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Creating Parsimony at the Expense of Precision?

Conceptual and Applied Issues of Aggregating Belief-Based Constructs
in Physical Activity Research.

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Running Head: BELIEF-BASED CONSTRUCTS AND PHYSICAL ACTIVITY

Creating Parsimony at the Expense of Precision?

Conceptual and Applied Issues of Aggregating Belief-Based Constructs
in Physical Activity Research.

Abstract

The aggregation of measured social cognitive beliefs to form scales is a common procedure in physical activity research. In this paper, we propose that specific beliefs may actually have unique associations with physical activity, which are obscured by the practice of aggregation. Further, we point out that beliefs may be related in a more complex manner than the theory behind scale aggregation. Both of these factors are interpreted in terms of limiting physical activity intervention efforts. Therefore, the purpose of this study was to examine alternatives to summative scales of physical activity beliefs using structural equation modeling. Demonstrations were performed using belief-based constructs of self-efficacy, pros, and cons with a large Canadian random sample (N=683) over three, six-month time points. Results demonstrated that items of belief-based scales are multidimensional and that a correlated belief structure fit the observed data better ($p < .05$) and explained more variance in vigorous physical activity (an additional 6-7%) than aggregated scales. Finally, a causally ordered structure among beliefs was supported, suggesting that items within a scale may be linked causally rather than as indicators of a higher-order latent variable. Implications for future research and physical activity interventions were discussed.

Belief-based social cognitive theories are popular frameworks for understanding health behavior. Examples of these theories include social cognitive theory (Bandura, 1998), the theory of reasoned action (Ajzen & Fishbein, 1980) and planned behavior (Ajzen, 2002), the transtheoretical model of behavior change (Prochaska & Velicer, 1997), the health belief model (Rosenstock, 1974), and protection motivation theory (Rogers, 1984). A health behavior domain that has used these theories extensively for both research and practice is physical activity, given the well-documented benefits, but less than optimal participation rates (U.S. Department of Health and Human Services, 1996). However; recent calls for even more theoretical work related to exercise and physical activity have been made (Baranowski, Anderson & Carmack, 1998; Sallis, 2001).

This attention stems from three critical factors identified in reviews of theory and intervention research. First, current social cognitive theoretical frameworks used to predict or explain physical activity generally explain only 30% of physical activity behavior (e.g., Baranowski et al., 1998; Lewis, Marcus, Pate, & Dunn, 2002). Thus a search for more predictors to explain physical activity behavior continues. Second, most of our best-constructed intervention campaigns demonstrate that these current social cognitive mediators of physical activity actually fail to fully mediate intervention attempts (see Baranowski et al., 1998; Lewis et al., 2002 for a detailed review). For example, McAuley, Courneya, Rudolph and Lox (1994), in one of the first self-efficacy guided intervention campaigns for physical activity, found that self-efficacy failed to fully mediate the effect of the intervention on physical activity. Finally, reviews of our physical activity intervention literature (e.g., Dishman & Buckworth, 1996; Baranowski et al., 1998; Lewis et al., 2002) suggest only modest actual behavior change success and minimal changes in long-term physical activity. Therefore the need to continue improving theory-based physical activity interventions is warranted.

A host of factors will undoubtedly contribute to improvement of the theory and practice of physical activity intervention. In this paper we explore alternative conceptualizations of belief-based

social cognitive constructs on theoretical, applied, and statistical grounds and question the common procedure of aggregating potentially disparate beliefs about physical activity into a summative scale.

The theoretical foundation for belief aggregation is based on the argument that beliefs are facets of higher order constructs (e.g., Bandura, 1998). This theorizing suggests that any relationship or coordination between beliefs comes from a common higher-order cause (see Figure 1a). Known as reflective scaling (Blalock, 1964), this type of theorizing allows for item aggregation because items are assumed to be affected by the same underlying latent concept. The assumption is used for single order (i.e., unidimensional) measurement practice (i.e. classic test score theory) and second order scales in personality and intelligence research, whereby constructs are conceived as temporally stable (e.g., Costa & McCrae, 1995). This higher order structure, however, may not accurately reflect the causal world of social cognitive constructs we assume are changeable (see also Rhodes & Courneya, 2003). The key flaw in this assumption is the temporal chain of causality. For example, the temporal sequence of a higher-order model suggests that interventions would need to target the higher-order construct, which would then cause changes in the specific beliefs.

Since different interventions for beliefs are very easy to envision (e.g., confidence to overcome different barriers, different benefits or hazards of a behavior), it seems more conceivable that changes in beliefs would precede changes in the higher-order construct (see Figure 1b; Rhodes & Courneya, 2003). This type of model is known as a formative scale (Blalock, 1964), whereby multidimensional constructs form a cause or creation of some latent variable. The confusion of formative scales for reflective scales is common in social sciences (Blalock, 1964; Cohen, Cohen, Teresi, Marchi, & Velez, 1990). Further, though the theory behind formative scales is conceivable for social cognitive beliefs, the likelihood of this conception being the most accurate representation of causal structure may diminish with large groups of beliefs (see Sutton, 2002).

A formative scale presumes that what the beliefs have in common is important and that specific characteristics of the measured beliefs are unimportant. Specific beliefs, however, may actually have

unique associations with physical activity, which are obscured by the practice of aggregation. First, since theoreticians are currently focused on explaining as much of the variance in physical activity as possible, an aggregated formative scale of beliefs may not explain as much variance as a correlated belief structure with independent influences on physical activity behavior (see Figure 1c). Second, if this correlated belief structure explains more variance in physical activity, it may also act as a better mediator (i.e., casting a finer net) when examining relations between interventions and physical activity. Finally, examination of the beliefs individually should allow for a better understanding of which beliefs are particularly influential for physical activity prediction/explanation. In turn, this may help applied researchers focus on key targets for belief change rather than trying to change an aggregate construct.

The principle reason for assuming a reflective model over a formative model in previous social cognitive theorizing is probably because clusters of beliefs (e.g., costs, benefits, barriers) are generally inter-related. Thus traditional assumption is that beliefs must “reflect” the common cause of a higher order variable. Still, relationships between beliefs could also “reflect” common causes from other unmodeled first order variables (Figure 1b and 1c). For example, confidence to overcome fatigue and confidence to overcome time demands are often modeled as items of an overall self-efficacy construct, but their relationship may alternatively be explained by identical physical activity experiences as a common cause. Thus individuals who are tired may also be pressed for time and their appraisal of physical activity is under the same experience. However, if these individuals were in a situation of fatigue and plenty of free time (or vice versa), the responses may differ dramatically, thus suggestive of separate efficacy constructs.

Another alternative to the higher-order reflective model suggests beliefs could be linked causally if hypothesized to exist at an ordered level of abstraction (Figure 1d). Sutton (2002) has made this point about social cognitive belief structure and Hayduk (1996) outlines this potential causal sequence as a limitation of standard factor analysis procedures. For example, assessment of the health

benefits and the psychological benefits of physical activity are often aggregated as items of a higher-order pros, behavioral beliefs, or outcome expectation scale. A more accurate reflection of the relationship between these beliefs may be causal. Thus, evaluation of the psychological benefits of physical activity may be a critical influence on ones evaluation of the (overall) health benefits of physical activity, which in turn is an influence on physical activity.

Despite this theorizing against summative scales of beliefs, current analytical practices have supported an aggregated scale approach. These practices do not accurately test alternative models. Specifically, standard statistical tests such as factor analysis and internal consistency assessment are based on the assumption of a reflective scale, but do not make sense for a formative scale (Blalock, 1964; Cohen et al., 1990). First, though measures created from summing beliefs often show high internal consistency, this may not reflect unidimensionality. A measure of internal consistency among items is based on the assumption of unidimensionality, though it does not test this assumption (Cortina, 1993; Crocker & Algina, 1986). Internal consistency assumes that the communality of variance (i.e., intercorrelation) between items is an indication of a latent true score variance in a reflective scale. However, if items are multidimensional, but correlated due to causes not conceived as a reflective higher order structure, the estimate will be inaccurate. Ajzen (2002) has made this point regarding internal consistency of beliefs in the theory of planned behavior.

Second, standard factor analysis procedures for assessing multidimensionality of beliefs in these scales may also be inappropriate. Exploratory factor analysis techniques to detect multidimensionality are limited by the number of items (e.g., usually a minimum of 3) required to determine a factor (see Hayduk, 1996 and Russell, 2002 for a review). Therefore, factor analysis is not sensitive enough to distinguish multiple factors with a series of distinct single-item beliefs. For example, if 2 beliefs represent 2 correlated factors, factor analysis will only identify a single factor because the items only share this communality of variance. Further, factor analysis assumes a reflective scale model and does not test for any alternative model for inter-item relation. Thus, causal

ordering of items (Figure 1d) or unmodeled single order common causes (e.g., Figure 1b and 1c) can not be examined. If researchers conceive their belief-based scale as more formative than reflective, factor analysis may not be appropriate.

Therefore, the purpose of this study is to examine alternatives to summative scales of physical activity beliefs. First, belief-based scales were examined at the item level for unidimensionality, as this is the base assumption for scale aggregation (Cronbach & Meehl, 1955; Thurstone, 1931). Second, constructs were then tested to predict vigorous physical activity as multidimensional independent predictors or as a formative scale. Third, as a demonstration of the alternative causal ordering conceptualization (Figure 1d), we tested the mediation effect of specific items between physical activity behavior and other items theorized at a more specific (face value) level of abstraction. All demonstrations were performed with a large Canadian random sample over three, six-month time points. Finally, for this demonstration, we used the belief-based constructs of self-efficacy, pros, and cons. Bandura's (1998) construct of self-efficacy is arguably the most important predictor of physical activity (see Culos-Reed, Gyurcsik & Brawley, 2001), and pros and cons of physical activity are similarly measured in all belief-based social-cognitive theories. Further, these constructs have been utilized for several physical activity intervention studies (Baranowski et al., 1998). Thus self-efficacy, pros, and cons serve as excellent examples for testing this measurement query.

Method

Participants and Procedures

Participants were a representative sample of 1602 adults between the ages of 18-65 years from the Ottawa-Carleton region of Ontario, Canada. A computer-assisted telephone interviewer system was used, which randomly generated resident telephone numbers from the region's telephone exchange. One adult from each household was randomly selected based on the nearest birthday. This data set has been utilized for a previous analysis of exercise stage transition and a detailed description of participants and procedures can be found in Plotnikoff, Hotz, Birkett and Courneya (2001a). In brief,

the telephone randomization protocol produced 4, 122 eligible households with 2520 refusals resulting in 1602 time 1 (March 1997) participants. The 1602 participants were contacted again by telephone at time 2 (September 1997) and through a mail-based survey at time 3 (March 1998). The attrition at times 2 and 3 resulted in 683 individuals (43.9% of the original sample) completing all three survey periods.

Demographics for the sample ($N = 683$) was as follows: mean age was 40.6 years ($SD = 11.04$), 54% were female, 63% were married/common law, 60% were working full-time, 11% were working part-time, 8 % were retired, 4% were students, and 44% of the sample had completed university. In terms of health behavior indicators, 21% of the sample were smokers and 14% were regular drinkers of alcohol (>3 times per week over the past year), and 21% were moderately regular drinkers of alcohol (2 to 3 times per week over the past year). This sample of 683 participants was utilized to create the variance/covariance matrices for the analyses (list-wise deletion).

Instruments

All questions were related to regular vigorous physical activity, which was defined for participants as “strenuous activities which usually make you sweat, breathe harder, and feel your heart beat.” Examples of vigorous physical activities were provided and the term “regular” was defined as “at least three times per week for at least 20 minutes each time.” Participants were instructed to answer all questions based on this definition of regular vigorous physical activity.

Self-efficacy. Interviews were conducted with a cross section of the community to confirm, add, and reword Marcus and colleagues' (1992) existing self-efficacy measure for a Canadian population. From these responses, a telephone interview questionnaire (using random digit dialing) was developed and pretested with 135 participants to establish item comprehension. Self-efficacy was assessed with five point rating scales, ranging from 1 (not at all confident) to 5 (extremely confident). The items assessed perceived confidence for doing regular vigorous physical activity when one: is tired, in a bad mood, has to do it by one's self, finds it boring, can't notice any improvements in fitness, has other

demands on one's time, feels stiff or sore, and perceives the weather to be poor. Internal consistency was high (time 1 $\alpha = .87$, time 2 $\alpha = .89$) and principle components factor analysis using oblique rotation identified a single factor for time 1 (eigenvalue = 4.27, 53% of variance explained) and time 2 (eigenvalue = 4.54, 57% of variance explained).

Pros and cons. Pros and cons of physical activity were based on the transtheoretical model. The existing scales comprise of ten pro and six con items (Marcus et al., 1992). To ensure measurement relevance to the Canadian population, cross-section pilot analyses were conducted for confirmation, addition, and rewording. From these responses, a telephone interview questionnaire was pretested with a range of professional and nonprofessional groups to establish comprehension (further details can be found in Plotnikoff, Blanchard, Hotz, & Rhodes, 2001b). Items used to measure pros were: 1) physical activity would help me reduce tension or stress; 2) I would feel more confident about my health by getting physical activity; 3) Getting physical activity would help me sleep better; 4) Physical activity would help me have a more positive outlook; and 5) Physical activity would help me control my weight. Items used to measure cons were: 1) I am too tired to get physical activity because of my other daily responsibilities; 2) physical activity would take too much of my time; 3) I would have less time for my family and friends if I participated in physical activity; 4) I'd worry about looking awkward if others saw me being physically active; and 5) Getting more physical activity would cost too much money. All items were scaled using 5-point likert type scales from 1 (not at all) to 5 (very much). Internal consistency for the scales was adequate (pros time 1 $\alpha = .77$, time 2 $\alpha = .83$; cons time 1 $\alpha = .69$, time 2 $\alpha = .69$) and principle components factor analysis using oblique rotation identified single factors for time 1 (pros eigenvalue = 2.68, 54% of variance explained; cons eigenvalue = 2.26, 45% of variance explained) and time 2 (pros eigenvalue = 3.09, 62% of variance explained; cons eigenvalue = 2.22, 44% of variance explained).

Vigorous physical activity. Physical activity was measured by indicators of weekly vigorous physical activity frequency and energy expenditure. A measure of vigorous physical activity frequency "tristage" was calculated based on a stages of exercise change strategy developed by Reed, Velicer, Prochaska, Rossi & Marcus (1997). Those in precontemplation (not currently exercising and not intending to start in the next 6 months) and contemplation (not currently exercising, but intending to start in the next 6 months) were coded as 1; those in preparation (exercising, but not regularly) were coded as 2; and those in action (currently exercising for less than 6 months) and maintenance (currently exercising for more than 6 months) were coded as 3. Details of the energy expenditure calculation are reported elsewhere (Plotnikoff, Hugo & Cousineau, 2001c). Activity level was calculated as energy expenditure (kilocalories/kilogram/day) from the frequency, duration, and intensity of 20 pre-listed and other self-reported activities within the past month. The energy expenditure assessment was based on the instrument employed in the 1990 Ontario Health Survey, which has been validated with the Minnesota Leisure Time Physical Activity Questionnaire (Alison, 1996).

Model Specification and Analysis Procedures

Research questions were investigated using structural equation modeling. Models were estimated with maximum likelihood procedures and assessed using LISREL 8.20 for Windows (Jöreskog & Sörbom, 1997). For specification of the structural concepts, the loading for each concept's first indicator was pre-set to 1.0 in the structural equation model to create a scale.

The first stage tested the unidimensionality of the items within each scale (self-efficacy, pros, cons). This procedure utilized the recommended procedure for testing unidimensionality by Andersen and Gerbing (1988). However, given that each item was tested for unidimensionality with the other scale items, fixed error variance estimates based on the suggested modeling procedures of Hayduk (1996) were deemed necessary. A priori fixed error estimates on single indicators still allow for the researcher to exert meaning upon the latent concept and place theoretical constraint within the model

(Hayduk, 1996). These fixed error variance estimates were based on the suggested procedures of Schumacker and Lomax (1996) and used an averaged error for each scale item of $1-\alpha$. Specifically, as α represents the proportion of true score variance in a scale (Cronbach & Meehl, 1955), then $1 - \alpha$ represents the proportion of error variance in the scale.

The second stage of the analysis was conducted to examine whether items of self-efficacy, pros, and cons influence vigorous physical activity best as a formative scale or as individual beliefs. This analysis procedure replicates a similar research question for the theory of planned behavior (see Rhodes & Courneya, 2003). A formative scale was modeled. This χ^2 was then tested against a model whereby effects were freed of all respective unidimensional beliefs on vigorous physical activity. This procedure is degree of freedom and statistically equivalent to using LISREL's equality constraints for nested models. The creation of the formative scale was achieved by using a phantom variable. The loading for the structural disturbance term for this general factor (phantom variable) was pre-set to 0 in the structural equation models to identify that all variance of this concept is a direct result of commonality between its respective self-efficacy, pro, or con beliefs respectively. Effects of beliefs upon their respective general factor were fixed at 1.0, as this is the assumption when creating a scale.

The demonstration of potential causal structure among beliefs was conducted using pros and cons items selected at different a priori face value theorized levels of abstraction. Specifically, pros items "physical activity would help me reduce tension or stress", "Getting physical activity would help me sleep better", and "Physical activity would help me have a more positive outlook" were deemed as potentially at a more specific level of abstraction than the item "I would feel more confident about my health by getting physical activity". Therefore, this latter item was modeled as a mediator between the former three items and vigorous physical activity. Similarly, the con item "I would have less time for my family and friends if I participated in physical activity" was considered at a more specific level of

abstraction than the item “physical activity would take too much of my time”. This latter item was subsequently modeled as a mediator between the former item and vigorous physical activity.

Assessment of Model Fit

A number of statistics exist to assess the adequacy of structural models. The most useful statistic for testing nested and alternative models is the chi-square statistic (χ^2). The χ^2 goodness-of-fit test assesses the adequacy of the theorized model’s creation of a covariance matrix and estimated coefficients in comparison to the observed covariance matrix. For comparison of nested and alternative models, the χ^2 difference value versus degrees of freedom provides a statistical test for which model fits the observed data better. Inclusion of absolute and incremental fit indices are also recommended (Hu & Bentler, 1999). Absolute fit indices assess how well an a priori model reproduces the sample data, while incremental fit indices measure the proportionate improvement in fit by comparing a target model with a more restricted baseline model. Root mean square error of approximation (RMSEA) was included as an absolute fit index and the comparative fit index (CFI) was included as an index of incremental fit. General rules of thumb for acceptability of model fit using these indexes are $>.94$ for the CFI and $<.07$ for RMSEA (Hu & Bentler, 1999).

Results

Descriptives and correlations for time 1 and 2 self-efficacy, pros, and cons measures have been previously reported in Plotnikoff et al. (2001a). Tests of unidimensionality for the items of self-efficacy, pros, and cons are found in tables 1 to 3 respectively. Results identified all items were multidimensional for time 1 ($p < .05$) and only two self-efficacy items were unidimensional ($p > .05$) at time 2. Specifically, confidence to participate in physical activity “when I am a little tired” and “when I am in a bad mood or feeling depressed” were identified to tap the same latent concept.

Results of the comparison analysis between the formative scale model and the specific belief model for predicting vigorous physical activity are presented for time 1 (beliefs) to time 2 (behavior)

and time 2 (beliefs) to time 3 (behavior) in Table 4. For time 1 belief prediction of time 2 vigorous physical activity, the specificity model for separate effects of beliefs on vigorous physical activity fit the data significantly better than the formative scale model for self-efficacy [$\chi^2(7)$ difference = 18.94, $p < .01$], pros [$\chi^2(4)$ difference = 14.30, $p < .01$], and cons [$\chi^2(4)$ difference = 9.63, $p < .01$]. Further, explained variance of vigorous physical activity was six percent higher for self-efficacy (total = 34%) and pros (total = 9%), and seven percent higher for cons (total = 19%) using the specific belief modeling procedure over the formative scale model. Specific effects for the beliefs on vigorous physical activity are presented in Table 5. In the self-efficacy model, confidence to overcome fatigue, doing it alone, and doing it despite other time demands were significant ($p < .01$) influences on vigorous physical activity. In the pros model, only confidence that physical activity would improve health had a significant ($p < .01$) effect on vigorous physical activity, while the other pro beliefs did not. Finally, the cons model identified that the significant ($p < .01$) beliefs predicting vigorous physical activity were taking too much time and costing too much money. Factor loadings for the latent vigorous physical activity variable were estimated from .69-.73 for the tri-stage indicator and .48-.52 for the energy expenditure indicator.

The analysis for predicting vigorous physical activity at time 3 from beliefs obtained at time 2 yielded slightly different results from the previous analysis. As confidence to participate in physical activity “when I am a little tired” and “when I am in a bad mood or feeling depressed” were identified to tap the same latent concept at time 2 (see Table 1), these items were modeled as indicators of a general “confidence to overcome negative affect” construct. Still, the specificity model for separate effects of beliefs (time 2) on vigorous physical activity (time 3) fit the data significantly better than the formative scale model for self-efficacy [$\chi^2(6)$ difference = 24.38, $p < .01$], and cons [$\chi^2(4)$ difference = 23.26, $p < .01$], but not pros [$\chi^2(4)$ difference = 4.78, $p > .05$]. Explained variance of vigorous physical activity was six percent higher for self-efficacy (total = 41%) seven percent higher for cons (total =

26%), and only one percent higher for pros (total = 10%) using the specific belief modeling procedure over the formative scale model. In the self-efficacy model, confidence to overcome negative affect (factor loading for fatigue = .86 and bad mood = .78), doing it alone, doing it despite other time demands, and doing it despite bad weather were significant ($p < .01$) influences on vigorous physical activity. The cons model identified that beliefs about physical activity taking too much time, being too tired to do it, and costing too much money were significant ($p < .01$) influences on physical activity behavior, while taking time from family and friends, and looking awkward were not. Finally, in the pros model, the general pros scale had a significant ($p < .01$) effect of .30 on vigorous physical activity. Factor loadings for the latent vigorous physical activity variable ranged from .69-.74 for the tri-stage indicator and .58-.63 for the energy expenditure indicator.

Results of the mediator analyses suggested that causal ordering among beliefs may be an acceptable alternative hypothesis in the pros and cons scales. Specifically, effects of the pros items “manage stress”, “sleep better”, and “have a positive outlook” on vigorous physical activity were mediated by the item “confidence about health” for time 1 prediction of time 2 vigorous physical activity [$\chi^2(6, N=683) = 8.89, p = .18; RMSEA = .03; CFI = 1.00$] and for time 2 prediction of time 3 vigorous physical activity [$\chi^2(6, N=683) = 3.36, p = .76; RMSEA = .00; CFI = 1.00$] (see figure 2a). Modification indices and standardized residuals suggested no changes to the models, supporting the mediation hypothesis.

Similarly, the effect of the con item “less time for my family and friends” on vigorous physical activity was mediated by the item “less time”, for time 1 prediction of time 2 vigorous physical activity [$\chi^2(2, N=683) = 3.17, p = .20; RMSEA = .03; CFI = 1.00$] and for time 2 prediction of time 3 vigorous physical activity [$\chi^2(2, N=683) = 2.07, p = .35; RMSEA = .01; CFI = 1.00$] (see Figure 2b). Like the pros analysis, modification indices and standardized residuals suggested no changes to the models, supporting the mediation hypothesis.

Discussion

In this paper, we argued that the current theory for aggregating beliefs, the higher-order reflective model (see Figure 1a), has improper temporal sequencing and that a formative scaling model makes better conceptual sense (Figure 1b). However, we further argue that specific beliefs may actually have unique associations with physical activity, which are obscured by the practice of aggregation. Finally, we point out that beliefs may be causally linked and that standard analysis procedures are inadequate to examine this possibility or formative scaling models. Therefore, the purpose of this study was to examine alternatives to summative scales of physical activity beliefs. Demonstrations were performed using belief-based constructs of self-efficacy, pros, and cons with a large Canadian random sample for prediction of physical activity across two 6-month time periods.

First, belief-based scales were examined at the item level for unidimensionality, as this is the base assumption for scale aggregation (Cronbach & Meehl, 1955; Thurstone, 1931). Second, constructs were then tested to predict vigorous physical activity as multidimensional independent predictors or as a formative scale. Third, as a demonstration of the alternative causal ordering conceptualization (Figure 1d), we tested the mediation effect of specific items between vigorous physical activity and other items theorized at a more specific (face value) level of abstraction.

We believe our findings provide enough evidence to call into question the current conceptualization and practice of aggregating typical belief-based social cognitive constructs. First, the required assumption of unidimensionality when aggregating items to form a scale was not supported. Despite all scales reporting adequate internal consistency and unidimensionality in exploratory factor analysis, our structural equation modeling test found all beliefs across time 1 and time 2 were multidimensional with the exception of two self-efficacy items at time 2. This demonstrates the inadequacy of factor analysis to detect unidimensionality in single-item indicators of constructs (see Russell, 2002) and that Cronbach's α is not a direct test of unidimensionality.

Second, a formative scale (Figure 1b) does not seem to represent belief structure as well as a correlated cluster of independent beliefs, each with influences on vigorous physical activity (Figure 1c). Five out of the six models found modeling the beliefs as independent influences on behavior was superior to modeling the beliefs as part of a general factor ($p < .05$). Further, the additional explained variance of vigorous physical activity using this approach ranged from 6-7%. Cohen (1988, 1992) would consider this addition a medium effect size. Further, many social cognitive theorists have interpreted the benefit of additional constructs to social cognitive frameworks on the basis of much lower added explained variance in behavior (e.g., Conner & Armitage, 1998; Rhodes, Jones, & Courneya, 2002).

Finally, alternative modeling of pros and cons items as causes of each other and mediators between some beliefs and vigorous physical activity was found an acceptable model fit. This demonstration highlights that a far more complex structure among beliefs may exist in our standard scales than what warrants simple aggregation. In our demonstration, more specific (theorized) beliefs were hypothesized as the potential cause of more global (theorized) beliefs. We see the “mapping” of belief structure as an important future enterprise for researchers.

The practical implications of this study are likely more important than the above noted theoretical implications. First, the added explained variance of correlated beliefs over a summative scale suggests that aggregation may sacrifice precision. This practice of summing multidimensional constructs has been similarly criticized in the self-esteem/self-concept literature as missing the essence of multidimensionality (Marsh, 1997; Wylie, 1989) and appears similar to belief-based social cognitive constructs. An alternative conception for postulated higher-order constructs (e.g., outcome expectations, pros, cons, self-efficacy, etc.) is that they reflect categorizations of beliefs, but not constructs. This is similar rationale to how ethnicity, gender, and age relate to the category of demographics. Thus, researchers may feel a need to create a summative index (i.e., a formative scale), but the overall meaningfulness of just what this index represents might be questionable. Further, the

reduction of precision will likely affect our understanding of just how well beliefs predict physical activity and our ability to mediate intervention-behavior relations. As these factors are a current focus in physical activity research (e.g., Baranowski et al., 1998; Lewis et al., 2002), creation of a summative index may not be optimal.

Second, the correlated belief model identifies specific beliefs as more predictive of vigorous physical activity than others. Given only modest improvements from past intervention efforts (Baranowski et al., 1998; Sallis, 2001), this approach may help identify specific intervention targets rather than just trying to change a general aggregate construct. Self-efficacy beliefs at time 1 predicting vigorous physical activity at time 2 demonstrated that confidence to overcome fatigue, exercising alone, and other demands were key ($p < .01$) predictors, while confidence to overcome a bad mood, boredom, no improvement, muscle soreness, and bad weather were not. Rather than targeting interventions on all efficacy beliefs as suggestive of an aggregate scale, the results suggest that interventions targeting confidence to overcome fatigue, exercising alone, and other demands may be sufficient.

The efficacy beliefs at time 2 for predicting vigorous physical activity at time 3 replicated findings from the previous time but also identified that confidence to overcome bad weather was an additional significant ($p < .01$) independent predictor of vigorous physical activity. The differences between six month periods may reflect anticipated seasonal variations from Canadian weather patterns. Prediction of the first six months covered the March to September period, which is characterized by sunshine and warm temperatures (70 to 90°F). The second six-month predictions, however, covered the September to March period, which is characterized by significant snowfall and cold temperatures (-20 to 20°F). Expectations of the Canadian winter theoretically explain why confidence to overcome bad weather is an additional predictor of vigorous physical activity for this time period.

For the pros, only “confidence about health from getting more physical activity” was a predictor of vigorous physical activity, while “managing stress”, “better sleep”, “having a positive outlook”, and “weight control” were not. However, when we modeled these beliefs using a hypothesized causal structure (see Figure 2a), “confidence about health from getting more physical activity” mediated the effects of “managing stress”, and “having a positive outlook” on vigorous physical activity. Thus, “managing stress”, and “having a positive outlook” may be important causes of “confidence about health from getting more physical activity” which, in turn, causes physical activity behavior.

For the cons, beliefs about physical activity “taking too much time” and “costing too much money” were influences on physical activity behavior, while “taking time from family and friends”, and “looking awkward” were not. The only discrepancy between time periods was “being too tired”. This was not an important belief in the first prediction time period but was an influence at the second time period. Perhaps this was again due to the difference in weather between the assessment times. Similar to the pros analysis, when we modeled these beliefs using a causal structure, “taking too much time” mediated the effect of “taking time from family and friends”. Thus, “time from family and friends”, may be an important cause of the more general “taking too much time” belief which, in turn, may cause vigorous physical activity (see Figure 2b). Identification of these potential causal structures underscores the importance of insuring that all beliefs in a scale are at the same hypothesized level of abstraction. Otherwise, non-significant beliefs may be dismissed as unimportant when they are actually antecedents of more generalized beliefs (see also Sutton, 2002).

Despite the prospective predictions and the population-based sampling of the present study, there are limitations that need to be taken into consideration when interpreting the results and planning for future research. First, though the specific self-efficacy, pro, and con beliefs were identified as superior over a summed scale for predicting vigorous physical activity, single item measurement of these beliefs is not optimal measurement methodology. The advocating of a correlated belief structure over an aggregated scale does not imply that beliefs should be single item, merely unidimensional. We used

a theoretically sound procedure for estimating measurement error across beliefs, but future research would benefit by multi-item scales for each of these relevant beliefs with demonstrated unidimensionality. Still, the item burden (several items per each belief) may become unwieldy. Thus single item measures may be the cost incurred when attempting to construct a precise measurement model.

Second, though the self-efficacy, pros and cons scales are acceptable within the physical activity literature (see Plotnikoff et al., 2001a), other measures of these constructs may yield different findings. For example, other scales have been created to measure self-efficacy for physical activity (e.g., McAuley, 2002; Sallis, Pinski & Grossman, 1988), pros and cons may vary (Ajzen, 2002), and formative scales may best represent some constructs. Nevertheless, we feel this paper represents a solid discussion of the assumptions underlying the aggregation of belief-based items and a demonstration of tests for these assumptions.

Third, the latent concept created for vigorous physical activity did not possess optimal measurement properties. This demonstrates the advantage of structural equation modeling in that concepts are estimated free of error, but suggests that future research will benefit from either more reliable and valid self-report measures of vigorous physical activity or more objective measures (e.g., pedometers). Precision of measurement is important not only for independent concepts, but also for dependent concepts like behavior.

Fourth, the overall study response rate was modest and the authors experienced a significant attrition rate (56%) over the three time points. These factors create unknown biases that limit the population generalizability of the results. However, it is important to note that these participants (N=683) were compared (t-tests and chi-square analyses revealed no meaningful differences) with the 1602 who completed only the time 1 assessment, which revealed similar demographic, social cognitive, and behaviour (i.e., stage of change for physical activity and energy expenditure) scores (Plotnikoff et al., 2001a, 2001b), limiting potential generalization bias. Further, the current study is not

necessarily claiming population generalizability as its central aim; its focus is on the theoretical and applied use of belief-based scales.

Fifth, the six-month time lag between independent and dependent measures may be too long a duration for optimal prediction of physical activity. The current research explained 32% and 38% of vigorous physical activity for time 1 to 2 and time 2 to 3 respectively. However, given the reciprocally determined nature of social-cognitive beliefs, the environment, and behavior as theorized by Bandura (1998), many unexpected factors may have limited the predictive value of beliefs across a half a year. Therefore, future research may better understand behavior by including measurements at more frequent time intervals.

Finally, critics of our advocacy may argue that the introduction of a potential multitude of beliefs into causal structure destroys the theoretical parsimony we have achieved in social cognitive theories and invites multicollinearity problems in analysis. These are both valid and important points. Data reduction, model simplification, and careful theorizing of causal structure will be essential for belief-level analysis. We believe, however, that researchers and theoreticians should strive for parsimony but not be bound to it. Alternative models that better represent our observed world, no matter how complex, will likely aid in the success of better understanding physical activity.

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Figure Captions

Figure 1. Alternative belief models and behavior.

Figure 2. Alternative Causal structures for Pros and Cons Beliefs. Note * = $p < .01$; Top = Time 1 beliefs predicting time 2 behavior, Bottom = Time 2 beliefs predicting time 3 behavior.

Table 1.

Chi Square Difference Tests for Self-Efficacy Beliefs.

	Time 1							
	2	3	4	5	6	7	8	
1. Fatigue	14.12**	35.95**	38.07**	31.36**	35.45**	38.85**	17.81**	
2. Bad Mood		20.60**	36.79**	24.71**	23.05**	31.76**	11.39**	
3. Doing it Alone			12.36**	38.09**	28.91**	44.81**	28.28**	
4. Boredom				33.82**	23.97**	53.23**	24.16**	
5. No Improvement					29.20**	43.81**	21.76**	
6. Other Demands						34.05**	22.07**	
7. Muscle Soreness							27.81**	
8. Bad Weather								
	Time 2							
	2	3	4	5	6	7	8	
1. Fatigue	3.73	16.15**	34.08**	17.92**	30.18**	25.60**	20.03**	
2. Bad Mood		12.54**	33.25**	18.98**	44.16**	27.27**	18.47**	
3. Doing it Alone			9.92**	21.09**	45.48**	29.94**	14.54**	
4. Boredom				20.71**	41.71**	50.07**	38.94**	
5. No Improvement					35.88**	34.60**	28.64**	
6. Other Demands						48.50**	42.82**	
7. Muscle Soreness							22.10**	
8. Bad Weather								

Note: ** $P < .01$. Tests performed at 1 degree of freedom.

Table 2.

Chi Square Difference Tests for Pro Beliefs

	2	3	4	Time 1 5
1. Manage Stress	42.82**	19.26**	21.83**	44.40**
2. Health Confidence		43.88**	42.42**	61.99**
3. Better Sleep			8.36**	33.32**
4. Positive Outlook				26.62**
5. Weight Control				
				Time 2
1. Manage Stress	19.68**	9.26**	13.38**	36.41**
2. Health Confidence		17.69**	15.20**	30.19**
3. Better Sleep			5.33*	21.97**
4. Positive Outlook				9.19**
5. Weight Control				

Note: * = $p < .05$; ** $p < .01$. Tests performed at 1 degree of freedom.

Table 3.

Chi Square Difference Tests for Con Beliefs

	2	3	4	Time 1 5
1. Too Much Time	16.23**	16.51**	139.77**	89.54**
2. Less Time for Friends and Family		22.87**	170.89*	86.92**
3. Too Tired			89.98**	72.56**
4. Look Awkward				81.79**
5. Cost Too Much				
				Time 2
1. Too Much Time	26.83**	34.84**	105.85**	90.52**
2. Less Time for Friends and Family		40.06**	109.14**	82.75**
3. Too Tired			81.66**	87.07**
4. Look Awkward				109.75**
5. Cost Too Much				

Note: ** $P < .01$. Tests performed at 1 degree of freedom.

Table 4.
Formative Scale Models Versus Specific belief Models for Self-Efficacy, Pros, and Cons
(N=683).

Model	χ^2	DF	P-Level	RMSEA	CFI	Variance of Vigorous Physical Activity Explained
Beliefs (time 1) Predicting Vigorous Physical Activity (time 2)						
General Self-Efficacy	21.63	14	.03	.03	1.00	.28
Specific Efficacy Beliefs*	2.69	7	.91	.00	1.00	.34
General Pros	18.92	8	.02	.05	0.99	.03
Specific Pro Beliefs*	4.62	4	.33	.02	1.00	.09
General Cons	19.74	8	.01	.05	0.99	.12
Specific Con Beliefs*	10.11	4	.04	.05	0.99	.19
Beliefs (time 2) Predicting Vigorous Physical Activity (time 3)						
General Self-Efficacy	52.81	19	.00	.05	0.99	.35
Specific Efficacy Beliefs*	28.43	13	.01	.04	0.99	.41
General Pros	7.59	8	.47	.00	1.00	.09
Specific Pro Beliefs	2.81	4	.59	.00	1.00	.10
General Cons	26.98	8	.00	.06	0.95	.19
Specific Con Beliefs*	3.72	4	.45	.00	1.00	.26

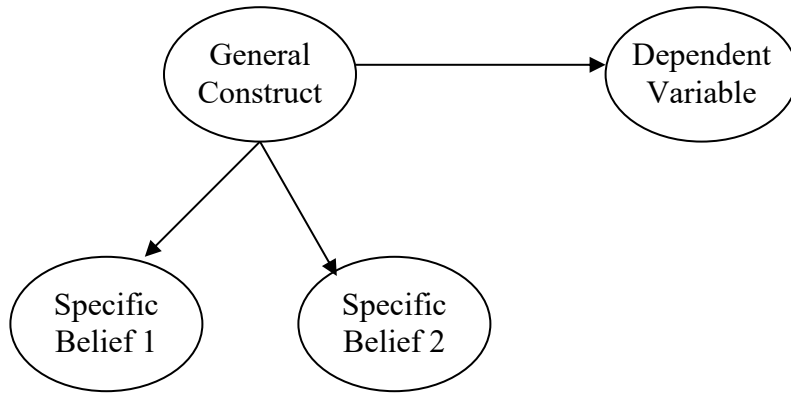
Note: * = $p < .05$

Table 5.
Standardized Effects of Beliefs on Vigorous Physical Activity.

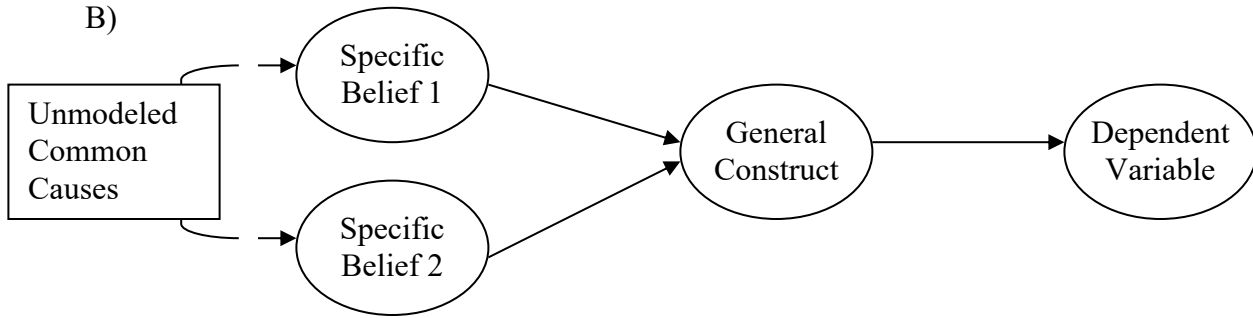
Belief	Effect on Activity Time 2	Effect on Activity Time 3
Self-Efficacy		
Fatigue	.33*	na
Alone	.17*	.16*
Time demands	.25*	.19*
Bad mood	.01	na
Boredom	-.06	.04
No improvement	.03	-.12
Muscle soreness	-.11	-.11
Bad weather	.11	.14*
Fatigue/bad mood	na	.45*
Pros		
	na	.30*
Improve health	.29*	na
Manage stress	.13	na
Get better sleep	-.12	na
Positive outlook	.02	na
Weight control	-.03	na
Cons		
Takes too much time	-.46*	-.39*
Costs too much money	-.17*	-.18*
Time from friends/family	.13	.14
Too tired	-.07	-.23*
Look awkward	.04	.14

Note: * = $p < .01$; na = not applicable. Effects on time 2 represent social cognitive beliefs measured at time 1 predicting vigorous physical activity at time 2. Effects on time 3 represent social cognitive beliefs measured at time 2 predicting vigorous physical activity at time 3.

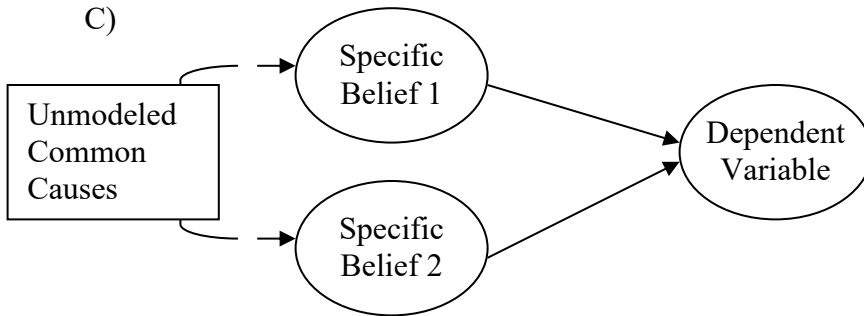
A)



B)



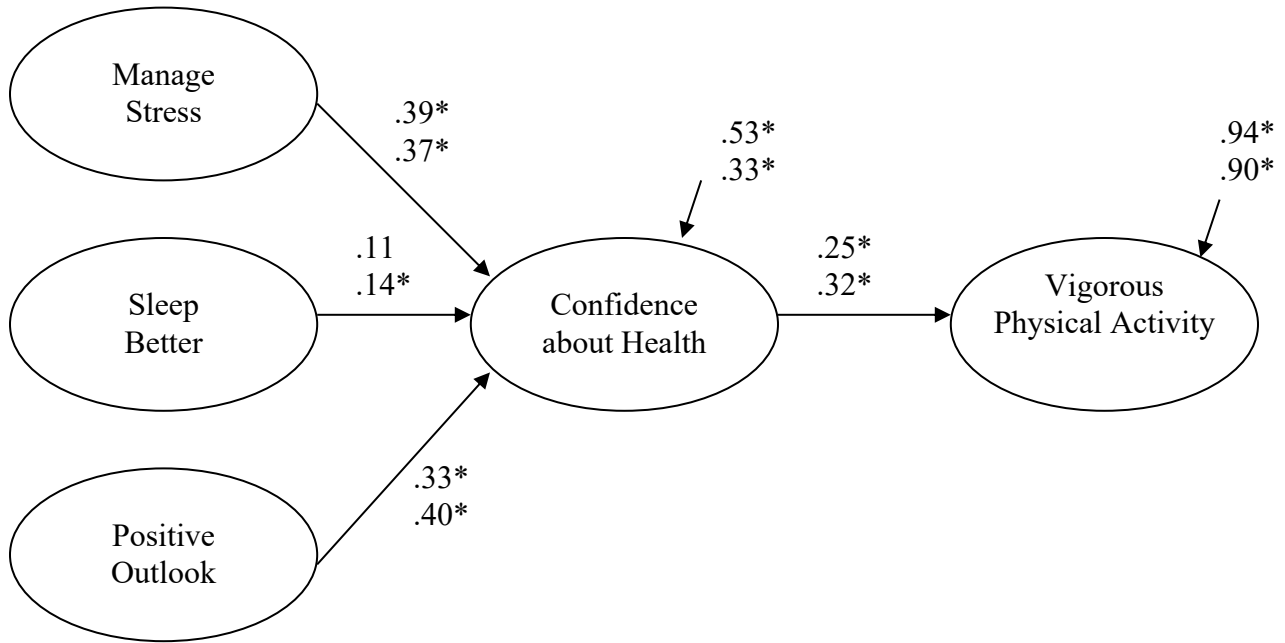
C)



D)



A) Pros



B) Cons

