Journal of Sport & Exercise Psychology, **2016, 38, 317-330**
http://dx.doi.org/10.1123/jsep.2016-0256

Human Kinetics
ORIGINAL RESEARCH

Should We Be Looking at the Forest or the Trees? Overall Psychological Need Satisfaction and Individual Needs as Predictors of Physical Activity

Jennifer Brunet,[1,2,3] Katie E. Gunnell,[1,4] Pedro Teixeira,[5] Catherine M. Sabiston,[6] and Mathieu Bélanger[7,8,9]

[1]University of Ottawa; [2]Institut de Recherche de l'Hôpital Montfort; [3]Ottawa Hospital Research Institute; [4]The Children's Hospital of Eastern Ontario Research Institute; [5]University of Lisbon; [6]University of Toronto; [7]Université de Sherbrooke; [8]Centre de Formation Médicale du Nouveau-Brunswick; [9]Vitalité Health Network

The objectives of this study were to examine whether (a) measures designed to assess satisfaction of competence, autonomy, and relatedness needs in physical activity contexts can represent both general and specific needs satisfaction and (b) the specific needs are associated with concurrent moderate-to-vigorous-intensity physical activity (MVPA) participation (Time 1) and MVPA participation 4 months later (Time 2), beyond general psychological need satisfaction (PNS). Data from 544 adolescents (M_{age} = 14.1 years, SD = 0.6) were analyzed. A bifactor model specifying four factors (i.e., one general PNS and three specific needs) provided a good fit to the data. Extending the model to predict Time 1 and Time 2 MVPA participation also provided a good fit to the data. General PNS and specific needs had unique and empirically distinguishable associations with MVPA participation. The bifactor operationalization of PNS provides a framework to delineate common and distinctive antecedents and outcomes of general PNS and specific needs.

Keywords: psychological need satisfaction, physical activity, bifactor model, self-determination theory, longitudinal study, adolescents

Regular participation in moderate-to-vigorous-intensity physical activity (MVPA) can effectively reduce the risk of developing several health conditions (e.g., hypertension, Type 2 diabetes, heart diseases, stroke, obesity, depression, certain cancers) and enhance quality of life and well-being in adolescents (Andersen, Riddoch, Kriemler, & Hills, 2011; Eime, Young, Harvey, Charity, & Payne, 2013; Janssen & LeBlanc, 2010). However, only 5% of adolescents 12–17 years of age living in Canada meet recommendations of engaging in at least 60 min of MVPA per day (ParticipACTION, 2015). As such, considerable efforts have been devoted to identifying factors associated with MVPA participation in adolescents to inform the design of effective behavior change interventions. Fostering the satisfaction of adolescents' basic psychological needs for competence, autonomy, and relatedness has been considered important for promoting MVPA participation (Cox, Smith, & Williams, 2008; McDavid, Cox, & McDonough, 2014; Taylor, Ntoumanis, Standage, & Spray, 2010).

Under the framework of self-determination theory (Deci & Ryan, 1985), Deci and Ryan (2000) proposed the basic psychological needs theory that rests on the assumption that people have an innate propensity to fulfill three basic psychological needs: competence, autonomy, and relatedness. The need for *competence* refers to the necessity to feel successful in producing aspired outcomes (White, 1959). The need for *autonomy*

Jennifer Brunet is with the School of Human Kinetics, University of Ottawa, Ontario, Canada; Institut de Recherche de l'Hôpital Montfort (IRHM), Montfort Hospital, Ontario, Canada; and the Cancer Therapeutic Program, Ottawa Hospital Research Institute (OHRI), Ontario, Canada. Katie E. Gunnell is with the School of Human Kinetics, University of Ottawa, Ontario, Canada, and the Healthy Active Living and Obesity Research Group, The Children's Hospital of Eastern Ontario Research Institute, Ontario, Canada. Pedro Teixeira is with Centro Interdisciplinar de Estudo da Performance Human (CIPER), Faculty of Human Kinetics, University of Lisbon, Lisbon, Portugal. Catherine M. Sabiston is with the Faculty of Kinesiology & Physical Education, University of Toronto, Ontario, Canada. Mathieu Bélanger is with the Department of Family Medicine, Université de Sherbrooke, Moncton, New Brunswick, Canada; Centre de Formation Médicale du Nouveau-Brunswick, Moncton, New Brunswick, Canada; and Vitalité Health Network, Moncton, New Brunswick, Canada. Address author correspondence to Jennifer Brunet at jennifer.brunet@uottawa.ca.

refers to the necessity to feel volitional in one's actions and to be the originator of these actions (deCharms, 1968). The need for *relatedness* refers to the necessity to feel connected to and understood by others (Baumeister & Leary, 1995). Deci and Ryan (2000) emphasized the importance of satisfying each of the three psychological needs for optimal functioning and ongoing psychological growth. Moreover, Deci and Ryan (2011) proposed that satisfaction of the psychological needs fosters a wide range of adaptive behavioral outcomes such as MVPA participation.

Researchers have provided support for Deci and Ryan's (2000, 2011) theorizing that the three psychological needs are related yet distinct constructs in the physical activity domain (Ng, Lonsdale, & Hodge, 2011; Vlachopoulos & Michailidou, 2006; Wilson, Rogers, Rodgers, & Wild, 2006). Many have also provided evidence that perceptions of competence, autonomy, and relatedness are associated with physical activity–related outcomes in bivariate analyses (see Teixeira, Carraça, Markland, Silva, & Ryan, 2012 for review). Yet, when researchers have used multivariate analyses in which all three psychological needs are examined as correlates of physical activity–related outcomes at the same time, perceived competence has generally been the most robust correlate (Edmunds, Ntoumanis, & Duda, 2006; McDonough & Crocker, 2007; Vlachopoulos & Michailidou, 2006). Accordingly, one could be led to infer that the need for competence is functionally important in the physical activity domain, whereas the need for autonomy and relatedness is not or is less important. However, such an inference may be, at least partly, based on a statistical artifact caused by the shared variance between all three psychological needs (i.e., intercorrelations among competence, autonomy, and relatedness; Cohen, Cohen, West, & Aiken, 2013).

To account for the notion that higher satisfaction of one need is often associated with higher satisfaction of the other needs, researchers have computed composite scores of psychological need satisfaction (PNS) by aggregating competence, autonomy, and relatedness scores (Hagger, Chatzisarantis, & Harris, 2006; Ntoumanis, 2005; Rahman, Thogersen-Ntoumani, Thatcher, & Doust, 2011; Sebire, Standage, & Vansteenkiste, 2009; Standage, Duda, & Ntoumanis, 2005). These scores are assumed to broadly reflect overall or general PNS, whereby higher scores reflect an increasing satisfaction of competence, autonomy, and/or relatedness. Using this approach, researchers have found that general PNS is positively associated with physical activity–related outcomes (Hagger et al., 2006; Ntoumanis, 2005; Rahman et al., 2011; Sebire et al., 2009; Standage et al., 2005).

Although the *general-factor approach* (i.e., where an overall PNS variable is examined) and the previously described *specific-factor approach* (i.e., where perceptions of competence, autonomy, and relatedness are examined as separate variables) complement each other, the selection of one approach over the other currently has to be made in the absence of a strong a priori theoretical justification and in light of notable limitations. The main limitation of the general-factor approach is that it can lead to conceptual ambiguity (Chen, Hayes, Carver, Laurenceau, & Zhang, 2012) as it combines the three psychological needs into one overall score. Combining scores into one overall score is problematic because certain psychological needs may emerge as particularly important in certain domains as pointed out by Ryan (1995). Consequently, a composite PNS score conceals which need(s) is(are) more or less salient and could potentially attenuate associations with physical activity–related outcomes. The specific-factor approach can also lead to conceptual ambiguity (Chen et al., 2012; Reise, Morizot, & Hays, 2007) as it cannot be relied on to investigate how the potential overlap among the psychological needs relates to selected outcomes. Thus, whereas both the general- and specific-factor approaches are useful when they are used in isolation, they restrict researchers' ability to test tenets of basic psychological needs theory and self-determination theory more broadly. The bifactor model approach may offer a viable analytical alternative to account for the dilemmas inherent in the general- and specific-factor approaches (Reise, 2012).

The Bifactor Model and Its Application Within Self-Determination Theory

Disentangling the extent to which variance in MVPA participation may be explained by general PNS and by satisfaction of specific psychological needs may be achieved through bifactor modeling, which is designed to enable the examination of multifaceted constructs that comprise several distinct yet related constructs (Chen et al., 2012; Reise et al., 2007). When estimating a bifactor model, correlations among measured items are accounted for in (a) a general factor representing the shared variance among *all* items and (b) specific factors representing the shared variance among *subsets* of items assumed to be highly similar in content. A bifactor model can be tested within a confirmatory factor analytical (CFA) framework or an exploratory structural equation modeling (ESEM) framework. As shown in Figure 1, all measured items are permitted to load on a general factor (i.e., general PNS) as well as on one designated specific psychological need factor (i.e., competence, autonomy, or relatedness) in a bifactor CFA (Reise, 2012). Further, measured items are not permitted to load on nonintended specific factors as cross-loadings are set to zero. In a bifactor ESEM, all measured items are also permitted to load on a general factor as well as on one designated specific psychological need factor, yet cross-loadings between measured items and nonintended specific factors are permitted (Asparouhov & Muthén, 2009). By testing a bifactor CFA or a bifactor ESEM, researchers can therefore model both the broad central construct of PNS (i.e., general PNS) and specific constructs of PNS (i.e., satisfaction of specific psychological needs) within a single model as separate latent variables instead of having to choose between the

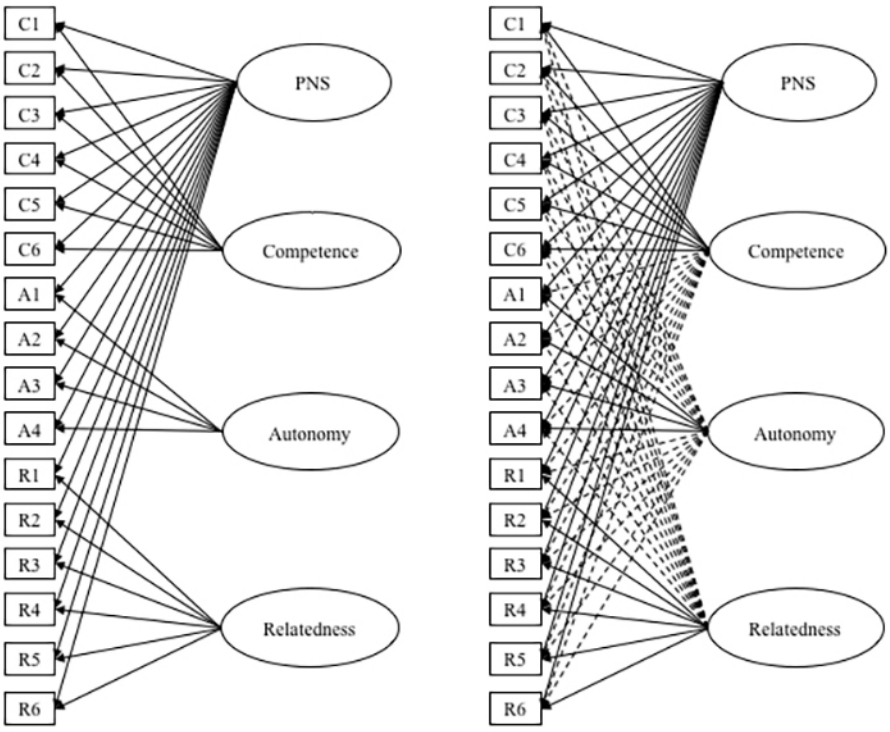

Figure 1 — Graphical representation of the bifactor model of specific psychological needs and general psychological need satisfaction (PNS). The left figure is the bifactor CFA and the right figure is the bifactor ESEM. *Notes:* Dotted lines represent nontarget loadings.

general-factor approach or the specific-factor approach. In turn, researchers can examine the unique contribution of each specific factor and the general factor on MVPA participation.

Although the bifactor model shares some common features with the higher order factor model, the bifactor model offers two noteworthy advantages (Chen et al., 2012). From a conceptual standpoint, only the bifactor model allows researchers to consider both the specific psychological needs in addition to a general PNS factor. Within the bifactor model, the psychological needs are modeled as independent latent factors that researchers can directly examine to determine the strength of the associations between satisfaction of each specific psychological need and relevant outcomes. In a higher order model, researchers would have to examine the disturbance associated with the first-order latent factors to examine satisfaction of each psychological need as predictors of outcomes. Consequently, from a practical standpoint, only the bifactor model allows researchers to examine whether satisfaction of each psychological need is independently associated with MVPA participation beyond the contribution of general PNS.[1]

The usefulness of combining the general- and specific-factor approaches within the bifactor model has recently been demonstrated in the physical activity domain (Appleton, Ntoumanis, Quested, Viladrich, & Duda, 2016; Gunnell & Gaudreau, 2015; Myers, Martin, Ntoumanis, Celimli, & Bartholomew, 2014; Stenling, Ivarsson, Hassmén, & Lindwall, 2015). For example, Myers et al. (2014) demonstrated the utility of the bifactor model by showing that psychological need thwarting (i.e., the perception that psychological needs are being actively undermined in the sport context; Bartholomew, Ntoumanis, Ryan, Bosch, & Thøgersen-Ntoumani, 2011) in athletes was best represented by a combination of a general psychological need thwarting factor and three specific psychological need thwarting factors. However, because researchers have stressed that the absence of need thwarting does not imply PNS or vice versa, and showed that PNS and thwarting differentially predict various outcomes (Bartholomew et al., 2011; Gunnell, Crocker, Wilson, Mack, & Zumbo, 2013), it is not possible to say whether the pattern of results reported by Myers et al. holds for PNS. Hence, using the bifactor model to examine the structure of PNS may provide clarification to the question of how the satisfaction of the three psychological needs are jointly and uniquely contributing to explaining variance in MVPA participation in adolescents.

The Present Study

In the current study, a bifactor model of PNS was tested with a sample of adolescents to examine whether satisfaction of the three specific psychological needs in the physical activity domain accounted for unique variance beyond the shared variance captured in general PNS (Objective 1). It was hypothesized that a bifactor model

with one general PNS factor and three specific factors (i.e., competence, autonomy, and relatedness) would provide a good fit to the data. The second objective was to examine whether general PNS and the satisfaction of competence, autonomy, and relatedness were uniquely associated with concurrent MVPA participation (Time 1) and MVPA participation assessed 4 months later (Time 2) in adolescents. It was hypothesized that general PNS and satisfaction of all three specific psychological needs would have significant and positive associations with Time 1 and Time 2 MVPA participation. Demonstrating that satisfaction of the specific psychological needs accounts for unique variance in MVPA participation, beyond general PNS, has implications for theory testing and future research as it would suggest that researchers interested in examining the associations between PNS and MVPA participation should consider both general PNS and satisfaction of specific psychological needs. Furthermore, it would provide evidence that strategies designed to foster general PNS and/or strategies designed to foster satisfaction of specific psychological needs should be adopted when developing interventions to promote MVPA participation in this generally insufficiently active population.

Method

Participants and Procedures

The data used for this study were drawn from the Measuring Activities of Teenagers to Comprehend their Habits (MATCH) study, an ongoing prospective study of boys and girls 8.9–12.5 years of age at study inception (mean age = 10.8, *SD* = 0.6). Participants were recruited from Grade 5 (53.2%) and Grade 6 classes in 17 schools across the province of New Brunswick, Canada. Schools were selected to represent a mix of languages (French, English), geographic locations (rural, suburban, urban), and socioeconomic statuses (low, medium, high). The MATCH study was approved by the Centre Hospitalier de l'Université de Sherbrooke ethics committee before data collection; all participants provided written informed assent, and their parents/guardians provided written informed consent.

Further details about the methods and procedures of the MATCH study are reported elsewhere in a protocol paper (Bélanger et al., 2013) and in an empirical paper in which the associations between PNS and MVPA participation were tested over several years (Gunnell, Bélanger, & Brunet, 2016). Briefly, the first questionnaire was administered during regular class time in the Fall of 2011. Additional data collection took place every 4 months and will continue until participants complete secondary school. Data obtained from the last two completed survey cycles at the time of analyses (i.e., Winter 2015 [Time 1] and Spring 2015 [Time 2]) were used for the current study. The analytical sample was comprised of 309 girls and 225 boys. Participants were on average 14.1 years of age (*SD* = 0.6; range = 12.5–17.0) at Time 1 and lived in neighborhoods with a mean individual-level income of $32,067 (*SD* = $8,468, *n* = 219 not reported) as estimated by linking participants' six-digit residential postal codes reported in 2014–2015 to area-level income from the 2006 Canadian Census.

Measures

MVPA participation was assessed at Time 1 and Time 2 using two items developed by Prochaska, Sallis, and Long (2001) for use with children and adolescents that focused on the total amount of activity undertaken at moderate-to-vigorous intensity. Participants were provided with a definition of MVPA and given examples of physical activities. Next, they were asked to indicate (a) how many days they were physically active for a total of at least 60 min per day during the past week and (b) how many days they were physically active for a total of at least 60 min per day during a typical week. Participants responded to each item using a scale ranging from 0 to 7 days. An average of the two scores was calculated at Time 1 and Time 2 to represent Time 1 and Time 2 MVPA participation, respectively. Researchers have reported acceptable score reliability (i.e., intraclass correlation = .77) and validity (i.e., scores correlated significantly with accelerometer data at $r \geq .40$) for this measure in previous studies with adolescents (Prochaska et al., 2001; Ridgers, Timperio, Crawford, & Salmon, 2012). In the current study, the correlation coefficients for both items at Time 1 and Time 2 were .86 and .82, respectively, and the intraclass correlation coefficient was .79 across the two time points.

Perceptions of competence, autonomy, and relatedness need satisfaction in the physical activity domain were assessed at Time 1 using the six-item competence subscale of the Intrinsic Motivation Inventory (IMI; McAuley, Duncan, & Tammen, 1989), the seven-item autonomy subscale from the General Need Satisfaction Scale (GNSS; Gagné, 2003), and the six-item Relatedness to Others in Physical Activity Scale (ROPAS; Wilson & Bengoechea, 2010), respectively. These measures were selected after consultation with various subject experts regarding the measurement of PNS in adolescents and because they have been used in previous studies with adolescent samples (Sebire, Jago, Fox, Edwards, & Thompson, 2013; Standage, Gillison, Ntoumanis, & Treasure, 2012; Taylor et al., 2010). The IMI and GNSS items were modified by making them specific to physical activity (see Table 1). Participants indicated their agreement with each item on the IMI and GNSS using a 7-point response scale ranging from 1 (*not at all true*) to 7 (*very true*), and their agreement with each item on the ROPAS using a 6-point response scale ranging from 1 (*false*) to 6 (*true*). There were three negatively worded items on the GNSS (i.e., "When I participate in physical activity, I feel pressured," "When I participate in physical activity, I frequently have to do what I am told," and "When I participate in physical activity, there is not much opportunity for me to decide for myself how to do things") and one on the IMI (i.e.,

Table 1 Item-Level Information, Descriptive Statistics, and Factor Loadings for the Bifactor CFA

			Psychological need satisfaction		Competence		Autonomy		Relatedness	
Items	Score range	Mean/ intercepts	λ	*SE*	λ	*SE*	λ	*SE*	λ	*SE*
Competence										
1. I think I am pretty good at physical activity.	1–7	4.78	.71	.03	.48	.06				
2. I think I do pretty well at physical activity compared with others.	1–7	3.98	.53	.04	.49	.06				
3. After working at physical activity for a while, I felt pretty competent.	1–7	5.02	.76	.03	.14	.05				
4. I am satisfied with my performance at physical activity.	1–7	5.03	.78	.03	.30	.06				
5. I am pretty skilled at physical activity.	1–7	5.04	.79	.03	.46	.06				
Autonomy										
1. When I participate in physical activity, people I interact with regularly tend to take my feelings into consideration.	1–7	4.25	.68	.03			.35	.05		
2. When I participate in physical activity, I feel like I am free to decide for myself how to participate.	1–7	4.49	.63	.04			.59	.08		
3. When I participate in physical activity, I generally feel free to express my ideas and opinions.	1–7	4.45	.75	.03			.41	.06		
4. When I participate in physical activity, I feel like I can pretty much be myself.	1–7	5.07	.87	.02			.09[a]	.06		
Relatedness										
1. I feel like I have developed a close bond with others.	1–6	4.30	.69	.04					.44	.06
2. I feel like I fit in well with others.	1–6	4.45	.73	.04					.48	.06
3. I feel like I am included by others.	1–6	4.59	.69	.04					.50	.05
4. I feel like I am part of a group who share my goals.	1–6	4.56	.73	.04					.54	.05
5. I feel like I am supported by others in this activity.	1–6	4.63	.70	.04					.60	.04
6. I feel like others want me to be involved with them.	1–6	4.58	.67	.04					.63	.04

Note. CFA = confirmatory factor analysis; λ = standardized factor loadings.

[a]Indicates nonsignificant factor loading at $p > .05$.

"Physical activity is not something I can do very well"). Negatively worded items were omitted from the analyses reported herein because they can evoke a different type of response, they share variance distinct from the concepts that the factors measure (van Sonderen, Sanderman, & Coyne, 2013), and these specific items adversely affected model fit in another MATCH study using data from previous time points (Gunnell et al., 2016). Two further reasons the negatively worded items were deleted are that researchers have argued that negatively worded items may actually be used to assess need dissatisfaction, frustration, or thwarting and have shown that positively and negatively worded items may have different associations with outcomes (e.g., Bartholomew et al., 2011; Sheldon & Gunz, 2009). Evidence of score reliability and validity for the IMI, GNSS, and ROPAS have been reported in previous studies with adolescent samples (Sebire et al., 2013; Standage et al., 2012; Taylor et al., 2010).

Translation of Measures and Invariance Across Language

The source language for all items used in the current analyses was English. All items were therefore translated into French using a rigorous back-translation procedure (see Bélanger et al., 2013) for use in French-language schools. The extent to which the bifactor model including the IMI, GNSS, and ROPAS items exhibited measurement and structural invariance between French- and English-speaking participants ($n_{English}$ = 108; n_{French} = 421) was tested using a multigroup CFA framework described by Vandenberg and Lance (2000). Invariance testing for the bifactor model including the IMI, GNSS, and ROPAS items consisted of examining different levels of invariance by comparing a series of nested models in which equality constraints were added progressively. Levels of measurement invariance tested were as follows: (1) no constraints (i.e., configural invariance); (2) factor loadings constrained (i.e., weak invariance); (3) factor loadings and intercepts constrained (i.e., strong invariance); and (4) factor loadings, intercepts, and errors constrained (i.e., strict invariance). Measurement invariance was supported as (a) the change in comparative fit index (CFI) and the change in the root mean square error of approximation (RMSEA) values between successive nested models were less than |.010| and |.015|, respectively, and (b) each of the four measurement models had CFI and Tucker–Lewis index (TLI) values that remained above .90, and RMSEA values that remained below .08 (Chen, 2007; Cheung & Rensvold, 2002; Vandenberg & Lance, 2000). Subsequently, the extent to which the model exhibited structural invariance was then examined to determine whether the variances and means for the general PNS and specific need latent factors were invariant. The addition of equality constraints in successive models did not result in significant decreases in model fit, indicating that French- and English-speaking participants had equivalent means and variability in general PNS and specific psychological need satisfaction.

Measurement invariance could not be tested for Time 1 and Time 2 MVPA participation because these were modeled as manifest variables. Nevertheless, the MVPA French items used in the MATCH study were similar to the items used in the World Health Organization Health Behavior in School-aged Children study (Currie, Gabhainn, Godeau, & Committee, 2009), which also employed back-translation and pilot surveys to translate the two items developed by Prochaska et al. (2001) into French. Further, equality of Time 1 and Time 2 MVPA scores across language groups was examined in successive models by constraining the variances, means, and covariances of Time 1 and Time 2 MVPA to examine potential decreases in fit resulting from noninvariance. The addition of equality constraints in successive models did not result in a significant decrease in fit, indicating that French- and English-speaking participants had equivalent amounts of variability in Time 1 and Time 2 MVPA, had comparable amounts of Time 1 and Time 2 MVPA on average, and had similar correlations between general PNS and specific needs and Time 1 and Time 2 MVPA participation, respectively. Finally, equality of the regression coefficients from general PNS and the specific needs to Time 1 and Time 2 MVPA and from Time 1 MVPA to Time 2 MVPA across groups was examined. After the regression coefficients were constrained to be equal across groups, the fit of the model relative to a model where the regression coefficients were permitted to vary across groups was similar, indicating that both groups had a similar pattern of associations.[2]

Data Analysis

Analyses were conducted in Mplus 7.31 (Muthén & Muthén, 1998–2015) within a multigroup framework that allowed parameters to be constrained to be equal across the English- and French-speaking groups. To address Objective 1, a bifactor CFA was tested using Time 1 PNS data in which all positively worded items on the IMI, GNSS, and ROPAS were permitted to load on a general PNS factor as well as their designated specific psychological need factor (i.e., competence, autonomy, or relatedness). Furthermore, factor loadings between positively worded items and nonintended specific psychological need factors (i.e., cross-loadings) were set to zero. To identify this model, the variance of each latent factor was set to 1.0. Recognizing that setting cross-loadings to zero might be overly restrictive and lead to biased parameter estimates (Asparouhov & Muthén, 2009), a bifactor ESEM was also tested. By estimating a bifactor ESEM with target rotation (Browne, 2001), a priori hypotheses about the factor structure were specified as with the bifactor CFA (i.e., a general PNS factor and three specific psychological need factors). In addition, in the bifactor ESEM, each item was permitted to freely load on the general PNS factor as well as the designated specific psychological need factors it was designed to measure. However, in contrast to the bifactor CFA, factor loadings between positively worded items and nonintended specific psychological need factors were specified to be *close* to zero rather than specified

to be exactly zero. Both bifactor models were estimated using the full information robust maximum likelihood (MLR) estimator to account for missing data at the item level (Enders, 2010) and to account for potential nonnormality. Moreover, consistent with recommendations (Asparouhov & Muthén, 2009; Reise, 2012), both models were estimated with all four latent factors constrained to be uncorrelated since intercorrelations between the specific psychological needs are captured in the general PNS and because this ensures interpretability of the results.

Model fit was assessed using a combination of common goodness-of-fit indices: CFI, TLI, and RMSEA with its 90% confidence interval (90% CI). Although there are no strict criteria for evaluating these fit indices, conventional guidelines suggest that values of .90 and .95 or higher for the CFI and TLI indicate acceptable and excellent fit of the model, respectively, and values of .08 and .06 or lower for the RMSEA indicate acceptable and excellent model fit, respectively (Browne & Cudeck, 1983; Hu & Bentler, 1999). The strength of the factor loadings, standard errors, and the residual variances for each model were also examined to assess model fit. To compare both bifactor models, the Aikaike information criterion (AIC) and the Bayesian information criterion (BIC) were examined. As a rule of thumb, models with lower AIC and BIC values represent better fit (Burnham & Anderson, 2003). Composite reliability coefficients (ω; Raykov, 1997) were calculated as a function of the standardized item factor loadings (λ_i) and the variances of the measurement error (e_i).

The final part of the analysis was to examine the extent to which general PNS and satisfaction of the specific psychological need of competence, autonomy, and relatedness were associated with MVPA participation (i.e., Objective 2) using the best fitting bifactor model (i.e., either the bifactor CFA or the bifactor ESEM). To this end, a structural equation model was tested by regressing Time 1 and Time 2 MVPA participation on the general PNS and the specific psychological need factors, and by regressing Time 2 MVPA participation on Time 1 MVPA participation. The fit of this model was assessed using the CFI, TLI, and RMSEA, and path coefficients were examined.[3] To test the indirect associations of general PNS and satisfaction of the specific psychological needs with Time 2 MVPA participation via Time 1 MVPA participation, the same structural equation model was reestimated using bootstrapping resampling procedures (N = 5,000) to compute 95% bias-corrected CIs (95% BcCIs; Preacher & Hayes, 2008). If a 95% BcCI did not include zero, the indirect association was deemed significant. This model was estimated using the maximum likelihood (ML) estimator since MLR with bootstrapping is not available in Mplus 7.31.

Results

Comparison Between the Bifactor Models Obtained With CFA and ESEM

The bifactor CFA—MLR$\chi^2_{(210)}$ = 498.354, p < .001, CFI = .94, TLI = .94, RMSEA = .07 (90% CI [.06, .08]), BIC = 24,549.69, AIC = 24,293.43)—provided an acceptable degree of fit to the data.[4] In contrast, the bifactor ESEM was inadmissible because the residual covariance matrix was positive definite on account of a large and significant negative residual associated with the item "I feel like I fit in well with others." To rectify the negative residual, the residual variance for this item was constrained to >.0001 based on the recommendation by Chen, Bollen, Paxton, Curran, and Kirby (2001). However, the model remained inadmissible because of the positive definite residual covariance matrix, and the negative residual was still present. Thus, because the bifactor CFA was associated with acceptable model fit, it was retained to address Objective 2.

The ranges, means/intercepts, standardized factor loadings, and standard errors for each item derived from the bifactor CFA are presented in Table 1. The hierarchical omega coefficient for general PNS was .97, and the subscale omega coefficients were .91, .91, and .94 for the specific factors of competence, autonomy, and relatedness, respectively. Each item loaded significantly on the general PNS factor ($\lambda \geq .53$, $p < .001$), as well as on its intended specific psychological need factor ($\lambda \geq .14$, $p <$ .01), with the exception of one item from the GNSS (i.e., "When I participate in physical activity, I feel like I can pretty much be myself") that had a near zero factor loading ($\lambda = .09$, $p = .10$) on its designated specific factor of autonomy. Although unexpected, researchers have noted that it is possible for items to load significantly only on the general factor but not the specific factor within bifactor models (Jennrich & Bentler, 2011; Myers et al., 2014). This means that the variance of this particular autonomy item was solely explained by the general PNS factor. Most of the items displayed stronger factor loadings on the general PNS factor compared with their designated specific psychological need factor, suggesting that most of their variances were shared with the general PNS factor but that there were still well-defined specific psychological need factors. Hence, even when extracting the variance shared among the specific psychological needs by creating a general PNS latent factor, three additional psychological need factors were still necessary to capture the leftover variance that was unique to subsets of items (i.e., each specific psychological need).

Associations of General and Specific Factors of PNS With MVPA Participation

The fit statistics for the structural equation model including Time 1 and Time 2 MVPA participation as outcomes were MLR$\chi^2_{(267)}$ = 588.81, p < .001, CFI = .94, TLI = .94, RMSEA = .07 (90% CI [.06, .08]).[4] An examination of the path coefficients shown in Figure 2 indicated that (a) general PNS was significantly and directly associated with Time 1 MVPA participation ($\beta = .38$); (b) perceptions of competence ($\beta = .16$) and relatedness ($\beta = .12$) were significantly and directly associated with Time 1 MVPA participation beyond general PNS; and (c) perceived relatedness ($\beta = .11$), general PNS ($\beta = .21$), and

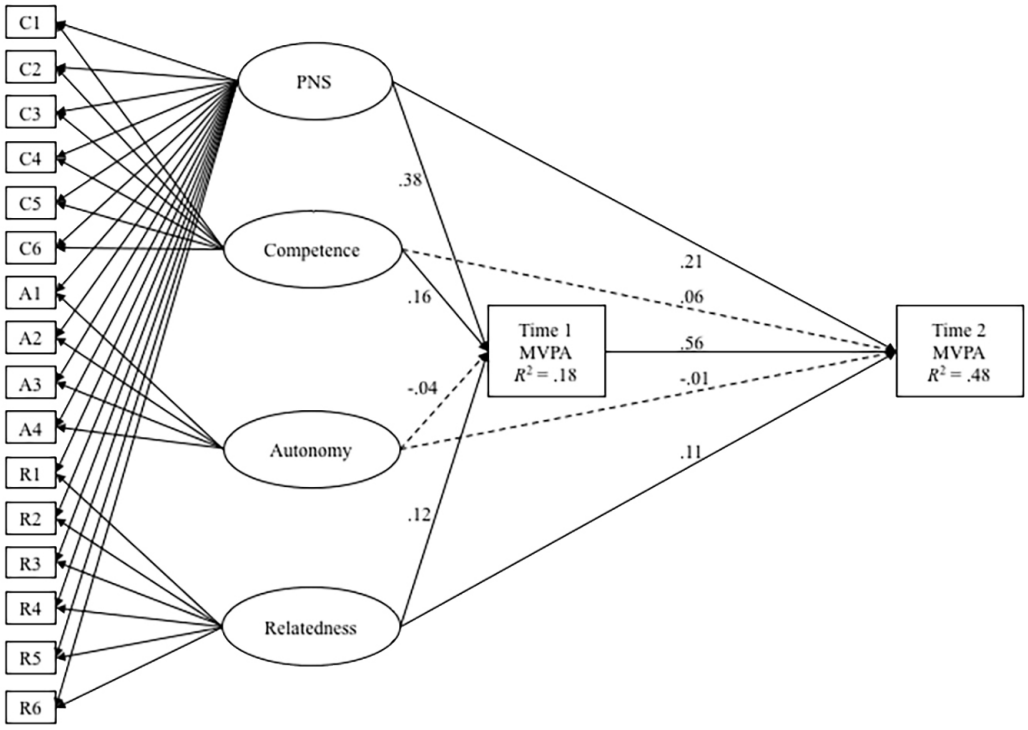

Figure 2 — Structural equation model of specific psychological needs and general psychological need satisfaction (PNS) predicting concurrent moderate-to-vigorous-intensity physical activity (MVPA) participation (Time 1) and MVPA participation assessed 4 months later (Time 2). *Notes:* Bold line indicates association at $p < .05$. Dashed line indicates association at $p > .05$. Standardized values are presented. Indirect effects are reported in the text

Time 1 MVPA participation (β = .56) were significantly and directly associated with Time 2 MVPA participation. Examination of the indirect effects obtained from the model reestimated using bootstrapping resampling procedures indicated that perceived competence (β = .08, 95% BcCI [.03, .27]) and general PNS (β = .22, 95% BcCI [.27, .53]) were significantly and indirectly associated with Time 2 MVPA participation via Time 1 MVPA participation, but perceptions of autonomy (β = –.03, 95% BcCI [–.19, .07]) and relatedness (β = .06, 95% BcCI [–.01, .24]) were not significantly indirectly associated with Time 2 MVPA participation via Time 1 MVPA participation. A total of 18.4% and 47.5% of the variance in Time 1 and Time 2 MVPA participation were explained, respectively.

Discussion

There has been much interest in how psychological factors such as those embedded in basic psychological needs theory (Deci & Ryan, 2000) relate to adolescents' MVPA participation. Studying the role of PNS, two different approaches have been used by researchers—namely, the *specific-factor approach*, which focuses on the satisfaction of specific psychological needs of competence, autonomy, and relatedness, and the *general-factor approach*, which focuses on overall PNS. Using either approach, researchers have provided evidence that satisfaction of each specific psychological need and general PNS are associated with physical activity–related outcomes (Hagger et al., 2006; McDavid et al., 2014; Sebire et al., 2009; Taylor et al., 2010). To reconcile the advantages of both approaches, the objectives of the current study were to investigate satisfaction of specific psychological needs and general PNS simultaneously by using bifactor modeling, and examine its utility in predicting MVPA participation in adolescents.

A Bifactor Perspective on PNS

To test Deci and Ryan's (2000) assertions that PNS is an antecedent of certain behaviors such as MVPA, the bifactor model allows researchers to build on previous work wherein researchers had only been able to operationalize PNS as either specific psychological needs or as general PNS. In the current study, support for the bifactor CFA operationalization on PNS was found, which suggests that adolescents' fulfillment of basic psychological needs could be represented simultaneously by a general PNS factor and three specific psychological need factors. This finding shares similarities with those recently described by Myers et al. (2014). Specifically, Myers et al. found support for a bifactor ESEM consisting of a broad general

factor (i.e., psychological need thwarting) and three narrower specific factors (i.e., competence, autonomy, and relatedness thwarting) among 654 athletes between 12 and 17 years of age. Although Myers et al. applied bifactor ESEM to a different scale (i.e., Psychological Need Thwarting Scale) among athletes and focused on psychological need thwarting, which is conceptually distinct from PNS (Bartholomew et al., 2011; Gunnell et al., 2013), the implication of both studies is that general PNS and satisfaction of each psychological need, whether one is considering need satisfaction or thwarting, could be examined simultaneously in future research. Accordingly, the bifactor model provides a useful framework to do so. For example, the bifactor model would allow researchers to identify which antecedents and/or outcomes are associated with general PNS and which are uniquely associated with the distinct psychological needs.

In addition to these specialized capabilities, the bifactor model provided information that might stimulate a critical discussion in the literature about the meaning of PNS and thus have implications for the development or refinement of existing PNS measures. Conceptually, the distinction between the psychological needs for competence, autonomy, and relatedness is clear. As described above, the need for competence refers to the necessity to feel successful in producing aspired outcomes (White, 1959), the need for autonomy refers to the necessity to feel volitional in one's actions and to be the originator of these actions (deCharms, 1968), and the need for relatedness refers to the necessity to feel close to and understood by others (Baumeister & Leary, 1995). In spite of these clear definitions, researchers must develop multiple questionnaire items for each psychological need to ensure high reliability and content validity through enhancing construct-relevant representation and breadth. Paradoxically, increasing construct-relevant representation could increase construct-irrelevant variance, which could lead to the items' being too broad and capturing variance of other distinct constructs (Messick, 1995). In other words, attempting to assess satisfaction of each psychological need using multiple self-report items can make it difficult to create nonoverlapping subsets of items. In support of this notion, positively worded items in the IMI, GNSS, and ROPAS were not pure markers of perceived competence, autonomy, and relatedness, respectively, because these items formed an additional general PNS factor beyond the specific psychological need factors. From this perspective, the general PNS could be capturing content overlap between the items measuring the specific psychological needs and/or general response tendencies. Using the bifactor model may help researchers discriminate specific psychological needs in predictive models by removing the variance attributable to the general PNS. That said, seeing as the bifactor model is an analytical framework used to capture the shared variance among all items (Chen et al., 2012; Reise et al., 2007), the general PNS could also be capturing the joint correlations (i.e., interdependencies) between the specific psychological needs. Thus, the bifactor model could also render it possible to examine how the covariance between the specific psychological needs relates to MVPA participation, above and beyond the absolute level of competence, autonomy, and relatedness.

The Role of PNS in Predicting MVPA Participation

Researchers have demonstrated that general PNS is positively related to physical activity–related outcomes (Hagger et al., 2006; Ntoumanis, 2005; Rahman et al., 2011; Sebire et al., 2009; Standage et al., 2005). This general pattern of relationship was supported in this study using bifactor modeling. More precisely, general PNS was positively associated with Time 1 and Time 2 MVPA participation, and these associations were of greater magnitude when compared with the associations between the specific psychological needs and MVPA participation. Although it would be logical to conclude that the assessment of general PNS is likely to be most useful, and thus the general-factor approach should be favored, a sole reliance on general PNS without consideration of the absolute level of competence, autonomy, and relatedness may overlook opportunities to identify which need(s) contribute(s) more or less to MVPA participation. Indeed, above and beyond general PNS, perceptions of competence and relatedness were directly associated with Time 1 MVPA participation, perceived relatedness was directly associated with Time 2 MVPA participation, and perceived competence was indirectly associated with Time 2 MVPA participation via Time 1 MVPA participation. These results confirm previous findings that specific psychological needs are positively related to physical activity–related outcomes (Edmunds et al., 2006; Gunnell, Crocker, Mack, Wilson, & Zumbo, 2014; McDonough & Crocker, 2007; Wilson & Rogers, 2008) and strengthen the importance of assessing specific PNS. Another argument for why the sole reliance on general PNS may not be optimal is that perceptions of competence, autonomy, and relatedness can vary considerably within individuals, and computing a composite score of PNS considers any individual differences in the specific psychological needs to be a source of measurement error. Consequently, this may distort the association between general PNS and MVPA participation. Based on these arguments and empirical evidence from the bifactor model, researchers may benefit from using the bifactor model as an analytical framework, whereby individual variability in specific PNS is not considered error in order to evaluate the degree to which general PNS and specific PNS are associated with MVPA participation in future research.

It should be noted, though, that consistent with previous findings (Edmunds et al., 2006; McDonough & Crocker, 2007; Vlachopoulos & Michailidou, 2006), autonomy need satisfaction was not uniquely associated with Time 1 or Time 2 MVPA participation. At first glance, this finding appears to be at odds with Deci and Ryan's (2011) contention that satisfaction of autonomy

fosters participation in various activities. Yet, using the bifactor model, it is possible to see that items designed to assess autonomy need satisfaction significantly loaded on the general PNS factor, which in turn was related to MVPA participation, suggesting that autonomy satisfaction is important insofar as autonomy satisfaction typically co-occurs with competence and/or relatedness need satisfaction (i.e., all three share something in common and typically co-occur to produce optimal outcomes; Deci & Ryan, 2000). However, when those shared aspects were removed from autonomy need satisfaction via the general PNS factor, the unique components of autonomy need satisfaction (i.e., the specific factor) did not significantly predict MVPA participation, which can be understood by considering validity evidence based on item content. For instance, McDonough and Crocker (2007) noted that autonomy items used in other subscales lack content validity because they may not capture the conceptual bandwidth of perceptions of autonomy. A closer inspection of the items used herein reveals that items appeared to focus on autonomy within the context of social relationships, making it clear why they shared variance with the other needs (notably relatedness) and loaded on the general PNS factor. Specifically, the items captured the extent to which participants' decisions were respected, honored, and heeded by others (e.g., "When I participate in physical activity, I generally feel free to express my ideas and opinions"). As such, positively worded items from the GNSS may not include important predictive aspects of autonomy such as affective feelings of volition (rather than decisional feelings) and fully endorsing one's own actions (Deci & Ryan, 2000). Thus, an interesting direction for future research would be to develop additional items that capture salient aspects of autonomy need satisfaction that are not socially or relationally constituted and determine whether item content influences the unique predictive ability of autonomy need satisfaction above general PNS.

Implications

The current findings have important implications for future research directions aimed at developing interventions to foster PNS to promote MVPA participation in adolescents. Based on the current findings, promoting overall PNS as well as competence and relatedness need satisfaction may be complementary and provide the most robust method for increasing MVPA participation in adolescents. To this end, it would be useful for researchers to extend prior research into factors that may foster PNS and distinguish between factors that may play a role in fostering general PNS, specific psychological needs, and/or both. Drawing on self-determination theory (Deci & Ryan, 1985) and the extant literature (see Hagger & Chatzisarantis, 2007; Standage, 2012, for reviews), autonomy support, provision of structure and optimally challenging activities, positive feedback, subjective perceptions of personal success, and perceived involvement can reflect important antecedents of PNS. Accordingly, researchers may want to test the associations between these factors and general PNS and specific PNS using the bifactor model to identify strategies to prioritize based on their target outcome (i.e., general PNS, specific psychological needs, and/or both). Given that satisfaction of all three psychological needs typically co-occurs (Deci & Ryan, 2000), it is likely that some strategies foster both general PNS and specific PNS. Yet, there may be some strategies that may be more effective in fostering general PNS versus specific psychological needs (and vice versa). For instance, interpersonal supports (i.e., autonomy support, structure, and involvement) in the social environment and autonomous forms of motivation are thought to lead to greater satisfaction of all three psychological needs collectively. Therefore, one could imagine an intervention that seeks to foster general PNS through enhancing autonomous motivation and interpersonal supports. Conversely, Sheldon and Filak (2008) have conducted experiments wherein they specifically target each specific psychological need. They found that relatedness manipulations enhanced relatedness but not autonomy and competence, indicating that it is possible to target specific psychological needs without fostering satisfaction of other psychological needs. Thus, using bifactor modeling, researchers could begin to conduct studies to determine whether strategies aimed at fostering general PNS are more, less, or equally effective in promoting MVPA participation compared with strategies aimed at fostering specific psychological needs of competence and relatedness.

Limitations

Despite the theoretical and methodological contributions related to this research, the limitations of this study should be noted. First, the pool of items used in this study to assess PNS was derived from three separate measures developed by different researchers at different time points. It may be useful to confirm the tenability of the bifactor model with other physical activity–based multidimensional PNS measures that were developed simultaneously to include specific subscales assessing satisfaction of each psychological need (e.g., The Basic Psychological Needs in Exercise Scale by Vlachopoulos & Michailidou, 2006; The Psychological Need Satisfaction in Exercise Scale by Wilson et al., 2006). Second, four negatively worded items were removed for the analyses. It may be worth replacing the negatively worded items with positively worded items to further enhance content validity in future research. Last, despite having used measures that have established score reliability and validity, the self-report data could be biased by social desirability, possibly affecting participants' responses. For example, it is possible that participants under- or overreported actual frequency of MVPA participation, which indicates that there is a need for more research to determine whether general PNS and the specific psychological needs are associated with directly measured MVPA participation in adolescents.

In addition to the limitations associated with this research, it is important to acknowledge that using the bifactor model is not always warranted despite statistical justification. Indeed, although the bifactor model offers researchers a viable model for analyzing and improving precision through its explicit modeling of both general PNS and specific PNS, it would be premature (and likely inappropriate) to conclude that the bifactor model should become the de facto model to operationalize PNS. Critically, it must be realized that assuming that there is only one way to analyze PNS may be untenable. The bifactor model considered in this study is one approximation of the data, but there are other simpler models with fewer parameters that are tenable (e.g., single factor, three factor). More work is needed to compare the predictive validity of the bifactor model to the predictive validity of simpler models to determine if and when the added complexity of the bifactor model is warranted. Nevertheless, based on the present findings, it seems that the bifactor model would be advantageous, relative to alternative models, when the purpose is to facilitate discovery of the antecedents and/or outcomes associated with general PNS and those uniquely associated with the specific PNS.

Conclusions

Consideration of the "forest" (i.e., general PNS) may be no better than consideration of the "trees" (i.e., specific PNS) or vice versa. Rather, the current study provides evidence that researchers should work with the "forest" and the "trees" for two reasons. First, general PNS and satisfaction of the three specific psychological needs were shown to be empirically distinct constructs. Second, general PNS and the specific psychological needs were uniquely associated with adolescents' MVPA participation assessed concurrently and 4 months later. These findings are relevant for theoretical discussions in the context of self-determination theory (Deci & Ryan, 1985) and basic psychological needs theory (Deci & Ryan, 2000) specifically, as well for the design of MVPA interventions to be tested with adolescents. That said, the bifactor model should not be seen as a panacea for all studies investigating PNS as there are other unidimensional and multidimensional models that would help researchers answer their research questions when the complexity of the bifactor model is unwarranted. As such, because different analytical approaches have respective advantages and limitations, the extent to which researchers choose to use more complex models should be guided by considerations of their research question(s), hypothesis(es), and research contexts.

Acknowledgments

We are grateful to the anonymous reviewer for suggesting we test a bifactor ESEM. The MATCH study is supported by the New Brunswick Health Research Foundation (No. 20130729) and by the Social Sciences and Humanities Research Council and Sport Canada through the joint Sport Participation Research Initiative (Nos. 862-2010-0001 and 862-2014-0002). This manuscript was prepared while the first author was supported by a Canadian Cancer Society Career Development Award in Prevention. The fourth author holds a Canada Research Chair in Physical Activity and Mental Health.

Notes

[1]In the higher order model, the associations between the disturbances of lower order factors (i.e., competence, autonomy, and relatedness) and external variables can be assessed in addition to the association between the higher order factor (i.e., general PNS), but results from these nonstandard models are difficult to interpret (Chen et al., 2012).

[2]The complete set of results can be obtained from the corresponding author upon request.

[3]In an initial structural equation model with the bifactor CFA, 24 participants were identified as multivariate outliers based on Mahalanobis distance criteria and removed from the database. Given the results were not significantly different from the initial structural equation model, only the results from the structural equation model excluding multivariate outliers are presented in the interest of parsimony.

[4]Results are from a multigroup model where parameters were constrained to be equal across language groups.

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