		Small	✓	*
CR	0	0	0.066	None	✓	Small	✓	*
DR	0	0	0.047	None	✓	None	✓	*
ER	0.052	0	0.168	None	✓	Small	✓	*
SO	0	0	0.021	None	✓	Small	✓	None
SR	0.040	0	0.152	None	✓	Small	✓	*
CC	0.028	0	0.132	Small	✓	Small	✓	*
HR	0	0	0.026	None	✓	Small	✓	None
RM	0.004	0	0.089	Small	✓	Small	✓	*
SC	0.039	0	0.150	Small	✓	Medium	✓	*
SL	0.034	0	0.142	Small	✓	Medium	✓	*
Confirmed					10		13	
Part III. Comparing stable C (C to C; N = 38) versus regressing (C to PC; N = 46)								
Temptations	0	0	0.076	None	✓	None	✓	*
Pros	0.012	0	0.108	Small	✓	None	✓	Small
Cons	0	0	0	None	✓	None	✓	*
CR	0.001	0	0.085	Small	✓	Small	✓	*
DR	0	0	0	Small		Small		None
ER	0.007	0	0.099	None	✓	None	✓	Small
SO	0	0	0	None	✓	None	✓	*
SR	0	0	0.002	Small		Small		None
CC	0	0	0.069	None	✓	Small	✓	*
HR	0.008	0	0.100	None	✓	None	✓	Small
RM	0.029	0	0.139	None	✓	Small	✓	*
SC	0	0	0.036	None	✓	None	✓	*
SL	0	0	0	Small		None	✓	*
Confirmed					10		11	

Consciousness raising (CR), dramatic relief (DR), environmental reevaluation (ER), social-liberation (SO), self-reevaluation (SR), counter conditioning (CC), helping relationships (HR), reinforcement management (RM), stimulus control (SC) and self-liberation (SL). $\omega^2 < 0$ were set to 0; effect size (ES): small ES 0.01; medium ES 0.059; large ES 0.139. ✓ indicates agreement with initial prediction. * No revisions made to ES diet-based prediction.

Table IV. *Diet stage transition comparisons for PR on 13 TTM constructs: Study 3*

Construct	Observed ES (ω^2)	95% CI, about ω^2		Predicted ES from smoking	Agreement with smoking predictions	Predicted ES from diet	Agreement with diet prediction	Revised prediction for diet
		Lower	Upper					
Part I. Comparing stable PR (PR to PR; N = 119) versus progressing (PR to A/M; N = 138)								
Temptations	0.002	0	0.035	Large		Medium		Small
Pros	0	0	0.018	Large		None	✓	*
Cons	0.017	0	0.063	Large		Small	✓	*
CR	0.001	0	0.032	Small	✓	Small	✓	*
DR	0.006	0	0.043	Small	✓	None	✓	Small
ER	0.005	0	0.040	Small	✓	None	✓	*
SO	0	0	0.025	None	✓	None	✓	*
SR	0.026	0	0.078	Small	✓	None	✓	Small
CC	0.030	0.000	0.084	None	✓	None	✓	Small
HR	0	0	0.019	None	✓	None	✓	*
RM	0.001	0	0.031	None	✓	None	✓	*
SC	0.001	0	0.033	None	✓	Small	✓	*
SL	0.009	0	0.050	None	✓	Small	✓	*
Confirmed					10		11	
Part II. Comparing stable PR (PR to PR; N = 119) versus regressing one stage (PR to C; N = 69)								
Temptations	0	0	0.028	None	✓	None	✓	*
Pros	0	0	0.027	Small	✓	None	✓	*
Cons	0	0	0	None	✓	None	✓	*
CR	0	0	0.022	None	✓	Small	✓	*
DR	0	0	0.029	None	✓	None	✓	*
ER	0.011	0	0.063	None	✓	None	✓	Small
SO	0	0	0.023	None	✓	None	✓	*
SR	0	0	0.012	None	✓	Small	✓	None
CC	0	0	0	None	✓	Small		None
HR	0	0	0.026	None	✓	None	✓	*
RM	0	0	0.031	None	✓	Small	✓	*
SC	0	0	0.027	Small	✓	Small	✓	*
SL	0.002	0	0.046	Small	✓	Small	✓	*
Confirmed					13		12	
Part III. Comparing stable PR (PR to PR; N = 119) versus regressing two stages (PR to PC; N = 99)								
Temptations	0.03	0	0.093	None	✓	Small	✓	*
Pros	0.02	0	0.067	Small	✓	Small	✓	*
Cons	0.03	0	0.094	None	✓	None	✓	Small
CR	0.00	0	0.036	Medium		Small	✓	*
DR	0.00	0	0.013	Medium		Small	✓	None
ER	0.00	0	0	Small		None	✓	*
SO	0.00	0	0.022	None	✓	None	✓	*
SR	0.00	0	0.035	Large		Small	✓	*
CC	0.01	0	0.045	None	✓	Small	✓	*
HR	0.00	0	0.038	None	✓	None	✓	*
RM	0.04	0.001	0.100	Small	✓	Small	✓	*
SC	0.01	0	0.055	Small	✓	None	✓	Small
SL	0.00	0	0.043	Large		Small	✓	*
Confirmed					8		13	

Consciousness raising (CR), dramatic relief (DR), environmental reevaluation (ER), social-liberation (SO), self-reevaluation (SR), counter conditioning (CC), helping relationships (HR), reinforcement management (RM), stimulus control (SC) and self-liberation (SL). $\omega^2 < 0$ were set to 0; effect size (ES): small ES 0.01; medium ES 0.059; large ES 0.139. ✓ indicates agreement with initial prediction. * No revisions made to ES diet-based prediction.

stable and progress to A/M (7 out of 13 confirmed). The greatest number in agreement was found in the comparison between the stable and progress to C (13 confirmed). Based on the diet predictions, the fewest in agreement was in the comparison between stable and progress to PR (10 confirmed).

Study 2: Contemplation

Table III summarizes the comparisons between those who remained in C and those who moved. Of the 39 smoking-based predictions, 33 (85%) were in agreement. Of the 39 diet-based predictions, 37 (95%) were in agreement. The comparison between the stable group and those who progressed to PR had the most predictions corroborated for both the smoking-based (13) and diet-based predictions (13). The stable versus regression comparison had the fewest number in agreement for the smoking-based (10) and the diet-based predictions (11).

Study 3: Preparation

Table IV summarizes the diet stage transition comparisons for PR. Effect sizes were minimal for all comparisons made ranging from no effect to a small effect, 0–0.03. Of the 39 smoking-based predictions, 31 (79%) were in agreement while 36 (92%) out of the 39 diet-based predictions were in agreement. For the smoking-based predictions, the comparison between the stable group and those who regressed to C had the most predictions corroborated (13), while the comparison between the stable and regress to PC had the fewest (8). However, for the diet-based predictions, the later comparison had the most predictions confirmed (13). The fewest number in agreement for diet was the stable versus progress to A/M (11).

Discussion

The present study provides evidence of the predictive power and generalizability of the TTM. The results suggest that predictions can be made with a moderate to high degree of accuracy on whether the use of the TTM constructs predicts stage transitions in dietary fat intake. Not surprisingly, the diet-based predictions were more accurate than those based on smoking data. Of the diet-based predictions, 92–95% were corroborated when CI about ω^2 was used to evaluate the results. These results are promising considering that this is the first study to test *a priori* effect size predictions for dietary fat.

The results of this study are consisted with previous studies that made *a priori* predictions based on the TTM applied to smoking cessation. Velicer *et al.* [35] confirmed 36 of 40 *a priori* predictions, a rate of 90%, and Johnson *et al.* [36] confirmed 11 of 11 predictions. Overall, the effect sizes predicted for dietary fat were of a lesser magnitude than what has been reported for smoking [35]. Of the 117 diet-based predictions, 28 were modified for the next round of testing with 18 of them being decreased a magnitude (e.g. medium to small) for the next round of testing.

While this study added to the evidence of the predictive power of the TTM, multiple prediction studies are needed before firmer conclusions can be made. For this purpose, new effect size predictions were set for future studies (see the last column of Tables II–IV). It is important that these predictions be tested on representative samples and evaluated for fit, modified and retested until the effect sizes can be predicted with a greater degree of accuracy than in the present study. Degree of accuracy can also be defined by how well predictions are informing behavior change interventions or how much impact the interventions are having. For example, making 92% of the predictions may not be 100%, but it could have considerable impact on behavior change. A standard of accuracy does not exist yet because so few studies have evaluated the predictive power of health behavior change theories.

The evidence that the TTM is generalizable is building, yet few studies have investigated how the TTM varies among problem behaviors [19]. The patterns of the constructs across the stages of change are well established for smoking. These patterns have been used to determine how well the TTM generalizes to other applications other than smoking and have provided a basis for validating newly developed measures. Measures that create

patterns that deviate from the expected are considered poorly developed or may be considered a variant related to the behavior examined. For example, in smoking, the processes of change are known to follow a curvilinear course across the stages of change [22]. However, this pattern has not been replicated in dietary fat reduction [25, 26]. The differences might be related to smoking being a cessation behavior that involves stopping a behavior, whereas reducing dietary fat involves both acquisition and cessation behaviors, that is, starting healthful eating practices and stopping unhealthful ones. In this study, the patterns expected in smoking were applied to dietary fat reduction to better understand whether the theory functions differently in diet than it does in smoking cessation.

The study found that there is a moderate degree of generalizability from smoking to diet. Smoking-based predictions produced confirmation rates of 77–85%. Although the percent confirmed is not much lower than the diet-based predictions (92–95%), the results suggest that use of constructs varies across behavior and stage. Differences between smoking and diet were found more for the pros, cons and temptation than for the processes of change.

The pros and cons appear to be affecting transitions differently in diet than in smoking. Pros are expected to influence early stage progression in smoking but this might not transfer to diet. The pros had less of an effect than expected on the transition from PC to C. They also seem to be less influential in diet for progression out of PC, C and PR and regression from PR. But, the pros may be as important in diet as they are in smoking for progression from PC to PR and regression from PR to PC. The cons may also be less influential on progression in diet. This pattern was seen in progression from PC to C, PC to A/M, C to A/M and PR to A/M. Additionally, the cons may have more of an influence on regression from PR to PC in diet than in smoking.

There appear to be differences between diet and smoking in the construct of temptation. This study suggests that temptation influences transitions in diet more than in smoking. The most striking differences were the greater influence of temptations on progress out of PC and on regression from PR in diet compared with smoking.

Less is known about how much of an effect is expected for the processes of change compared with other TTM constructs. Only one study from smoking has tested predictions for the entire set of processes of change [36], and it was on a cross-sectional sample that did not include predictions for stage transitions. The lack of previous data made it difficult to compare how well the patterns seen in smoking generalize to diet. Although the effect size predictions for the processes of change faired better than the other constructs, there were some unexpected results. For the PC comparisons, it was expected that the constructs of CR, DR and all of the behavioral processes of change would have more of an effect than they did on the transition from PC to PR. These disagreements were approximately one magnitude less than predicted, for example, small versus medium, which may be a result of extrapolating predictions from cross-sectional data to longitudinal data. Another interesting finding was found in the C comparisons. The constructs of ER and HR had more of an influence on the regression transition than expected. ER also had a greater effect than predicted on the regression from PR to C. This suggests that other people are influencing relapse in C. ER increased and HR decreased, suggesting that those who relapsed realize the impact they are having on others yet may not be getting the support they need from others. For the PR comparisons, a few processes had a greater effect than expected. CC, SR and DR were effecting progress from PR to A/M and SC affected regression from PR to PC.

There are some limitations to this study which include small sample size, the confounding of intervention effects and measurement error. The sample size of each of the three studies may not be large enough to make conclusions about minimal to small effect sizes. Cohen proposes that extremely large sample sizes are needed to draw firm conclusions about the absence of an effect [53]. Smaller sample sizes also make the CI larger, which could lead to falsely confirming a prediction. Testing the predictive power of the TTM requires a large sample size,

especially when constructs are emphasized in some stages but not in others. Large-scale studies that include theory testing in their primary aims may be required before breakthroughs can be made in health behavior change.

A possible confounder was the inclusion of the intervention group only. The intervention group received treatment that may have emphasized certain constructs and not others, consequently influencing survey answers toward those constructs. For example, if a person was low on the pros at baseline, the intervention could have influenced the pros more than if he or she were in the control group. Inclusion of a naturalistic study or one that includes a control group would have strengthened this study.

As with many studies, measurement error was a potential limitation. Although the measures were developed using sequential methods, a shorter form of the processes of change for dietary fat intake was used in the original study to reduce response burden. The short-form version contained two items per process, which may not be as reliable as the previously developed scales that include three items per process of change.

The primary strength of this study is that it tests the TTM using methods that are congruent and consistent with the theory. An effort was made to respect how the TTM is conceptualized, for example, making sure that all TTM constructs were included and reflecting the proposition that construct use varies by stage of change.

Another strength is that making *a priori* predictions allows the theory to be examined more critically. This is a risky test of a theory, yet it generates more questions and directs us toward the next study. In this study, new predictions have been generated for the next study already. Systematically testing the theory may add to the accumulation of knowledge, or the nomological net, in a more efficient way than inductive or unguided research. The present study provides information on what is known about the TTM so far, what improvements could be made and how it might be best tested and implemented. The findings may minimize the gaps in the research about the predictive power of the TTM. More importantly, assessing predictive power provides data that can be used to help researchers choose among the competing theories of behavior change. This study provides effect size and CI data, which are ideal for comparison and meta-analytical studies. Moreover, the results of this research may provide an incentive for future testing and modification of the TTM applied to dietary fat intake.

One of the most notable contributions to the literature is that it is the first study to propose expected effect sizes for 13 TTM constructs (pros, cons, temptation and 10 processes of change) applied to dietary fat intake. Evaluating the predictive power of the TTM has provided estimates of effect size that can be used for future prediction studies and for comparisons across studies. Knowing how much effect each construct is having at each stage adds data that can help refine the TTM. Cohen [53] proposed that effect sizes along with CIs are more informative for psychology theories than ordinal information. The information provided in this study allows researchers to make informed decisions that are based on more than a p value.

A better understanding of the how well the TTM generalizes across behaviors is an important contribution to theory development and to intervention research on multiple behaviors. A broad scope is a necessary quality when designing interventions that target multiple behaviors.

This study also contributes to the advancement of the theory and science of health behavior change. Few behavior change scientists evaluate theories given that it requires a considerable amount of time and resources, for example, large sample sizes. Yet, there is a need for more theories to be evaluated. Researchers, practitioners and policy makers are beginning to consider evidence-based evaluations when selecting a theory of behavior change for research and practice. The present study not only provides evidence for a theory but also encourages the critical and empirical evaluation of theories and stimulates new questions about theory, the TTM, and the health behavior of dietary fat intake.

Conflict of interest statement

None declared.

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