Gaining insight into doctoral persistence: Development and validation of Doctorate-related Need Support and Need Satisfaction short scales

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Post-print - to be published in Learning and Individual Differences, accepted in April 2018

Abstract

Based on self-determination theory, a few studies have identified competence satisfaction as a major determinant of doctoral persistence. However, these studies did not use scales validated in the domain of doctoral studies, and failed to include all dimensions of the target constructs of need support and need satisfaction, or used a composite score of need support. To address these limitations, we conducted two studies (total N = 1458) aimed at developing and validating short, self-report scales of Doctorate-related Need Support and Need Satisfaction (D-N2S). The scales exhibited satisfactory psychometric properties of reliability as well as construct, criterion-related, known-groups, predictive, and face kinds of validity. All but one dimension (i.e., relatedness satisfaction) were positively related to doctoral persistence intentions and all but two dimensions (i.e., autonomy support and relatedness satisfaction) were negatively related to actual dropout. As expected, doctoral students in social sciences and humanities reported higher levels of autonomy support and autonomy satisfaction but lower levels of relatedness satisfaction than doctoral students in sciences and technology or health sciences. Representing another important contribution of our research, results further suggest that dimensions of need support (or satisfaction) should not be combined into a general measure of support (or satisfaction).

Keywords: short scales; self-determination theory; supervisor support; need satisfaction; doctoral persistence.

1. Introduction

In recent years there has been a dramatic expansion in the enrolment of doctoral students. However, approximately 50% of these students fail to complete their doctorate (Golde, 2000). In order to understand the causes of this high attrition rate, research on doctoral persistence has mainly focused on three sets of factors: Characteristics of doctoral students, characteristics of supervisors or features of doctoral programs, and features of the supervisory process (for a review, see Bair & Haworth, 2004). The general conclusion is that the phenomenon is complex and "there is no one reason why doctoral students leave" (Gardner, 2010, p. 62). However, a robust finding is the association between doctorate completion and both the quantity and quality of contact between the student and her or his supervisor(s) (Bair & Haworth, 2004).

1.1. Features of the supervisory process

Dealing with a high level of requirements, many doctoral students doubt their abilities and consider quitting when they believe they lack the necessary skills to succeed as researchers (Golde, 2000). They thus expect to receive constructive feedback from their supervisor(s) and progress more when it is given (Ives & Rowley, 2005). Doctoral students are, in particular, required to build independent thinking while simultaneously managing long-term deadlines (Lovitts, 2005). Hence, striking a balance between guidance and autonomy is a key element of successful supervision (Overall, Deane, & Peterson, 2011). Doctoral studies also involve the integration of students in a lab and/or program, and ultimately into the scientific community (Gardner, 2010). In this regard, evidence suggests that doctoral students are more likely to persist if they develop a meaningful and collegial relationship with their supervisor(s), other faculty or other doctoral students, and engage in social and scientific activities related to their doctoral programs (Tinto, 1975).

However insightful, the literature on doctoral persistence has been criticized because it lacks a comprehensive theory, thereby preventing the coherent accumulation of knowledge (Bair & Haworth, 2004). A promising framework to conceptualize and investigate the relationships between supervisors' support and doctoral students' selfperceptions, on the one hand, and doctorate completion, on the other hand, is selfdetermination theory (SDT; Deci & Ryan, 1985, 2000), and its offshoot, basic needs theory (BNT; Ryan & Deci, 2002).

1.2. Self-determination theory

A macro-theory of human motivation, SDT sets out with the fundamental assumption that individuals are active organisms with inherent tendencies toward selfactualization (Deci & Ryan, 1985, 2000). However, to account for the frequently observed cases of apathy or alienation, these inherent tendencies are regarded as potentialities requiring specific nutrients and social conditions to become actualities. Specifically, the fulfillment of individuals' potential involves the satisfaction of three basic psychological needs, namely, for competence, autonomy, and relatedness, which are considered to be essential nutrients responsible for the initiation and orientation of human activity. The need for competence refers to individuals' feelings of efficiency and mastery. The need for autonomy refers to individuals' feelings of volition and free will. The need for relatedness refers to individuals' feelings of connection and closeness with others (see also Van den Broeck, Vansteenkiste, De Witte, Soenens, & Lens, 2010).

According to SDT, need satisfaction - that is, the perception that one is acting with a sense of autonomy, competence, and relatedness - provides the motivational foundation for individuals' engagement in an activity and, more broadly, for their optimal functioning. Specifically, individuals are expected to be intrinsically motivated (i.e., doing something because it is inherently interesting or enjoyable), rather than extrinsically motivated (i.e., doing something because it is a means to an end) or amotivated, when they can freely choose to pursue the activity (autonomy), when they master the activity (competence), and when they feel connected and supported by people who are important to them (relatedness); and they are expected to be more engaged in an activity when intrinsically motivated. Empirical research has substantiated these claims (for a review, see Deci, Vallerand, Pelletier, & Ryan, 1991).

A mini-theory, namely BNT, was later developed to account for the role played by the social context in the satisfaction of the three basic needs (Ryan & Deci, 2002). A central tenet of BNT is that the availability of involvement, autonomy support, and structure within the social context contributes to the satisfaction of the three basic needs. In other words, the quality of an individual's interactions with the social context can be measured by the extent to which they fulfill her or his basic needs. Need support can thus be defined as the extent to which the social context fulfills individuals basic needs for competence, autonomy, and relatedness through the provision of structure, autonomy support, and involvement. It can be operationalized either in terms of individuals' perceptions or in terms of concrete behaviors. Prior research has distinguished several behaviors or components within each dimension of need support (for a review, see Stroet, Opdenakker, & Minnaert, 2013). Involvement, which is associated with the need for relatedness, includes showing affection, expressing attunement, dedicating resources (e.g., time), and being dependable. Autonomy support, which is associated with the need for autonomy, includes providing choice as opposed to attempting to control the student's work, appreciating the student's point of view, and promoting curiosity-based explorations. Structure, which is associated with the need for competence, includes presenting clear instructions, offering guidance, communicating positive expectations, and providing constructive feedback (see also Hospel & Galand, 2016).

According to BNT, the three dimensions of support are essential motivational triggers of (intrinsic) motivation, engagement in an activity, and eventually persistence. As such, people will tend to persist in an activity and stay in contexts that support their need satisfaction. These predictions have been substantiated in different domains, including health, psychotherapy or education (for reviews, see Deci & Ryan, 2008; Stroet, Opdenakker, & Minnaert, 2013). In sum, SDT adopts a dialectical approach whereby differences in motivation, achievement, and well-being are considered to be the product of the interaction between individuals' inherent tendencies, on the one hand, and patterns of social relationships and contingencies that support or frustrate these tendencies, on the other hand.

1.3. The present research

SDT may be a useful framework for gaining insight into doctoral persistence and to investigate the motivational potential of supervisory processes. Indeed, the three dimensions of need support and the three dimensions of need satisfaction postulated by the theory correspond fairly well to the challenges mentioned earlier in relation to the experiences of doctoral students. SDT thus allows the integration of these previous findings in a single, coherent framework in a domain where empirical investigations have been for the most part a-theoretical. Moreover, contrary to SDT, the few theoretical frameworks (e.g., the interactionist model of student attrition; Tinto, 1993) that have been applied to doctoral studies do not give motivation a central role despite the fact that motivation has been proposed as a key explanatory variable in studies on doctoral persistence (e.g., Litalien, Guay, & Morin, 2015). Finally, although still few in number, studies on doctorate-related need support and need satisfaction have yielded encouraging results. Losier (1994) presented longitudinal data consistent with the view that the provision of autonomy support and involvement predict future persistence intentions through the satisfaction of SDT's three basic needs. Litalien and Guay (2015) showed that doctoral students who perceived their social context to be more supportive of their needs expressed lower levels of dropout intentions because such a context strengthened their intrinsic motivation toward doctoral studies, which in turn satisfied their need for competence.

However, this body of research is limited in several respects. First, some dimensions of need support or need satisfaction were omitted. Losier (1994) did not include structure and his measure of involvement referred to sources of support other than the supervisor. Litalien and Guay (2015) included neither autonomy satisfaction, nor relatedness satisfaction, and they used a composite score of need support. While identifying competence satisfaction as a major determinant of doctoral persistence, previous research may have overlooked the (relative) importance of other dimensions of need support or need satisfaction.

Second, the scales used included items that do not seem to measure the intended construct. For instance, to measure autonomy support, Losier (1994) used items like

'My supervisor is concerned about me' (our translation) which seems to tap more into involvement. In a similar vein, the same items were sometimes used to measure different dimensions. For instance, the item 'My supervisor gave me the tools to develop my skills' (our translation) was used to measure autonomy support in Losier (1994), whereas it was used to measure structure in Litalien and Guay (2015).

Although not explicitly guided by SDT, the study by Overall, Deane, and Peterson (2011) ought to be mentioned here. These scholars used an extended list of items to measure the degree to which doctoral students felt their supervisor(s) provided them with academic, autonomy, and personal support. These dimensions match fairly well with, respectively, the dimensions of structure, autonomy support, and involvement. Overall and her colleagues adapted items from the Learning Climate Questionnaire (Williams & Deci, 1996), which is grounded in SDT, to measure autonomy support and elaborated other items to measure academic and personal support in the domain of doctoral studies. The items were factor analyzed and factor loadings were all >.70 (N. Overall, personal communication, October 7, 2013) but factor analyses were carried out for each dimension separately. It is thus impossible to exclude the possibility that some items tap into more than one dimension of supervisor support. This problem is heightened by the fact that inter-correlations between dimensions were large, ranging from .63 to .87. In Litalien and Guay (2015), inter-correlations between dimensions of support were similarly large, ranging between .75 and .90. Thus, a third limitation - that also applies to the study of Overall et al. (2011) - is that the scales used to measure need support or need satisfaction have not been formally validated in the domain of doctoral studies

Because of the large size of inter-correlations between the different dimensions of need support observed in their studies, Litalien and Guay (2015) decided to compute a

general need support score. Thus they could not assess the extent to which the indirect effects of need support on doctoral persistence through need satisfaction were dimension-specific. This brings us to a fourth and last limitation: To our knowledge, no research has examined the relationships between need support and need satisfaction in a single measurement model.

In order to address the above limitations, we constructed short, self-report scales of Doctorate-related Need Support and Need Satisfaction (D-N2S). The development and validation of domain-specific scales is customary in the SDT literature (e.g., Gillet et al., 2008; Van den Broeck et al., 2010). Ryan (1995) provides three kinds of rationale for such practice. At a methodological level, adapting measures to the features of a specific domain allows error variance to be minimized, thus maximizing reliability, although this may come at the expense of generalizability. At a practical level, results collected by means of domain-specific measures allow us to make concrete recommendations, thereby avoiding the problems usually associated with general formulations. At a theoretical level, SDT acknowledges differences in the way basic needs are supported between domains and that these differences may affect the way basic needs are expressed and how external (i.e., supportive practices) and internal (i.e., basic needs) drives translate into self-regulation. Taken together, these rationales suggest that domain-specific scales are desirable when testing SDT.

The development and validation of the D-N2S were undertaken in accordance with the procedure recommended by Schipolowski, Schroeders, and Wilhem (2014) over two studies that are part of a larger multi-institutional project called 'Research on PhD'. One strand of the project involved a longitudinal study, which was approved by the Belgian Commission for the Protection of Privacy. Doctoral students from two Belgian universities were invited to complete an online questionnaire on four occasions, six months apart, over a period of eighteen months. In addition, at each new wave of data collection, new recruits were solicited. The questionnaire was available in both English and French. In this article, we report the results for the French version. In study 1, we developed a pool of items, translated items into French when necessary, and selected two sets of items (one for each scale). In study 2, we validated the factor structure of the scales and assessed the known-groups, criterion-related, and predictive validities of the different dimensions of the scales.

In the context in which the studies were carried out, namely the Wallonia-Brussels Federation, admission to doctoral studies is conditional upon having successfully completed (preferably, at least "cum laude") a second cycle of higher education studies (also called Master degree) or a similar degree, having submitted a written research proposal, having one or two supervisors (who are on a tenure track), and having a supervisory committee, which meets annually to guide and advise the doctoral student as well as to resolve potential conflicts between the doctoral student and her or his supervisor(s). The doctoral degree is obtained on completion of a doctoral program consisting of advanced academic training and a research assignment relating to the preparation of a doctoral thesis. Dropout rates in the Wallonia-Brussels Federation, and in Belgium more generally, are very similar to the above reported international figures and range between 47% (van der Haert, Arias, Emplit, Halloin, & Dehon, 2014) and 49.9% (Groenvynck, Vandevelde, & Van Rossem, 2013). Time to degree varies depending on type of funding. It is in principle of four years when doctoral students benefit from a fellowship, and therefore work full time on research, or of six years when doctoral students benefit from an assistantship and therefore dedicate 50% of their time to research and the other 50% essentially to teaching. In reality, many doctoral students need more than the funded time to complete their PhD. Time to degree tends to be even

longer for the significant number of doctoral students who have no funding (van der Haert et al., 2014).

2. Study 1

The aims of this study were: 1) to develop a large pool of items for the need support and need satisfaction scales; 2) to translate items that were borrowed from scales originally written in English into French; and 3) to select two sets of items on the basis of exploratory factor analyses (EFA), item statistics, maximization of construct coverage, and reliability coefficients.

2.1. Method

We started by adopting items from the scales of Dupont, Galand, Nils, and Hospel (2014) and Overall et al. (2011) for the need support scale, and from the scales of Gillet, Rosnet, and Vallerand (2008) and Van den Broeck et al. (2010) for the need satisfaction scale. Additional items were developed based on an analysis of 21 qualitative interviews we conducted with former doctoral students (Author, 2015, 2016) and official documents discussing the duties of supervisors issued by the universities in which we recruited our participants (e.g., Author's university, 2012). The developed pool of items was then discussed with, amended and supplemented by twelve delegates of the doctoral students representing 4 departments in social sciences and humanities, 2 in sciences and technology, and 3 in health sciences. This led to a first list of 40 items (see Appendix).

In a second step, items that were adopted from scales originally written in English were translated into French as instructed by Brislin (1986). In each of two pairs of bilingual psychologists, one translator was asked to translate the original item into French and the other to translate it back into English. The procedure was repeated once more before the fifth author judged the translated items to be good cultural (as opposed to literal) equivalents of the original, and the back-translated items to be close enough to the original.

The total set of items was then randomized in an online questionnaire that was emailed to 3228 doctoral students from two Belgian universities. Participants were first presented with an informed consent form and were requested to give their consent by clicking on a radio button before accessing the questionnaire. The form included information about the purpose of the research, expected duration and procedure, participants' right to decline to participate and to withdraw from the research once participation has begun, confidentiality of participation, and whom to contact for questions about the research and research participants' rights. Two additional reminders were emailed to doctoral students who did not complete the questionnaire, one two weeks, and the other three weeks, after the initial email. Data collection spanned five weeks.

Responses were made on a Likert scale ranging from 1 (Totally disagree) to 5 (Totally agree). For the need support scale, participants were invited to answer items with reference to their mentor, that is, the person who primarily fulfilled the supervisory role for them, who may or may not have been their official supervisor. Across studies, >82% of participants considered their supervisor(s) to be also their mentor(s). For the need satisfaction scale, participants were invited to answer the items following the stem 'In the context of my PhD...'.

One thousand sixty-five doctoral students started the French version of the questionnaire (107 started the English version). Forty-two indicated they had received or quit their PhD or had not yet enrolled. Of the 1023 remaining respondents, 858 completed the questionnaire. Seventeen participants reported not having a mentor. Little's test (1988) for data missing completely at random (MCAR) was nonsignificant,

 $\chi^2(215) = 242.28$, p = .10, and thus data from non-completers were dropped (Kline, 1998).

Table 1 provides demographic characteristics of the sample and allows for a comparison with population parameters as determined by administrative data drawn from two cohorts of doctoral students enrolled at the two surveyed universities from 2005-2006 to 2013-2014 (Author, 2017). Examination of this table indicates that the sample of study 1 was fairly representative of the population in terms of gender, age at start of PhD, grade obtained for second cycle studies, and discipline but less so in terms of nationality and funding. Specifically, non-EU nationals and unfinanced doctoral students were underrepresented.

[INSERT TABLE 1 ABOUT HERE]

Six months later, the 858 participants who had completed the questionnaire were again contacted and invited to complete a revised version of the questionnaire. We used the same follow-up procedure as before except that non-completers who had sent us their personal details six months before received a fourth reminder by phone or post after four weeks. Six hundred and forty-seven participants started the questionnaire and 615 completed it. Thirty-three reported having obtained their PhD since their first participants. Forty-five participants reported not having a mentor. Little's test for MCAR was nonsignificant, $\chi^2(73) = 88.93$, p = .10, and so data from non-completers were dropped.

2.1.1. Statistical analyses

To examine the factor structure of our scales, we conducted EFA (principal axis factoring) using a direct oblimin rotation. The optimal number of factors to be retained was based on the Schwarz Bayesian information criterion (BIC; Schwarz, 1978, as cited

in Preacher, Zhang, Kim, & Mels, 2013). Items were selected if they had moderate to high pattern coefficients (i.e., >.40), and minimal cross-loadings (i.e., <.32; Kline, 2013; Tabachnik & Fidell, 2007). A scale's dimension was considered theoretically sound if it maximized the construct coverage (Schipolowski et al., 2014).

2.2. Results and discussion

2.2.1. Data screening

To examine the appropriateness of the data for multivariate statistical analyses, we computed a series of item statistics (see Appendix). One item (i.e., 'My mentor only points out the insufficiencies, mistakes, and limitations of my work') did not meet the cut-off criterion of .30 set for corrected item-total correlations, which is indicative of insufficient variance (Nunnally & Bernstein, 1994), and was thus excluded from further analyses. Squared multiple correlations revealed neither singularity nor multi-collinearity (all <.90; Kline, 1998). Our sample exceeded MacCallum, Widaman, Zhang, and Hong's (1999) minimum requirements for factor analysis, with samples being in the range of 100 to 200 and factors having three to seven indicators each. The Kaiser-Meyer-Olkin's value was .94 for the need support scale and .85 for the need satisfaction scale, indicating that the data were suitable for factor analysis.

2.2.2. Factor analysis and item selection

2.2.2.1. Need Support scale

The BIC supported a four-factor solution. The first three factors clearly represented involvement, structure, and autonomy support, respectively. The fourth factor included two autonomy support items (i.e., 'My mentor takes my ideas into account', 'My mentor listens to my propositions on how I would like to do things'). However, because

factors with less than three indicators are generally weak and unstable (MacCallum et al., 1999), we excluded these two items.

Four additional items were excluded for the following reasons. Two involvement items (i.e., 'My mentor does not demonstrate any interest in what I do', 'My mentor behaves inappropriately towards me') had no loadings >.40 and similar loadings (ranging from |.27| to |.34|) on the factors representing involvement and structure. One involvement item (i.e., 'My mentor is available when needed') loaded on the factor representing structure, whereas one structure item (i.e., 'My mentor makes me feel I can succeed') loaded on the factor representing involvement.

As we aimed to reduce the total number of items, when a dimension included two redundant items, we deleted the item with the lowest corrected item-total correlation. As a result, we removed the item 'My mentor constantly controls my work' for the autonomy support dimension and the item 'My mentor teaches me about the technical knowledge and skills that I need' for the structure dimension. This resulted in each need support dimension containing 4 items. This number was higher than for the need satisfaction dimensions because need support dimensions include more components (up to four, whereas need satisfaction dimensions are usually conceptualized as including two components each) and we wanted to maximize the constructs' coverage.

The factor structure of this set of items was then examined via EFA (Table 2). The BIC supported a three-factor solution that clearly included involvement, autonomy support, and structure. Altogether, these factors explained 63% of the variance in the data. For involvement, $\alpha = .84$. For autonomy support, $\alpha = .62$. For structure, $\alpha = .85$. Concerning the analysis of responses from participants who completed our questionnaire twice, six months apart, test-retest correlations were calculated after excluding the responses of 45 participants who reported having switched to another (co-

)supervisor during the course of their PhD. Test-retest correlation = .68, .64, and .67 (all ps < .001) for, respectively, involvement, autonomy support, and structure. Given the rather long time interval between the two assessments, we consider these coefficients to be satisfactory.

[INSERT TABLE 2 ABOUT HERE]

2.2.2.2. Need Satisfaction scale

The BIC supported a four-factor solution. The first three factors included items measuring relatedness, autonomy, and competence satisfaction, respectively. The fourth factor included autonomy satisfaction items (i.e., 'I have the feeling that my thesis project does not belong to me', 'It is difficult for me to think of my thesis project as being my own', 'I feel personally responsible for my thesis project') that tap specifically into feelings of ownership of the thesis. Although some researchers identify self-ownership as a core component of the need for autonomy (Sheldon & Hilpert, 2012; Stefanou, Perencevich, DiCintio & Turner, 2010), other researchers do not include experiences of self-ownership in their conceptualization of the need for autonomy (e.g., Ryan & Deci, 2002; Van den Broeck et al., 2010). We thus deleted these items. Another autonomy satisfaction item (i.e., 'I have little control over the organization of my work') had none of its loadings >.40 and was thus deleted. The scale was further shortened using the same procedure as above, which led to the removal of five competence satisfaction items and one relatedness satisfaction item. In the final set of items, each need satisfaction dimension contained 3 items.

The factor structure of this set of items was then examined via EFA (Table 2). The BIC supported a three-factor solution that clearly included relatedness, autonomy, and competence satisfaction. Altogether, these factors explained 69% of the variance in the data. For competence satisfaction, $\alpha = .74$. For autonomy satisfaction, $\alpha = .78$. For

relatedness satisfaction, α = .79. Test-retest correlation = .69, .70, and .67 (all *ps* < .001), respectively.

3. Study 2

The aims of this study were: 1) to further validate the factor structure of the scales developed in study 1 and to test the construct validity of their dimensions on the basis of confirmatory factor analyses (CFA), and to assess 2) the known-groups validity, 3) the criterion-related validity, as well as 4) the predictive validity of the different dimensions of the scales. Concerning the second aim, we examined whether the D-N2S scales related to an environmental variable (i.e., discipline). Differences in the way disciplines conduct research have been documented (Bair & Haworth, 2004; Gardner, 2007; Golde, 2005; Lovitts, 2001; Moses, 1990; Smeby, 2000; Turner, Miller, & Mitchell-Kernan, 2002). In sciences and technology or in health sciences, research tends to be conducted in laboratories by teams of doctoral students and postdoctoral fellows working together under the direct supervision of the lab manager, whereas in social sciences and humanities research tends to be an individual endeavor undertaken in departments where doctoral students often work on unrelated topics. Moreover, in science and technology or in health science, doctoral students work more often on their supervisor's research project, whereas in social sciences and humanities the topic of their dissertation is more often of their own choosing.

Other research has suggested that these differences in practices translate into different doctoral students experiences (Barnes, Williams, & Stassen, 2012; Golde, 2005; Ridding, 1996; Zhao, Golde, & McCormick, 2007). For instance, in Ridding (1996), doctoral students in science reported having more peers readily available in their labs and interacting more often with them than doctoral students in history and education. Disciplinary differences in doctoral students' experiences were also found for perceptions of autonomy support and feelings of autonomy. In science, doctoral students reported that supervisors exercised more control on the choice of research topics as well as other aspects of the doctoral students' research. Moreover, whereas establishing ownership over their own ideas was not considered a salient issue by doctoral students in science, for students in history and education, it was taken for granted that 'ownership' of their dissertations was essential. Consequently, we expected doctoral students doing their PhD in social sciences and humanities to report higher levels of autonomy support (Hypothesis 1a) and autonomy satisfaction (Hypothesis 1b) but lower levels of relatedness satisfaction (Hypothesis 1c) than doctoral students in the two other disciplines (i.e., science and technology, and health sciences).

Concerning the third aim, we examined the associations between, on the one hand, need support and need satisfaction and, on the other hand, doctoral students' engagement and doctoral persistence intentions. Engagement refers to the extent of a persons' active involvement in an activity (Connell & Wellborn, 1991). Recent reviews resulted in a tripartite conceptualization that included behavioral, cognitive, and emotional dimensions (e.g., Fredricks, Blumenfeld, & Paris, 2004). Although SDT does not make dimension-specific predictions concerning engagement, positive associations between each dimension of need support and need satisfaction, on the one hand, and each dimension of engagement, on the other hand, have been found (for reviews, see Dupont et al. 2014; Stroet et al., 2013). However, because most studies did not assess each dimension of need support and/or need satisfaction simultaneously (but see Dupont et al., 2014), their unique effects on each dimension of engagement is difficult to predict. Persistence can be understood as the process by which an individual diligently works toward the completion of a task (Tinto, 1975). In line with SDT, previous research has revealed positive (negative) associations between autonomy support and

need satisfaction, on the one hand, and academic or doctoral persistence (dropout) intentions, on the other hand (for a review, see Litalien & Guay, 2015). In view of the foregoing, the need support and need satisfaction dimensions were expected to relate positively to doctoral students' engagement (Hypotheses 2a and 2b) and doctoral persistence intentions (Hypotheses 3a and 3b).

Concerning the fourth aim, we examined whether the D-N2S is predictive of actual dropout over a period of one year. Specifically, we expected the need support and need satisfaction dimensions to relate negatively to actual dropout (Hypotheses 4a and 4b). We next examined the associations between need support and need satisfaction. Although the association of each dimension of need support with the corresponding need satisfaction is neither perfect nor unique (Connell & Wellborn, 1991, Stroet et al., 2013), in line with BNT, we expected structure to relate more strongly to competence satisfaction (Hypothesis 5a), autonomy support to relate more strongly to relatedness satisfaction (Hypothesis 5b), and involvement to relate more strongly to relatedness satisfaction (Hypothesis 5c).

3.1. Method

A revised online questionnaire was sent to an independent sample of 1963 doctoral students (1557 of whom 406 of whom were contacted for study 1 but did not participate) from the same two Belgian universities. The same informed consent form and follow-up procedure were used as in study 1. Seven hundred fifty-five doctoral students started the French version of the questionnaire (one hundred twelve started the English version). Seven indicated they had received or quit their PhD or had not yet enrolled. Of the 748 remaining respondents, 600 completed the questionnaire. Forty-five participants reported not having a mentor. Little's test for data missing completely

at random (MCAR) was nonsignificant, $\chi^2(59) = 71.39$, p = .13. Consequently, data from non-completers were dropped.

Participants first indicated the extent to which they agreed with each of the 21 items of the D-N2S. For the involvement, autonomy, and structure dimensions of the need support scale, $\alpha = .88$, .60, and .87, respectively. For the competence, autonomy, and relatedness dimensions of the need satisfaction scale, $\alpha = .71, .75$, and .76, respectively. They then completed a series of scales measuring constructs found in past research to represent outcomes of need support and need satisfaction. These scales were: Behavioral engagement (adapted from Dupont, Meert, Galand & Nils, 2013; e.g., 'Lately, I work intensely on my PhD', 4 items, $\alpha = .87$), cognitive engagement (adapted from Galand, Raucent & Frenay, 2010; e.g., 'When I work on my PhD, time flies', 4 items, $\alpha = .82$), emotional engagement (adapted from Galand & Philippot, 2005; e.g., 'Lately, when I work on my PhD, I feel anxious, stressed out'; reversed, 8 items, $\alpha =$.84), and doctoral persistence intentions (adapted from Neuville, Frenay, Schmitz, Boudrenghien, Noël, & Wertz, 2007; e.g., 'I am seriously considering quitting my PhD'; reversed, 6 items, $\alpha = .82$). All of the above scales were adapted so that each item referred specifically to the PhD, and were scored on a 5-point scale ranging from 1 (Totally disagree) to 5 (Totally agree). The last part of the questionnaire contained questions measuring environmental variables including discipline as well as demographic variables.

One year after participants completed the questionnaire, the two universities' administrations provided us with information about which participants had dropped-out. By that time, 37 (6%) had dropped-out. This rate is similar than for participants who completed the questionnaire in English (9%; $\chi^2(1) = .93$, p = .334, V = .04) but is significantly lower than for non-respondents (17%; $\chi^2(1) = 42.59$, p < .001, V = .16).

Demographic characteristics of the sample are presented in Table 1. Examination of this table indicates that, as in study 1, the sample was fairly representative of the population in terms of gender, age at start of PhD, grade obtained for second cycle studies, and discipline but less so in terms of nationality and funding. Specifically, non-EU nationals and unfinanced doctoral students were again underrepresented.

3.1.1. Statistical analyses

To further validate the factor structure of our scales and test the construct validity of the dimensions, we conducted CFA using maximum-likelihood estimation with Stata 14 (StataCorp, 2015). As in Van den Broeck et al. (2010), we performed CFA in study 1 as well as in study 2 in order to rule out potential methodological explanations if CFA solutions obtained in study 2 failed to confirm EFA solutions obtained in study 1.

In each study and for each scale, a one-factor model (Model A) was compared to the hypothesized three-factor model (Model B). In the latter, the covariances between the latent factors representing the three dimensions of need support (or need satisfaction) were freely estimated. In other words, Model A was the same as model B, except the covariances between the three latent need support (or need satisfaction) were constrained to 1. Next, two models were tested that specify relationships between the need support and need satisfaction scales. Specifically, in Model C, need support and need satisfaction were modeled as higher order factors with each of them being represented by their three first-order factors. In this model, the covariance between the two higher order factors was freely estimated. Model D contains six latent factors representing the three dimensions of need support and the three dimensions of need satisfaction. In this model, the covariances between the six latent factors were freely estimated.

The logic of the model comparisons was as follows. By comparing a model in which the three need support (or need satisfaction) dimensions are specified (Model B) with a model in which they are not specified (Model A), we examine the extent to which the three dimensions of need support (or need satisfaction) should be differentiated from each other. Better fit for model B indicates the dimensions are not collinear and are tapping different constructs. By comparing a model in which the need support and need satisfaction factors are freely correlated (Model D) to a model in which need support and need satisfaction factors are freely correlated through higher-order factors representing the constructs of need support and need satisfaction (Model C), we examine the extent to which the relationship between need support and need satisfaction is dimension-specific. Better fit for model D indicates that the dimensions of need support and of need satisfaction should be examined separately by researchers, not treated as single aggregates.

Results and discussion

3.1.2. Factor structure and construct validity

Table 3 shows that, for the measurement models of both scales, the unconstrained three-factor solution fitted the data well in both Samples 1 and 2. Moreover, significant differences in χ^2 -value indicated that Model B fitted the data significantly better than the one-factor model¹. Concerning the need support scale, all items had significant loadings (ranging from |.47| to |.81|, *p* < .001, with an average loading of .70 in both studies) on

¹ Because of the low reliability of the autonomy support sub-scale, we tested two two-factor models in which autonomy support was taken together with another need and contrasted with the remaining need. CFA (available upon request) revealed that the three-factor model fitted the data better than any of the two-factor models (All SBS- χ^2 differences > 136.37**). We thank an anonymous reviewer for this suggestion.

their intended latent factor. Concerning the need satisfaction scale, all items had significant loadings (ranging from |.55| to |.93|, p < .001, with an average loading of .72 in both studies) on their intended latent factor. Across the two studies, the latent variables of involvement and autonomy support correlated on average .57, involvement and structure correlated on average .70, autonomy support and structure correlated on average .24, competence and autonomy satisfaction correlated on average .39, competence and relatedness satisfaction correlated on average .14, and autonomy and relatedness satisfaction correlated on average .22.

[INSERT TABLE 3 ABOUT HERE]

Concerning the measurement models specifying relationships between the need support and need satisfaction scales, Table 4 shows that Model D was superior to Model C in terms of fit to the data in both studies. These results indicate that need support and need satisfaction items are more meaningfully grouped and inter-correlated at the firstorder level of the factors (or dimensions) rather than at the second-order level of the constructs.

[INSERT TABLE 4 ABOUT HERE]

3.1.3. Known-groups validity

Mean differences and effect sizes for discipline are presented in Table 5. As can be seen, hypotheses 1a through 1c were supported, as doctoral students in social sciences and humanities reported higher levels of autonomy support and satisfaction but lower levels of relatedness satisfaction than students in the other disciplines. Unexpectedly however, doctoral students in health sciences reported higher levels of competence satisfaction than the other students. Across the two studies, single-paper meta-analyses (McShane & Böckenholt, 2017) estimated the effect of discipline (contrast: sciences and technology = -1, health sciences = -1, social sciences and humanities = 2) on

autonomy support at .45 (SE = .077; z = 5.81, p < .001), on autonomy satisfaction at .35 (SE = .081; z = 4.28, p < .001), and on relatedness satisfaction at .58 (SE = .151; z = 3.85, p < .001). The effect of discipline (contrast: sciences and technology = -1, health sciences = 2, social sciences and humanities = -1) on relatedness satisfaction was estimated at .44 (SE = .121; z = 3.61, p < .001).

[INSERT TABLE 5 ABOUT HERE]

3.1.4. Criterion-related validity

Table 6 shows the descriptive statistics and intercorrelations of measures in study 1 and in study 2. As can be seen, need support and need satisfaction dimensions related, on the whole, positively to doctoral students' engagement. Surprisingly, though, involvement and autonomy support were not significantly related to behavioral engagement, relatedness satisfaction was not significantly related to behavioral engagement in study 1, and autonomy support was not significantly related to cognitive engagement in study 1. Hypotheses 2a and 2b thus received partial support. Support for hypotheses 3a and 3b was stronger as all correlations between, on the one hand, dimensions of need support and need satisfaction and, on the other hand, doctoral persistence intentions were significant.

[INSERT TABLE 6 ABOUT HERE]

In line with hypotheses 5a and 5b, structure and autonomy support more strongly related to, respectively, competence and autonomy satisfaction. Involvement, on the other hand, was more strongly related to autonomy satisfaction and, in study 2, competence satisfaction, than with relatedness satisfaction. Hypothesis 5c received thus only partial support. Comparison of these correlations using the procedure of Meng, Rosenthal, and Rubin (1992) as implemented in the Cocor R package (Diedenhofen & Musch, 2015) learned that relatedness satisfaction was more strongly related to

involvement than to autonomy support ($z_{study1} = 3.37$; $z_{study2} = 3.57$, p's < .001) but was equally related to involvement and structure ($z_{study1} = 0$; $z_{study2} = .79$, ns). Autonomy satisfaction was more strongly related to autonomy support than to involvement ($z_{study1} = 4.80$, p < .001; $z_{study2} = 1.30$, p = .098) and structure ($z_{study1} = 8.75$; $z_{study2} = 3.92$, p's < .001). Competence satisfaction was more strongly related to structure than to involvement ($z_{study1} = 4.05$, p < .001; $z_{study2} = 2.72$, p < .01) and autonomy support ($z_{study1} = 4.75$; $z_{study2} = 3.25$, p's < .001).

Predictive validity

To assess the predictive validity of our scales, we performed logistic regression analyses. As expected, involvement (odd ratio = .69, p = .036), structure (odd ratio = .62, p = .008), competence satisfaction (odd ratio = .52, p = .001), and autonomy satisfaction (odd ratio = .63, p = .02) were negatively associated with actual dropout. However, no significant association was found for relatedness satisfaction (odds ratio = .74; ns) and the negative association with autonomy support was only marginally significant (odds ratio = .67, p = .096). Hypotheses 4a and 4b thus received partial support.

4. General discussion

In this article, we reported the results of two studies (N = 858, N = 600) aimed at developing and validating short, self-report scales of Doctorate-related Need Support and Need Satisfaction (D-N2S). Our analysis allowed us to document problems with existing ad hoc scales, opening up the opportunity to offer measures validated in the domain of doctoral studies. It further allowed us to test the psychometric properties of the D-N2S and to provide preliminary evidence for their reliability and validity.

4.1. Comparisons with existing scales

Previous research using measures of need support in the domain of doctoral studies found large inter-correlations (i.e., $.75 \ge r \le .90$ from Litalien & Guay, 2015; $63 \ge r \le$.87 from Overall et al., 2011). In our study, average need support inter-correlations ranged between .18 and .60. This suggests that the scales used in previous research contain more common variance and less unique variance corresponding to each need support dimension, compared to the D-N2S.

In our studies, average need satisfaction inter-correlations (i.e., $.20 \ge r \le .41$) were similar to those from Losier (i.e., $.24 \ge r \le .44$; 1994) and, consistent with his findings, we found that competence satisfaction explained the largest share of variance in doctoral persistence intentions. However, in our research, average correlations between dimensions of need satisfaction and doctoral persistence intentions were larger (i.e., .19 $\ge r \le .57$, as opposed to $.11 \ge r \le .31$). This could be partly explained by the fact that Losier (1994) only made minimal changes to adapted items and did not include items taking into account key constituents of the doctoral experience (see, e.g., Lovitts, 2005), which might have limited his scale's explanatory value. However, because doctoral persistence intentions were not measured with the same items in our respective studies, one should not rely solely on the above comparisons in order to make judgments regarding the validity of the D-N2S.

4.2. Dimensionality and validity

Our results also speak to the issue of dimensionality that has transpired in the SDT literature across domains. For example, some researchers treat need satisfaction as a one-dimensional construct (e.g., Meyer, Enström, Harstveit, Bowles, & Bevers, 2007), whereas others treat the three hypothesized factors separately (e.g., Van den Broeck et al., 2010). Likewise, the relationships between need support and need satisfaction have been modeled in various ways. Some researchers have associated need support and need

satisfaction at the level of the constructs while treating one or both as one-dimensional (e.g., Litalien & Guay, 2015). Others have also associated need support and need satisfaction at the level of the constructs but treated each one as tri-dimensional (e.g., Standage, Duda, & Ntoumatis, 2005). Still others have associated need support and need satisfaction at the level of the factors (e.g., Dupont et al., 2014).

Consistent with SDT, and providing construct validity to the D-N2S, our results suggest that need support and need satisfaction are each comprised of three separate yet related dimensions. They further show that models associating the respective dimensions of need support and need satisfaction at the construct level provide a good fit to the data. Yet, models associating these dimensions at the factor level provided a superior fit in both our studies. Results finally indicate that autonomy support and structure are more strongly related to, respectively, autonomy and competence satisfaction. Unexpectedly, however, relatedness satisfaction correlated equally weakly with involvement and structure. This sub-scale also proved to be of limited value in explaining doctoral students' engagement and persistence.

One reason for the latter findings could lie in the fact that all items measuring relatedness satisfaction make reference to the research team. Golde (2005) highlighted the central role played by the local research community in filtering disciplinary norms and in shaping doctoral students' experience. However, the supervisor is not the primary provider of relatedness-enhancing support at the level of the research team or doctoral program (Gardner, 2010). Moreover, other reference groups could possibly support relatedness satisfaction in the domain of doctoral studies and affect decision about persistence. This analysis suggests that the relatedness satisfaction sub-scale leaves room for improvement. Some of its items could be substituted by items that do not make reference to the research team (e.g., 'In the context of my PhD, there is

nobody I can share my thoughts with if I wanted to'; adapted from Van den Broeck et al., 2010) or that make reference to the discipline as a whole (e.g., 'I feel close and connected with other researchers in my discipline'; adapted from Sheldon & Hilpert, 2012).

In line with previous research, and providing evidence for the criterion-related validity of the D-N2S, we found that doctoral students engaged and persisted more when their needs were satisfied and when they perceived their mentor to be supportive of their needs. In addition, we have found that that the effects of need support and need satisfaction on engagement materialize mainly through the emotional dimension. However outcomes other than engagement and doctoral persistence (e.g., motivation to pursue an academic career, wellbeing) could be examined in order to further test the criterion-related validity of the scales.

Supporting the known-groups validity of the D-N2S, disciplinary differences between groups of doctoral students were found in predictable ways (e.g., Bair & Haworth, 2004). Doctoral students in social sciences and humanities reported higher levels of autonomy support and satisfaction but lower levels of relatedness satisfaction than other students. However, doctoral students in health sciences unexpectedly reported higher levels of competence satisfaction than other doctoral students. This could be related to features of doctoral programs. Indeed, from the interviews we conducted with twelve delegates of the doctoral students during the scale development phase, it appeared that doctoral students in health sciences are faced with higher level of requirements. For instance, these doctoral students are sometimes required to publish up to three articles as first author before being allowed to submit their dissertation, a level of requirements that did not seem to prevail in other disciplines. Because these requirements are communicated at the start of the doctoral program, this may have contributed to increased feelings of competence to the extent that social contexts where clear instructions and reference points are presented provide doctoral students with structure.

Supporting the predictive validity of the D-N2S, all dimensions of need support and need satisfaction - except for autonomy support and relatedness satisfaction - seem to prevent dropout. Results further suggest that competence satisfaction is a major determinant of actual dropout. These findings confirm the observations made with doctoral persistence intentions and are consistent with previous research (Litalien & Guay, 2015; Losier, 1994). However, our findings extend this research in two ways. First, by relating need support and need satisfaction with an objective measure, that is, actual dropout. Second, by including all need support and need satisfactions dimensions and analyzing them at the level of factors, we were able to show that all but one (i.e., relatedness satisfaction) positively predicted doctoral persistence intentions and all but two dimensions (i.e., autonomy support and relatedness satisfaction) negatively predicted actual dropout. Future research may examine the extent to which these effects are independent of each other and, if so, if they are additive or multiplicative (Jang, Reeve, & Deci, 2010).

Our item selection procedure emphasized both measurement precision and construct representation (Schipolowski et al., 2014). This enabled us to construct brief scales and to limit redundancy in the items. These characteristics may enhance face validity in the eyes of respondents (Rammstedt & Beirlein, 2014) and reduce nonresponse error (Ganassali, 2008). It must be acknowledged, however, that our measure of need support does not completely cover the breadth of the target construct. This is especially the case for the autonomy support sub-scale, which focuses mainly on the controlling component. Previous research has highlighted the particularly damaging effects of a controlling environment on students' motivation and engagement (e.g., Reeve, 2009). Still, we would like to encourage further research to include other components of autonomy support. In this respect, we believe two recent conceptual clarifications deserve attention in the domain of doctoral studies and may lead researchers to measure the extent to which supervisors 1) develop doctoral students' self-reliance in thinking (Stefanou et al. 2010) and 2) connect the PhD and research activities to the values, interest, and goals of doctoral students (Katz & Assor, 2007).

4.3. Reliability

The sub-scales of the D-N2S displayed good levels of internal consistency across studies except for the autonomy support sub-scale. Low levels of internal consistency are not uncommon for short scales because they usually contain: 1) few items, and 2) comparatively heterogeneous items intended to cover the breadth of the targeted construct, two characteristics that tend to reduce inter-item correlations (Rammstedt & Beierlein, 2014). Therefore, other coefficients should be relied on to make judgments on the reliability of a short scale (e.g., test-retest correlations; see also Schipolowski et al., 2014). Autonomy support test-retest correlations were similar to those of other subscales, which, on the whole, were considered satisfactory given the long time interval between the two assessments.

4.4. Limitations

Several limitations warrant discussion. First, the moderate response rate (36% for the first and 44% for the second study) may limit the generalizability of our findings. However, previous studies (Krosnick, 1999) suggest that representativeness is a better criterion for evaluating the validity of a study than response rate. In this regard, administrative data from the two surveyed universities (Author, 2017) suggest that both studies were representative in terms of gender, age at start of PhD, grade obtained for second cycle studies, and discipline. However, in both studies, non-EU nationals and doctoral students without funding were underrepresented. Moreover, because participation in our studies was voluntary, it is possible that more motivated doctoral students were overrepresented. This possibility seems to be supported by the results of study 2 showing that non-respondents more often dropped-out than participants. To address this limitation, probability-based sampling methods (Ganassali, 2008) could be used in future research. Second, the cross-sectional nature of our data does not allow us to draw inferences about the direction of effects, which only longitudinal or experimental data could.

Finally, in the process of scale development, care was taken to include positively and negatively worded items in the pool of items. This was done to avoid acquiescence bias and because previous research has shown that need frustration can have a bigger motivational potential than need satisfaction. For instance, in Sheldon and Gunz (2009), it was the negatively worded items that drove the effect of their need satisfaction scale on the goal-oriented behaviors of their participants (but in Van den Broeck et al. (2010), the positively and negatively worded items did not perform differently). However, the use of negatively worded items can produce a number of undesirable effects, including reduced reliability and fuzzy factor structures (McCoach, Gable, & Madura, 2013), which have been explained in terms of, e.g., careless responding (Woods, 2006). When both positively and negatively worded items are included in the same scale, this frequently results in negatively worded items loading together on a separate methodologically based factor or in factor structures requiring the estimation of separate method latent factors or correlated error among negatively worded items (see also Barnette, 2000). These observations may help explain the lower level of internal consistency and factor loadings of the autonomy support subscale, which primarily

contains negatively worded items. One way of addressing this issue is to control for careless responding (Meade & Craig, 2012).

5. Conclusions

In the SDT literature, physiological analogies are sometimes made to illustrate the nature, content, and workings of basic needs. For instance, Sheldon and Hilpert (2012) compared basic needs to vitamins before adding that 'particular pathologies can result from particular need deficiencies just as scurvy result from Vitamin C deficiencies and skin problems result from Vitamin D deficiencies. Combining the three sub-scales into one thus risks masking such effects' (p. 441). Our findings allow us to extend their warning to need support: Because each dimension of need support is expected to have a distinct pattern of effects with, among other things, need satisfaction, and because supportive practices might have opposite effects on two or more basic needs (Author, 2015; Katz & Assor, 2007), combining dimensions into a single, general measure of support (or satisfaction) risks overlooking such effects.

Besides the above theoretical implication, a practical implication of our research is the development of the D-N2S. We hope that the availability of these measures will facilitate their combined administration in future studies and assist education researchers in drawing implications for improving doctoral supervision as well as doctoral students' engagement, persistence, and, ultimately, well-being.

Acknowledgements

Funding: The Belgian Fund for Scientific Research - FNRS [Grant F.R.F.C.2.4609.12] supported this work. We thank Rodrigo Brito, Diane de Lima Mayer, Djouaria Ghilani, and Rachel Leproult for their assistance with the translation of the scales. We thank Annalisa Casini and Bibiane Freché for their assistance with the design of the online questionnaire. We are also extremely grateful to Betty Chang, Virginie Hospel, the editor, and three anonymous reviewers for their comments on a previous draft.

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Demographic characteristics (%)	Population	Study 1 V	Study 2 V
Gender			
Male	56	43	48
Female	44	57	52
		.12***	.07**
Nationality			
Belgian	61	77	72
Other EU nationality	18	15	15
Non-EU nationality	21	8	13
		.19***	.12***
Age at start of PhD			
< 26	47	59	51
≥ 26	53	41	49
		.11***	.04
Grade obtained for second cycle studies	2	2	2
Success without honours	3	3	3
Cum laude	29	27	27
Magna cum laude	51	49	49
Summa cum laude	17	21	21
		.06	.02
Discipline	20	22	27
Sciences and technology	38	33	37
Health sciences	20	22	20
Social sciences and humanities	42	45	43
		.0/**	.03
Funding	11	25	20
	11	23 62	20
Fellowship or grant	41	02	30 21
No financing	44	10	$\frac{21}{2}$
Otner	4) 27***)))***
		.3/****	.23

Table 1. Sample and Population Demographic Characteristics.

Note. ^a Includes double funding (e.g., part-time assistantship and part-time fellowship) and educational loans from employers. Effect size of the differences between each study and the population was calculated using Cramer's *V*. Levels of significance are from χ^2 -tests. * p < .05. ** p < .01. *** p < .001.

		5	
	1	2	3
Need Support scale			
My mentor			
behaves warmly towards me when we discuss my research	.71	06	09
shows that he/she respects me and values me	.69	02	10
reassures me when I need it	.60	26	.02
is concerned about me, not only as a researcher but also as an individual	78	07	.07
directs my work a lot, without really asking for my opinion (R)	01	00	.68
gives me little freedom in how I carry out my work (R)	02	.01	45
encourages me to work in an independent way	04	17	49
puts me under a lot of pressure (R)	20	.18	43
defines clear objectives for me	07	.80	05
gives me good advice on how I should plan and carry out my research	.05	75	01
provides me with constructive feedback on my work	.03	68	10
discusses with me the difficulties I face and possible solutions	.17	65	01
Need Satisfaction scale			
In the context of my PhD			
I often doubt the quality of my work (R)	02	08	.66
I have confidence in my ability to finish my PhD	00	11	64
I have the feeling that I am not moving forward (R)	02	.01	.67
I rarely get the chance to make choices (R)	.00	70	00
I usually feel free to express my ideas and opinions	.09	.65	07
I can influence the development of my thesis' project	05	.73	.03
I have little sympathy for the other members of my team (R)	54	06	01
I get along well with the members of my team	.84	.01	.04
I feel well integrated in the team	.79	03	05

Table 2. Standardized pattern coefficients for direct oblimin-rotated factors of the NeedSupport and Need Satisfaction Scales in study 1.

Note. Absolute coefficients >.40 are shown in bold.

Need Si	ipport sca	lle						
Study	Model	SBS- χ^2	df	SBS- χ^2 difference	<i>df</i> difference	SRMR	RMSEA	CFI
1	А	825.62**	54	_		.10	.13**	.77
1	В	195.34*	51	630.28**	3	.05	.06*	.96
2	А	721.23**	54			.11	.15**	.75
2	В	154.63**	51	566.60**	3	.04	.06*	.96
Need Sc	ntisfaction	scale						
Study	Model	SBS- χ^2	df	SBS- χ^2 difference	<i>df</i> difference	SRMR	RMSEA	CFI
1	А	1197.71**	27	_		.17	.23**	.43
1	В	84.58**	24	1113.13**	3	.04	.05	.97
	-							
C	А	789.47**	27			.15	.22**	.42

Table 3. Goodness of fit summary for one- and three-Factor CFA models of the Need Support and Need Satisfaction Scales in studies 1 and 2.

Note. Model A = one-factor. Model B = unconstrained three-factor. * p < .01. ** p < .001.

Study	Model	SBS- χ^2	df	SRMR	RMSEA	CFI	AIC
1	C	656.72**	182	.07	.06**	.92	45369.66
	D	433.54**	174	.05	.04	.96	45136.71
2	C	542.16**	182	.07	.06**	.91	30232.72
	D	426.77**	174	.05	.05	.94	30121.77

Table 4. Goodness of fit summary for CFA models testing the relationships between the Need Support and Need Satisfaction Scales in studies 1 and 2.

Note. Model C = unconstrained six-factor. Model D = unconstrained two-higher order factor. * p < .01. ** p < .001.

Variables		Study 1		Study 2				
Measures	S&T ($n = 279-282$) M(SD) ω^2	HS (<i>n</i> = 186-189) <i>M</i> (<i>SD</i>)	SSH (<i>n</i> = 371-384) <i>M</i> (<i>SD</i>)	S&T ($n = 222-223$) M (SD) ω^2	HS (<i>n</i> = 109-117) <i>M</i> (<i>SD</i>)	SSH (<i>n</i> = 234-260) <i>M</i> (<i>SD</i>)		
Autonomy support	4.04 ^a (.70) .03***	3.94 ^a (.75)	4.23 ^b (.68)	4.01 ^a (.71) .02**	4.04 ^a (.77)	4.22 ^b (.68)		
Competence satisfaction	3.02 (.96) .01†	3.18 (.91)	2.99 (.94)	3.10 ^a (.92) .02**	3.38 ^b (.97)	3.07 ^a (.95)		
Autonomy satisfaction	4.16^{ab} (.75) 02**	4.01 ^a (.80)	4.25 ^b (.74)	4.07 ^a (.76) 01*	4.07 ^a (.80)	4.25 ^b (.72)		
Relatedness satisfaction	4.28 ^a (.76) .02**	4.21 ^a (.83)	4.05 ^b (.85)	4.23 ^a (.81) .06***	4.35 ^a (.82)	3.89 ^b (.84)		

Table 5. Mean differences and effect sizes for discipline in studies 1 and 2.

Note. Means with different subscripts are significantly different from each other at p > .05 in a S-N-K or Games-Howell (when homogeneity of variance was rejected) post-hoc comparison. Effect size was calculated using ω^2 = omega squared (Olejnik & Algina, 2000). S&T = Sciences and technology. HS = Health sciences. SSH = Social sciences and humanities. † p < .1. * p < .05. ** p < .01. *** p < .001.

											Study 2	
Measure	1	2	3	4	5	6	7	8	9	10	М	SD
1. Involvement		.43**	.58**	.25**	.44**	.22**	.08	.16**	.39**	.33**	4.13	.94
2. Autonomy Support	.43**		.16**	.18**	.49**	.06	04	.10*	.24**	.23**	4.11	.72
3. Structure	.60**	.20**		.35**	.30**	.19**	.16**	.21**	.37**	.34**	3.57	1.00
4. Competence Satisfaction	.20**	.12**	.32**		.30**	.12**	.26**	.28**	.66**	.50**	3.14	.95
5. Autonomy Satisfaction	.39**	.54**	.28**	.25**		.20**	.14**	.19**	.40**	.36**	4.15	.75
6. Relatedness Satisfaction	.21**	.08*	.21**	.12*	.21**		.14**	.08	.22**	.20**	4.10	.83
7. Behavioral Engagement	.05	01	.23**	.25**	.11*	.06		.44**	.24**	.20**	3.90	.83
8. Cognitive Engagement	.13**	.06	.21**	.22**	.18**	.07*	.45**	_	.38**	.19**	3.64	.81
9. Emotional Engagement	.33**	.28**	.38**	.66**	.41**	.15**	.19**	.30**		.56**	3.60	.74
10. Doctoral persistence	.26**	.22**	.36**	.55**	.32**	.17**	.30**	.28**	.61**		4.14	.81
Study 1 M	3.97	4.10	3.57	3.04	4.17	4.16	3.94	3.61	3.50	4.07		
SD	.89	.71	.95	.94	.76	.82	.80	.82	.75	.80		

Table 6. Descriptive statistics and correlations between measures in study 1 (N = 841 to 858) and study 2 (N = 555 to 600).

Note. Study 1 below the diagonal; Study 2 above the diagonal. * p < .05. ** p < .001.

Appendix.

Items	ISC	R^2	h^2
Need support scale			
My mentor			
Involvement			
1. behaves warmly towards me when we discuss my research	.72	.55	.63
2. shows that he/she respects me and values me	.70	.52	.60
3. reassures me when I need it	.68	.49	.55
4. is available when needed ¹	.54	.32	.38
5. does not demonstrate any interest in what I do $(R)^1$.47	.24	.31
6. is concerned about me, not only as a researcher but also as an individual	.59	.42	.49
7. behaves inappropriately towards me $(R)^1$.46	.23	.28
Autonomy support			
8. takes my ideas into account ¹	.52	.51	.61
9. directs my work a lot, without really asking for my opinion (R)	.63	.40	.50
10. gives me little freedom in how I carry out my work (R)	.39	.17	.20
11. encourages me to work in an independent way	.46	.26	.30
12. puts me under a lot of pressure (R)	.44	.24	.31
13. constantly controls my work $(R)^2$.35	.24	.33
14. listens to my propositions on how I would like to do things ¹	.54	.52	.61
Structure			
15. teaches me about the technical knowledge and skills that I need ^{2}	.56	.36	.41
16. defines clear objectives for me	.64	.47	.53
17. gives me good advice on how I should plan and carry out my research	.71	.56	.64
18. makes me feel I can succeed ¹	.62	.36	.41
19. provides me with constructive feedback on my work	.67	.47	.54
20. only points out the insufficiencies, mistakes, and limitations of my work $(R)^{1}$.26		
21. discusses with me the difficulties I face and possible solutions	.72	.53	.60
Need satisfaction scale			
In the context of my PhD			
Need for competence			
22. I sometimes feel I am not very competent $(R)^2$.59	.50	.58

23. I reckon I am in a position to meet the demands of my advisor(s) and of my supervisory committee ^{2}	.62	.46	.54
24. I often doubt the quality of my work (R)	.65	.54	.63
25. I have confidence in my ability to finish my PhD	.67	.52	.60
26. I have the feeling that I am not moving forward (R)	.68	.50	.59
27. I clearly see where I am $going^2$.58	.35	.39
28. I do not progress as fast as the other PhD students in my research team $(R)^2$.57	.37	.42
29. I am progressing as planned ²	.64	.47	.55
Need for autonomy			
30. I rarely get the chance to make choices (R)	.63	.45	.54
31. I usually feel free to express my ideas and opinions	.55	.37	.45
32. I can influence the development of my thesis' project	.62	.43	.52
33. I have little control over the organization of my work $(R)^1$.34	.15	.19
34. I have the feeling that my thesis project does not belong to me $\left(R\right)^{1}$.67	.64	.72
35. It is difficult for me to think of my thesis project as being my own $(R)^1$.62	.60	.67
36. I feel personally responsible for my thesis project ¹	.59	.39	.43
Need for relatedness			
37. I have little sympathy for the other members of my team (R)	.45	.27	.32
38. I get along well with the members of my team	.69	.59	.68
39. I often feel alone $(R)^2$.45	.24	.38
40. I feel well integrated in the team	.70	.59	.68

Note. (R) = Reversed item; ISC = corrected item-total correlations; R^2 = squared multiple correlation; h^2 = final communality estimate; ¹Item deleted from the final scale on grounds of poor statistical soundness; ²Item deleted from the final scale on grounds of scale length optimization (CFA available upon request attest to the discriminant validity of the longer forms of the scales).