Measuring Psychological Need States in Sport: Theoretical Considerations and a New Measure

Abstract

Objectives

Research guided by Self-determination Theory (Deci & Ryan, 1985; Ryan & Deci, 2017) has repeatedly demonstrated the importance of focusing on both the bright (satisfaction) and dark (frustration) sides of the three basic psychological needs. Recently, researchers have also argued for the utility of assessing a third need state, that of "unfulfillment". In this paper, we outline an effort to develop and provide initial validity evidence for scores of a new multidimensional and sport-specific measure, the Psychological Need States in Sport-Scale (PNSS-S), to assess the satisfaction, frustration, and unfulfillment of all three needs.

Method

In Study 1, we developed 46 candidate items, and tested evidence for the factorial structure of the responses to the newly developed items, internal consistency and discriminant validity of the subscale scores. Following refinement, the replication of the favored model was tested using an independent sample of athletes in Study 2. Evidence for the nomological network of the subscales of the new measure was also demonstrated in Study 2.

Results

Factor models incorporating all three need states showed poor fit with the data. However, following post-hoc modifications, a six-factor model assessing the need states of satisfaction and frustration, separately for autonomy, competence, and relatedness, was found to have good fit to the data. After refinement, the 29-item six-factor model was found to demonstrate good fit, good standardized factor loadings, factor correlations in the expected directions, and acceptable estimates of internal consistency in Study 2. Tests of nomological networks showed that the six need states were significantly predicted by contextual autonomy, competence, and relatedness support/thwarts as expected. Autonomy and competence need satisfaction were significantly associated with engagement; and competence and relatedness need satisfaction

were significantly associated with positive affect. In addition, autonomy and competence need frustration were significantly associated with exhaustion and all three need frustration states significantly predicted negative affect.

Conclusions

A tripartite conceptualization of the need states was not empirically supported. Nevertheless, the PNSS-S makes a unique contribution to the sport literature, as it represents the first sport-specific measure of six distinct, yet, correlated states of the satisfaction and frustration of autonomy, competence, and relatedness needs.

Key words: self-determination theory, need satisfaction, need frustration, need unfulfillment, scale development, exploratory structural equation modeling

Research grounded in Self-determination Theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2017) has repeatedly focused on both the bright and dark side experiences of the three basic psychological needs, and explored their differential associations with motivation and psychological functioning (Bartholomew, Ntoumanis, & Thøgersen-Ntoumani, 2011; Vansteenkiste & Ryan, 2013). Recently, researchers have also argued for the utility of assessing the unfulfillment of psychological needs as a third need state (e.g., Cheon et al., 2019; Costa, Ntoumanis, & Bartholomew, 2015), which, alongside need satisfaction and frustration, could aid a more comprehensive understanding of athlete motivation and well-being/ill-being. Existing investigations in sport, however, are either limited to the use of separate measures of perceived need satisfaction and need frustration (e.g., Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011; Ng, Lonsdale, & Hodge, 2011), or involve adaptations of non-sport-specific measures (e.g., Chen et al., 2015) to assess both these two need states simultaneously. Items of these measures also reflect references to interpersonal behaviors of significant others, as well as one's personal experiences that occur as a result of behaviors of significant others. In this two-study paper, we aimed to address the gap in the literature pertaining to the absence of a single sport-specific measure of the three need states by developing and providing initial validity evidence for a new multidimensional measure of athletes' psychological need states of satisfaction, frustration, and unfulfillment.

Basic Psychological Need Satisfaction, Frustration, and Unfulfillment

Assessments of basic psychological need relevant constructs in the SDT literature have undergone significant advancements in recent times. Traditionally, the state of need satisfaction was the focus of the theory. Researchers considered it to be a unipolar construct, with scores ranging from low to high. High scores on measures of need satisfaction were associated with adaptive outcomes. For example, in the sport context, high need satisfaction was shown to be associated with outcomes such as autonomous motivation (e.g., Ntoumanis

& Standage, 2009), subjective vitality (e.g., Adie, Duda, & Ntoumanis, 2008), positive affect (e.g., Mack et al., 2011), enjoyment (e.g., Quested et al., 2013), and positive developmental experiences (e.g., Taylor & Bruner, 2012). Contrastingly, low scores on measures of need satisfaction were associated with maladaptive outcomes. For example, in the context of sport, need satisfaction scores were found to be negatively associated with burnout (Hodge, Lonsdale, & Ng, 2008), and physical symptoms (Reinboth, Duda, & Ntoumanis, 2004). However, this pattern of results did not always hold, and some researchers found low need satisfaction scores to be unrelated to ill-being (e.g., Sheldon & Bettencourt, 2002; Reinboth & Duda, 2006; Quested & Duda, 2010).

The inconsistent results linking low need satisfaction to maladaptive outcomes were explicated by Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani (2011), who asserted that experiencing low levels of need satisfaction was qualitatively different to experiencing need frustration[1]. The researchers illustrated their point with the example of a male athlete experiencing loneliness in his sport. Such an experience might be the result of the athlete's inability to meaningfully connect with his teammates, or because he had been subjected to purposeful exclusion by his teammates. According to Bartholomew and colleagues (2011), the former would be a case of low need satisfaction (or what the researchers referred to as "need dissatisfaction"), and the latter would be a case of need frustration. Psychological need frustration was thus conceptualized as the negative personal experiential state of feeling that one's needs are actively undermined by others in a given context (Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011). Through this dual-process model, the researchers demonstrated need frustration to be a stronger (in an absolute sense) predictor of maladaptive outcomes relative to need satisfaction (e.g., burnout, disordered eating, depression, negative affect, and perturbed physical arousal; Bartholomew, Ntoumanis, Ryan, Bosch, & Thøgersen-Ntoumani, 2011).

Although Bartholomew and colleagues (2011) presented a conceptually-based argument for the distinction between need frustration and need dissatisfaction, they did not empirically test if the two constructs had unique factorial structure and predictive value; this consideration was examined by Costa et al. (2015). The researchers developed and assessed items to capture need dissatisfaction (defined as a "lack of need satisfaction", p. 12) and demonstrated, using multi-trait multi-method confirmatory factor analysis (MTMM; CFA), that these items could be perceived differentially from those of need frustration in the context of interpersonal relationships. However, in testing for evidence of differential predictive utility using structural equation modeling (SEM), the authors reported need dissatisfaction to have poor predictive effects, as it failed to predict the outcome measures of interpersonal competence (index of optimal functioning) and interpersonal sensitivity (index of diminished functioning) uniquely.

Costa and colleagues' (2015) attempt to assess the predictive ability of need dissatisfaction was speculated to be unsuccessful due to the outcomes they employed (Cheon et al., 2019). For instance, in the past, need frustration has been demonstrated to best predict "darker" outcomes associated with maladaptive functioning (e.g., burnout and disordered eating; Bartholomew, Ntoumanis, Ryan, Bosch et al., 2011). Need dissatisfaction, on the other hand, has been proposed to be a better predictor of more passive forms of maladaptive functioning, such as disengagement and boredom (Cheon et al., 2019).

In the case of the need for autonomy, the utility of the third need state of dissatisfaction, along with that of satisfaction and frustration was recently tested by Cheon et al. (2019) in a classroom intervention study. The researchers proposed that maladaptive student behaviors can take two forms. Students can either demonstrate reactive and defiant functioning in the form of disruptive behavior and oppositional defiance, or they can exhibit passive and diminished functioning, which could take the form of a lack of motivation,

boredom or disengagement. Defiant functioning was hypothesized to be a consequence of need frustration. In contrast, student passivity or diminished functioning was expected to occur as a result of need dissatisfaction. The researchers were able to demonstrate that students' experiences of autonomy dissatisfaction were distinct from autonomy satisfaction and autonomy frustration by employing exploratory structural equation modeling (ESEM). Furthermore, autonomy dissatisfaction was found to predict unique variance in classroom disengagement (an outcome of diminished functioning) along with low autonomy satisfaction, and low autonomy frustration. Cheon and colleagues (2019) clarified that autonomy dissatisfaction and low autonomy satisfaction were not to be equated as they were found to load on to separate factors with few cross-loadings. Additionally, they highlighted that autonomy dissatisfaction and autonomy frustration may each bear on disengagement in two different ways; the former more likely to result in passive disengagement, and the latter more likely to result in active disengagement. Thus, by demonstrating the three autonomy-relevant experiential states to be operationally distinct, and the considerable unique predictive utility of autonomy dissatisfaction in student classroom disengagement, Cheon et al. (2019) underscored the utility of examining not just one (need satisfaction) or two (need satisfaction and frustration), but three (need satisfaction, frustration, and dissatisfaction) need states.

The term need dissatisfaction has been used predominantly in the SDT literature (e.g., Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011; Cheon et al., 2019; Costa et al., 2015) to refer to the lack of need fulfillment. Some researchers have, however, used the term dissatisfaction to refer to the experience of need frustration (e.g., Neubauer & Voss, 2016, 2018; Sheldon & Hilpert, 2012). For example, Neubauer and Voss (2018) stated that the dimensions of need satisfaction and dissatisfaction are psychometrically distinct constructs, and not just mere opposites of one another. According to the Merriam-Webster Dictionary, however, dissatisfaction implies the opposite of satisfaction. In an effort to avoid

147 confusion, in this paper, we will henceforth use the term "need unfulfillment" to refer to the
148 negative experiential state of a lack of need fulfillment, and "need frustration" to refer to the
149 negative experiential state of perceiving one's needs to be actively being undermined in a
150 given setting.

151 The case for the third state of need unfulfillment is further emphasized by an
152 examination of the socio-contextual antecedents of the need states. The perceived
153 interpersonal style of social agents within one's environment could influence one's
154 experience of basic psychological need satisfaction, frustration, and unfulfillment (Cheon et
155 al., 2019). It is well established that perceived need support from others results in need
156 satisfaction, whereas perceived need thwarting results in need frustration (Vansteenkiste &
157 Ryan, 2013). The experience of unfulfillment is speculated to result from interpersonal
158 behaviors that are perceived to reflect need indifference on part of the social agent (Cheon et
159 al., 2019). Need indifferent have been posited to be neglectful of others' basic psychological
160 needs; on experiencing such interpersonal behaviors, one's needs are not actively thwarted,
161 but instead, are overlooked (Cheon et al., 2019).

162 Illustrative examples of the experience of need unfulfillment in sport could include
163 athletes feeling uncertain about their perspectives being valued, or experiencing ambiguity
164 with regards to why they do certain tasks in training sessions (autonomy unfulfillment);
165 feeling under-challenged and feeling that they are not improving and achieving as much as
166 they would like to (competence unfulfillment); or feeling as though they do not having much
167 in common with others in their team, being disinterested in their teammates, and feeling they
168 do not quite "fit in" (relatedness unfulfillment).

169 **Existing Self-report Assessments of Need States in Sport and Other Life Domains**

170 The original focus on only the construct of need satisfaction resulted in the
171 development of numerous self-report measures to assess this need state in a variety of

contexts such as education (e.g., Activity-Feeling States Scale; AFS, Reeve & Sickenius, 1994), work (e.g., Basic Needs Satisfaction at Work Scale; BNSW-S, Deci et al., 2001; Work-related Basic Need Satisfaction Scale; W-BNS, Van den Broek et al., 2010), and exercise (Basic Psychological Needs in Exercise Scale; BPNES, Vlachopoulos & Michailidou, 2006; Psychological Need Satisfaction in Exercise Scale; PNSES, Wilson, Rogers, Rodgers, & Wild, 2006). For investigations with athletes, researchers simply adapted such measures to make them relevant to the sport context (e.g., Gagne, Ryan, & Bargmann, 2003; Hodge, et al., 2008).

To address the issue of the absence of a sport-specific measure, Ng and colleagues (2011) developed and provided initial validity evidence for the Basic Needs Satisfaction in Sport Scale (BNSSS). The 20-item measure comprises five dimensions assessing autonomy satisfaction (three factors: choice, internal perceived locus of causality- IPLOC, and volition), competence satisfaction, and relatedness satisfaction. The first empirical assessment of need frustration as a distinct construct was conducted by Bartholomew, Ntoumanis, Ryan, and Thøgersen-Ntoumani (2011) who developed and provided initial validity evidence for responses to the Psychological Need Thwarting Scale (PNTS). The researchers found support for a 12-item, three factor model assessing the frustration of each of the three basic psychological needs. Current assessment of these need states is limited to the measurement of satisfaction and frustration using the two aforementioned scales that have been developed based on different samples (i.e., the BNSSS with adult athletes and the PNTS with youth athletes), and have dissimilar scale anchors (1 = *not at all true* to 7 = *very true* for the BNSSS, and 1 = *strongly disagree* to 7 = *strongly agree* for the PNTS).

In non-sport contexts, researchers have recently examined both the positive and negative experiential need states simultaneously (e.g., Basic Psychological Need Satisfaction and Frustration Scale, BPNSFS, Chen et al., 2015; The Balanced Measure of Psychological

Needs, BMPN, Sheldon & Hilpert, 2012; The Need Satisfaction and Frustration Scale, NSFS, Longo, Gunz, Curtis, & Farsides, 2016). For example, the 24-item BPNSFS assesses autonomy satisfaction and frustration, competence satisfaction and frustration, and relatedness satisfaction and frustration. The scale developers provided evidence for the dimensionality of the responses to the measure across a culturally diverse sample. Although researchers have used this measure for investigations in sport (e.g., Li, Ivarsson, Lam, & Sun, 2019), physical education (e.g., Haerens, Aelterman, Vansteenskiste, Soenens, & Petegem, 2015), and exercise (Emm-Collison, Standage, & Gillison, 2016), items of non-sport specific measures might reflect experiences or situations that are not of particular relevance to athletes or sport.

Additionally, a number of conceptual issues have been associated with the items of the scales currently available for use in research on this topic, both in and outside of the sport domain. One key issue with many of the existing measures of need states is their employment of some items that assess the social context (in terms of need support or need thwarting), instead of assessing the feeling states (in terms of need satisfaction or need frustration). In the sport context, for instance, the BNSSS includes the item “There are people in my sport who care about me” as an item tapping relatedness satisfaction. However, this item entirely reflects the actions of others in the form of relatedness support, without assessing how these actions make one feel. Another example of an item assessing behaviors of others instead of one’s feeling states is “There were people telling me what I had to do” from the BMPN (Sheldon & Hilpert, 2012). Some items in the PNTS tap personal experiences of need frustration as a result of actions of others’ in one’s social contextual (e.g., “There are times when I am told things that make me feel incompetent”); they do not assess the social context per se (an example of the latter would be an item which would indicate that an athlete is told by their coach that they are incompetent). Being told that one is incompetent is not the same

as feeling incompetent because one might not necessarily lead to the other. Nevertheless, revisions to items of the PNTS so that they solely assess one's personal experiences of need frustration, would be advantageous.

Some existing measures have limited utility because they include items that conflate need frustration and need unfulfillment. For example, the BMPN includes the subscale of dissatisfaction, which is defined as the "salient absence of the experiences" of autonomy, competence, and relatedness satisfaction (p. 442). However, the subscale includes items tapping need frustration (e.g., "I had a lot of pressures I could do without"), as well as items potentially tapping need unfulfillment (e.g., "I felt unappreciated by one or more people"). As researchers have demonstrated need frustration to be a good predictor of "darker" outcomes (e.g., disordered eating, Bartholomew, Ntoumanis, Ryan, Bosch et al., 2011), a more accurate representation of the experience of need frustration might be achieved from a subscale comprising only of items that capture the "darker" or "more deleterious" experiential states. An illustrative example of an item capturing the experience of competence frustration would be an athlete who feels like a failure. Competence unfulfillment, on the other hand, would be more appropriately assessed by items reflecting feelings that arise from lack of competence fulfillment; an example being an athlete who feels he/she cannot do all of the tasks in training.

Confirmatory factor analysis (CFA) has been identified to be the most pertinent approach for scale development efforts in this area because it assumes one leverages a strong theoretical base (Hurley et al., 1997; Williams, 1995). As such, CFA has been employed as the primary analytical technique to test the factorial structure of the need states in the measures described in this section. However, due to the stringent requirement of zero cross-loadings between items and non-intended factors, CFA may lead to overestimated correlations between factors and undermining of discriminant validity evidence (Marsh,

Morin, Parker, & Kaur, 2014). For example, correlations as high as .83 have been observed among factors in the BNSSS and PNTS.

ESEM (Asparouhov & Muthen, 2009), bifactor modeling, and a combination of the two can aid in managing the limitations associated with the use of CFA (Morin, Arens, & Marsh, 2016). First, in ESEM, it is acknowledged that items are not solely associated with the dimension that they have been developed to assess; they are also related to other non-intended dimensions. Cross-loadings between items and non-intended factors are admissible in ESEM, such that factor loadings are not as overestimated as compared to those resulting from CFA. Second, bifactor models (Holzinger & Swineford, 1937; Reise, 2012) have utility in examining multidimensional instruments as they allow for concurrent estimation of one or more general-factors (e.g., need satisfaction) that explain the covariance among all items, as well as more specific-factors (e.g., autonomy, competence, and relatedness satisfaction) which explicate the commonality among item sub-dimensions over and above the general factor (Chen, Hayes, Carver, Laurenceau, & Zhang, 2012; Myers, Martin, Ntoumanis, Cemili, & Bartholomew, 2014). By juxtaposing bifactor models against CFA or ESEM models, researchers can ascertain whether general-factors alone are adequate, or if they function alongside specific-factors. Third, bifactor ESEM models (e.g., Sánchez-Oliva, Morin, Teixeira, Carraça, Palmeira, & Silva, 2017; Tóth-Király, Morin, Bőthe, Orosz, & Rigó, 2018) can be advantageous as they not only allow for the presence of cross-loadings between items and non-intended factors, but also simultaneously enable the assessment of general- and specific-factors.

Present Research

A systematically developed measure of all three need states, with items that are all pertinent to sport participation, is necessary for psychometrically sound assessments of these key constructs in sport and therefore a more comprehensive understanding of the athletic

experience. We aimed to develop and test the initial validity evidence for scores of the Psychological Need States in Sport-Scale (PNSS-S), a new multidimensional measure assessing athletes' experiences of need satisfaction, frustration and unfulfillment, separately for autonomy, competence, and relatedness. Over two studies, we aimed to assess validity evidence testing the internal structure (to determine the extent to which the items of a measurement instrument are in line with the construct of interest via factor analyses; Chan, 2014) and relations to other variables (to examine nomological networks of antecedent and consequence variables surrounding the construct of interest using structural equation modeling) in accordance with the *Standards for Educational and Psychological Testing* (The *Standards*; developed by the American Educational Research Association [AERA], American Psychological Association [APA], and National Council on Measurement in Education [NCME], 2014). Additionally, we sought to examine evidence for reliability and discriminant validity of the subscale scores of the PNSS-S.

Study 1

The aim of Study 1 was to (a) develop a pool of items to assess need satisfaction, frustration, and unfulfillment among athletes, and (b) determine evidence for internal structure, internal consistency, and discriminant validity of the subscale scores of the new measure.

Method

Participants

The sample consisted of 301 competitive athletes (N_{male} = 92, N_{female} = 209), with an average age of 20.27 years (*SD* = 7.36), recruited in the United Kingdom (*n* = 195) and in Australia (*n* = 106). Athletes competed in a variety of individual and team sports such as Australian football, soccer, swimming, and netball. One hundred and seventy-nine athletes

were competitive at the club level, 19 at the university level, 47 at the regional/state level, 27 at the county level, 20 at the national level, and six at the international level at the time of the study. Three athletes did not report the level at which they competed. Athletes reported an average competitive experience of 9.43 years (*SD* = 7.29), trained on average 2.47 times a week (*SD* = 1.56), and had been training with their current main coach for 1.95 years (*SD* = 3.16).

Measure

PNSS-S (Psychological Need States in Sport-Scale). The PNSS-S items were designed to examine athletes' experiences of satisfaction, frustration, and unfulfillment of their three basic psychological needs for autonomy, competence, or relatedness. Sixteen items were written to assess the satisfaction of the needs. The content of these items was informed by existing self-report measures of need satisfaction in sport or similar contexts (e.g., BNSSS, Ng et al., 2011; BPNES, Vlachopoulos & Michailidou, 2006; PNSES, Wilson, Rogers, Rodgers, & Wild, 2006, autonomy items collated by Standage, Duda, & Ntoumanis, 2003; the competence subscale of the Intrinsic Motivation Inventory, IMI, McAuley, Duncan, & Tammen, 1980, and the acceptance subscale of the Need for Relatedness Scale, NRS - 10, Richer & Vallerand, 1998). Items began with the stem "In my main sport, I…". An example of an item assessing autonomy satisfaction is "have the freedom to make training decisions". Items were carefully written to avoid explicit references to the social context (e.g., "feel supported").

Items of the PNTS (Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011) were refined so as to reflect the "darker" experience of need frustration while avoiding references to the social context (e.g., "feel useless" and "feel isolated"). Only one of the PNTS items was retained; five others were updated in terms of their wording. Nine

completely new items were written. Thus, a total of 15 items were written to assess need frustration.

Finally, 15 items for need unfulfillment were developed by our research team. Need unfulfillment was defined as the feeling state of one's needs being set aside or neglected (Cheon et al., 2019) and "feeling that something is not as good as it should be" (Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011, p. 78). Based upon this operational definition, an initial pool of items was developed by the first author in collaboration with two senior academic experts of the research team. These items were then reviewed by the rest of the research team who made suggestions for improving these items and/or proposed alternative items. All authors agreed that the final set of items demonstrated sufficient face and content validity evidence. An example for competence unfulfillment is "feel that I am not good enough". Recommendations by DeVellis (2012) informed the item writing process. Items were kept brief, were not double-barreled, did not borrow heavily from any one existing measure, did not tap multiple needs, and did not explicitly refer to the social context. The initial item pool is listed in Supplementary File 1.

A 7-point response scale with the anchors 1 = *strongly disagree*, 4 = *neither disagree nor agree*, 7 = *strongly agree* was employed. The 7-point response format is congruent with previous measures assessing these constructs in sport (e.g., Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani; Ng et al., 2011). Seven-point rating scales are also in line with survey takers' preferences and perform well in terms of their discriminative power (Preston & Coleman, 2000). Prior to survey administration, participants were advised to consider their experiences in competition and in training and indicate the degree to which they disagreed or agreed with each statement. Participants were assured that were no right or wrong responses to encourage honest responses.

Procedure

Ethical approval was obtained for both studies in this paper from the first author's university ethics committee. Subsequently, sports club committee members and coaches were contacted in order to explain the purpose of the study and to invite their athletes to participate. In some cases, athletes were contacted directly. Athletes were eligible if they trained with a coach at least once a week, competed regularly during the sport season, and were over 14 years of age. Participation in the study was voluntary. Parental consent was sought for participants in the age group 14-17 years. All athletes completed a consent form prior to taking the survey, which was administered in person either before or after a training session.

Data Analyses

The factorial structure of the new measure was examined using CFA, ESEM, and bifactor CFA and ESEM. The factor structures tested were theoretically justifiable and targeted the three states of satisfaction, frustration, and unfulfillment as well as just the two states of satisfaction and frustration (see Table 1, Models 1-24, and Supplementary File 2) separately for the needs of autonomy, competence, and relatedness. Statistical analyses were conducted in Mplus 8.0 (Muthén & Muthén, 1998 - 2017).

For CFA models, latent factors were permitted to correlate, with cross-loadings of items on unintended factors being constrained to zero. Similar to CFA, in the case of ESEM models, items were allowed to load on their predefined latent factors, but cross-loadings were freely estimated, albeit they were targeted to be as close as possible to zero using target rotations (Browne, 2001). For the bifactor CFA models, items could load on their predefined general-factors (G-factors) and specific-factors (S-factors). S-factors were designated as orthogonal to one another, and to the G-factor(s). If a model had multiple G-factors, these were estimated as correlated. Lastly, bifactor ESEM models were operationalized in manner

similar to the bifactor CFA models, with the exception of employing orthogonal bifactor target rotation for the S-factors (Reise, 2012).

Goodness-of-fit was evaluated using the χ^2 goodness-of-fit index, Comparative Fit Index (CFI), Tucker-Lewis index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square (SRMR). Adequate and excellent model-to-data fit was indicated by CFI and TLI values of or greater than .90 and .95 respectively, and RMSEA and SRMR values of or smaller than .08 and .06, respectively (Hooper, Coughlan, & Mullen, 2008; Hu & Bentler, 1999; Marsh, Hau, & Grayson, 2005; Marsh, Hau, & Wen, 2004). The strength of factor loadings was informed by the recommendations put forth by Comrey and Lee (1992) (i.e., > .71 = "excellent", >.63 = "very good", > .55 = "good", >.45 = "fair", <.30 = "poor"). The internal consistency of the subscale scores was determined through an assessment of Raykov's composite reliability coefficient (RHO; Raykov, 1997). In line with the recommendation by Nunnally (1978), internal consistency estimates greater than .70 were deemed adequate. Factor correlations were examined for evidence of discriminant validity (Brown, 2015), with values of or over .80 suggesting substantial overlap amongst the factors of the measure (John & Benet-Martinez, 2000).

Results

Item Distribution

Prior to the factor analyses, data were scanned for univariate normality. Median values for skewness and kurtosis for the 46 items were .581 and .816 respectively, and ranged from -2.00 to 3.41 for skewness, and -1.00 to 8.00 for kurtosis. Given the presence of a few large values, data were analyzed using a robust maximum likelihood estimator (MLR). MLR yields robust fit indices and standard errors in the case of non-normal data and operates well when categorical variables with a minimum of five response categories are employed (Bandalos, 2014; Rhemtulla, Brosseau-Laird, & Savalei, 2012).

Configurations Involving the Three Need States (Satisfaction, Frustration, and Unfulfillment)

Results of the factor analyses for need satisfaction, frustration, and unfulfillment are reported in Table 1. In total, 12 models pertaining to various configurations of the three need states were tested. Most of these models demonstrated poor model-data fit, some did not converge, and problems were encountered with other models for which information relevant to model fit (e.g., standard errors) could not be calculated. Increasing the number of iterations and changing the convergence criteria failed to resolve problems with model convergence and model fit (more details are available from the lead author upon request). An examination of the parameter estimates of the models that did converge indicated several items with poor standard factor loadings (<.30) and cross-loadings on unintended factors (>.20) that were larger than the target factor loadings. At this stage, items assessing the new dimension of need unfulfillment were also examined on their own (i.e., without those assessing need satisfaction and frustration). Model results are presented in Supplementary File 4. The three-factor ESEM solution demonstrated promise, although it did not reach an acceptable TLI level. Internal consistency estimates based on this model were found to be adequate, with Raykov's composite reliability coefficient for autonomy unfulfillment = .71, competence unfulfillment = .75, and relatedness unfulfillment = .80. These results indicated that the issue was not that the need unfulfillment items were inappropriate, but that there was no evidence to demonstrate that need unfulfillment could be modeled as a distinct need state when tested alongside the need satisfaction and frustration. As no support was found for any configuration involving the three need states, the focus of the study shifted to assessing the two experiential states of need satisfaction and frustration (for which there is considerable support in the literature, e.g., Chen et al., 2015).

<Insert Table 1 here>

Configurations Involving the Two Need States (Satisfaction and Frustration)

Of the 12 models that were tested pertaining to the two need states, only one model (Model 22; Bifactor ESEM with two G- and six S-factors) demonstrated acceptable fit [χ^2 = 458.463 (262), p < .001, CFI = .95, TLI = .91, SRMR = .02, RMSEA = .05 (90% CI .04, .056]. However, an examination of the factor loadings indicated that the G-factor of need frustration had only two salient significant loadings above .30, whereas the G-factor of need satisfaction had no items with significant factor loadings. Further examination of the S-factors indicated that autonomy satisfaction S-factor had no items with significant factor loadings, making this model unsuitable. Factor loadings for bifactor models are presented in Supplementary File 3. One model that seemed promising, even though it did not reach an acceptable TLI level, was Model 18 (Six-factor correlated ESEM model). In this model, all factors demonstrated at least three items with significant loadings over .30 on their target factors, only a few items exhibited unintended cross-loadings which were smaller than target factor loadings, and all factor correlations were in expected directions.

At this stage, a decision was made to first examine one-factor CFAs for the factors in this model, systematically remove problematic items, and then re-run the six-factor ESEM model with the best performing items. For these analyses, CFA was seen as an appropriate approach, given that the goal was to select items with strong primary factor loadings to ultimately inform the final six-correlated factor ESEM model. In doing so, for all the CFAs, model misspecification was identified through assessments of standardized factor loadings and modification indices, in a manner similar to item reduction approaches used in previous SDT-based scale development procedures (e.g., Rocchi, Pelletier, Cheung, Baxter, & Beaudry, 2017). Alongside these statistical criteria, the conceptual coverage of the items was also considered (i.e., ensuring that the remaining items captured autonomy, competence, and relatedness). Items with standardized factor loadings below .30, as well as items with

multiple (two or more) moderate-sized or large modification indices (over 10) were taken into consideration for deletion. As such, 10 of the 31 items were deleted in a systematic manner in several iterations. The resultant one-factor models had excellent fit (see Table 2).

<Insert Table 2 here>

Subsequently, the six-correlated factor ESEM model was re-tested with the remainder of the 21 items from the six one-factor CFA models (see Table 2). This revised model demonstrated good fit [χ^2 (99) = 171.110, $p < .001$, CFI = .97, TLI = .94, SRMR = .02, RMSEA .05 (90% CI .04, .06)]. With the exception of two items (one each for competence satisfaction and relatedness satisfaction), standardized factor loadings were significant and above .30 (range .28 to .89; see Table 3). Few cross-loadings greater than .20 on unintended factors were present. Subscale correlations ranged from -.18 to .60 and were in the expected directions (see Table 4). Raykov's composite reliability coefficients are also reported in Table 4. Barring competence satisfaction (.66) and relatedness satisfaction (.52), these were over .70 for all factors.

<Insert Table 3 here>

<Insert Table 4 here>

The two items with standardized factor loadings below .30 ("I feel that I am improving", and "I feel valued") were deleted, and 10 new items were written in an effort to have a more equal number of items per subscale. It was expected that these new items would also help improve estimates for the two subscales with internal consistency estimates under .70 when examined in a new sample of athletes in Study 2.

Study 2

The aims of Study 2 were two-fold. First, we aimed to test the revised item pool from Study 1 with an independent sample of athletes. Second, we also aimed to test the

nomological network of the six dimensions of the psychological need states by examining their relations with perceived coach interpersonal behaviors and positive and negative athlete outcomes. Based on previous literature linking perceptions of coach need support and thwarting to athlete need satisfaction and frustration (e.g., Pulido, Sanchez-Oliva, Sanchez-Miguel, Amado, & Garcia-Calvo, 2018; Rocchi, Pelletier, & Desmarais, 2017), it was hypothesized that perceived coach autonomy support would primarily predict athlete autonomy satisfaction, perceived coach competence support would primarily predict athlete competence satisfaction, and perceived coach relatedness support would primarily predict athlete relatedness satisfaction. Contrastingly, it was hypothesized that perceived coach autonomy thwarting would primarily predict athlete autonomy frustration, perceived coach competence thwarting would primarily predict athlete competence frustration, and perceived coach relatedness thwarting would primarily predict athlete relatedness frustration.

In terms of the relations between the need states and athlete outcomes, based on previous literature in sport and other domains (e.g., Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011; Chen et al., 2015; Gunnell, Crocker, Wilson, Mack, & Zumbo, 2013), it was hypothesized that satisfaction of each of the three needs would predict the positive athlete outcomes of dedication and positive affect independently. Contrastingly, the frustration of each of the three needs was hypothesized to predict the negative athlete outcomes of exhaustion and negative affect independently.

Method

Participants

The sample consisted of 333 competitive athletes recruited in Australia (N_{male} = 183, N_{female}= 150), with an average age of 19.99 years (*SD* = 5.43). Athletes represented a number of individuals and team sports such as Australian football, basketball, and athletics. One hundred and ninety-nine athletes competed at the club level, 81 at the state level, 39 at the

national level, and 14 competed internationally. They had been competing in their sports for 8.75 years (*SD* = 5.32), had been training with their main coaches for 2.07 years (*SD* = 1.67) on an average of 2.51 times per week (*SD* = 1.62).

Procedure

Athletes were recruited using procedures similar to those described in Study 1. In addition to collecting data in person, the questionnaire was also made available online, via Qualtrics, and was advertised through social media. All participating athletes were eligible to go into a prize draw to win shopping vouchers. Undergraduate student athletes (*n* = 5) at the School of Psychology at the first author's university were offered course credit (2 points) for participation.

Measures

Athlete need satisfaction and frustration. The 29-item PNSS-S developed in Study 1 was used to assess athletes' states of satisfaction and frustration across the three basic psychological needs. Similar to Study 1, athletes were requested to consider their general experiences in their main sport, and indicate the extent to which they disagreed or agreed with each statement using a 7-point response format (1 = *strongly disagree*, 4 = *neither disagree nor agree*, 7 = *strongly agree*).

Coach interpersonal behaviors. The 24-item Interpersonal Behaviors Questionnaire in Sport (IBQ in Sport; Rocchi, Pelletier, & Desmarais, 2017) was implemented to examine athletes' perceptions of their coaches' interpersonal behaviors. The measure consists of six factors representing supportive and thwarting coach behaviors pertaining to the three basic psychological needs. The items began with the stem "My Coach…". Illustrative items from the competence supportive and thwarting subscales include "Provides me valuable feedback", and "Points out that I will likely fail", respectively. Athletes indicated their disagreement or agreement with each statement using a 7-point response scale (1 = *do not agree at all* to 7 =

completely agree). The six-factor structure of the IBQ in Sport was tested using ESEM. Model-to-data fit was found to be excellent [χ^2 (147) = 280.033, $p < .001$, CFI = .98, TLI = .96, SRMR = .01, RMSEA = .05 (90% CI .04, .06)]. Raykov's reliability estimates for the subscale scores ranged from .82 to .91.

Positive outcomes. The dedication subscale of the Athlete Engagement Questionnaire (AEQ; Lonsdale, Hodge, & Jackson, 2007) was employed to assess dedication, which reflects "a desire to invest effort and time towards achieving goals one views as important" (p. 472). The subscale consists of four items, to which participants responded using a 5-point rating scale (1 = *almost never* - 5 = *almost always*). An example item is "I am determined to achieve my goals in sport". Fit for the one-factor CFA model was excellent [χ^2 (2) = .511, $p < .001$, CFI = 1.000, TLI = 1.012, SRMR = .00, RMSEA = .00 (90% CI .00, .07)]. Ravkov's composite reliability coefficient for the subscale score was .91.

The 10-item positive affect subscale of the 20-item short version of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was used as a second positive outcome. Athletes indicated the extent to which they had experienced emotions such as "excited" and "proud" over the past month using a 5-point scale ranging from (1 = *very slightly or not at all* - 5 = *extremely*). Fit for the one-factor CFA model was good [χ^2 (35) = 93.069, $p < .001$, CFI = .96, TLI = .95, SRMR = .03, RMSEA = .07 (90% CI .05, .09)]. Ravkov's composite reliability coefficient for the subscale score was .93.

Negative Outcomes. The emotional and physical exhaustion subscale of the Athlete Burnout Questionnaire (ABQ; Raedeke & Smith, 2001) was administered as a negative athlete outcome. Participants responded to five items using a 5-point response format (1 = *almost never* - 5 = *almost always*). An example of an item is "I have been feeling physically worn out from my sport". Fit for the one-factor CFA model was excellent [χ^2 (5) = 10.862, *p*

542 < .001, CFI = .99, TLI = .98, SRMR = .02, RMSEA = .06 (90% CI .00, .12)]. Raykov's
543 composite reliability coefficient for the subscale score was .91.
544 The 10-item positive affect subscale of 20-item short version of the Positive and
545 Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was employed as the
546 second negative athlete outcome. Athletes were requested to indicate the extent to which they
547 had experienced emotions such as "upset" and "nervous" over the past month using the same
548 5-point response format as the positive affect subscale. Fit for the one-factor CFA model was
549 poor [χ^2 (35) = 130.507, p < .001, CFI = .87, TLI = .83, SRMR = .06, RMSEA = .09 (90% CI
550 .07, .12)]. Ravkov's composite reliability coefficient for the subscale score .83.
551 **Data Analyses**
552 **Scale structure, reliability, and discriminant validity evidence.** The revised six-
553 factor ESEM solution was tested[2] to examine whether the factor structure held when assessed
554 with a new sample of athletes. Similar to Study 1, a multifaceted approach informed model-
555 to-data fit, Raykov's reliability coefficient served as an estimate of internal consistency, and
556 correlations between the subscales served as evidence of discriminant validity.
557 **Structural equation modeling (SEM).** Four separate analyses were conducted to
558 examine the relations between a) dimensions of need support and need satisfaction, b)
559 dimensions of need satisfaction and the outcomes of dedication and positive affect, c)
560 dimensions of need thwarting and need frustration, and d) dimensions of need frustration and
561 the outcomes of exhaustion and negative affect. Researchers have previously taken a similar
562 approach in order to avoid issues of multicollinearity that may arise from including all the
563 variables in the same analysis (e.g., Chen et al., 2015). We faced problems with net
564 suppression effects when attempting to analyse all variables together[3]. All analyses were
565 completed in Mplus 8.0.
566 **Results**

Data were screened for normality before conducting the main analyses. Median values for skewness and kurtosis were -.306 and 1.544, respectively. Skewness values ranged from -1.868 to 1.971, and kurtosis values ranged from -1.137 to 4.637. As such, all analyses were conducted using MLR.

Scale Structure, Reliability, and Discriminant Validity Evidence

Fit indices for the six-factor ESEM model were indicative of good fit [χ^2 (247) = 438.72, $p < .001$, CFI = .97, TLI = .95, SRMR = .02, RMSEA = .05 (90% CI .04, .06)]. Standardized factor loadings were found to be statistically significant and ranged from .35 to .86. Six items had significant cross-loadings over .20 on unintended factors (e.g., "I am able to overcome challenges", a competence satisfaction item, had a cross loading of .35 on the autonomy satisfaction subscale, and the autonomy frustration item "feel excessive pressure" had a cross-loading of .29 on the competence frustration subscale). However, in all such instances, cross-loadings were lower than intended factor loadings, and hence not considered to be overly problematic. Factor correlations were in the expected directions, and internal consistency estimates were above the recommended value of .70 for all subscales scores. Standardized factor loadings, cross-loadings, item means, standard deviations, skewness, kurtosis are reported in Table 5. Factor correlations and internal consistency estimates are reported in Table 6.

<Insert Table 5 here>

<Insert Table 6 here>

SEM

First, a correlational analysis was conducted to explore the associations between the variables (see Table 7). Next, the relations between the variables entered in the SEM were examined. Model-to-data fit was found to be acceptable [χ^2 (267) = 745.712, $p < .001$, CFI = .93, TLI = .90, SRMR = .04, RMSEA = .07 (90% CI [.07, .08)] in the case of the six-factor

model with three subscales pertaining to perceptions of coaches' need supportive behaviors and the three athlete need satisfaction subscales. Autonomy satisfaction was primarily predicted by perceived autonomy support, competence satisfaction was primarily predicted by perceived competence support, and relatedness satisfaction was primarily predicted by perceived relatedness support. Standardized path coefficients for the structural portion of the model are reported in Figure 1.

<Insert Table 7 here>

<Insert Figure 1 here>

Model-to-data fit was found to be acceptable [χ^2 (343) = 765.357, $p < .001$, CFI = .93, TLI = .92, SRMR = .04, RMSEA = .06 (90% CI .05, .07)] for the five-factor model with the three athlete need satisfaction subscales and two outcomes of dedication and positive affect. Dedication was significantly predicted by autonomy and competence satisfaction, and positive affect by competence and relatedness satisfaction. Standardized path coefficients for the structural portion of the model are reported in Figure 2.

<Insert Figure 2 here>

Model-to-data fit was found to be excellent [χ^2 (244) = 354.479, $p < .001$, CFI = .98, TLI = .97, SRMR = .02, RMSEA = .04 (90% CI .03, .04)] in the case of the six-factor model with three subscales pertaining to perceptions of coaches' need thwarting behaviours and the three athlete need frustration subscales. Autonomy frustration was primarily predicted by perceived autonomy thwarting, and competence frustration was primarily predicted by perceived competence thwarting. Unexpectedly, relatedness frustration was marginally better predicted by perceived competence thwarting than by perceived relatedness thwarting. Standardized path coefficients for the structural portion of the model are reported in Figure 3.

<Insert Figure 3 here>

Model-to-data fit was found to be acceptable [χ^2 (345) = 585.433, $p < .001$, CFI = .95, TLI = .94, SRMR = .04, RMSEA = .05 (90% CI .04, .05)] for the five-factor model with the three athlete need frustration subscales and two outcomes of exhaustion and negative affect. Exhaustion was significantly predicted by autonomy and competence frustration, and negative affect by autonomy, competence, and relatedness frustration. Standardized path coefficients for the structural portion of the model are reported in Figure 4.

<Insert Figure 4 here>

Discussion

Since the development of the PNTS (Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011), SDT-based research on psychological needs has increasingly demonstrated the importance of focusing on both experiences of need satisfaction and need frustration. Recently, researchers have also argued for the utility of assessing a third need state, that of unfulfillment. These theoretical developments have resulted in continued refinement of the terminology used in this area as well as attempts to develop measures that operationalize these key constructs. The present work aimed to further extend these efforts and address the conceptual and psychometric issues that have been associated with existing measures in this area. Specifically, given the absence of a sport-specific measure to examine experiences of both need satisfaction and need frustration, and the growing interest in the potential utility of assessing need unfulfillment, we aimed to develop a new multidimensional measure assessing athletes' experiences of satisfaction, frustration, and unfulfillment, separately for autonomy, competence, and relatedness needs.

Dimensionality of the Need States

One of our aims was to clearly conceptualise and systematically assess need unfulfillment, the third state which has garnered increasing interest over the recent years

(e.g., Cheon et al., 2019; Costa et al., 2015), alongside those of need satisfaction and need frustration. We tested various theoretically plausible configurations of the three need states using CFA, ESEM, and bifactor analyses, yet none of the representations pertaining to the simultaneous assessment of satisfaction, frustration, and unfulfillment were supported by the data. At this stage, the evidence for the existence of need unfulfillment as a distinct construct appears to be mixed. Support for its existence is based on Costa et al.'s (2015) finding via MTMM analysis that need unfulfillment is empirically distinct from need satisfaction and frustration. Furthermore, in the case of the need of autonomy, unfulfillment was shown to have unique utility in predicting disengagement, an outcome of diminished functioning by Cheon et al. (2019). However, findings from our paper indicate a lack evidence that need unfulfillment is distinct from need satisfaction and frustration. In addition, Costa et al. (2015) found need unfulfillment to have poor predictive value. Perhaps the items we created to assess need unfulfillment were not operationalised in a manner that rendered them adequately distinguishable from those of need satisfaction and frustration. Although the items were clearly distinct to our research team, it is possible that athletes are not able to see such distinctions and, therefore, perhaps this line of work has limited practical value.

In light of the extant supporting literature for a model involving the two need states of satisfaction and frustration (e.g., Chen et al., 2015), we subsequently shifted the focus of the study towards developing and providing initial validity evidence for the first sport-specific measure of these two need states. Of all the theoretically justifiable configurations that were tested, a six-factor solution ESEM involving the satisfaction and frustration of each of the three basic psychological needs, appeared promising. Our analyses began with ESEM, before testing single factor CFA solutions, as we were mindful that the three psychological needs have been shown to be empirically interrelated in the SDT literature (Ryan & Deci, 2017), with the potential for items to cross-load on additional factors. As CFAs have strict

requirements of zero-cross loadings of items on non-intended factors (Asparouhov & Muthén, 2009), starting out with single-factor CFAs would have resulted in the loss of conceptually relevant items that cross-loaded on non-target constructs. Following some modifications in Study 1, the cross-validation of the revised model was supported in Study 2.

In essence, the results indicated that athletes' responses to the PNSS-S items could be best explained by a model comprising six dimensions of autonomy satisfaction and frustration, competence satisfaction and frustration, and relatedness satisfaction and frustration, scores of all of which were internally reliable. Aligned with similar findings from non-sport-specific contexts (e.g., Chen et al., 2015; Cordeiro, Paixao, Lens, Lacante, & Luyckx, 2016; Longo et al., 2016), results of this research suggest that athletes' need states are comprised of six dimensions that are distinct, yet correlated, and should hence be assessed independently.

Evidence for Nomological Network

In an effort to provide initial evidence for the nomological network surrounding the subscales of the PNSS-S, we examined the relations between the need states, perceived coach interpersonal behaviours, and positive and negative athlete outcomes. Autonomy, competence, and relatedness satisfaction were primarily predicted by their corresponding contextual factors of perceived coach autonomy, competence, and relatedness support, respectively. In contrast, autonomy and competence frustration were primarily predicted by their corresponding contextual factors of perceived coach autonomy, and competence thwarting, respectively. These findings are in line with theory (e.g., Deci & Ryan, 2000; Vansteenkiste & Ryan, 2013) and previous investigations linking perceptions of interpersonal behaviors to the need states (e.g., Pulido et al., 2018; Rocchi, Pelletier, & Desmarais, 2017).

Contrary to our hypothesis, relatedness frustration was slightly better predicted by perceived competence thwarting, as compared to relatedness thwarting. An examination of

690 the items of the relatedness thwarting subscale of the IBQ in sport (Rocchi, Pelletier, &
691 Desmarais, 2017) could help explain this finding. The subscale includes items that are better
692 representative of what Cheon et al. (2019) refer to as need indifference (e.g., "My coach is
693 distant when we spend time together"), as opposed to actively thwarting of it (e.g., an
694 example of such an item would be "My coach rejects me"). In comparison to need thwarting,
695 which involves active undermining of others' basic psychological needs, need indifference is
696 proposed to only "set aside" others' needs (Cheon et al., 2019). Resultantly, need indifference
697 may not predict need frustration with the same strength as need thwarting behaviors.
698 Competence thwarting may have emerged as a stronger predictor of relatedness frustration
699 given that the need for competence has been found to be particularly salient in the context of
700 sport (e.g., Adie, Duda, & Ntoumanis, 2012). Additionally, as the need-specific dimensions
701 of interpersonal behaviors are stipulated to be interrelated (e.g., Ryan, 1991; Ryan & Deci,
702 2017), competence thwarting may have emerged as a stronger predictor as a result of the
703 inadequacy of the relatedness thwarting subscale.

704 In terms of the relations between the dimensions of the need states and athlete
705 outcomes, the satisfaction of autonomy and competence needs predicted athlete dedication in
706 a significant manner, whereas the satisfaction of competence and relatedness needs predicted
707 positive affect in a significant manner. Dedicating time and energy to sport-related
708 aspirations and deriving positive emotions from sport engagement are likely consequences
709 for athletes who experience a sense of self-directedness, effectance, and connectedness in
710 their sport. The satisfaction of all three basic psychological needs is considered to be
711 indispensable for well-being (Deci & Ryan, 2000), and researchers have previously examined
712 athlete experiences of need satisfaction as key motivational precursors to athlete engagement
713 (Curran, Hill, Hall, & Jowett, 2014; Lonsdale et al., 2007), and positive affect (Mack et al.,
714 2011).

715 The results indicated that the relations between relatedness satisfaction and athlete
716 dedication, and autonomy satisfaction and positive affect, were non-significant. In their
717 investigation of the antecedents of athlete engagement in sport, Hodge, Lonsdale, and
718 Jackson (2009) did not find the need for relatedness to play a substantial role in terms of
719 predicting engagement (of which dedication is a key component), when compared to the
720 other two needs. Moreover, Reinboth et al. (2004) found relatedness to be unrelated to athlete
721 outcomes. Cognitive Evaluation Theory (CET), a sub-theory of SDT, emphasises the distal
722 role of relatedness satisfaction in the maintenance of intrinsic motivation (Deci & Ryan,
723 2000). It is likely that subsequent outcomes (such as dedication and engagement) are also
724 implicated (Reinboth et al., 2004). Autonomy satisfaction has previously been found to be
725 unrelated to positive affect in sport and related domains when assessed using the positive
726 emotions subscale of the PANAS (e.g., Gunnell et al., 2013; Mack et al., 2011; McDonough
727 & Crocker, 2007). It might be the case that the items of the PANAS are better suited to
728 capture the positive emotions resulting from the experiences of effectance/mastery and
729 connectedness with others, over those resulting from feeling volitional or self-directed in
730 one's sporting pursuits.

731 In terms of the relations between need frustration subscales and negative outcomes,
732 autonomy and competence frustration predicted athlete exhaustion in a significant manner,
733 whereas frustration of each of the three needs predicted negative affect in a significant
734 manner. Feeling isolated, being forced to have to train in certain ways, and thinking of
735 oneself as a failure are likely to predispose athletes to extreme fatigue and adverse emotions,
736 and need frustration has been shown to be implicated in these maladaptive athlete outcomes
737 (e.g., Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011). In line with the results
738 reported by Hodge et al. (2008) regarding the weak role of the need for relatedness in the
739 development of athlete burnout (of which exhaustion is key component), we found a non-

significant relation between relatedness frustration and exhaustion. This result, along with the non-significant association between relatedness and dedication, highlights the distal role of the need for relatedness in the development of athlete outcomes.

The consistency and strength with which the experiential states pertaining to the need for competence predicted positive and negative athlete outcomes as compared to autonomy and relatedness satisfaction and frustration add to the evidence for its salience in sport and related settings (e.g., Adie et al., 2012; Gunnell et al., 2013; Ntoumanis, 2001; Reinboth, Duda, & Ntoumanis, 2004; Standage et al., 2003). In sum, these results correspond to propositions outlined in SDT (e.g., Vansteenkiste & Ryan, 2013) and subsequent findings in support of need satisfaction and need frustration being distinct constructs, with need satisfaction dimensions mainly predicting indices of well-being, and need frustration dimensions mainly predicting indices of ill-being (e.g., Bartholomew et al., 2011b; Chen et al., 2015).

Limitations, Future Directions, and Conclusion

The results of these studies should be interpreted in light of a few caveats. First, the cross-sectional nature of the design raises issues of common method variance and prevents any causal inferences (e.g., Podsakoff, Mackenzie, Lee, & Podsakoff, 2003). Researchers could overcome this issue by employing longitudinal or experimental research designs and objective assessments of athlete outcomes (e.g., objective performance, biological indices of well-being; cf. Quested, Bosch, Burns, Cumming, Ntoumanis, & Duda, 2011). Second, we provided validity evidence based on internal structure and relations to other variables, but did not test the evidence for face and content validity. This was done bearing in mind that some of the original questionnaires that informed the item development process had consulted with athletes/expert panels (e.g., Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011; Ng et al., 2011). For researchers interested in further examining the third need state of need

765 unfulfillment, testing items with athletes would prove especially useful in understanding how
766 they differentiate between the three need states (e.g., using think-aloud protocols). Given that
767 athletes' responses to the items did not distinguish between the constructs of need
768 unfulfillment, need satisfaction and need frustration, researchers might also benefit from
769 employing differential data analytic strategies. For example, item response theory (IRT) may
770 aid the understanding of how athletes respond to the each of the items, and has been
771 suggested to be suitable approach in the case of research examining the key constructs
772 embedded within the SDT framework (Standage et al., 2019).

773 Despite these limitations, the present study adds to the literature on motivation in
774 sport. The PNSS-S is theoretically underpinned measure that captures both the dark and the
775 bright sides of the athletic experience, via the assessment of the satisfaction and frustration of
776 athletes' needs for autonomy, competence, and relatedness. Further, in the spirit of open
777 science and transparency, we recorded our unsuccessful efforts to measure the unfulfillment
778 of the three needs. Incorporating the new scale in future research alongside the constructs of
779 interpersonal behaviors, motivation regulations, and outcomes of adaptive and maladaptive
780 functioning should, therefore, provide a more nuanced understanding of these important and
781 distinct psychological need states in sport.

782

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Footnotes

1. Bartholomew et al. (2011) referred to need frustration as "need thwarting" in that manuscript. Thereafter, the term "need frustration" was widely adopted in the SDT literature to refer to one's personal experience, whereas "need thwarting" was used to refer to the undermining actions of significant others in one's social context).

2. We also tested all the other models from Study 1 involving the different configurations of need satisfaction and frustration (i.e., Models 13-24). Models 16, 20-23 did not converge. Models 13 and 17 were rejected on the basis of inadequate model-to-data fit. Models 14 and 15 had adequate fit, however, they were rejected due to high correlations between factors. Model 19 demonstrated adequate fit, however, only had one significant loading on the S-factor of competence satisfaction. More importantly, the factor correlation between the two G-factors was -.93, leading to the discriminant validity of the two factors being questioned. The standard errors of the model parameter estimates could not be computed in the case of Model 24.

3. At a request of an anonymous reviewer we ran two additional models in Study 2, with need satisfaction and positive as well as negative outcomes (dedication, positive affect, exhaustion and negative affect), and need frustration and positive as well as negative outcomes (dedication, positive affect, exhaustion and negative affect). There was no evidence of suppression effects for either model. Fit for the model with need frustration and all outcomes was acceptable [χ^2 = 1457.823 (817), p < .001, CFI = .93, TLI = .92, SRMR = .05, RMSEA = .05(90% CI .04, .05)]. Competence frustration and relatedness frustration negatively predicted dedication, and autonomy frustration and competence frustration negatively predicted positive affect in a significant manner.

In terms of need satisfaction and negative outcomes, both competence satisfaction and relatedness satisfaction negatively predicted exhaustion and negative affect in a significant manner. However, fit for this model was just under acceptable levels [χ^2 = 1755.823 (857), p < .001, CFI = .90, TLI = .89, SRMR = .05, RMSEA = .06(90% CI .05, .06)].

Table 1

Goodness-of-fit Statistics for Alternative CFA, ESEM, and Bifactor Models (Study 1)

Model	χ^2	*p*	*df*	CFI	TLI	SRMR	RMSEA [90% CI]
Models involving three need states							
1. Three-factor CFA	2824.822	<.001	986	.70	.69	.08	.08[.08, .08]
2. Nine-correlated factors CFA	2286.183	<.001	953	.78	.77	.08	.07[.06, .07]
3. H-CFA (Three-H, nine-L)	2479.336	<.001	977	.76	.74	.08	.07[.07, .07]
4. H-CFA (one-H,nine-L)	2687.855	<.001	980	.72	.71	.09	.08[.07, .08]
5.Three-factor ESEM	2684.475	<.001	900	.71	.67	.06	.08[.08, .08]
6. Nine-correlated factors ESEM	1319.624	<.001	657	.89	.83	.03	.06[.05, .06]
7. Bifactor CFA (correlated three-G, nine-S)				DNC			
8. Bifactor CFA (one-G, nine-S)	2494.206	<.001	943	.75	.72	.08	.07 [.07, .08]
9. Bifactor CFA (one-G three-S)	2691.925	<.001	946	.72	.69	.13	.08[.07, .08]
10. Bifactor ESEM (correlated three-G, nine-S)	1116.509	<.001	608	.92	.86	.02	.05[.05, .06]
11. Bifactor ESEM (one-G, nine-S)				-*			

12. Bifactor ESEM (one-G, three-S)					-*		
Models involving two need states							
13. Two-factor CFA	1406.126	<.001	433	.75	.73	.08	.09[.08, .09]
14. Six-correlated factors CFA	1045.020	<.001	419	.84	.82	.07	.07[.06, .08]
15.H-CFA (two-H, six-L)	1183.338	<.001	427	.81	.79	.08	.08[.07, .08]
16. H-CFA (one-H, six-L)					DNC		
17. Two-Factor ESEM	1336.331	<.001	404	.76	.73	.07	.09[.08, .09]
18. Six correlated-factors ESEM	556.471	<.001	294	. 93	. 89	.02	. 05 [.05, .06]
19. Bifactor CFA (two-G, six-S)					DNC		
20. Bifactor CFA (one-G, six-S)					DNC		
21. Bifactor CFA (one-G, two-S)	1164.733	<.001	403	.81	.78	.13	.08[.07, .08]
22. Bifactor ESEM (correlated two-G, six-S)	458.463	<.001	262	.95	.91	.02	.05[.04, .06]
23. Bifactor ESEM (one-G, six-S)					-*		
24. Bifactor ESEM (one-G, two-S)	1028.655	<.001	375	.83	.79	.04	.08[.07, .08]

Note. χ^2 = Chi-square test of exact fit; CFI = Comparative Fit Index; TLI = Tucker–Lewis index; RMSEA = Root Mean Square Error of Approximation; 90% CI = 90% confidence interval of the RMSEA; CFA = confirmatory factor analysis; H-CFA = Hierarchical CFA; H-factor = higher order factor estimated as a part of hierarchical model; L-factor = lower order factor estimated as a part of hierarchical model; ESEM = exploratory structural equation modeling; G-factor = global factor estimated as part of a bifactor model; S-factor = specific factor estimated as part of a bifactor model; DNC = did not converge; -* = The standard errors of the model parameter estimates could not be computed. The model may not be identified.

Table 2

Model Fit for Single-factor CFAs and Subsequent Six-factor ESEM (Study 1)

Models	χ^2	*df*	*p*	CFI	TLI	SRMR	RMSEA [90% CI]
AF CFA							
Initial (5)	15.97	5	.007	.95	.91	.03	.08 [.04, .013]
Final (3)	.000	0	.000	1.00	1.00	.01	.00 [.00, .00]
CF CFA							
Initial and final (4)	2.145	2	.34	1.00	1.00	.01	.02 [.00, .12]
RF CFA							
Initial (6)	19.293	9	.023	.96	.93	.03	.06 [.02, .10]
Final (4)	1.951	2	.377	1.00	1.00	.01	.00[.00, .11]
AS CFA							
Initial (5)	31.520	5	.000	.90	.80	.07	.13[.09, .18]
Final (3)	.000	0	.000	1.00	1.00	.00	.00[.00, .00]
CS CFA							

Initial (5)	29.006	5	.000	.93	.86	.05	.13[.08, .17]
Final (4)	1.935	2	.380	1.00	1.00	.01	.00[.00, .11]
RS CFA							
Initial (6)	17.028	9	.048	.98	.96	.03	.05[.00, .09]
Final (3)	.000	0	.000	1.00	1.00	.00	.00[.00, .00]
Final six-factor ESEM	171.110	99	.000	.97	.94	.02	.05[.04, .06]

Note. χ^2 = Chi-square; CFI = comparative fit index; TLI = Tucker-Lewis Index; SRMR = Root Mean Square Residual; RMSEA = Root Mean Square Error of Approximation; () = number of items in model; Initial = the model with all items; Final = the model with the problematic items removed; *AS* = autonomy satisfaction; *AF* = autonomy frustration; *CS* = competence satisfaction; *CF* = competence frustration; *RS* = relatedness satisfaction; *RF* = relatedness frustration CFA = confirmatory factor analysis. ESEM = exploratory structural equation modeling.

Table 3

Standardised Factor Loadings and Cross-loadings (Study 1)

Items	*M*	*SD*	Skewness	Kurtosis	Factor Loadings					
					AF	CF	RF	AS	CS	RS
STEM: *In my sport, I…*										
feel pushed to behave in certain ways	2.17	1.57	1.26	.56	**.61*** **		.22**			
feel forced to follow training decisions	2.87	1.79	.38	-1.29	**.84*** **					
feel forced to do training tasks that I would not choose to do	2.50	1.7	.80	-.54	**.71*** **					
feel like a failure	1.80	1.22	1.88	3.30		**.58*** **			-.20**	
feel useless	1.57	1.12	2.26	4.69		**.80*** **				
feel incapable	1.71	1.2	1.94	3.37		**.56*** **	.21*			
feel hopeless	1.48	1.1	2.82	8.00		**.79*** **				
feel disliked	1.50	1.08	2.66	7.13			**.73*** **			
feel excluded	1.71	1.36	2.19	4.20			**.36***			

Items	*M*	*SD*	Skewness	Kurtosis	Factor Loadings					
					AF	CF	RF	AS	CS	RS
STEM: *In my sport, I…*										
feel isolated	1.51	1.11	2.46	5.42			**.63*** **			
feel ignored	1.63	1.13	2.22	4.90			**.77*** **			
feel free to make choices with regards to the way I train	5.18	1.55	-0.54	-.53				**.60***		
have a say in how things are done	4.77	1.66	-.42	-.57				**.89** **		
have the freedom to make training decisions	4.77	1.55	-.28	-.56				**.69** **		
feel that I am capable	5.77	1.21	-1.08	.99		-.30*			**.58*** **	
feel skilled	5.41	1.2	-.68	.50					**.86*** **	
feel that I am improving	5.71	1.18	-1.05	1.22					**.34** **	.44***
am able to overcome challenges	5.64	1.07	-.83	.98					**.40** **	.26***
feel supported	5.86	1.14	-1.07	1.26			-.38***			**.64*** **
feel valued	5.54	1.18	-.93	1.25					.54***	**.28***
feel cared for	5.66	1.22	-.76	.07						**.54*** **

Items	*M*	*SD*	Skewness	Kurtosis	Factor Loadings					
					AF	CF	RF	AS	CS	RS
STEM: *In my sport, I…*										

Note. **p* < .05; ***p* < .01; ****p* < .001. Target factor loadings are in bold. For clarity purposes, only significant cross-loadings over .20 are reported; AS = autonomy satisfaction, AF = autonomy frustration, CS = competence satisfaction, CF = competence frustration, RS = relatedness satisfaction, RF = relatedness frustration.

Table 4

Internal Consistency and Factor Correlations (Study 1)

Subscales	Raykov's rho	1	2	3	4	5	6
(1) AS	.78	-					
(2) AF	.77	-.52***	-				
(3) CS	.66	.49***	-.13	-			
(4) CF	.78	-.18**	.44***	-.39	-		
(5) RS	.52	.41***	-.32***	.28**	-.30***	-	
(6) RF	.75	-.34***	.32***	-.35***	.60***	-.26**	-

Note. *$p < .05$; **$p < .01$; ***$p < .001$; *AS* = autonomy satisfaction; *AF* = autonomy frustration; *CS* = competence satisfaction; *CF* = competence frustration; *RS* = relatedness satisfaction; *RF* = relatedness frustration.

Table 5

Factor Loadings, Standard Errors, Means, SDs, Kurtosis and Skewness for PNSS-S Items (Study 2)

Items	Factor loadings						SE	Means	SD	Skewness	Kurtosis
	AS	AF	CS	CF	RS	RF					
STEM: *In my sport, I…*											
Feel free to make choices with regards to the way I train	**.71**						.07	5.52	1.97	-1.36	1.58
Have a say in how things are done	**.35**	-.32					.11	5.19	1.39	-.88	.15
Have the freedom to make training decisions	**.52**	-.25	.27				.10	5.19	1.39	-.94	.42
Pursue goals that are my own	**.71**						.08	5.81	1.22	-1.52	2.82
Feel like I can be myself	**.63**					-.22	.08	5.70	1.30	-1.27	1.47
Feel pushed to behave in certain ways		**.72**					.05	2.61	1.56	.92	- .26
Feel forced to follow training decisions	-.22	**.69**					.05	2.86	1.57	.69	-.57
Feel forced to do training tasks that I would not choose to do		**.53**					.05	2.45	1.45	1.10	.44

Items	Factor loadings						SE	Means	SD	Skewness	Kurtosis
	AS	AF	CS	CF	RS	RF					
STEM: *In my sport, I…*											
Feel excessive pressure		**.56**		.29			.06	2.54	1.52	1.05	.19
Must do what I am told		**.76**		-.21			.05	3.16	1.83	.47	-1.14
Feel that I am capable			**.79**				.10	5.83	1.16	-1.65	3.36
Feel skilled			**.54**				.08	5.53	1.17	-1.24	1.95
Am able to overcome challenges	.35		**.40**				.09	5.76	1.06	-1.57	3.76
Feel confident that I can do well			**.45**	-.26			.08	5.60	1.12	-1.35	2.38
Feel that I am good			**.86**				.10	5.62	1.22	-1.39	2.26
Feel like a failure				**.58**			.09	2.24	1.29	1.24	1.01
Feel useless				**.67**			.08	2.13	1.21	1.47	2.32
Feel incapable				**.71**			.10	2.10	1.23	1.51	2.16
Feel hopeless				**.77**			.10	1.95	1.17	1.65	2.91
Feel supported					**.76**		.08	6.07	1.25	-1.87	3.28
Feel cared for					**.84**		.07	5.91	1.22	-1.52	2.24

Items	Factor loadings						SE	Means	SD	Skewness	Kurtosis
	AS	AF	CS	CF	RS	RF					
STEM: *In my sport, I…*											
Feel connected					**.84**		.07	5.86	1.16	-1.40	2.08
Feel accepted					**.81**		.06	5.95	1.16	-1.65	3.19
Like the people around me					**.65**		.08	5.98	1.16	-1.72	3.42
Feel disliked						**.80**	.06	2.25	1.23	1.54	2.92
Feel excluded						**.74**	.05	2.26	1.28	1.51	2.48
Feel isolated						**.73**	.07	2.32	1.40	1.53	2.48
Feel ignored						**.84**	.05	2.28	1.30	1.36	1.84
Feel dismissed						**.69**	.08	2.17	1.22	1.56	2.71

Note. Factor loadings in this table are all significant at $p < .01$. Target loadings are in bold. For clarity purposes, only cross-loadings over .20 are reported. AS = autonomy satisfaction, AF = autonomy frustration, CS = competence satisfaction, CF = competence frustration, RS = relatedness satisfaction, RF = relatedness frustration.

Table 6

Factor Correlations and Internal Consistency for PNSS-S subscales (Study 2)

Subscales	Raykov's rho	1	2	3	4	5	6
(1) AS	.73	-					
(2) AF	.79	-.40	-				
(3) CS	.76	.54	-.37	-			
(4) CF	.78	-.53	.41	-.67	-		
(5) RS	.89	.61	-.43	.67	-.68	-	
(6) RF	.87	-.45	.27	-.52	.70	-.68	-

Note. Factor correlations are significant at $p < .01$. AS = autonomy satisfaction, AF = autonomy frustration, CS = competence satisfaction, CF = competence frustration, RS = relatedness satisfaction, RF = relatedness frustration. Raykov's composite reliability coefficients are presented on the diagonal of the correlation matrix.

Table 7

Correlations Between Variables (Study 2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 AS	-															
2 AF	-.63**	-														
3 CS	.69**	-.50**	-													
4 CF	-.60**	.60**	-.77**	-												
5 RS	.63**	-.58**	.72**	-.71**	-											
6 RF	-.48**	.45**	-.64**	.74**	-.68**	-										
7 ASup	.76**	-.52**	.67**	-.59**	.63**	-.57**	-									
8 AThw	-.57**	.80**	-.47**	.54**	-.51**	.40**	-.58**	-								
9 CSup	.62**	-.42**	.73**	-.67**	.66**	-.58**	.71**	-.45**	-							
10 CThw	-.57**	.54**	-.70**	.85**	-.67**	.68**	-.65**	.56**	-.75**	-						
11 RSup	.66**	-.59**	.66**	-.60**	.79**	-.53**	.63**	-.55**	.69**	-.61**	-					

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
12 RThw	-.59**	.63**	-.63**	.65**	-.72**	.64**	-.60**	.61**	-.63**	.65**	-.79**	-				
13 Dedication	.57**	-.46**	.67**	-.63**	.57**	-.58**	.63**	-.43**	.63**	-.63**	.51**	-.52**	-			
14 Exhaustion	-.48**	.57**	-.55**	.66**	-.54**	.57**	-.52**	.48**	-.49**	.61**	-.47**	.54**	-.49**	-		
15 PA	.59**	-.56**	.65**	-.63**	.65**	-.52**	.59**	-.51**	.61**	-.60**	.62**	-.61**	.60**	-.57**	-	
16 NA	-.52**	.51**	-.60**	.66**	-.59**	.59**	-.55**	.46**	-.55**	.62**	-.54**	.55**	-.54**	.58**	-.59**	-

Note. AS = autonomy satisfaction; AF = autonomy frustration; CS = competence satisfaction; CF = competence frustration; RS = relatedness satisfaction; RF = relatedness frustration; ASup = autonomy support; Athw = autonomy thwarting; CSup= competence support; CThw = competence thwarting; RSup = relatedness support; RThw = relatedness thwarting; PA = positive affect; NA = negative affect.

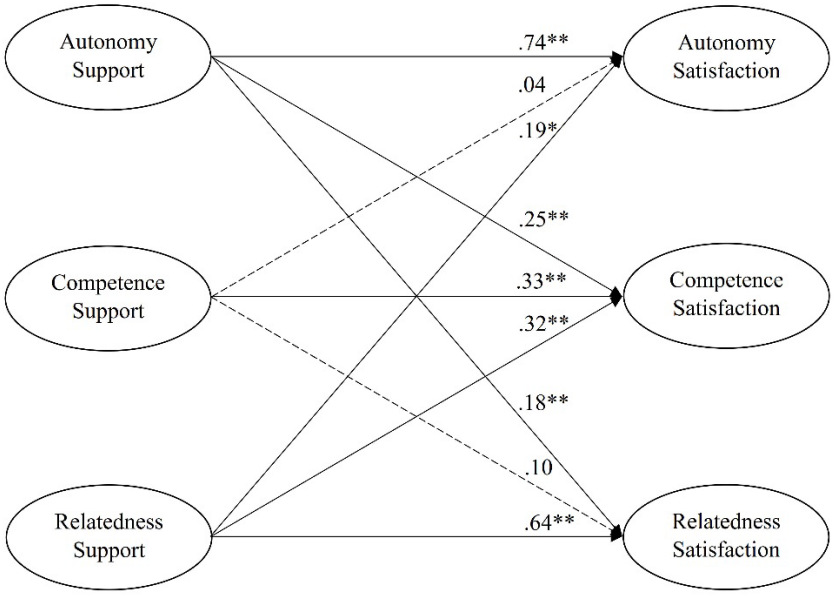


Figure 1. SEM with autonomy, competence, and relatedness support and autonomy, competence, and relatedness satisfaction

Note. Solid lines indicate significant paths; dotted lines indicate non-significant paths.

$^{**}p < .01$; $^{*}p < .05$

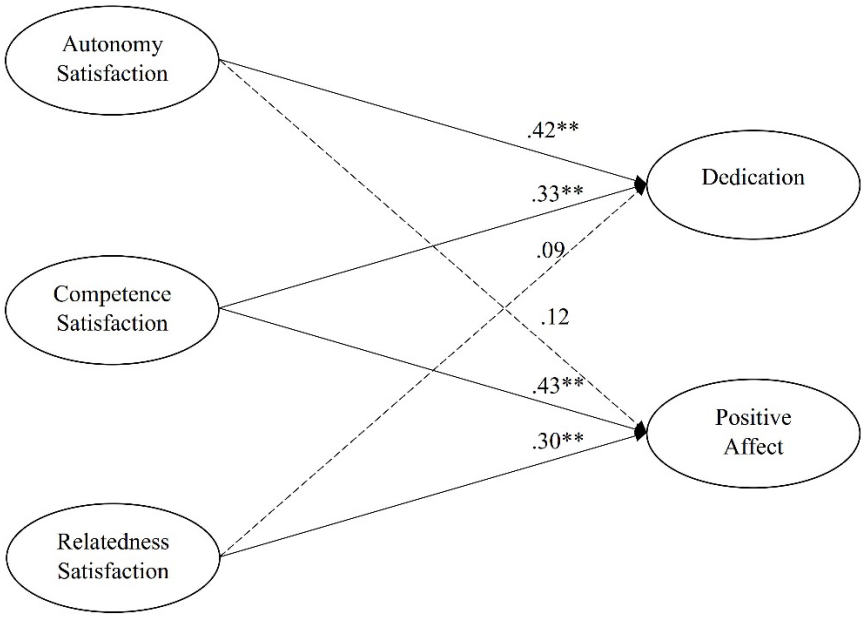


Figure 2. SEM with autonomy, competence, and relatedness satisfaction and positive outcomes

Note. Solid lines indicate significant paths; dotted lines indicate non-significant paths.

$^{**}p < .01$; $^{*}p < .05$

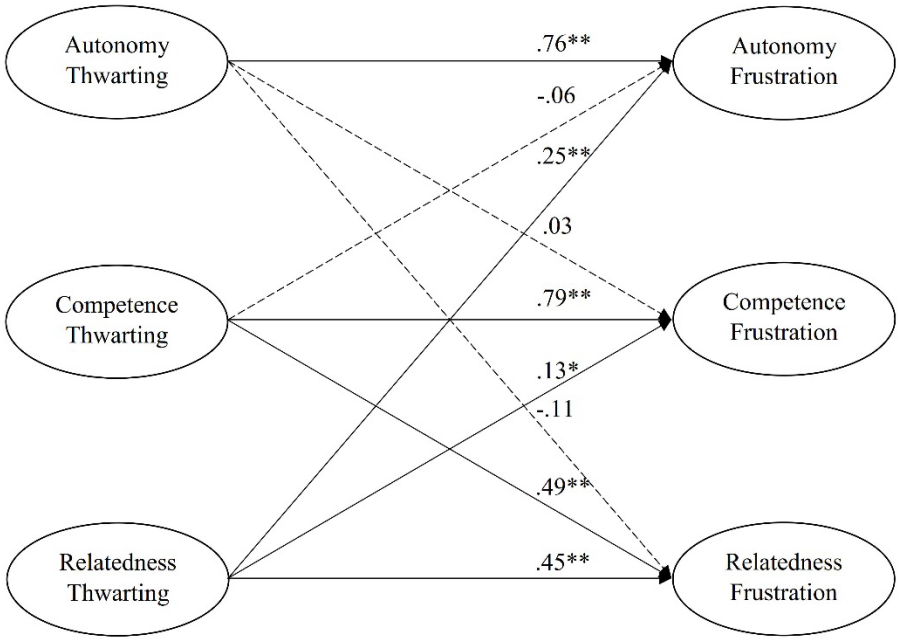


Figure 3. SEM with autonomy, competence, and relatedness thwarting and autonomy, competence, and relatedness frustration

Note. Solid lines indicate significant paths; dotted lines indicate non-significant paths.

$^{**}p < .01$; $^{*}p < .05$

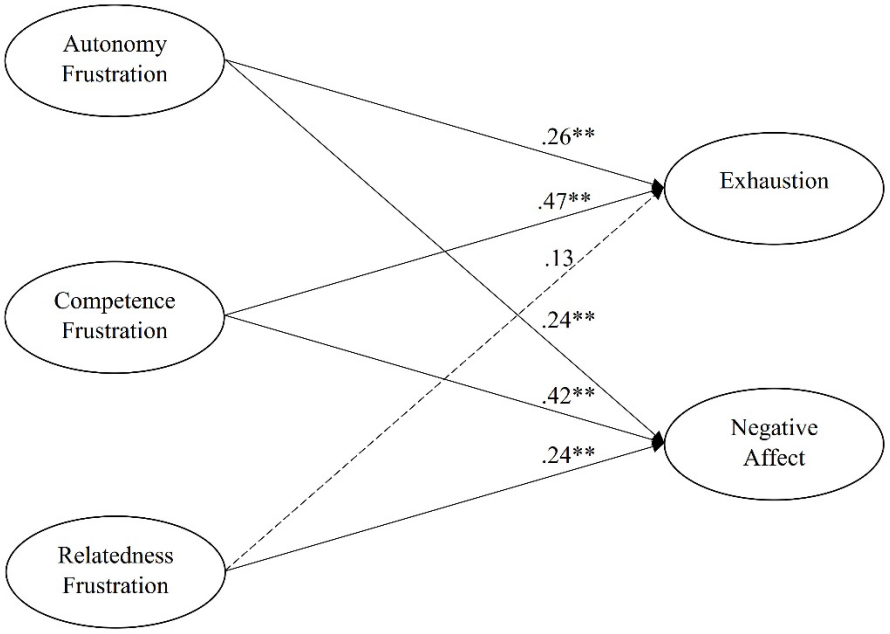


Figure 4. SEM with autonomy, competence, and relatedness frustration and negative outcomes

Note. Solid lines indicate significant paths; dotted lines indicate non-significant paths.

$^{**}p < .01$; $^{*}p < .05$

Supplementary File 1

Initial Pool of 46 PNSS-S Items (Study 1)

Stem: In my sport I…
Autonomy Satisfaction
feel that I participate because I want to
feel free to make choices with regards to the way I train
have a say in how things are done
do activities that interest me
have the freedom to make training decisions
Competence Satisfaction
am satisfied with my progress
feel that I am capable
feel skilled
feel that I am improving
am able to overcome challenges
Relatedness Satisfaction
feel supported
feel listened to
feel valued
feel cared for
feel included as an important part of the group/team
feel valued as an important member of my group/team
Autonomy Frustration
am not free to make choices with regards to the way I train
feel pushed to behave in certain ways
feel forced to follow training decisions
feel a lot of unwanted pressure
feel forced to do training tasks that I would not choose to do
Competence Frustration
feel like a failure
feel useless
feel incapable
feel hopeless

Relatedness Frustration

feel rejected

feel brushed aside

feel disliked

feel excluded

feel isolated

feel ignored

Autonomy Unfulfillment

find many of the activities set for me are boring

am unsure as to why we do certain tasks in training

contribute little to training decisions

am unclear if my ideas are valued

am confused as to when I can make decisions

Competence Unfulfillment

feel under-challenged

feel like I have achieved less than I would have liked to

feel like I have improved less than I would have liked to

feel that I am not good enough

am not satisfied with my level of competence

Relatedness Unfulfillment

have little in common with others

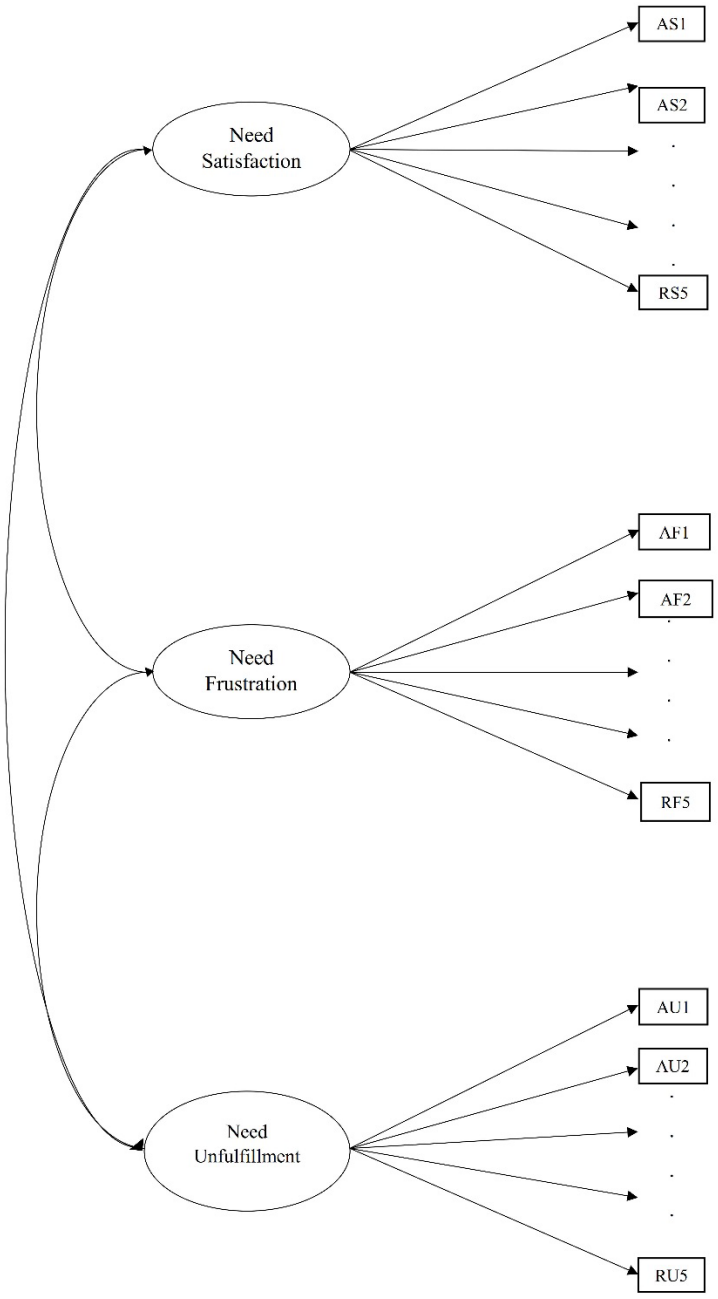
have little shared interest with others

feel I don’t quite fit in with the others

have no close friends

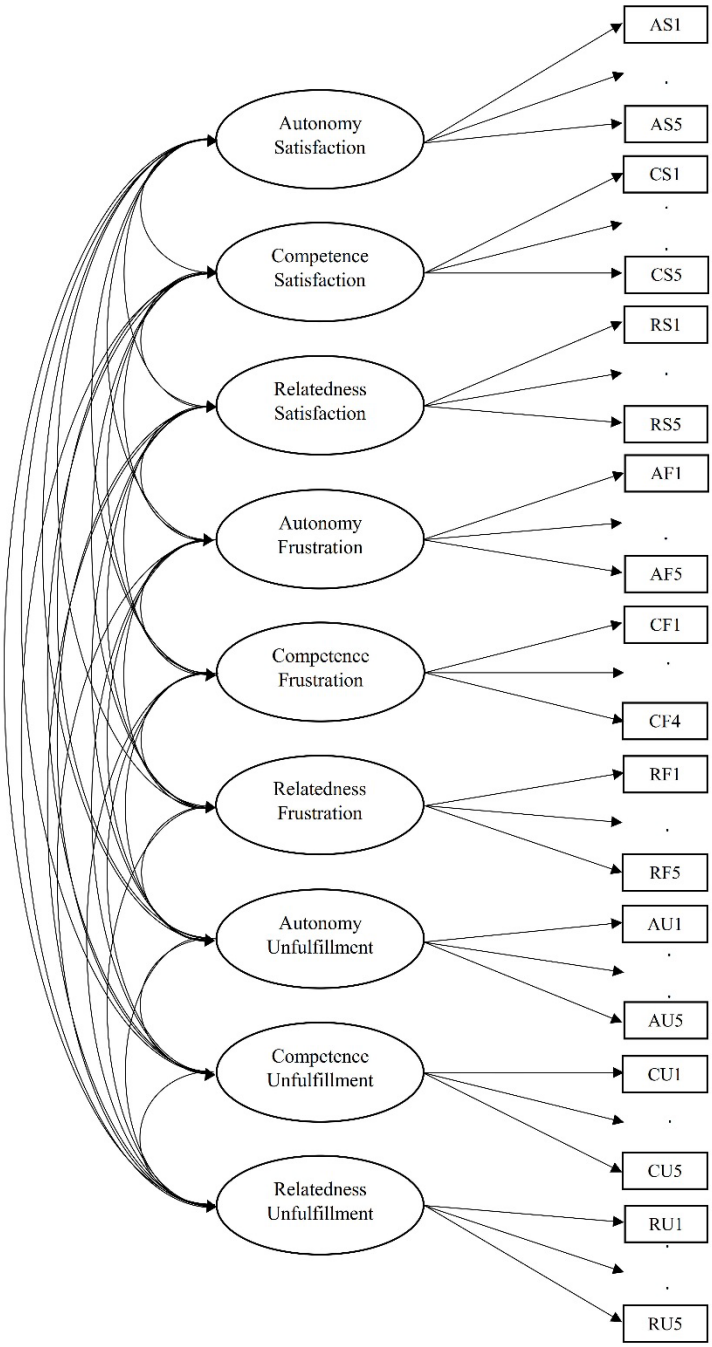
feel like my teammates know little about me

Supplementary File 2



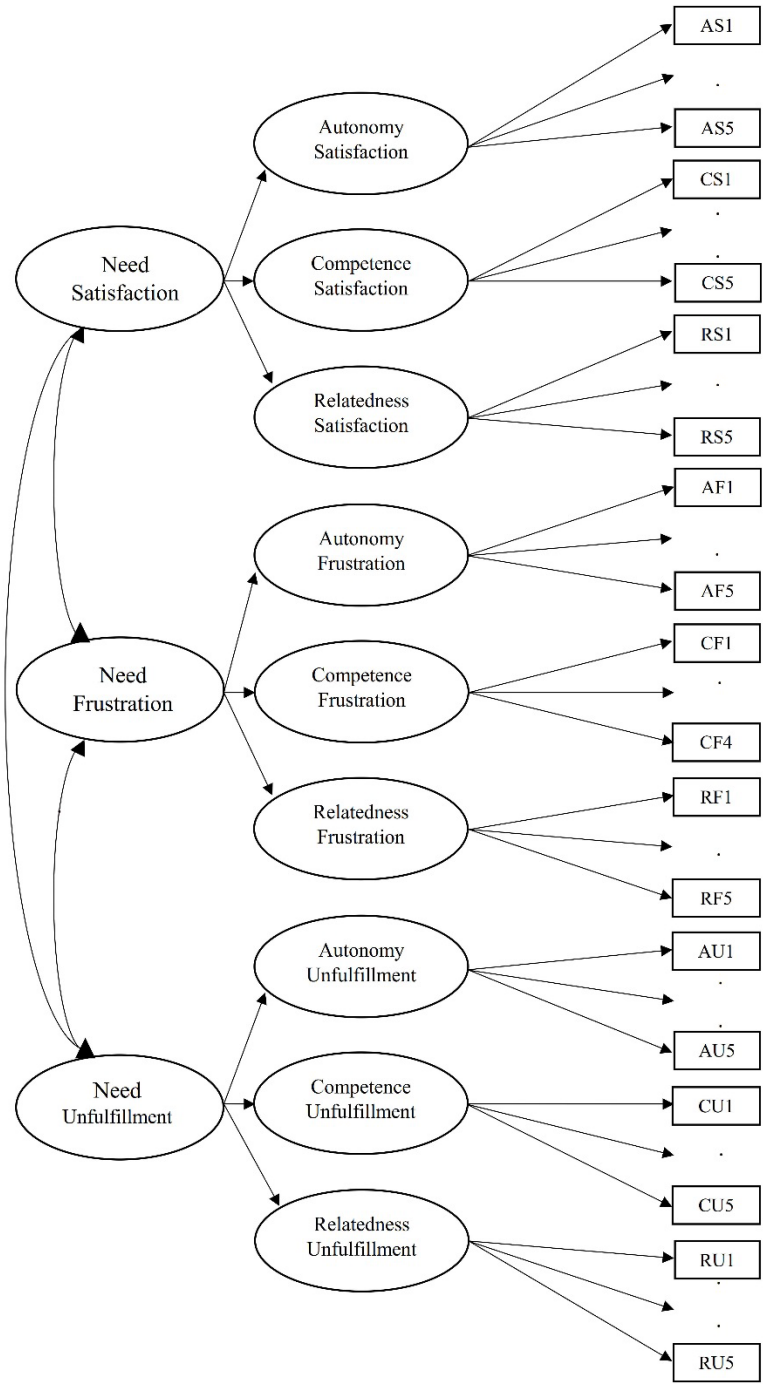
Model 1. Three-factor CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



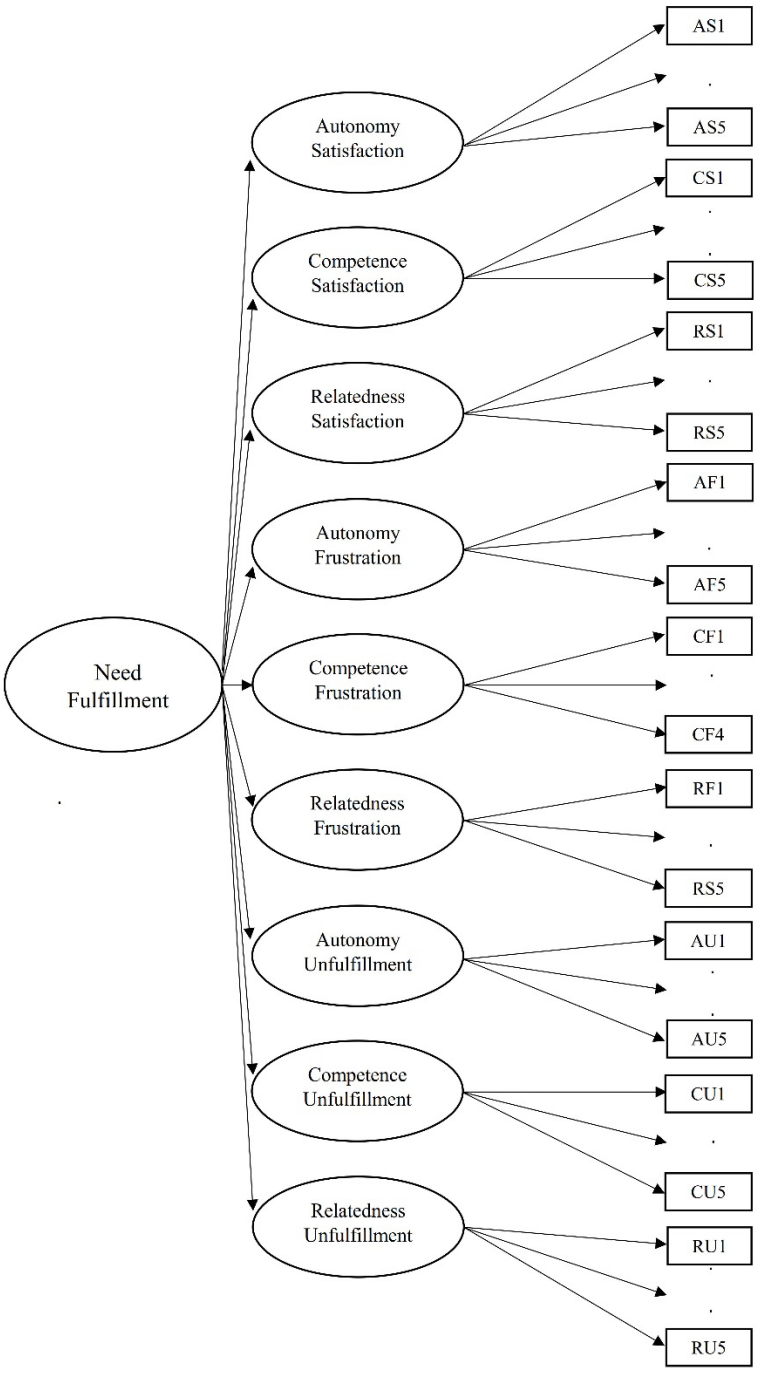
Model 2. Nine correlated factors CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



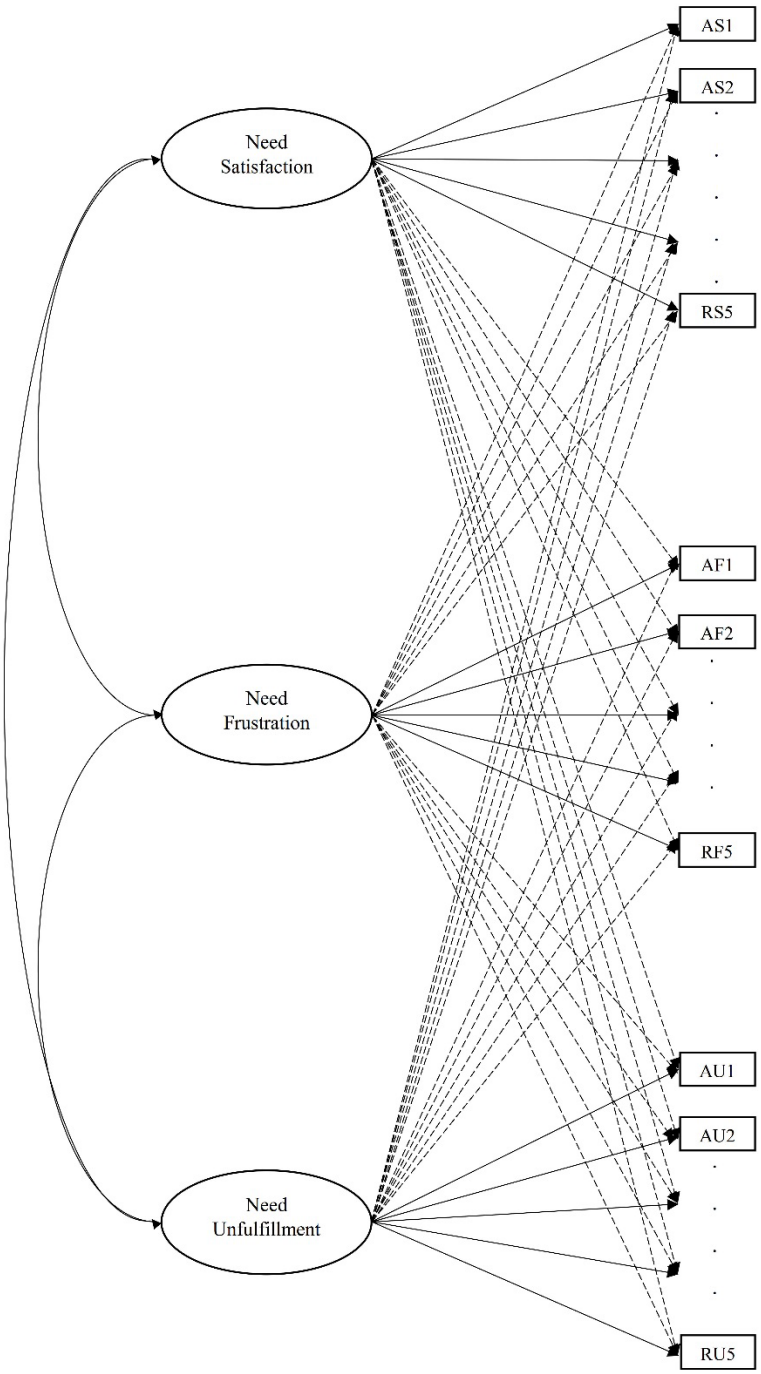
Model 3. Three higher order, nine lower order hierarchical CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



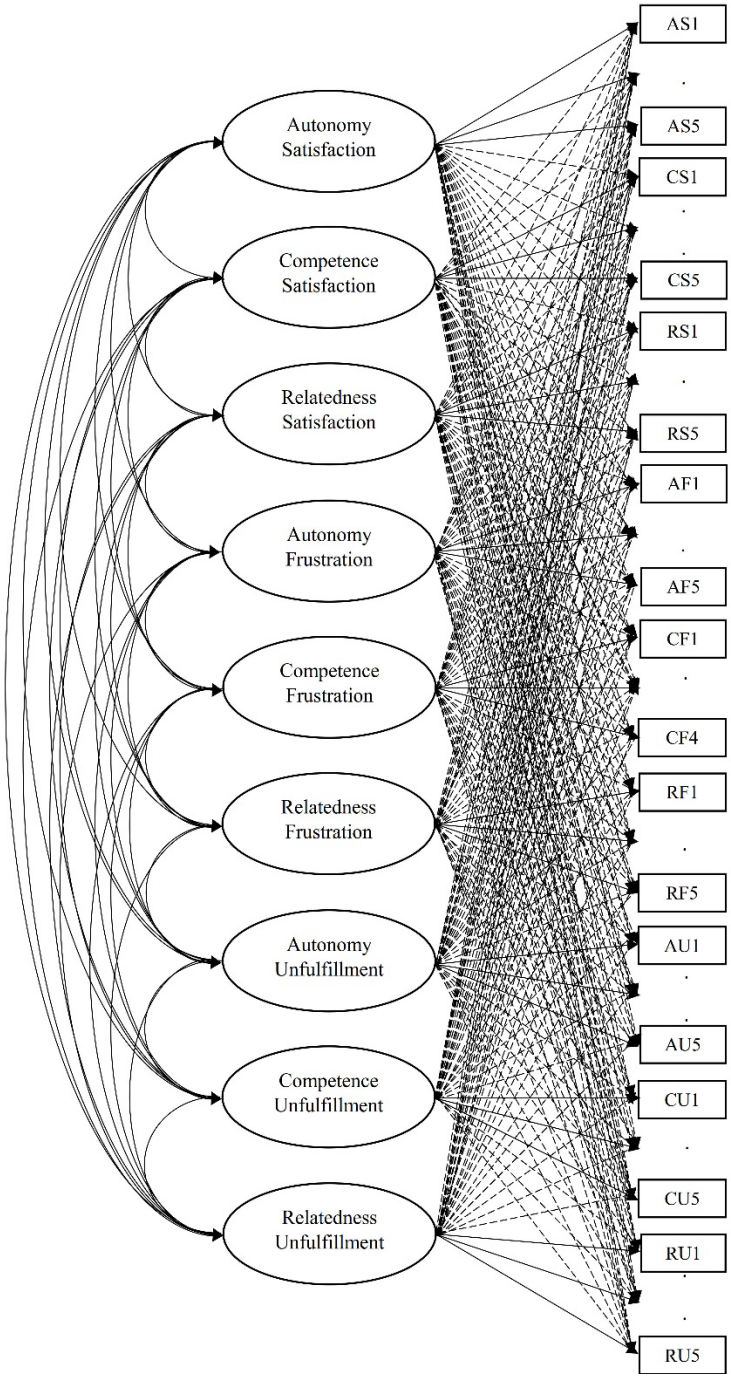
Model 4. One higher order, nine lower order hierarchical CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



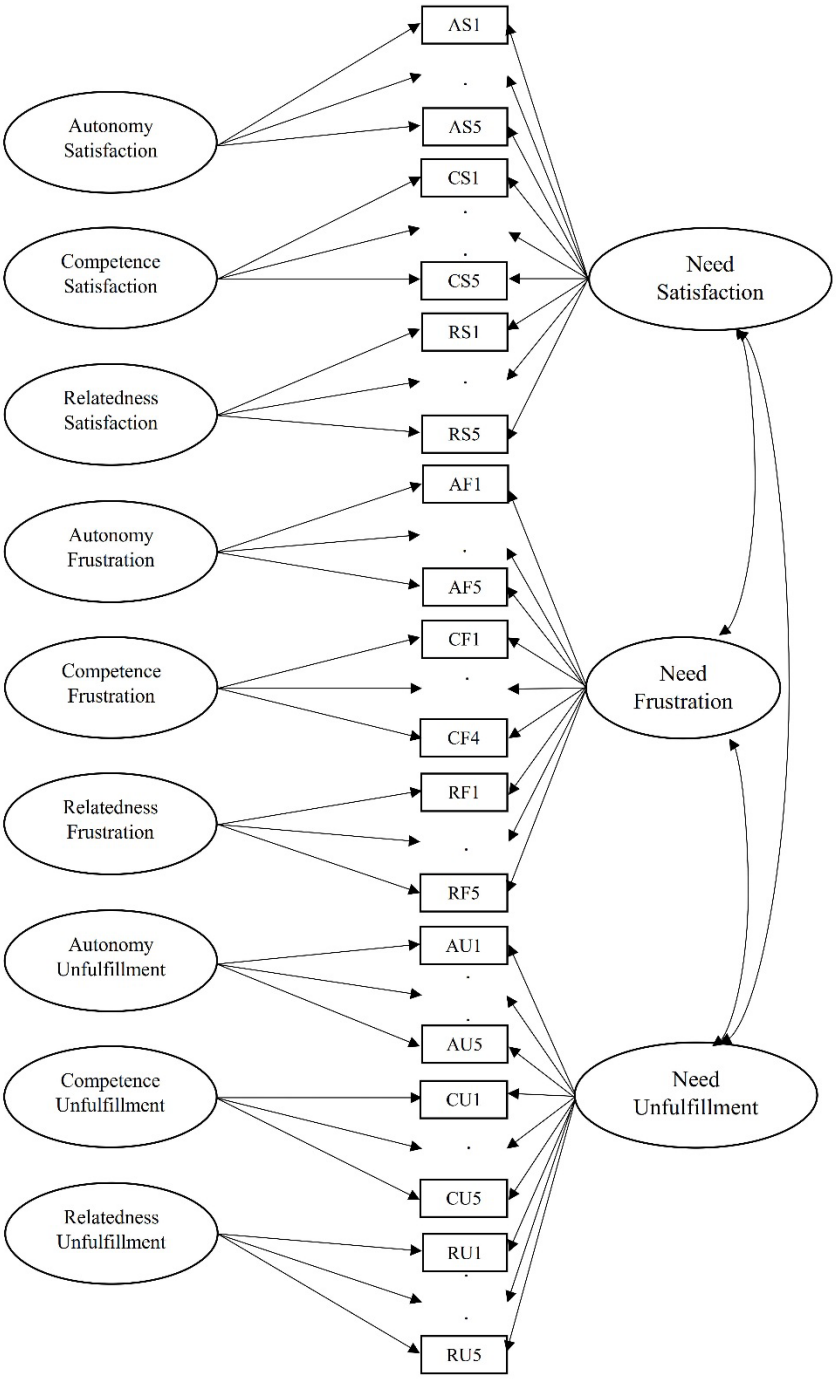
Model 5. Three-factor ESEM model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



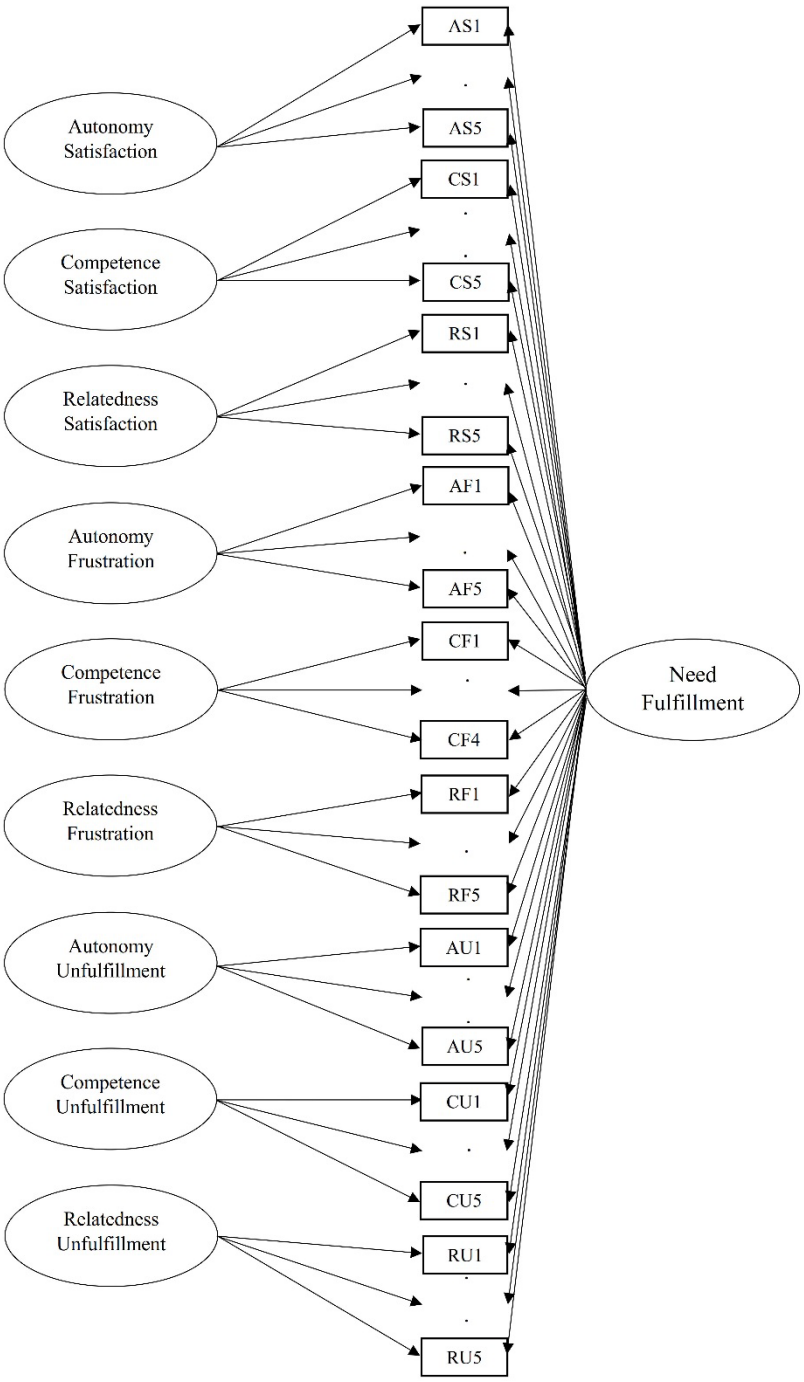
Model 6. Nine correlated factors ESEM model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



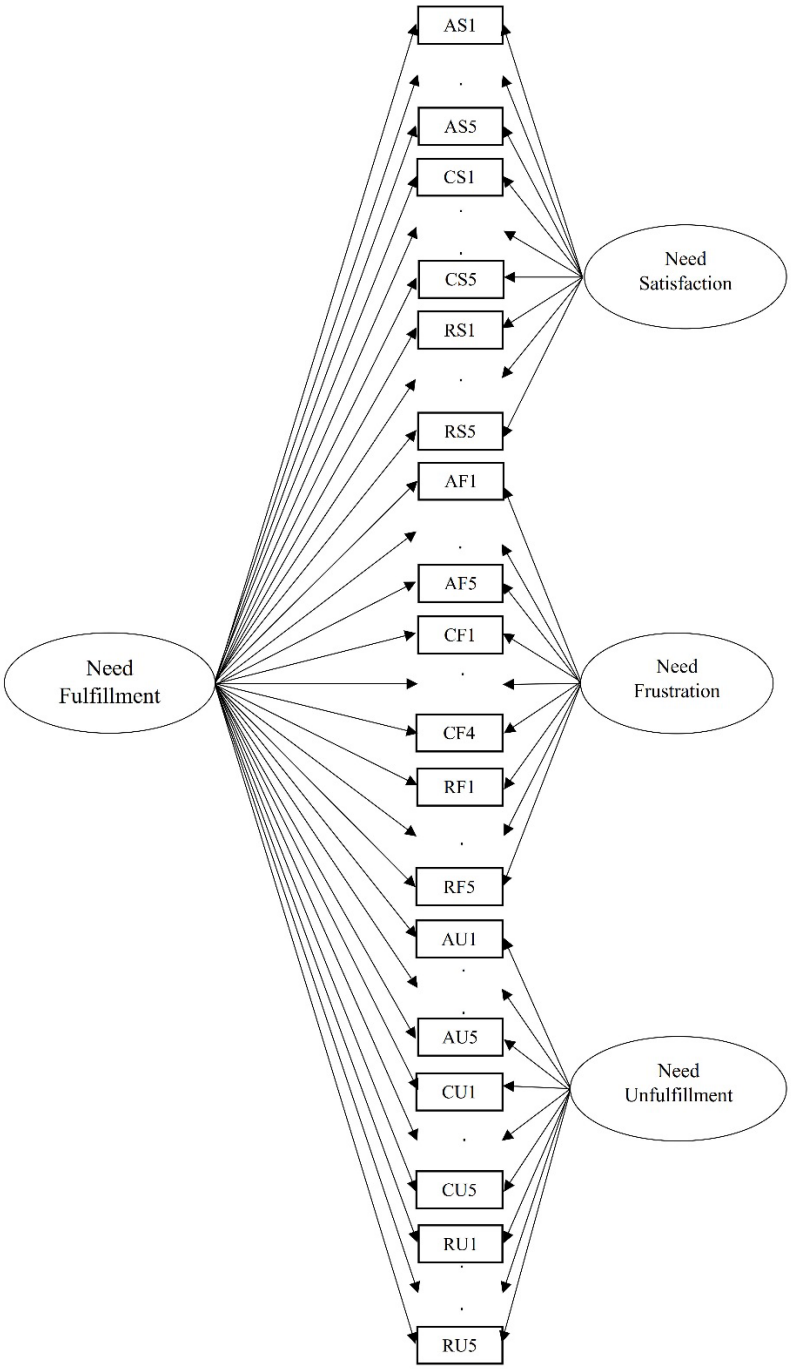
Model 7. Bifactor CFA model with three general-factors and nine specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



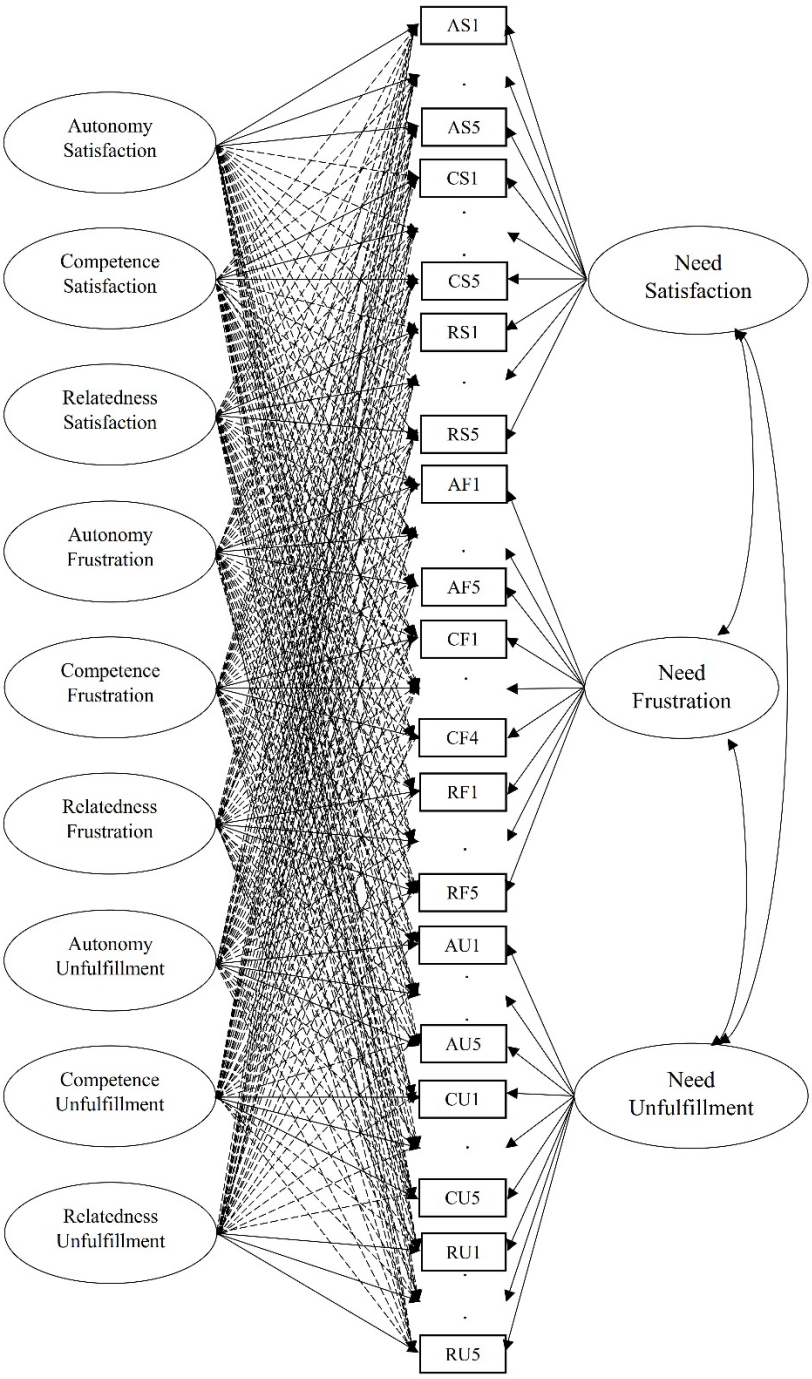
Model 8. Bifactor CFA model with one general-factor and nine specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



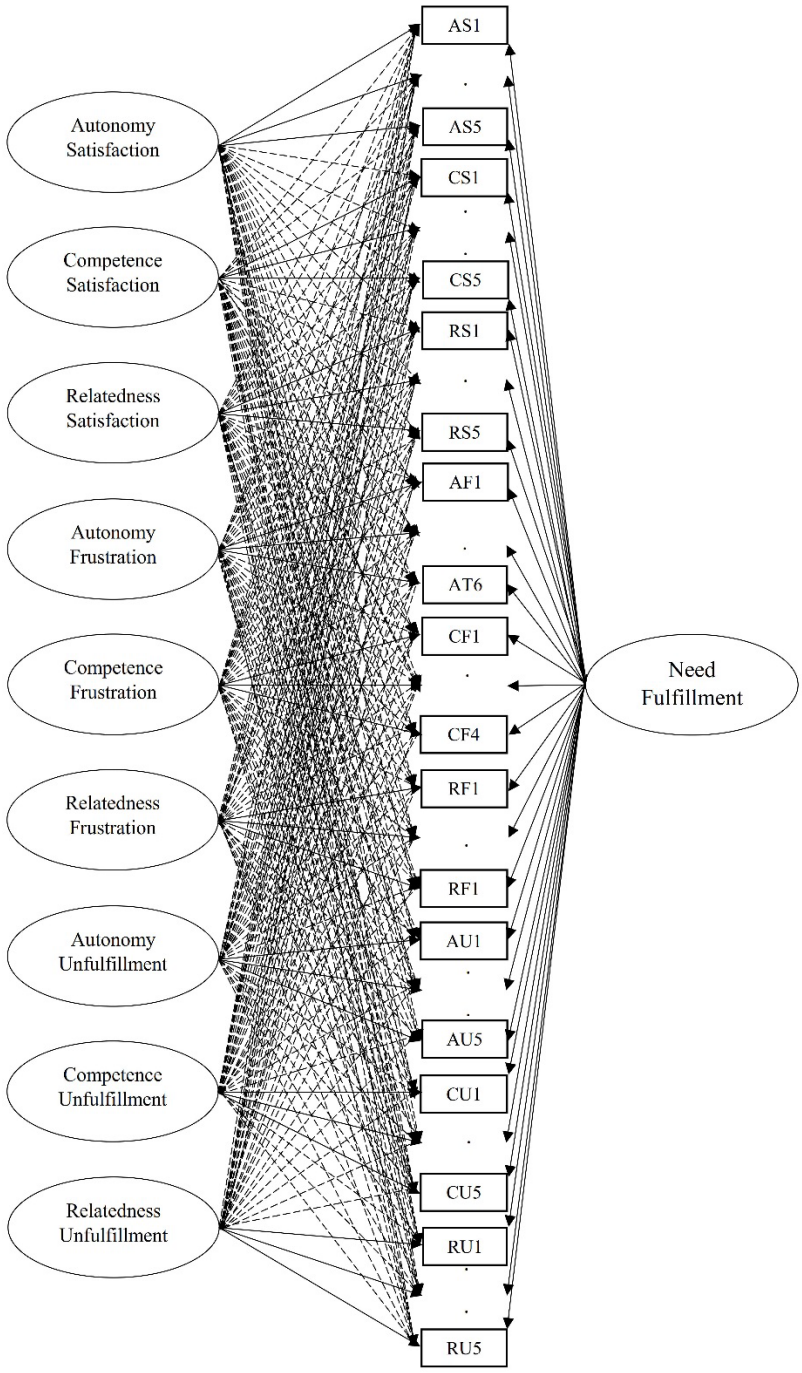
Model 9. Bifactor CFA model with one general-factor and three specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



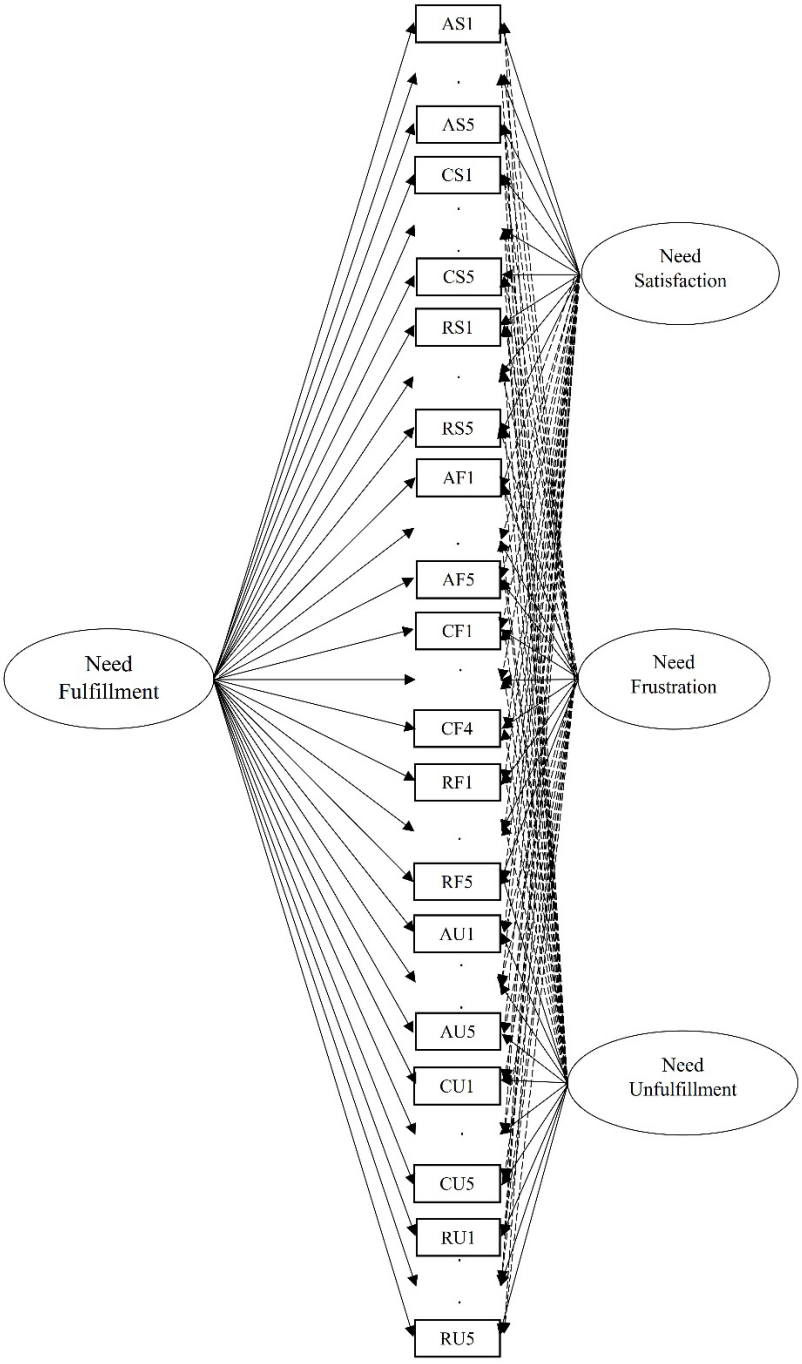
Model 10. Bifactor ESEM model with three general-factors and nine S-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



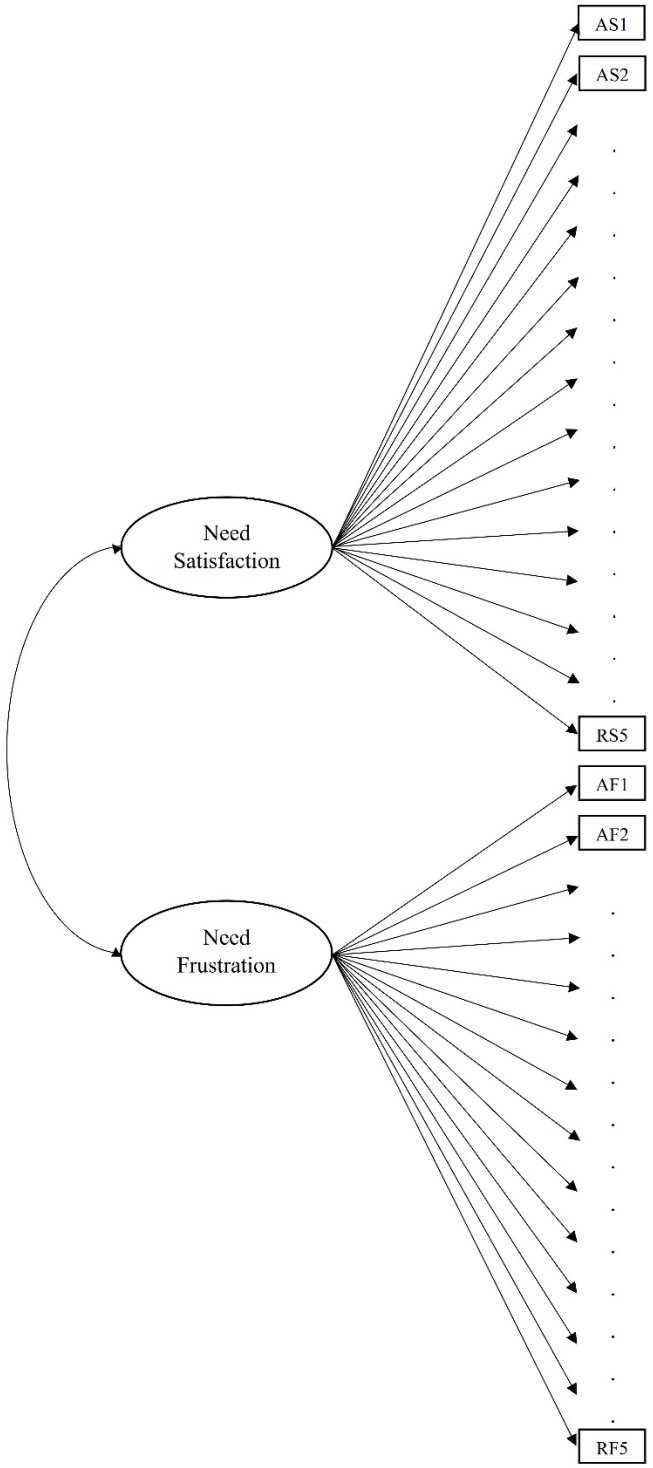
Model 11. Bifactor ESEM model with one general-factor and nine specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



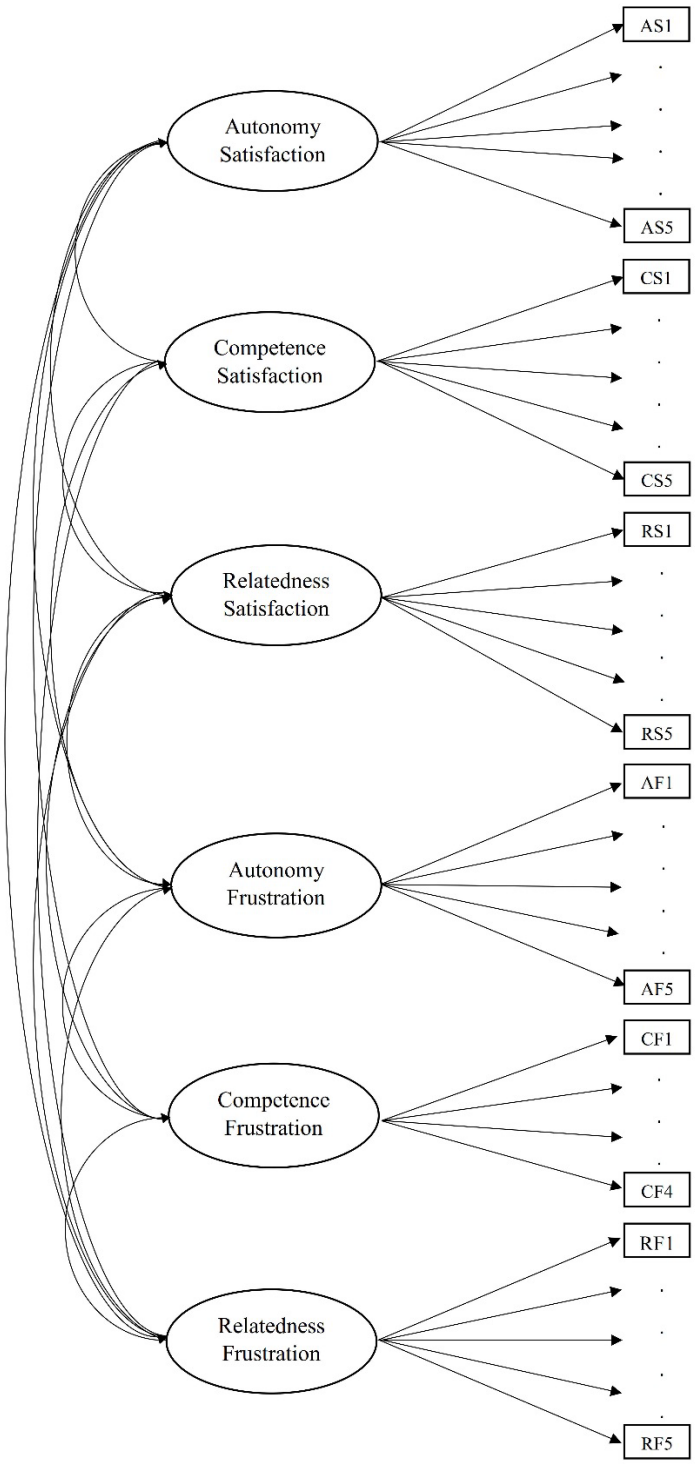
Model 12. Bifactor ESEM model with one general-factor and three specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items; AU = autonomy unfulfillment items; CU = competence unfulfillment items; RU = relatedness unfulfillment items.



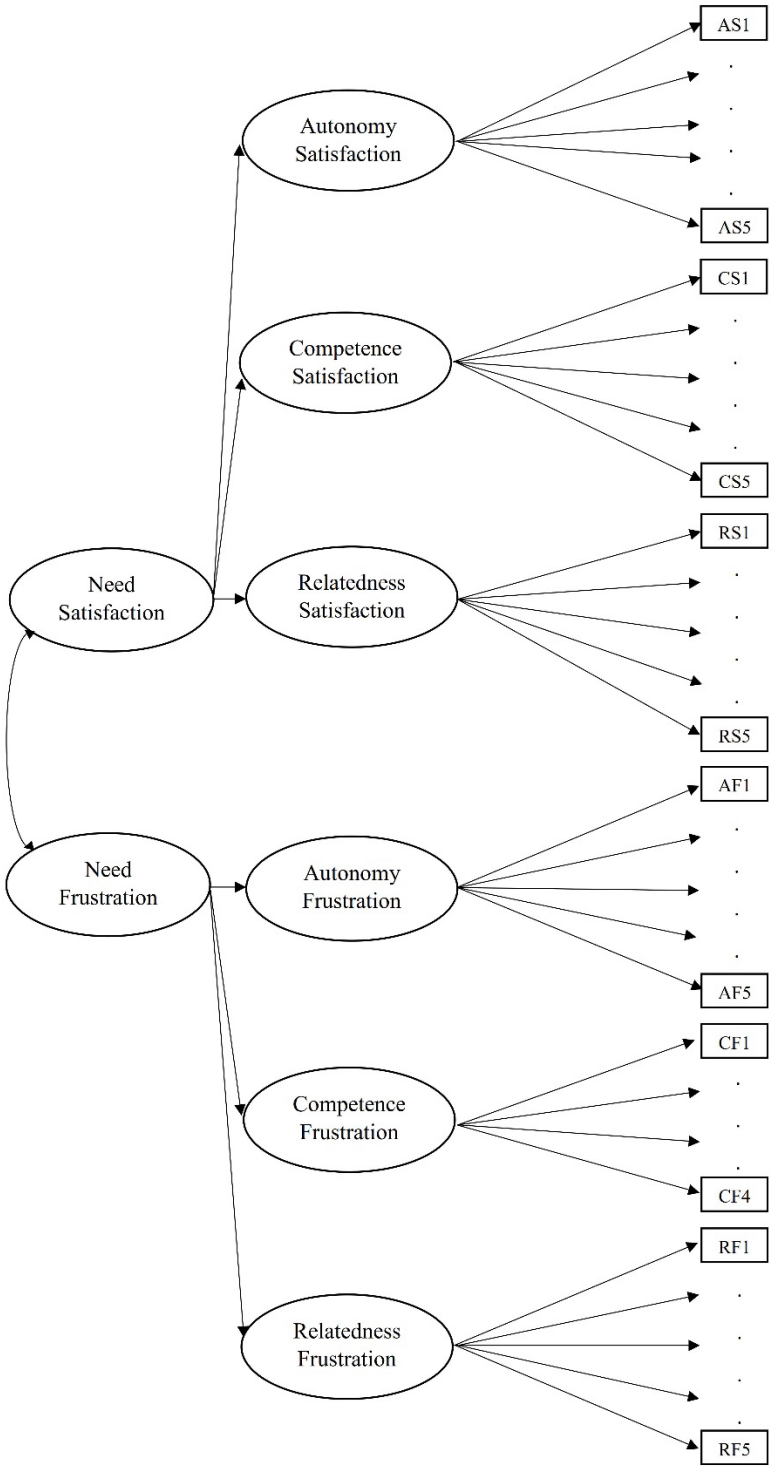
*Model 13.*Two-factor CFA Model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



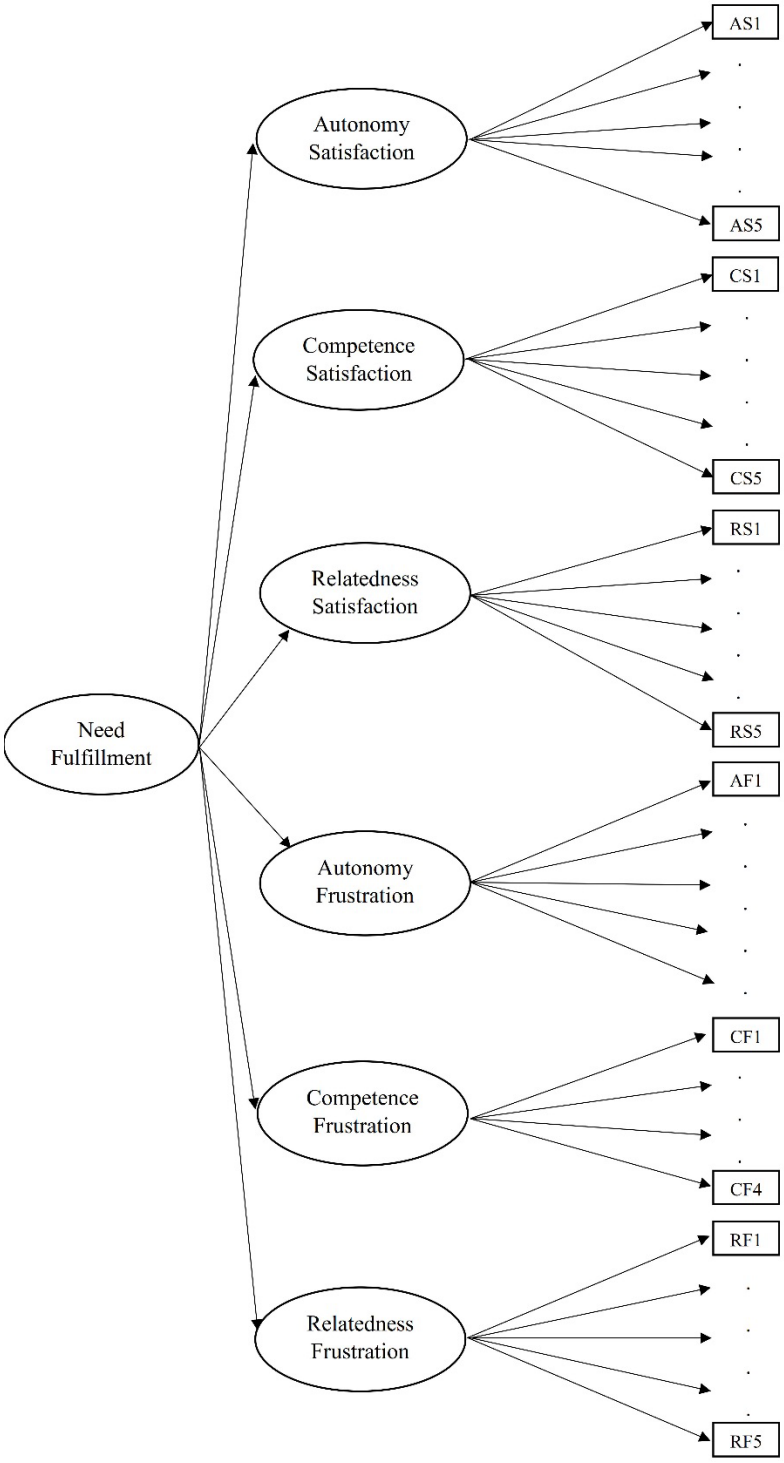
Model 14. Six correlated factors CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



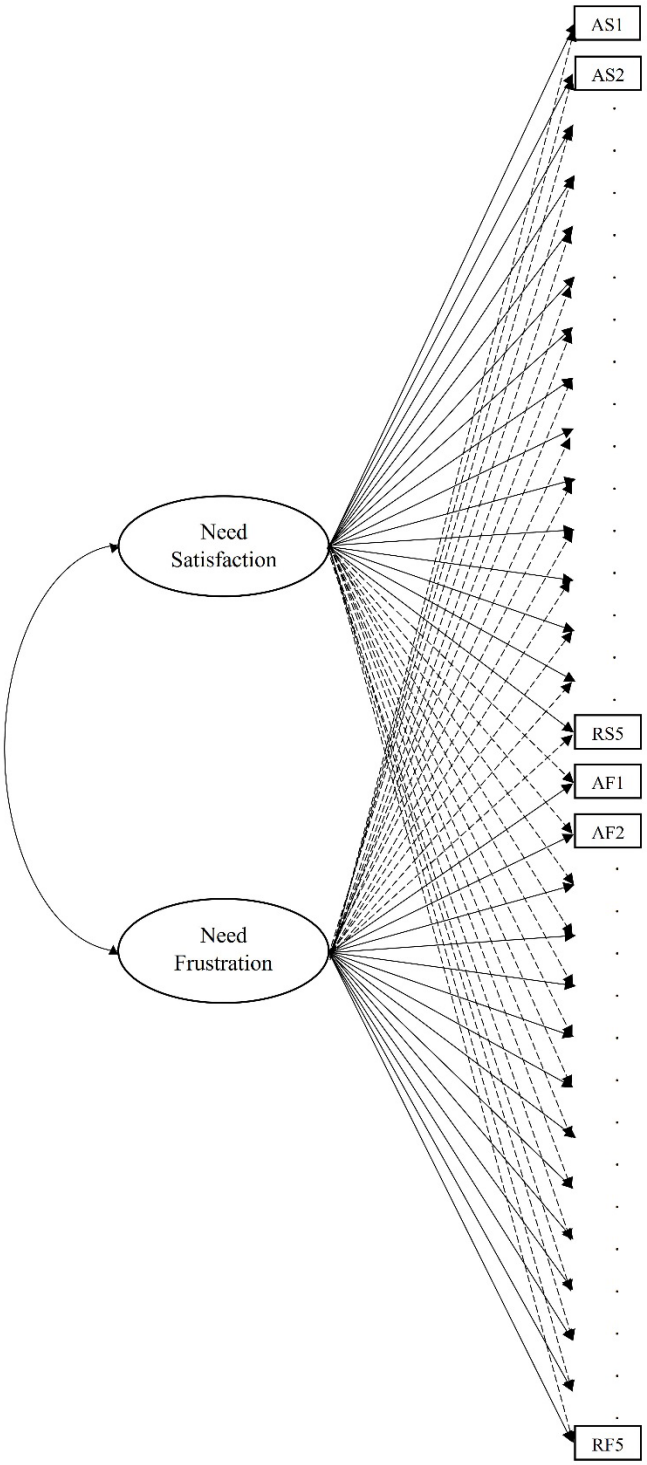
Model 15. Two higher-order; six lower-order hierarchical CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



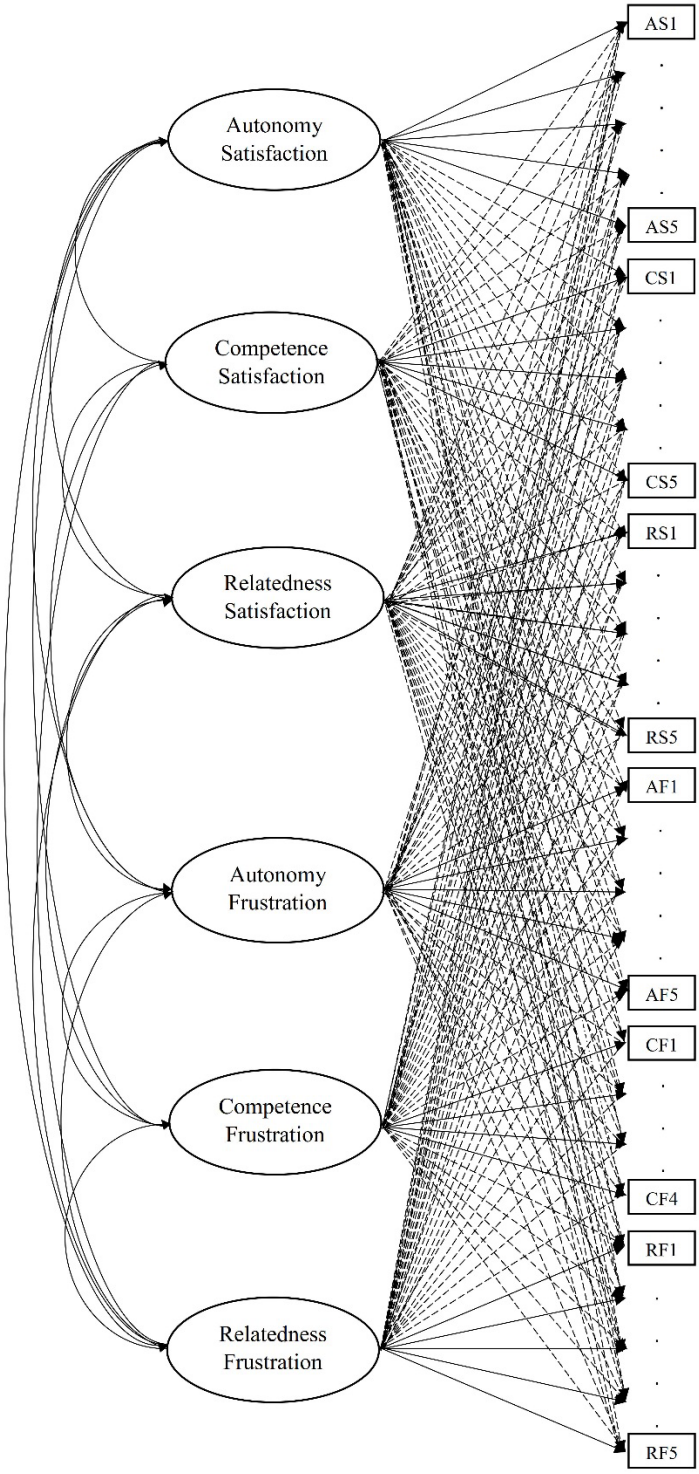
Model 16. One higher-order; six lower-order hierarchical CFA model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



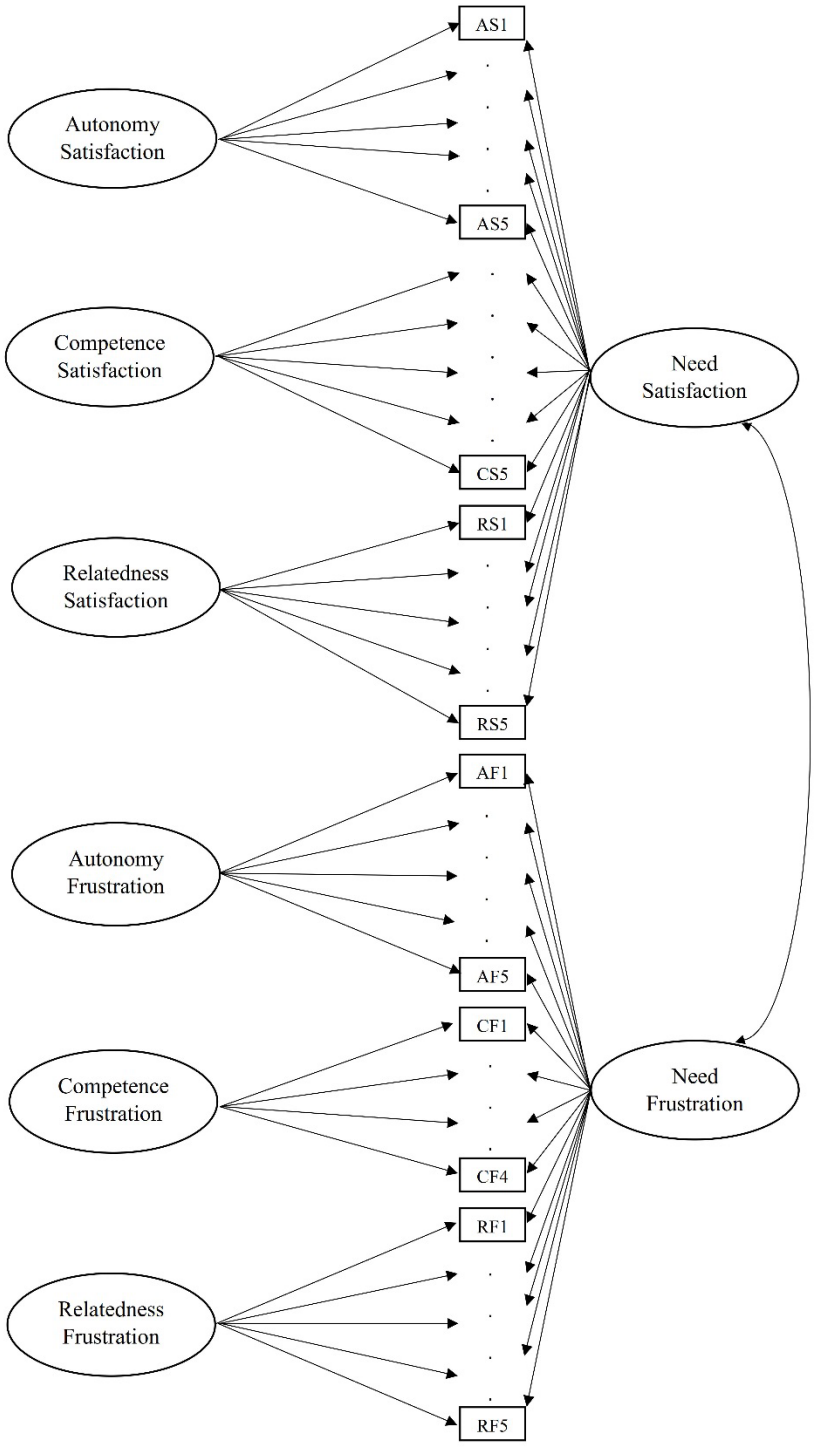
Model 17. Two factor ESEM model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



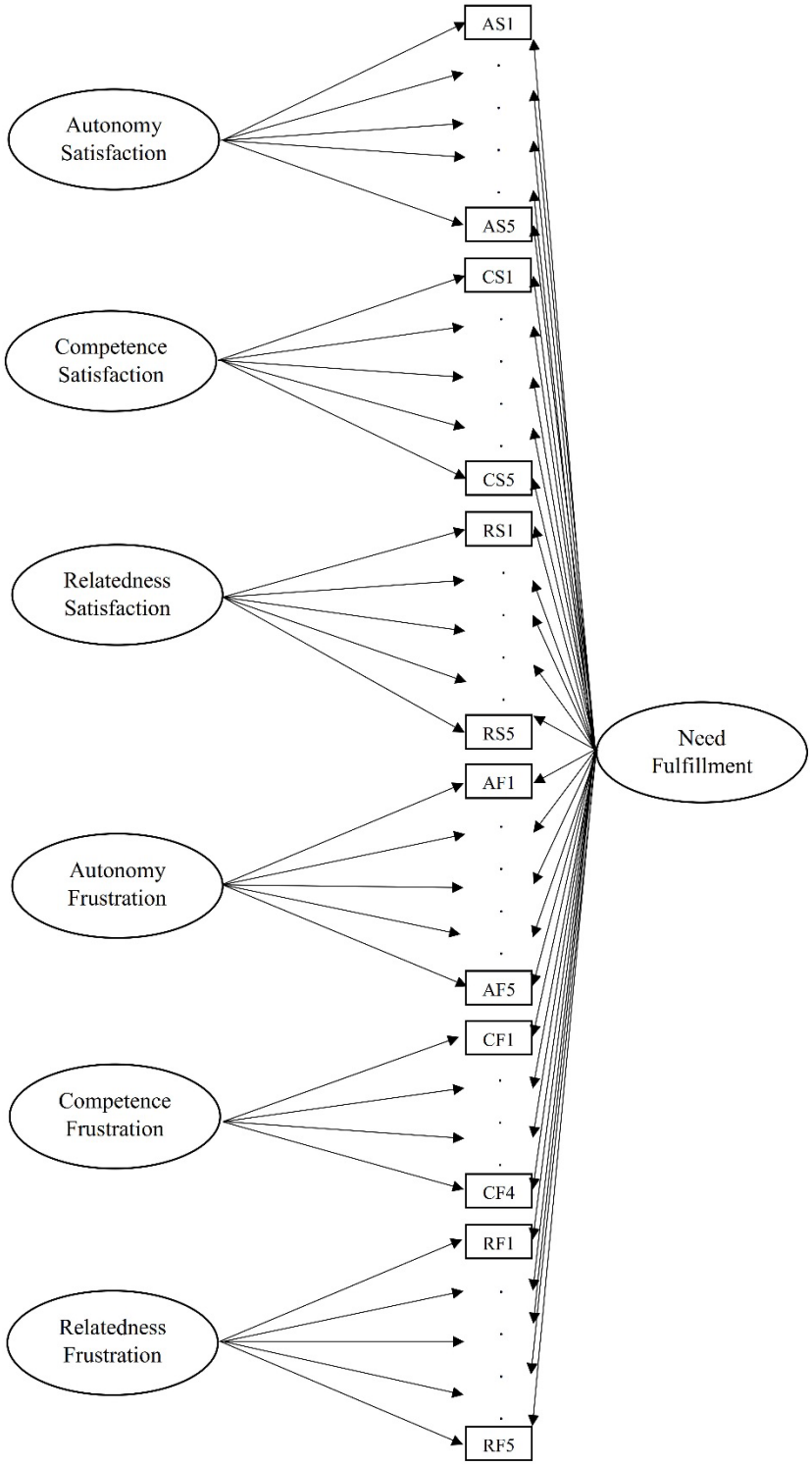
Model 18. Six correlated factors ESEM model

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



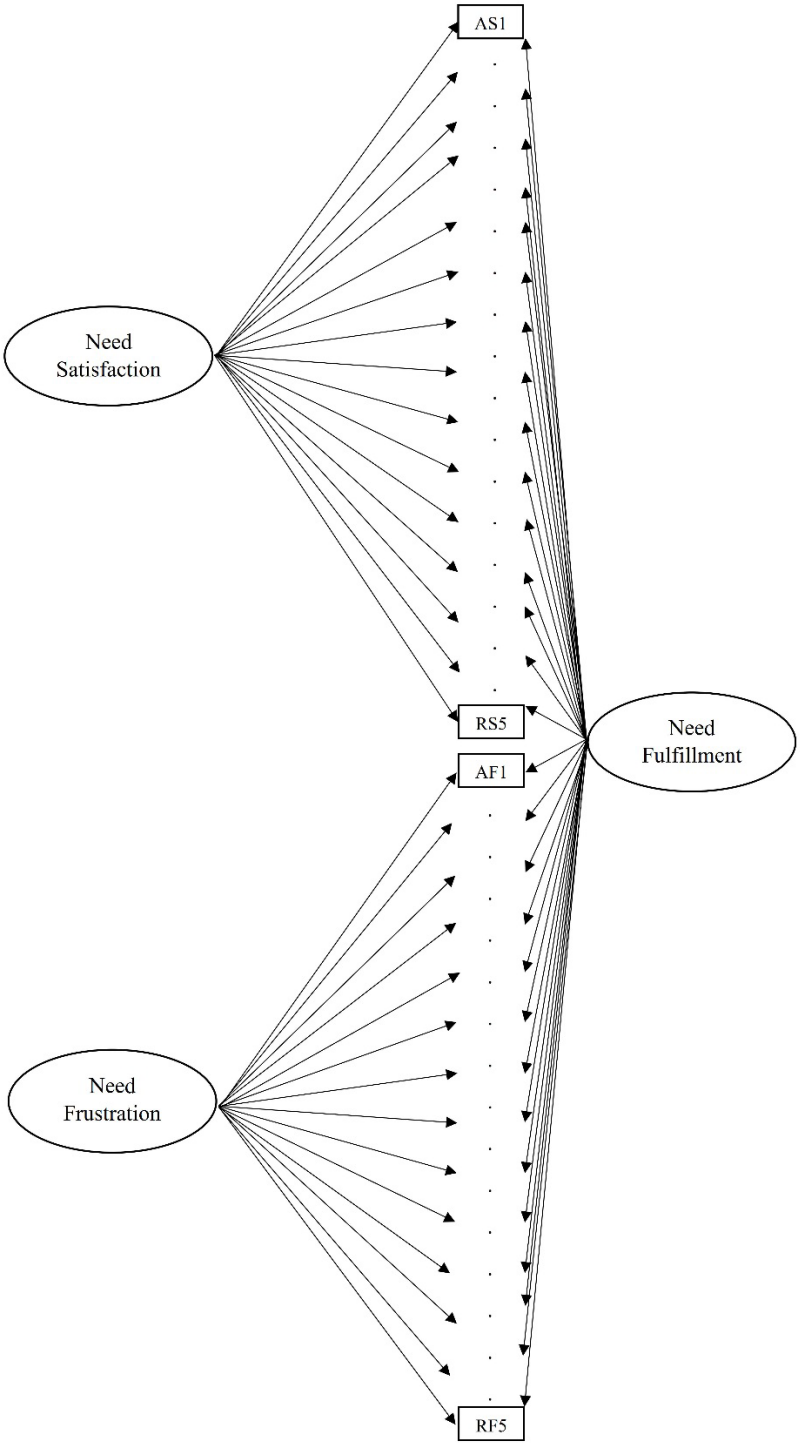
Model 19. Bifactor CFA model with two general-factors and six specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



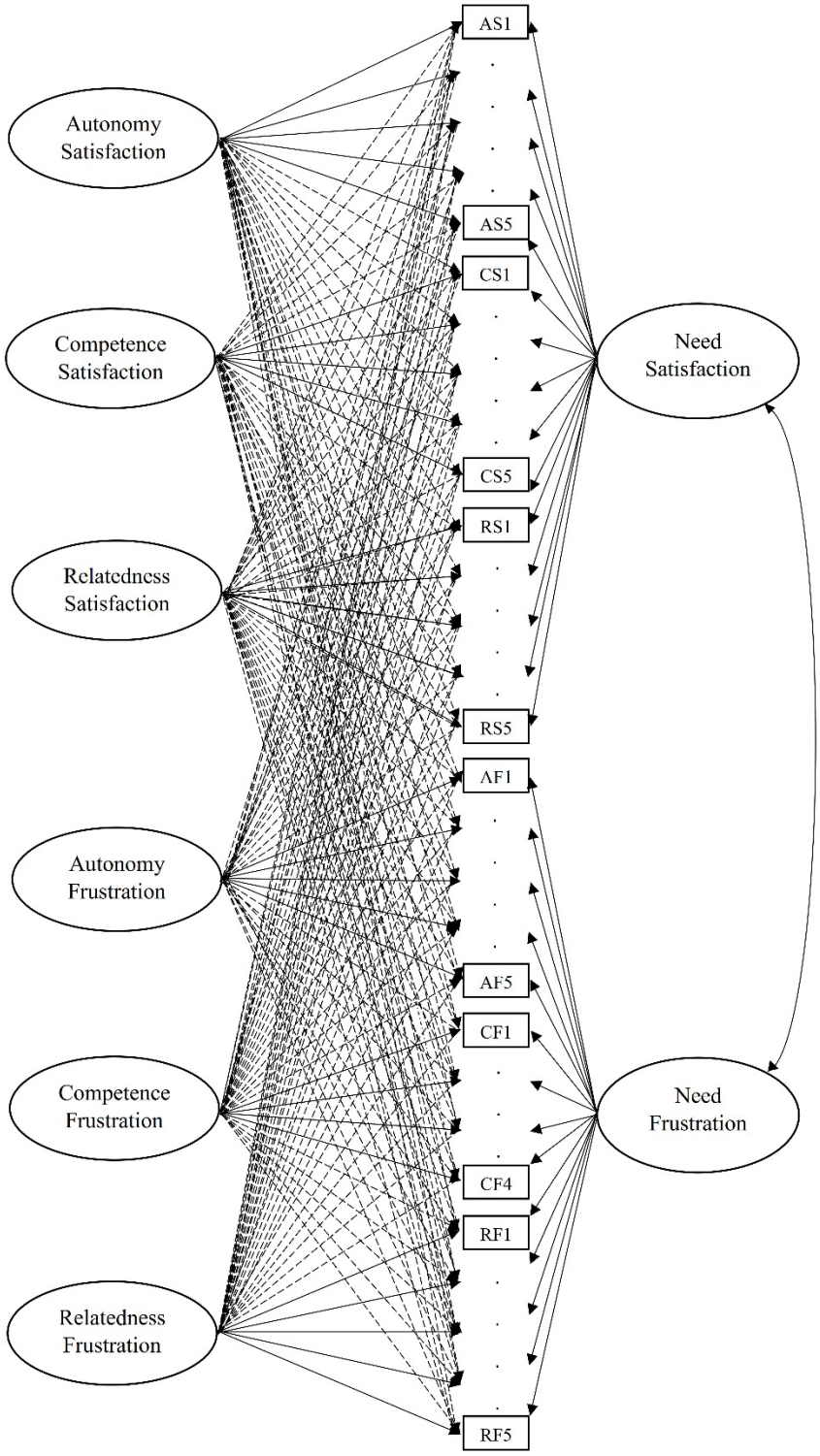
Model 20. Bifactor CFA model with one general-factor and six specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



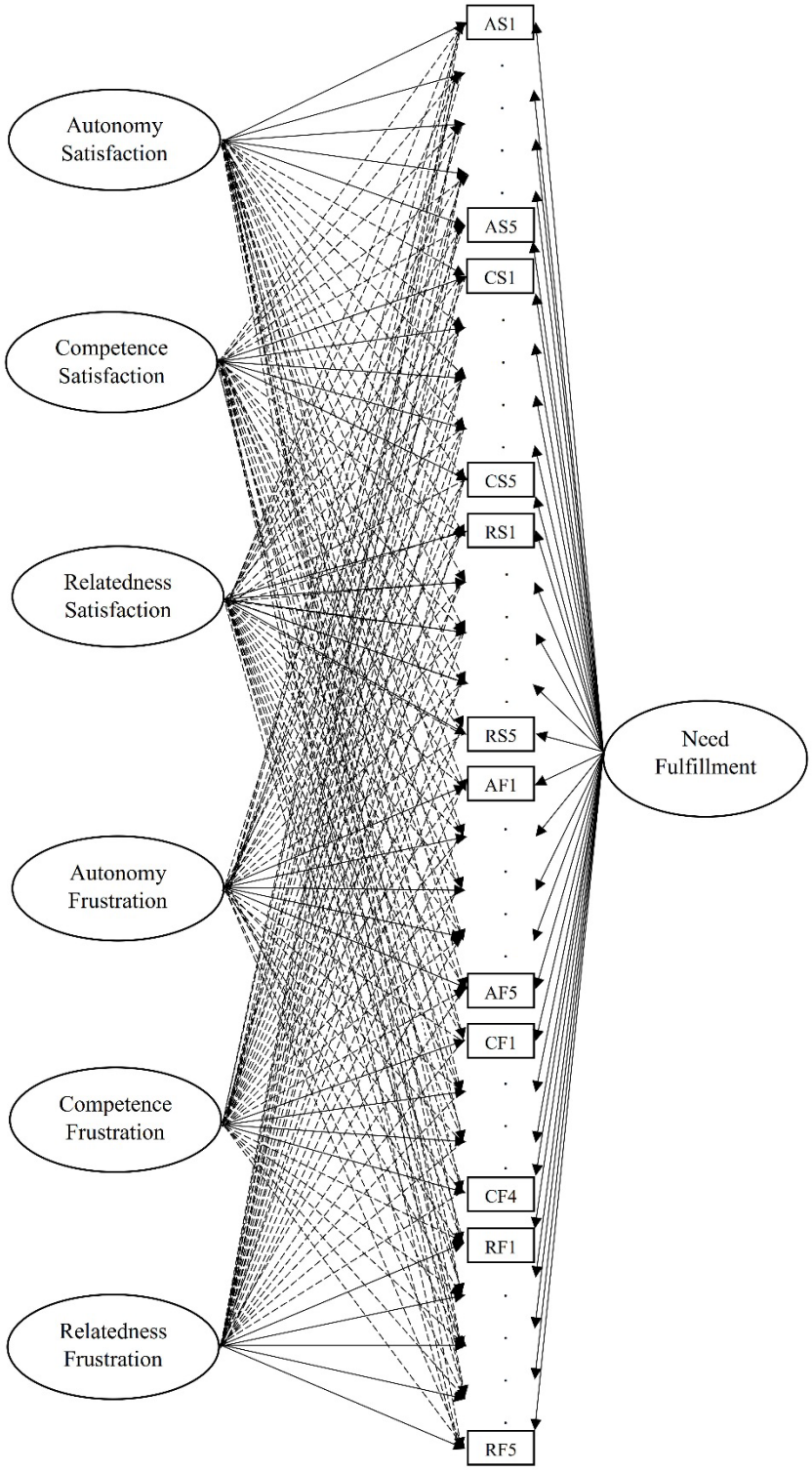
Model 21. Bifactor CFA Model with one general-factor and two specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



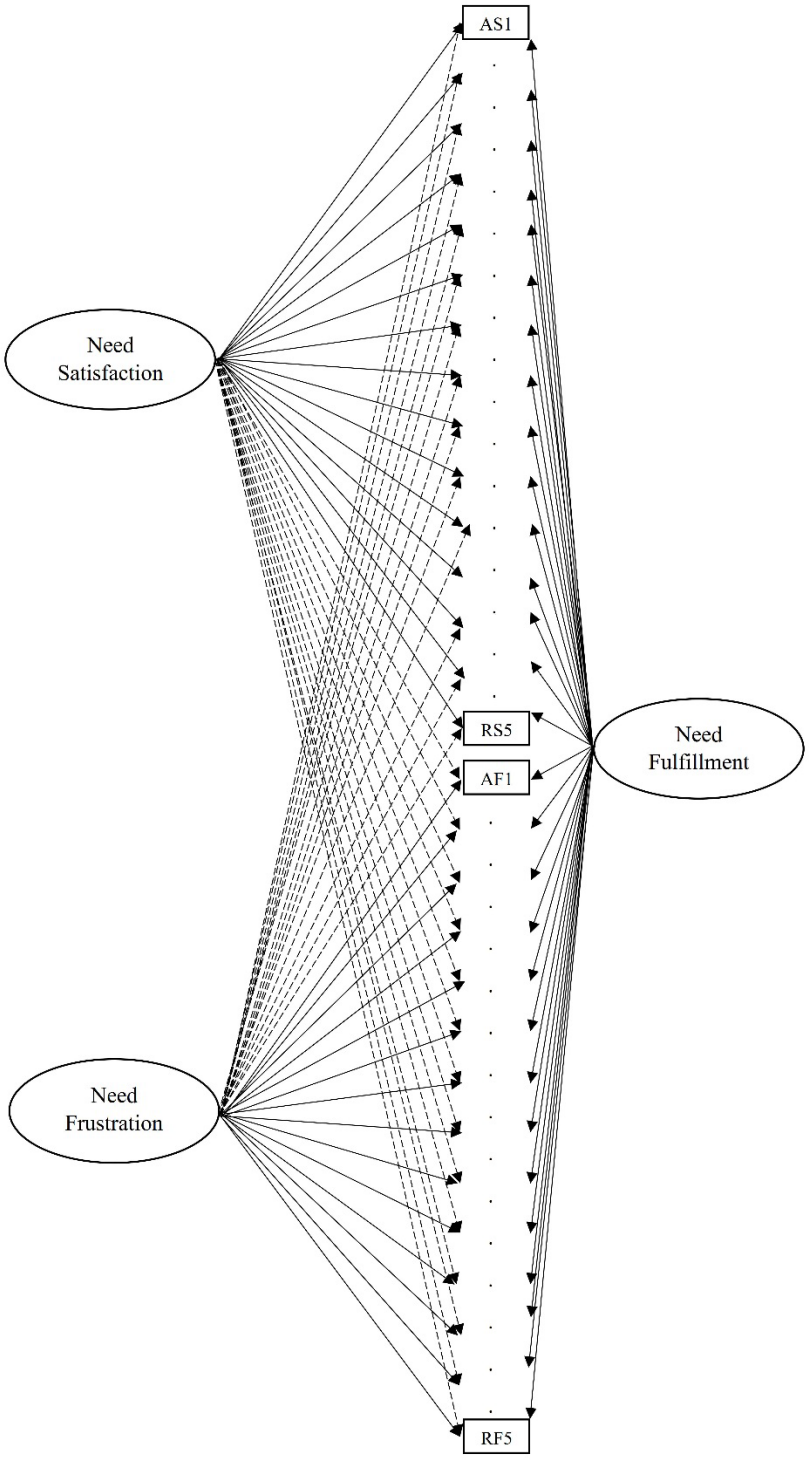
Model 22. Bifactor ESEM model with two general-factors and six specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



Model 23. Bifactor ESEM model with one general-factor and six specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items.



Model 24. Bifactor ESEM model with one general-factor and two specific-factors

Note. AS = autonomy satisfaction items; AF = autonomy frustration items; CS = competence satisfaction items; CF = competence frustration items; RS = relatedness satisfaction items; RF = relatedness frustration items

Supplementary File 3

Table 8

Factor Loadings for Model 10 (Bifactor ESEM 3-G, 9-S)

	G Factors			S Factors							
Items **Stem: In my sport, I…**	**SAT**	**FRUS**	**UNF**	**AF**	**CF**	**RF**	**AU**	**CU**	**RU**	**AS**	**CS**	**RS**
am not free to make choices with regards to my sport participation.		**-.08**		**.16**			.26*					
feel like a failure.		**.07**			**.71****	.40*						
feel rejected.		**.18**			.48**	**.55****						
feel pushed to behave in certain ways.		**-.24**		**.41***	.21*	.35**				.30*		
feel useless.		**.37**			**.60****	.42**			.20**			
feel brushed aside.		**.23**			.39**	**.49****	.22*					
feel forced to follow training decisions.		**-.35**		**.49**	.22*	.38**				.38**		
feel incapable.		**.18**			**.55****	.41**						
feel disliked.		**.33**				**.72****			.22**			
feel a lot of unwanted pressure.		**.07**		**.45***	.26**	.37*		.25**				
I feel hopeless.		**.35**		.23*	**.58****	.39*			.21**			
feel excluded.		**.15**		.36**	.27**	**.53****						
feel forced to do training tasks that I would not choose to do.		**-.32**		**.50**		.29*	.31**					
feel isolated.		**.14**			.27**	**.70****			.21*			
feel ignored.		**.21**				**.61****			.32**			
find many of the activities set for me are boring.			**-.25**			.20*	**.49****					
feel under-challenged.			**-.29**				.45*	**.26**				
have little in common with others.			**-.56****						**.38**			
am unsure as to why we do certain tasks in training.			**-.29**				**.48****	.25*				
feel like I have achieved less than I would have liked to.			**-.25**			.24*		**.63****				

	G Factors					S Factors					
Items **Stem: In my sport, I…**	**SAT**	**FRUS**	**UNF**	**AF**	**CF**	**RF**	**AU**	**CU**	**RU**	**AS**	**CS**	**RS**
have little shared interest with others.			**-.43**			.29*	.38*		**.38**			
contribute little to training decisions.			**-0.32**				**.32**			.31**		
feel like I have improved less than I would have liked to.			**-0.22**					**.70****				
feel I don't quite fit in with the others.			**-.43**		.25**	.26*		.23**	**.59***			
am unclear if my ideas are valued.			**-.06**				**.37**	.31**	.32**			
feel that I am not good enough.			**.04**		.43**			**.41****	.41**			.23*
have no close friends.			**-.02**			.26*			**.62****			
am confused as to when I can make decisions.			**.13**				**.37**		.47*			
am not satisfied with my level of competence.			**.18**		.33**			**.45****				
feel like my teammates know little about me.			**-.10**						**.53****			
feel that I participate because I want to.	**.30***					-.42**				**.11**		
am satisfied with my progress.	**.36****				-.34**			-45**			**.23**	
feel supported.	**.51****					-.57**						**-.08**
feel free to make choices with regards to the way I train.	**.35***			-.45**						**-.42**		
feel that I am capable.	**.46****				-.54**	-.23*					**-.22**	
feel listened to.	**.53****											**-.42**
have a say in how things are done.	**.48***									**-.51***		
feel skilled.	**.57****				-.37*						**-.40**	
feel valued.	**.62****											**-.19**
do activities that interest me.	**.51****									**.36**		
feel that I am improving.	**.42****				.28**		-.21*				**-.01**	
feel cared for.	**.49****					-.40**	-.30**					**-.11**

	G Factors					S Factors					
Items **Stem: In my sport, I…**	**SAT**	**FRUS**	**UNF**	**AF**	**CF**	**RF**	**AU**	**CU**	**RU**	**AS**	**CS**	**RS**
have the freedom to make training decisions.	**.41****			-.43**			-.23*			**-.33**		
am able to overcome challenges.	**.55****					-.34**					**-.22**	
feel included as an important part of the group/team.	**.41****					-.47*						**-.35**
feel I am a valued member of my team/group.	**.32****					-.28*						**-.17**

Note. *$p < .05$; **$p < .01$. Target factor loadings are in bold. For clarity purposes, only significant cross-loadings for S factors over .20 are reported. SAT = need satisfaction, FRUS = need frustration, UNF = need unfulfillment, AS = autonomy satisfaction, AF = autonomy frustration, CS = competence satisfaction, CF = competence frustration, RS = relatedness satisfaction, RF = relatedness frustration, AU = autonomy unfulfillment, CU = competence unfulfillment, RU = relatedness unfulfillment.

Table 9

Factor Loadings for Model 22 (Bifactor ESEM 2-G, 6-S)

	G-Factors		S-Factors					
Items **Stem: In my sport, I…**	**FRUS**	**SAT**	**AF**	**CF**	**RF**	**AS**	**CS**	**RS**
am not free to make choices with regards to my sport participation.	**.16**		**.21***					
feel like a failure.	**.04**			**0.54****	.45**		-.30**	
feel rejected.	**-.04**		.30**	.38**	**0.55****			
feel pushed to behave in certain ways.	**.43**		**.33***		.37**			
feel useless.	**-.10**			**0.69****	.50**		-.21**	
feel brushed aside.	**-.03**		.25*	.45**	**0.42****			-.25**
feel forced to follow training decisions.	**.64****		**.45****					
feel incapable.	**.08**			**0.57****	.48**		-.32**	
feel disliked.	**-.01**			.36**	**0.78****			-.28**
feel a lot of unwanted pressure.	**.10**		**.33****	.23*	.49**			
I feel hopeless.	**-.06**			**0.65****	.48**		-.21**	
feel excluded.	**.03**		.31*	.21**	**.65****			
feel forced to do training tasks that I would not choose to do.	**.48****		**.46****					
feel isolated.	**.07**			.27**	**.72****			-.30**
feel ignored.	**-.06**			.23**	**.69****			-.30**

	G-Factors		S-Factors				
Items **Stem: In my sport, I…**	**FRUS**	**SAT**	**AF**	**CF**	**RF**	**AS**	**CS**	**RS**
feel that I participate because I want to.		**.02**			-.35**	**-.10**		.40**
am satisfied with my progress.		**.07**	-.26*				**.33**	.47**
feel supported.		**.10**			-.27**			**.84****
feel free to make choices with regards to the way I train.		**-.16**	67**			**.29**		.37*
feel that I am capable.		**-.07**		-.23**	-.28**		**.88****	
feel listened to.		**-.40**			-.27**			**.51**
have a say in how things are done.		**-.61**				**.44**		
feel skilled.		**-.24**		-.31**			**.56****	
feel valued.		**-.33**						**.64****
do activities that interest me.		**-.24**				**-.42**		.45*
feel that I am improving.		**-.09**		-.28**			**.31****	.47**
feel cared for.		**-.19**			-.22**		.24*	**.59****
have the freedom to make training decisions.		**-.49**	-.48*			**.12**		
am able to overcome challenges.		**-.22**			-.26**		**.44****	.47*
feel included as an important part of the group/team.		**-.28**			-.40**		.30*	**.51****
feel I am a valued member of my team/group.		**-.12**	.22*					**.41****

Note. *$p < .05$; **$p < .01$. Target factor loadings are in bold. For clarity purposes, only significant cross-loadings for S factors over .20 are reported. SAT = need satisfaction, FRUS = need frustration, AS = autonomy satisfaction, AF = autonomy frustration, CS = competence satisfaction, CF = competence frustration, RS = relatedness satisfaction, RF = relatedness frustration.

Supplementary File 4

Table 10

Goodness-of-fit Statistics for Models Tested using Need Unfulfillment Items

Model	χ^2	*p*	*df*	CFI	TLI	SRMR	RMSEA [90% CI]
1. 3-factor CFA	332.427	<.001	.87	.79	.74	.08	.10 [.09,.11]
2. H-CFA(1-H, 3-L)	332.427	<.001	87	.79	.74	.08	.10 [.09,.11]
3.3-factor ESEM	151.591	<.001	63	.92	.87	.04	.07[.05,.08]
4. Bifactor CFA (1-G 3-S)	293.270	<.001	.75	.81	.73	.08	.10[.09,.11]
5. Bifactor ESEM (1-G, 3-S)				-*			

Notes. χ^2 = Chi-square test of exact fit; *p* = probability; *df* = degrees of freedom; CFI = Comparative Fit Index; TLI = Tucker–Lewis index; RMSEA = Root Mean Square Error of Approximation; 90% CI = 90% confidence interval of the RMSEA; CFA = confirmatory factor analysis; H-CFA = Hierarchical CFA; H-facto r = higher order factor estimated as a part of hierarchical model; L-factor = lower order factor estimated as a part of hierarchical model; ESEM = exploratory structural equation modeling; G-factor = global factor estimated as part of a bifactor model; S-factor = specific factor estimated as part of a bifactor model; -* = The standard errors of the model parameter estimates could not be computed. The model may not be identified.

Supplementary File 5

Table 11

Goodness-of-fit Statistics for Two-factor Solutions using All Items from Study 1

	Model	χ^2	*p*	*df*	CFI	TLI	SRMR	RMSEA [90% CI]
1.	Two-factor CFA	3156.278	<.001	1035	.65	.63	.09	.08[.08, .09]
2.	Six-correlated factors CFA	2755.327	<.001	974	.72	.69	.09	.08[.07, .08]
3.	H-CFA (two-H, six-L)	2914.257	<.001	982	.69	.67	.09	.08[.08, .08]
4.	H-CFA (one-H, six-L)				DNC			
5.	Two-Factor ESEM	2993.249	<.001	944	.67	.64	.07	.08[.08, .09]
6.	Six correlated-factors ESEM	1582.238	<.001	774	.87	.83	.03	.06[.05,.06]
7.	Bifactor CFA (two-G, six-S)				DNC			
8.	Bifactor CFA (one-G, six-S)				DNC			
9.	Bifactor CFA (one-G, two-S)	2660.299	<.001	943	.72	.70	.07	.08[.07, .08]
10.	Bifactor ESEM (correlated two-G, six-S)	1409.810	<.001	727	.89	.84	.03	.06[.05, .06]
11.	Bifactor ESEM (one-G, six-S)				-*			
12.	Bifactor ESEM (one-G, two-S)	2684.475	<.001	900	.71	.67	.06	.08[.08, .08]

Note. χ^2 = Chi-square test of exact fit; CFI = Comparative Fit Index; TLI = Tucker–Lewis index; RMSEA = Root Mean Square Error of Approximation; 90% CI = 90% confidence interval of the RMSEA; CFA = confirmatory factor analysis; H-CFA = Hierarchical CFA; H-factor = higher order factor estimated as a part of hierarchical model; L-factor = lower order factor estimated as a part of hierarchical model; ESEM = exploratory structural equation modeling; G-factor = global factor estimated as part of a bifactor model; S-factor = specific factor estimated as part of a bifactor model; DNC = did not converge; -* = The standard errors of the model parameter estimates could not be computed. The model may not be identified.