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Clarifying the Link Between Psychological Need Satisfaction and Positive Affect:
Longitudinal Within-Person Tests for Bi-directional Influence in Two Cultures

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Data Accessibility Statement

The study hypotheses were not preregistered. The data, scripts and materials for both Study 1 and Study 2 may be found here: https://osf.io/8a9yj/
Abstract

Positive affect is often considered the “hallmark of well-being”, associated with better health, longevity, and success. Self-determination theory (SDT) proposes that satisfying three basic psychological needs for autonomy, competence and relatedness (BNS) fosters optimal functioning, thriving, and positive affect. Meanwhile, broaden-and-build theory suggests that positive emotions predict future psychosocial resources such as need satisfaction. Previous research on the BNS–positive affect link has not sufficiently established to what extent changes in BNS precede changes in positive affect or vice versa. We tested this in two 3-wave longitudinal studies, conducted over 2 years in the UK (Study 1: N = 958) and over 2 months in Latin America (Study 2: N = 1200). Bivariate latent trait-state-occasion models revealed that within-person fluctuations in BNS significantly predicted subsequent fluctuations in positive affect in both studies, but fluctuations in positive affect predicted subsequent fluctuations in BNS only in Study 2. These findings consistently support SDT predictions, whereas they only partially support broaden-and-build theory predictions, helping to clarify the likely causal relations between BNS and positive affect.

Keywords: self-determination theory, positive affect, need satisfaction, longitudinal analyses, trait-state-occasion model
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A substantial body of research has shown how positive affect predicts various indicators of healthy and successful living (Lyubomirsky et al., 2005; Pressman & Cohen, 2005; Pressman et al., 2019). Positive affect is associated with longer lives, lower morbidity, as well as with slower disease progression and better survival in people with chronic illness (Pressman et al., 2019). Beyond health outcomes, a meta-analytic review conducted by Lyubomirsky et al. (2005) gathered together cross-sectional, longitudinal, and experimental evidence showing how higher positive affect is also strongly associated with success in many areas of peoples’ lives such as marriage, friendship, income, and performance. At the same time, positive affect itself is considered a key indicator of life going well, as it is reactive to and strengthened by various positive life conditions (Diener et al., 2018), thus being a key ‘symptom’ of various good things in life. While open questions remain about the direction of influence (Rohrer & Lucas, 2020), positive affect’s strong associations with various important life outcomes means that it is often considered “the hallmark of well-being” (Lyubomirsky et al., 2005, p. 803). Accordingly, researchers in the field are encouraging a better understanding of the processes surrounding positive affect, including the psychological mechanisms that may foster it (Pressman et al., 2019).

Self-determination theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2017) aims to identify what experiential relations humans need to have with their environment in order to function and feel well from an organismic perspective. The theory posits that humans have three such basic psychological needs – autonomy, competence, and relatedness – that are “essential for ongoing psychological growth, integrity, and well-being” (Deci & Ryan, 2000, p. 229) and thus key predictors of subjective well-being (SWB; Diener, 1984). A substantial body of research has supported this hypothesized link between basic needs satisfaction (BNS)
and various forms of well-being (reviewed in Ryan & Deci, 2017; Martela & Sheldon, 2019; Van den Broeck et al., 2016; Vansteenkiste et al., 2020).

While the link between BNS and positive affect has been previously observed, the vast majority of studies have been cross-sectional in nature (Ryan & Deci, 2007; Vansteenkiste et al., 2020; Yu et al., 2019). This is a key limitation for establishing causality and directionality between BNS and positive affect. Although SDT provides a theoretical rationale for BNS leading to positive affect, one could also argue for the opposite direction of influence based on the broaden-and-build theory of positive emotions (BBT; Fredrickson, 2001, 2013). BBT argues, and offers longitudinal and experimental evidence, that positive emotions not only feel good, but also build future resources such as broad-minded coping (Fredrickson & Joiner, 2002), interpersonal trust (Burns et al., 2008), and mindfulness (Fredrickson et al., 2008)—potentially building psychosocial resources related to autonomy, competence, and relatedness, and thus leading to increased need satisfaction in the future.

However, the prospective link from positive affect to BNS has remained unexplored.

To shed light on the direction of influence between BNS and positive affect, our study aims to explore both possible directions of influence, as well as the possibility of reciprocal relations between BNS and positive affect. Although some previous longitudinal research has explored temporal relations between BNS and positive affect (e.g., Garn et al., 2019; Tian et al., 2014), we capitalized on recent methodological advances in longitudinal research to conduct a stronger test of the two theorized directions of influence focusing on within-person processes while controlling for stable between-person trait-like variation in the two constructs (Cole et al., 2005; Hamaker et al. 2015). Accordingly, our two studies provide the first systematic longitudinal examination of whether within-person fluctuations in BNS predict future fluctuations in positive affect – and also whether within-person fluctuations in positive affect predict future fluctuations in BNS.
The Hypothesized Link from BNS to Positive Affect

According to SDT (Deci & Ryan, 2000; Ryan & Deci, 2017), autonomy, competence, and relatedness are basic psychological needs that function as “innate psychological nutriments” (p. 229): As plants need essential nutriments for survival, such as water, sunlight and minerals, so people need psychological nutriments for functioning well and for healthy growth and well-being (Reis et al., 2000). Autonomy refers to feeling that one’s behavior is self-endorsed and volitional, competence refers to feeling effective and efficient in one’s actions, and relatedness refers to feeling connected to, and cared for, by important others. Research based on SDT sees these three needs as universal requirements for well-being, and thus key antecedents of well-being across contexts, cultures, and developmental epochs (Ryan & Deci, 2017).

Much correlational research has shown that the satisfaction of these three needs is significantly associated with many indicators of well-being (Ryan & Deci, 2017; Vansteenkiste et al., 2020). Contemporaneous associations between BNS and well-being have been found across cultures (Chen, Vansteenkiste, et al., 2015; Church et al., 2013; Sheldon et al., 2001), in contexts including education (e.g., Jang et al., 2016), sports coaching (e.g., Curran et al., 2016) and work (Van den Broeck et al., 2016), and at life stages from adolescence (Jang et al., 2009) to old age (Kasser & Ryan, 1999). Manipulation of the three needs in a game-learning context has provided experimental evidence that need satisfaction can influence well-being (Sheldon & Filak, 2008). Previous longitudinal research has also found that BNS predicts SWB naturalistically over time (Sheldon & Elliot, 1999: Study 2; Tian et al. 2014; Garn et al. 2019). However, as we argue below, this longitudinal evidence has important methodological limitations that we seek to address in the current studies.
The Importance of Temporal Precedence

Temporal precedence is generally regarded as a necessary (albeit not sufficient) ingredient of lay and scientific conceptions of causality (Granger, 1980; Maziarz, 2015).

Hence, it is important to establish to what extent BNS predicts subsequent positive affect or vice-versa in natural settings. While SDT provides a good theoretical case for why BNS would predict future positive affect, one can also theorize a likely prospective link from positive affect to BNS, based on BBT (Fredrickson 2001, 2013)—thus providing a potential alternative explanation for findings showing contemporaneous associations between BNS and positive affect.

BBT research has provided longitudinal evidence for positive emotions prospectively facilitating approach behavior, which in turn helps building psychological resources (Fredrickson & Joiner, 2002). Given their capacity to build psychosocial resources, positive emotions may increase the satisfaction of basic psychological needs for autonomy, competence, and relatedness (Deci & Ryan, 2000). Facilitated by positive emotions, approach behavior might help people to escape from controlled contexts and negative forms of motivation and to identify more self-selected activities and ways of living, building autonomy. Positive emotions may also foster engagement in new activities and challenges, building new capabilities, and hence feelings of competence. Positive emotions are also known to help in building interpersonal relationships (Burns et al., 2008), thus increasing closeness to important others and feelings of relatedness. Thus, positive emotions may help people to “broaden and build” satisfaction of all three basic psychological needs postulated by SDT, expanding their ability to choose their actions (autonomy), willingness to learn new skills (competence) and social relationships (relatedness). Positive affect could thus be a prospective predictor of higher subsequent psychological need satisfaction.
Given that BBT predicts the reverse causal direction compared to SDT, evidence of contemporaneous associations between BNS and positive affect might be due exclusively to SDT processes, due exclusively to BBT processes, due to a combination of both directions (raising the possibility of feedback loops), or due to one or more unmeasured confounding variables. Accordingly, when examining temporal relations between BNS and positive affect, it would be crucially important to test both directions of influence.

To date, SDT research into the relationship between BNS and SWB has usually employed designs that are not sensitive to temporal precedence. For example, several diary studies have shown that daily variation in psychological need satisfaction is associated with contemporaneous daily variation in various indicators of well-being in student populations (Sheldon et al., 1996; Reis et al., 2000), in female young gymnasts (Gagné et al., 2003) and in mothers (Brenning et al., 2019). Henning et al. (2019), in turn, showed that there are systematic changes in the association between BNS and well-being over the retirement transition. However, the statistical analyses reported in these daily diary studies tested only contemporaneous relationships between the constructs without considering the temporal sequencing of changes on these two variables.

A somewhat more causally sensitive longitudinal examination was provided by Sheldon and Elliott (1999; Study 2), who found that BNS at Time 1 predicted SWB at Time 2, even when controlling for SWB and Time 1. Wang et al. (2017) examined the relations between materialism and SWB in a three-wave longitudinal study of Chinese students, concluding that BNS mediated the relations between materialism and SWB, while controlling for earlier states of BNS and SWB. However, neither of these two studies tested for the opposite direction of influence. Tian et al. (2014) tested a cross-lagged panel model examining the links in both directions between BNS and well-being among high-school students over a six-week period. The authors concluded there was a reciprocal relationship
between BNS at school and measures of both satisfaction and affect at school. However, using a cross-lagged design spanning three time-points over 14-15 months among a sample of Australian high-school students, Garn et al. (2019) found that BNS significantly predicted subsequent levels of positive affect, but not vice versa.

**The Importance of Within-Person Changes in Longitudinal Research**

While cross-lagged panel models provide important information about the predictability of people’s future states from their past states, they have been criticized recently for providing an insufficiently fine-grained perspective on developmental processes (Hamaker et al., 2015). A cross-lagged panel model can be used to test, for example, whether a person with higher than average BNS at T1 is likely to show higher than average positive affect at T2, while controlling for their level of positive affect at T1. However, these models do not fully separate stable trait-like between-person differences from within-person changes in the constructs of interest. Thus, a stronger test of the theorized causal effect of BNS on positive affect would be whether a person with higher than their usual level of BNS at T1 is likely to show higher than their usual level of positive affect at T2. To understand trajectories of people’s well-being, such within-person tests are arguably more important and practically relevant than popular cross-lagged panel analyses.

In recent years, the bivariate latent trait-state-occasion model (e.g., Cole et al., 2005; LaGrange & Cole, 2008; LaGrange et al., 2011) was developed to model temporal relations between within-person trajectories of two variables, and thus to explore how within-person changes in one construct predict subsequent within-person changes in another construct. This makes it possible to test whether people show higher than their usual levels of positive affect following occasions when they showed higher than usual levels of BNS, and vice versa. Using this model, our research is the first to date conducting a stronger test of the theorized causal links between BNS and positive affect according to SDT and BBT, by testing the
prospective within-person relationships in each direction while separating out variance due to stable between-person differences.¹

The Importance of Exploring Positive Affect in its Own Right

Despite calls to look at the three components of SWB independently, rather than collapsed together (Diener et al., 1999; Diener et al., 2010; Kushlev et al., 2020), prospective studies linking BNS and SWB have rarely explored which specific elements of SWB are associated with need satisfaction (e.g., Sheldon & Elliot, 1999; Sheldon & Krieger, 2007; but see Gagné et al., 2003). SWB researchers have emphasized that the three dimensions “are separable components that exhibit unique patterns of relations with different variables” (Diener et al., 1999, p. 276; Diener et al., 2010), and given the theoretical interest in positive affect on its own right (see Lyubomirsky et al., 2005; Pressman & Cohen, 2005; Pressman et al., 2019), we wanted to examine specifically how BNS is related to positive affect over time rather than using only composite well-being variables such as SWB.

To our knowledge, only Garn et al. (2019) have found significant associations between BNS and positive affect over time, but their study used a cross-lagged panel approach and was limited to a specific sample of Australian high-school students. Therefore, more research is needed to examine the specific prospective link between BNS and positive affect.

¹ The bivariate latent trait-state-occasion model (LaGrange et al., 2011) is conceptually analogous to the random intercept cross-lagged panel model recently popularized by Hamaker et al. (2015), but it was developed several years previously and uses latent rather than observed variables to reduce the potential impact of measurement error on model parameters. Very recently, we became aware of a latent variable extension of the random intercept cross-lagged panel model, published by Mulder and Hamaker (2021), which we believe is virtually identical to the models reported here.
affect in different populations and contexts and using within-person analyses. All in all, our study aims to provide the most robust test to date of the prospective relations between BNS and positive affect by using two three-wave longitudinal designs, by separating stable between-person variance from within-person processes, and by focusing on one specific and theoretically important component of SWB, namely positive affect.

**The Current Research**

To disentangle the ongoing, naturally occurring, relations between BNS and positive affect as these unfold over time, we conducted two 3-wave longitudinal studies. Since neither SDT nor BBT makes specific predictions about the timescale over which effects between these variables should be expected to occur, we opted to test these effects across longer (Study 1: yearly) and shorter (Study 2: monthly) time intervals. To increase generalizability, we examined the relations among adults from both the UK (Study 1) and Latin America (Study 2). Rather than using a cross-lagged panel model, here we conducted a stronger test of the theorized causal relations by using a trait-state-occasion approach which controls for stable between-person differences, thus allowing us to examine whether a person showing higher than *their usual* level of need satisfaction at T, will experience higher than *their usual* level of positive affect at T_{i+1} (and vice versa).² Specifically, we tested the following two hypotheses:

H1. Within-person variation in BNS prospectively predicts future within-person variation in positive affect.

H2. Within-person variation in positive affect prospectively predicts future within-person variation in need satisfaction.

² For interested readers, we also report cross-lagged panel models of our data in Online Supplementary Materials.
Study 1

Study 1 used a long-term, three-wave, two-year design, among UK adults (N = 958).

The large sample allowed us to model latent variables, reducing the biasing effects of measurement error (Finkel, 1995) so as to provide stronger estimates of stability paths as well as between-person stable trait-like variance, and thus more stringent tests of the hypothesized lagged parameters. Importantly, our three-wave design allowed us to conduct a bivariate trait-state-occasion model to test for within-person effects (H1 and H2). The hypotheses were not preregistered. Study materials, data, and scripts are available at: https://osf.io/8a9yj/

Method

Participants and Procedure

Study 1 was approved by the University of Sussex (UK) Institutional Review Board, and followed the British Psychological Society Ethical Guidelines. All participants provided written consent and were informed that they could withdraw from the study at any point. Respondents were former graduates, contacted through the alumni office of a university in England. At baseline, participants received an introductory email with a brief description of the study and a web-link to the survey. Respondents were informed that the project was part of a longitudinal study and were asked to consent to future waves (T2 and T3). We aimed to recruit enough participants to test a large (multiple latent variables across multiple time

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3 We collected additional measures in Study 1, which were not relevant for the present research (see https://osf.io/8a9yj/ for a full list). Cross-sectional analyses of T1 data only, focusing on the relationship between materialism and well-being and including measures of BNS and positive affect, were previously published by Unanue et al. (2014). Longitudinal analyses, focusing on the relationship between life-goals and environmental behavior and including no overlap with the measures used here, were previously published by Unanue et al. (2016).
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points) Structural Equation Modelling (SEM), comparable to previous studies using similar methods (e.g., LaGrange et al., 2011: \( N = 515 \)).

Consenting T1 participants (Wave 1) were sent an email one year (Wave 2) and two years later (Wave 3), containing web-links to questionnaires with identical measures. Thus, data were obtained for a three-wave longitudinal survey (T1 \( N = 958 \) [59% female; Mean age = 44.7; \( SD = 14.0 \)]; T2 \( n = 567 \); T3 \( n = 551 \)). Regarding attrition, those who completed Wave 3 (\( n = 551 \)) did not differ significantly in age, gender, BNS and positive affect from those who left after T1 or T2 (\( n = 407 \); \( p \geq .09 \)). The results of the Little MCAR test (Little, 1988) was nonsignificant, consistent with assuming that the missing data were completely at random (\( \chi^2 (70) = 83.33, p = .132 \)). Thus, we included all 958 participants in our structural analyses, using FIML to handle missing data (Newman, 2014).

Recommended sample sizes for SEM vary widely. Some authors recommend at least 200 participants, or 10 participants per parameter, as rules-of-thumb (Weston & Gore, 2006).

Recent Monte Carlo research shows that as few as 30 or as many as 460 participants may be needed for popular analyses, depending on the number of factors, indicators per factor, magnitude of loadings, and magnitude of correlations. Moreover, required sample size does not necessarily increase with model complexity (Wolf et al., 2013). Our current sample size exceeded the range identified by Wolf et al. (2013), was comparable to previous longitudinal SEM studies (Burkholder & Harlow, 2003), and yielded no improper estimates (Wolf et al., 2013); hence, we judged it sufficient.

**Measures**

**Positive affect.** We used the International Positive and Negative Affect Schedule Short Form (I-PANAS-SF; Thompson, 2007) to measure positive affect (5 items).

Participants rated how frequently they had felt emotions such as “inspired” and “attentive”
during the last month, from *never* (1) to *always* (5). Reliabilities ranged from .79 to .81 across waves. We modeled positive affect as a latent variable using its 5 items as indicators.

**Basic need satisfaction.** We used the 9-item scale developed by Sheldon et al. (2001) to assess BNS. Participants rated from *strongly disagree* (1) to *strongly agree* (6) whether they felt their needs for autonomy (3 items, e.g., “My choices expressed my “true self”), competence (3 items, e.g., “I was successfully completing difficult tasks and projects”) and relatedness (3 items, e.g., “I felt a sense of contact with people who care for me, and whom I care for”) were satisfied during the last month. Reliabilities ranged from .84 to .86 across waves. We used three item parcels as indicators for each BNS latent variable (Coffman & MacCallum, 2005). To ensure that our latent variable would equally represent all three needs, each parcel included one autonomy, one competence and one relatedness item.4

4 Satisfaction of the three basic needs typically covaries very highly, and SDT researchers commonly use measures of general need satisfaction when their theoretical interest is in need satisfaction as such rather than in distinguishing among the three needs (e.g., Deci et al., 2001; Haerens et al., 2015; Kasser et al., 1992; Van den Broeck et al., 2008; Van der Kaap-Deeder et al., 2020). We opted for item parceling as a pragmatic approach to keep the complexity of our trait-state-occasion models to a manageable level, while maintaining the benefits of latent variables for reducing measurement error. We rejected an alternative approach using autonomy, competence, and relatedness scores as item parcels, since this would risk leading to a conceptually unbalanced latent variable that disproportionately represented one need over the others and might skew the results (see Moshagen, 2021, for a critique). Our current approach of including all three needs in each parcel ensured that the resulting latent variable would accurately represent the breadth of the BNS construct and maintained consistency with our previous work in this area (Unanue et al., 2014).
Results

We used MPlus 8.0 (Muthén & Muthén, 2017) to model relations among latent measures of BNS and positive affect in a bivariate trait-state-occasion model. Descriptive statistics and correlations are shown in Table 1. Following recommendations of Hu and Bentler (1999) and Kline (2005), we assessed model fit through the root mean square error of approximation (RMSEA) and comparative fit index (CFI), with values of RMSEA < .06 (.08), and CFI > .95 (.90) indicating good (acceptable) fit.

We utilized an expanded bivariate latent trait-state-occasion model (based on Cole et al., 2005; LaGrange & Cole, 2008; LaGrange et al., 2011), which decomposed the variance of the measured state variables into between-person (trait) and within-person (occasion) components, allowing us to model the cross-lagged relations central to our hypotheses as within-person processes. Following LaGrange and Cole (2008), state variables for each construct at each time-point were modelled as latent variables with loadings of each indicator constrained to be equal over time, and freely estimated auto-correlated uniquenesses for each observed indicator over time. The state variables were then partitioned into trait (between-person) and occasion (within-person) variance: Trait variables loaded on all three state variables for their relevant construct with a fixed loading of 1, occasion variables loaded on the state variable for their respective time-point with a fixed loading of 1, and the residual variance of the state variables was fixed to zero. Figure 1 illustrates the measurement part of the model for BNS.

Based on LaGrange et al. (2011), we tested our hypotheses by modelling cross-lagged paths among the occasion variables. We modeled lagged paths from each occasion variable to the two occasion variables at the successive time point. Thus, BNS was represented as a potential antecedent and potential consequence of positive affect, while controlling for trait-
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level relationships and for stability across occasions. Covariances were estimated freely among the occasion variables within each time-point and among the trait variables.

First, we tested a model without any constraints. This model fitted the data well, $\chi^2(214) = 453.15, p < .001, \text{CFI} = .976, \text{RMSEA} = .034 (90\% \text{ CI}: .030, .039)$. Second, we constrained all the factor loadings of each latent variable to be equal across waves. The model also fitted the data well, $\chi^2(226) = 472.07, p < .001, \text{CFI} = .975, \text{RMSEA} = .034 (90\% \text{ CI}: .029, .038)$. Thus, the assumption of measurement invariance across waves is tenable: When constraints were imposed, the change in CFI was lower than .01 ($\Delta\text{CFI} = .001$). Then, following Cole et al. (2005), we constrained autoregressive and cross-lagged paths to be invariant over time. This model showed good fit, $\chi^2(230) = 472.63, p < .001, \text{CFI} = .976, \text{RMSEA} = .033 (90\% \text{ CI}: .029, .037)$, and a model comparison confirmed that there was no significant loss of fit due to our simplifying assumption, $\Delta\chi^2(4) = 0.06, p = .968$.

All indicators showed strong ($0.591 \leq \lambda \leq 0.897$) and significant ($p < .001$) standardized loadings on their target state variables. State variables showed strong standardized loadings on their target trait variables ($0.790 \leq \lambda \leq 0.839$) and on their target occasion variables ($0.544 \leq \lambda \leq 0.625$). Notably, all autoregressive paths were non-significant (all $p \geq .080$), suggesting that stability in these constructs was mostly due to trait-level variance rather than carry-over effects across time-points. Structural parameters for our expanded bivariate trait-state-occasion model are reported in Table 2.

**Prospective Relationships.** Supporting H1, we found that occasion BNS was a significant positive predictor of subsequent occasion positive affect, $B = .202, [95\% \text{ CI}: .052, .351], p = .008, \beta_{T1 \rightarrow T2} = .288, \beta_{T2 \rightarrow T3} = .315$. This prospective effect can be considered large in magnitude (Orth et al., in press). However, against H2, occasion positive affect did not significantly predict subsequent occasion BNS, $B = -.064, [95\% \text{ CI}: -.399, .272], p = .710, \beta_{T1 \rightarrow T2} = -.039, \beta_{T2 \rightarrow T3} = -.042$. 
Contemporaneous Relationships. Trait BNS showed a strong positive correlation with trait positive affect, $r = .824$, [95% CI .773, .874], $p < .001$. Occasion BNS also showed substantial positive correlations with occasion positive affect at T1 ($r = .571$, [95% CI .444, .698], $p < .001$), T2 ($r = .690$, [95% CI .541, .839], $p < .001$), and T3 ($r = .502$, [95% CI .372, .631], $p < .001$). Thus, concurrent associations between BNS and positive affect were positive and large in magnitude (Cohen, 1992), both at the level of stable individual differences (i.e. trait-level) and as these variables varied over time (i.e. occasion-level).

Study 2

Study 1 used a long-term longitudinal design, with one year between each of three waves. Study 2 utilized a short-term longitudinal design with one month between waves. This allowed us to compare the associations between BNS and positive affect using different time frames. We followed the same procedure as in Study 1 to conduct our statistical analyses.

The hypotheses were not preregistered. The data and the scripts are available at:

https://osf.io/8a9yj/

Method

Participants and Procedure

Study 2 was part of a large project on happiness and well-being funded by the Chilean government. It was approved by the University Adolfo Ibáñez (in Santiago, Chile) Institutional Review Board, and followed the same ethical standards as Study 1.

The university provided a list of alumni emails to which surveys were sent. As in Study 1, we aimed to recruit enough participants to test a large (multiple latent variables across multiple time points) SEM, comparable to previous studies (e.g., LaGrange et al., 2011: $N = 515$). At T1, participants were told that the project was part of a longitudinal study and were asked to consent to future waves one month (Wave 2) and two months (Wave 3) later. Those participants who decided not to participate in the study, were given the option to
unsubscribe from the mailing list and were not contacted later. Consenting T1 participants were sent an email containing web-links to questionnaires to assess their positive affect and BNS. Only participants who finished the T1 survey were invited to participate at T2 and T3.

Data were obtained in a three-wave longitudinal survey with one month between each wave (T1 N = 1200 [42.2% female; Mean age = 39.1; SD = 9.8]; T2 n = 383; T3 n = 388). At T1, considering those who answered the nationality question, respondents were from several countries in Latin America: Chile (78.8%), followed by Colombia (6.4%), Perú (4.1%), México (2.7%), Venezuela (2.1%), Argentina (1.8%), Ecuador (1.4%) and others (2.7%). The pattern of nationalities was similar at T2 and T3.

Regarding attrition, those who completed our main constructs at Wave 3 (n = 387) did not differ significantly in gender, BNS and positive affect from those who left after T1 or T2 (n = 550; p ≥ .06). Participants differed significantly in age (t_{783} = −2.21, p = .027). However, a detailed inspection revealed that the age differences were negligible. Indeed, participants who stayed (M_{age} = 39.9, SD = 10.3) differed only slightly (1 year approximately) from participants who left the survey (M_{age} = 38.5, SD = 9.4). In other words, the difference is significant, but with such a large sample we consider the effect size to be trivial enough to be ignored. The Little MCAR test (Little, 1988) was nonsignificant, consistent with assuming that missing data were completely at random ($\chi^2_{208} = 191.61, p = .786$). Thus, we included all 1200 participants in our structural analyses, using FIML to handle missing data (Newman, 2014).

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5 We collected additional measures in Study 2, which were not relevant for the present research (for a full list, see https://osf.io/8a9yj/)
As in Study 1, our current sample size exceeded the range identified by Wolf et al. (2013), was comparable to previous longitudinal SEM studies (Burkholder & Harlow, 2003), and yielded no improper estimates (Wolf et al., 2013); hence, we judged it sufficient.

**Measures**

**Positive affect.** As in Study 1, we used the International Positive and Negative Affect Schedule Short Form (I-PANAS-SF; Thompson, 2007) to measure positive affect (5 items). However, we decided to drop the item “alert”.6 Thus, we modeled positive affect as a latent variable using the remaining 4 items as indicators. Reliabilities ranged from .80 to .82 across waves.

**Basic need satisfaction.** We used the 12-items scale developed by Chen et al. (2014). Participants rated from 1 (not at all true) to 7 (very true) their satisfaction of the needs for

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6 We had two main reasons for this decision. First, the item “alert” did not load appropriately on its target factor in our structural models, and reliabilities increased substantially when the item was deleted. Second, we think the item was not correctly understood in the current study. This is possible, because the word “Alerta” may have different meanings in the Spanish language. Indeed, we have noticed that the same item has been translated in different ways. For example, López-Gómez et al. (2015) have used the word “Despierto”, Nolla et al. (2014) have used the word “Disposición”, and Díaz-García et al. (2020) have used the words “Despejado/a” and “Despierto/a”. Rey (2015) used the word “Alerta” as we did. Although our original back-translation procedure led us to use the Spanish word “Alerta”, we realized with hindsight that the item is problematic as an indicator of positive affect, as it may have both positive and negative connotations (e.g., apprehension or vigilance). Thus, we considered it safer to drop this item from our analyses.
autonomy, competence and relatedness (4 items for each need). Example items included “I feel my choices express who I really am” (autonomy), “I feel capable at what I do” (competence), and “I feel connected with people who care for me, and for whom I care” (relatedness). Reliabilities ranged from .90 to .93 across waves. We used four item parcels as indicators (Coffman & MacCallum, 2005). To ensure that our latent variable would equally represent all three needs, each parcel used one autonomy, one competence and one relatedness item (see Note 4).

Results

We used MPlus 8.0 (Muthén & Muthén, 2017) to model relations among latent measures of BNS and positive affect in a bivariate trait-state-occasion model, following the same procedures as in Study 1. Descriptive statistics and correlations are shown in Table 3.

First, we tested a model without any constraints. This model fitted the data well, \( \chi^2(214) = 509.97, p < .001, \text{CFI} = .978, \text{RMSEA} = .034 \) (90% CI: .030, .038). Second, we constrained all the factor loadings of each latent variable to be equal across waves. The model also fitted the data well, \( \chi^2(226) = 527.68, p < .001, \text{CFI} = .978, \text{RMSEA} = .033 \) (90% CI: .030, .037). Thus, the assumption of measurement invariance across waves is tenable because the change in CFI was lower than .01 when these constraints are imposed (\( \Delta \text{CFI} = .000 \); Cheung & Rensvold, 2002). Finally, we made the simplifying assumption of constraining autoregressive and cross-lagged paths to be invariant over time (Cole et al., 2005). Our model showed good fit, \( \chi^2(230) = 528.78, p < .001, \text{CFI} = .978, \text{RMSEA} = .033 \) (90% CI: .029, .037). Model comparison confirmed that there was no significant loss of fit due to this simplifying assumption, \( \Delta \chi^2(4) = 1.10, p = .894. \)

All indicators showed strong (.675 ≤ \( \lambda \) ≤ .968) and significant (\( p < .001 \)) standardized loadings on their target state variables. State variables showed strong standardized loadings on their target trait variables (.829 ≤ \( \lambda \) ≤ .933) and on their target occasion variables (.360 ≤ \( \lambda \).
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≤ .560). Notably, all autoregressive paths were non-significant (all \( p \geq .104 \)), suggesting that stability in these constructs was mostly due to trait-level variance rather than carry-over effects across time-points. Structural parameters for our expanded bivariate trait-state-occasion model are reported in Table 4.

**Prospective relationships.** Supporting H1, we found that occasion BNS was a significant positive predictor of subsequent occasion positive affect, \( B = .275, [95\% CI: .062, .489] \), \( p = .012 \), \( \beta_{T1\rightarrow T2} = .249, \beta_{T2\rightarrow T3} = .309 \). Additionally, H2 was supported: Occasion positive affect was a significant predictor of subsequent occasion BNS, \( B = .342, [95\% CI: .024, .660] \), \( p = .035 \), \( \beta_{T1\rightarrow T2} = .216, \beta_{T2\rightarrow T3} = .216 \). Both prospective effects can be considered large in magnitude (Orth et al., in press).

**Contemporaneous relationships.** Trait BNS showed a strong positive correlation with trait positive affect, \( r = .757, [95\% CI .704, .809] \), \( p < .001 \). Occasion positive affect was not significantly correlated with Occasion BNS at T1 (\( r = .085 [95\% CI: -.419, .588] \), \( p = .742 \)). However, these variables showed large (Cohen, 1992) residual covariances at T2 (\( r = .682, [95\% CI: .430, .934] \), \( p < .001 \)) and at T3 (\( r = .745, [95\% CI: .615, .874] \), \( p < .001 \)).

**General Discussion**

Based on self-determination theory (Deci & Ryan, 2000; Ryan & Deci, 2017), we hypothesized that BNS would predict subsequent positive affect across time, and provided the first longitudinal test of this relationship that examined within-person prospective effects, while controlling for stable between-person associations. Longitudinal data from two different cultural groups (UK and Latin-American adults) and timescales (2 years and 2 months) were analyzed. Our results strongly confirm the hypotheses based on SDT, but also open new avenues for research on the BNS-positive affect relationship by showing that fluctuations in positive affect can also, but does not always, predict future fluctuations in need satisfaction, as proposed by broaden-and-build theory (Fredrickson, 2001, 2013).
NEED SATISFACTION AND POSITIVE AFFECT 22

BNS Prospectively Predicts Positive Affect

Using bivariate expanded latent trait-state-occasion models, we found converging evidence across both studies that BNS is a reliable antecedent of positive affect: In Study 1 and Study 2, individuals with higher than *their usual* levels of BNS at T1 showed higher than *their usual* levels of positive affect one year and one month later, respectively. Accordingly, while separating within-person effects from stable between-person variance, and when controlling for autoregressive paths and the reverse path from positive affect to BNS, psychological need satisfaction is shown to be a prospective predictor of positive affect. These results thus provide the most robust evidence to date to support the SDT-based proposal that BNS plays a key role in fostering positive affect over time.

Positive Affect Sometimes Prospectively Predicts BNS: Opening a New Avenue for Future Research

We extended previous SDT research by providing the first proper test of the potential ‘reverse link’ from positive affect to BNS, as suggested by broaden-and-build theory (Fredrickson, 2001, 2013). Our within-person analyses showed mixed support for the prospective link from positive affect to BNS. In particular, while positive affect predicted subsequent BNS at the within-person level in Study 2, we did not find this prospective path in Study 1. These are interesting results from the point of view of BBT, as they suggest that having temporarily higher levels of positive affect might not be enough to enhance and foster BNS over longer periods of time (Study 1), but indeed may foster BNS over the short run (Study 2). Consistent with this interpretation, most studies into broaden-and-build theory have also tended to examine effects of positive affect on aspects of positive function over shorter rather than longer time intervals (e.g., Fredrickson & Joiner, 2002; Burns et al., 2008).

However, these different results might alternatively be attributed to cultural variation or to
the different measures used in the two studies. Hence, future research could test the
prospective effect of positive affect on BNS across a range of time-lags within a single study.
These results are also interesting from the point of view of SDT. They show that, over
the short-term, the relationship between BNS and positive affect might be reciprocal, with
both constructs feeding into each other, thus creating the possibility for positive feedback
loops. Methodologically, these results underscore the importance for longitudinal research to
adopt within-person research designs. While most longitudinal research to date has adopted
cross-lagged panel modelling or other approaches that do not separate between-person from
within-person variance, we encourage more research into within-person effects in various
fields of psychology.

Practical Implications
Evidence for the prospective effects of BNS on positive affect may have broader
implications for several areas of psychological practice. Given the role of positive affect as a
‘symptom’ of various good things in life, and how hard it is to isolate its effects on good life
outcomes (Rohrer & Lucas, 2020), some have warned against direct promotion of positive
affect, arguing that it matters more what causes positive affect. Here, promoting satisfaction
of basic psychological needs could turn out to be a more sustainable way of increasing
positive affect. An increase in positive affect through need satisfaction should improve not
only individuals’ mental health, but also their flourishing (Tugade et al., 2014). Need
satisfaction has been linked to positive organizational outcomes, such as work satisfaction,
work engagement, and lower turnover intentions (Gillet et al., 2013; Marescaux et al., 2013;
Van den Broeck et al., 2016), and positive affect has been associated with desirable outcomes
at work such as job performance, engagement, and citizenship behavior (Diener & Tay,
2017). By increasing need satisfaction, and through need satisfaction increasing positive
affect, managers may improve not only workers’ quality of life, but also companies’
profitability. In educational settings, need satisfaction has been associated with better teaching styles, and with higher student motivation and engagement (Tessier et al., 2010). By increasing need satisfaction, educators may additionally increase positive affect that has been linked with creativity and complex mental tasks (Lyubomirsky et al., 2005), as well as with attentional breadth and flexibility (Johnson et al., 2010). Thus, the prospective link from BNS to positive affect may play a beneficial role in various life domains (Vansteenkiste & Ryan, 2013). Considering the ‘reverse link’ from positive affect to BNS, fostering positive affect may also increase BNS (at least in the short run), which may lead to several benefits in domains such as family, education, work, mental health and flourishing (Ryan & Deci, 2017).

**Limitations**

Some limitations of the current research must be noted. First, our measures were self-reported, and shared method variance potentially could have inflated correlations among constructs within each wave. However, self-reports of one’s experience are arguably the most valid ways of measuring BNS and positive affect, since these are aspects of subjective experience. Moreover, we took several precautions to mitigate common-method bias, such as using construct-valid measurement scales, protecting respondent anonymity, and instructing the participants that there were no right or wrong answers (Conway & Lance, 2010; Podsakoff et al., 2003). Nonetheless, future studies might supplement the current measures with alternative methods, such as peer reports of BNS and positive affect.

Second, although the prospective longitudinal effects reported here through our trait-state-occasion models substantially strengthen the case for causal effects between BNS and positive affect by providing evidence of temporal precedence, they do not provide conclusive evidence for causality, nor do they suggest that the contemporaneous associations between the constructs are wholly attributable to such a causal pathway. Further variables not measured here may influence both constructs. However, such “third variable” explanations
would more easily account for the contemporaneous associations between BNS and positive affect than for the temporal relations observed here, since past influences of a third variable are likely to have been subsumed within the stable trait-like variance that we controlled for when estimating prospective predictions in our trait-state-occasion models.

Third, the two studies reported here differed in several ways, including the time lag between measurement occasions, the cultural background of samples, the specific questionnaires used, and the sample sizes. While these differences may help to increase confidence in the generality of our main finding that BNS prospectively predicted positive affect, they leave us with several possible alternative explanations for the pattern of findings that positive affect predicted BNS in Study 2 but not in Study 1. Thus, our tentative interpretation that the difference was due to the different time lags of the two studies must be taken with caution until future research has disentangled these various possibilities.

Fourth, caution is needed about generalizing these findings to other samples and research contexts. Although we sampled non-student populations, they were university graduates, and so our findings may not generalize to less educated groups. Hence, it would be desirable in future studies to include samples from additional cultures and educational groups. Nevertheless, we recruited participants for the two studies from two different world regions, with different economic development, and so the similarity of findings regarding the prospective effect of BNS on positive affect supports a degree of cross-cultural generalizability of this finding, in line with SDT’s claim that basic psychological needs should be operational across cultures (Ryan & Deci, 2017).

Fifth, although attrition was not problematic across the two studies, it remains possible that the percentage of participants who dropped out of our studies after the first wave may have differed in unknown, unmeasured ways from those who remained in the study. Importantly, attrition in online studies is high very often (Wood et al., 2010) and researchers
has shown that “the law of attrition” is almost a fact in all data collection without in person contact. Further, “high dropout rates may be a natural and typical feature” (Eysenbach, 2005, p. 1; Unanue et al., 2019).

Conclusion

Overall, our results have important implications for SDT and positive affect research. SDT is one of the most prominent theories of human wellness in mainstream psychology (Deci & Ryan, 2000; Ryan & Deci, 2017) and its assumption that BNS predicts positive affect is at the core of the theory (Vandenbroeck et al., 2016; Vansteenkiste et al., 2020). Therefore, providing longitudinal support for this assumption with rigorous methods makes our results a key input for the SDT field. Using more causally sensitive longitudinal models than previous research, by more adequately separating the focal within-person effects from between-person stable variance, we provide the strongest evidence to date that BNS indeed prospectively predicts future positive affect. Our second study also provides first evidence for a reverse link from positive affect to BNS. Thus, positive affect might be not only an outcome of BNS, but also a predictor of it—albeit perhaps only in the short term. This provides important evidence for the complex and rich temporal relations between BNS and positive affect, hopefully inspiring more research in the future on the relationship between these key constructs, but also among BNS and other key constructs of human well-being, eudaimonia, and flourishing (Martela & Sheldon, 2019; Ryan & Deci, 2001).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.
Data Accessibility Statement

The study hypotheses were not preregistered. The materials, data and the scripts for both Study 1 and Study 2 may be found here: https://osf.io/8a9yj/
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Table 1

Descriptives and Zero-order Correlations for Observed Variables in Study 1 (T1: N = 958; T2: N = 567; T3: N = 561)

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<th></th>
<th>M</th>
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<th>5</th>
<th>6</th>
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<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Need Satisfaction T1</td>
<td>4.3</td>
<td>0.8</td>
<td>.66**</td>
<td>.61**</td>
<td>.64**</td>
<td>.55**</td>
<td>.49**</td>
<td>.04</td>
<td>.16**</td>
</tr>
<tr>
<td>2. Need Satisfaction T2</td>
<td>4.3</td>
<td>0.8</td>
<td>.64**</td>
<td>.50**</td>
<td>.68**</td>
<td>.54**</td>
<td>.05</td>
<td>.14**</td>
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<tr>
<td>3. Need Satisfaction T3</td>
<td>4.4</td>
<td>0.8</td>
<td>.48**</td>
<td>.49**</td>
<td>.63**</td>
<td>.02</td>
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<td>4. Positive Affect T1</td>
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<td>0.6</td>
<td></td>
<td>.65**</td>
<td>.63**</td>
<td>.04</td>
<td>.19**</td>
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<tr>
<td>5. Positive Affect T2</td>
<td>3.5</td>
<td>0.6</td>
<td></td>
<td>.64**</td>
<td>.04</td>
<td>.14**</td>
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<tr>
<td>6. Positive Affect T3</td>
<td>3.5</td>
<td>0.6</td>
<td></td>
<td></td>
<td>-.02</td>
<td>.19**</td>
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<tr>
<td>7. Gender (female) at T1</td>
<td>0.6</td>
<td></td>
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<td></td>
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<td></td>
<td>-.13**</td>
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<tr>
<td>8. Age at T1</td>
<td>44.7</td>
<td>14</td>
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</table>

Note. * p < .05, ** p < .01
Table 2

Unstandardized [and Standardized] Estimates of Structural Parameters from Expanded Bivariate Trait-State-Occasion Model in Study 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>p</th>
<th>(95%CI)</th>
<th>Estimate</th>
<th>p</th>
<th>(95%CI)</th>
<th>Estimate</th>
<th>p</th>
<th>(95%CI)</th>
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<tr>
<td>Prospective relationships</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictive paths</td>
<td>BNS → PA</td>
<td>.202 (.288)</td>
<td>.008 (.052,.351)</td>
<td>.202 (.315)</td>
<td>.008 (.052,.351)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PA → BNS</td>
<td>-.064 [-.04]</td>
<td>.710 (-.339,.272)</td>
<td>-.064 [-.04]</td>
<td>.710 (-.399,.272)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PA → PA</td>
<td>-.098 [-.094]</td>
<td>.508 (-.388,.192)</td>
<td>-.098 [-.097]</td>
<td>.508 (-.388,.192)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Standardized contemporaneous relationships</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BNS with PA</td>
<td>[.824]</td>
<td>&lt;.001 (.773,.874)</td>
<td>[.571]</td>
<td>&lt;.001 (.444,.698)</td>
<td>[.690]</td>
<td>&lt;.001 (.541,.839)</td>
<td>[.502]</td>
<td>&lt;.001 (.372,.631)</td>
</tr>
</tbody>
</table>

Note. BNS = basic needs satisfaction; PA = positive affect; standardized paths in square brackets for prospective associations. Only standardized contemporaneous relationships are reported.
Table 3

Descriptives and Zero-order Correlations for All the Observed Variables in Study 2 (T1: N = 1200; T2: N = 383; T3: N = 388)

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<th>8</th>
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</thead>
<tbody>
<tr>
<td>1. Need Satisfaction T1</td>
<td>5.9</td>
<td>0.8</td>
<td>.83**</td>
<td>.81**</td>
<td>.49**</td>
<td>.60**</td>
<td>.56**</td>
<td>-.09**</td>
<td>.06</td>
</tr>
<tr>
<td>2. Need Satisfaction T2</td>
<td>5.9</td>
<td>0.9</td>
<td>.84**</td>
<td>.61**</td>
<td>.67**</td>
<td>.62**</td>
<td>-.16**</td>
<td>.12*</td>
<td></td>
</tr>
<tr>
<td>3. Need Satisfaction T3</td>
<td>5.8</td>
<td>1.0</td>
<td>.56**</td>
<td>.61**</td>
<td>.69**</td>
<td>-.13*</td>
<td>.12*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Positive Affect T1</td>
<td>4.1</td>
<td>0.6</td>
<td>.74**</td>
<td>.68**</td>
<td>-.08*</td>
<td>.13**</td>
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<tr>
<td>5. Positive Affect T2</td>
<td>4.1</td>
<td>0.7</td>
<td>.74**</td>
<td>-.10*</td>
<td>.11*</td>
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<tr>
<td>6. Positive Affect T3</td>
<td>4.1</td>
<td>0.7</td>
<td>-.11*</td>
<td>.17**</td>
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<td>7. Gender (female) at T1</td>
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<td>-.20**</td>
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<td>8. Age at T1</td>
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*Note. * p < .05, ** p < .01
Table 4

Unstandardized [and Standardized] Estimates of Structural Parameters from Expanded Bivariate Trait-State-Occasion Model in Study 2

<table>
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<tr>
<th>Parameter</th>
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<th>Estimate</th>
<th>p</th>
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<td><strong>Prospective relationships</strong></td>
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<tr>
<td>Predictive paths</td>
<td>Occasion 1 → Occasion 2</td>
<td></td>
<td></td>
<td>Occasion 2 → Occasion 3</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNS → PA</td>
<td>.275 [.249]</td>
<td>.012</td>
<td>(.062, .489)</td>
<td>.275 [.309]</td>
<td>.012</td>
<td>(.062, .489)</td>
<td></td>
<td></td>
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<tr>
<td>PA → BNS</td>
<td>.342 [.216]</td>
<td>.035</td>
<td>(.024, .660)</td>
<td>.342 [.216]</td>
<td>&lt;.035</td>
<td>(.024, .660)</td>
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<tr>
<td>Stability paths</td>
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<tr>
<td>BNS → BNS</td>
<td>.230 [.159]</td>
<td>.104</td>
<td>(-.047, .508)</td>
<td>.230 [.190]</td>
<td>.104</td>
<td>(-.047, .508)</td>
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<td><strong>Standardized contemporaneous relationships</strong></td>
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<tr>
<td>Trait level</td>
<td>Occasion 1</td>
<td>Occasion 2</td>
<td>Occasion 3</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNS with PA</td>
<td>.757 &lt;.001</td>
<td>(.704, .809)</td>
<td>.085</td>
<td>.742</td>
<td>(-.419, .588)</td>
<td>.682</td>
<td>&lt;.001</td>
<td>(.430, .934)</td>
<td>.745</td>
</tr>
</tbody>
</table>

Note. BNS = basic needs satisfaction; PA = positive affect; standardized paths in square brackets for prospective associations. Only standardized contemporaneous relationships are reported.
Figure 1

*Measurement Part of Expanded Trait-State-Occasion Model for Basic Needs Satisfaction*

Note. BNS = Basic Needs Satisfaction; BNS1-BNS3 = Basic Needs Satisfaction Item Parcels 1-3; T1-T3 = Time 1-Time 3.
Online Supplementary Materials for

Clarifying the Link Between Psychological Need Satisfaction and Positive Affect:

Longitudinal Within-Person Tests for Bi-directional Influence in Two Cultures

To supplement the bivariate extended latent trait-state-occasion models reported in our main text, we also conducted cross-lagged panel models testing the following less causally stringent versions of our main hypotheses:

H3. Earlier states of BNS prospectively predict later states of positive affect.

H4. Earlier states of positive affect prospectively predict later states of BNS.

Unlike our main analyses, the lagged paths in these models may be partially influenced by stable trait-like between-person variance, confounded with the within-person relationships that are especially relevant for inferring causality (see Hamaker et al., 2015). Details about the method (procedure, scales, etc.), model fit criteria and references may be found in our main text. Figure 1 illustrates our supplementary hypotheses H3 and H4.

Study 1: Supplementary Analyses

Cross-Lagged Panel Model

As in our main analyses, we modelled both constructs as latent variables using three (BNS) or five (positive affect) indicators per factor. Each measure at (T+1) was regressed on its own lagged measure at (T) as well as on the other lagged measure at (T) (Finkel, 1995). We allowed BNS and positive affect to co-vary freely within each time point. Thus, both constructs were represented as potential antecedents and potential consequences of the other construct, while controlling for stability paths. First, we tested a model without any constraints. This model fitted the data well, $\chi^2(217) = 513.39$, $p < .001$, CFI = .970, RMSEA = .038 (90% CI: .034, .042). Second, we constrained all the factor loadings of each latent variable to be equal across waves. The model also fitted the data well, $\chi^2(229) = 530.73$, $p <$
.001, CFI = .970, RMSEA = .037 (90% CI: .033, .041). According to Cheung and Rensvold (2002), the assumption of invariance is tenable if the reduction in CFI, when constraints are imposed, is less than .01. Here, the change in CFI met this criterion (ΔCFI = .000). Thus, we considered it acceptable to assume invariance of factor loadings over time. Finally, following Cole et al. (2005), we made the simplifying assumption of constraining autoregressive and cross-lagged paths to be invariant over time (i.e., T1 → T2 = T2 → T3). Hence, each hypothesis was represented by a single parameter representing the combined effect from T1 to T2 and from T2 to T3. The final model showed good fit, χ²(233) = 532.80, p < .001, CFI = .970, RMSEA = .037 (90% CI: .033, .041), and there was no significant loss of fit when comparing with our previous model, Δχ²(4) = 2.07, p = .722. All indicators loaded substantially on their target factors, with standardized loadings ranging from .591 to .911 across waves (all p < .001). Structural parameters for our Study 1 cross-lagged panel model are reported in Table S1.

**Prospective Relationships**

Consistent with H3, BNS was a significant positive prospective predictor of positive affect, B = .112, [95% CI: .047, .178], p < .001, β_{T1→T2} = .156, β_{T2→T3} = .158, representing a large effect size (Orth et al., in press). Consistent with H4, positive affect was also a significant positive prospective predictor of BNS, B = .142, [95% CI: .015, .269], p = .029, β_{T1→T2} = .100, β_{T2→T3} = .100, representing a medium-to-large effect size.

**Contemporaneous Relationships**

Positive affect was significantly and positively correlated with BNS at T1 (r = .746 [95% CI: .706, .786], p < .001), representing a large effect size (Cohen, 1992) and these variables also showed large residual covariances at T2 (r = .654, [95% CI: .572, .737], p < .001) and at T3 (r = .532, [95% CI: .439, .625], p < .001).
Study 2: Supplementary Analyses

Cross-Lagged Panel Model

We modelled all constructs as latent variables using four indicators per factor for both BNS and positive affect. Each measure at (T+1) was regressed on its own lagged measure at (T) as well as on the other lagged measure at (T) (Finkel, 1995). We allowed BNS and positive affect to co-vary freely within each time point. Thus, both constructs were represented as potential antecedents and potential consequences of the other construct, while controlling for stability paths. Our initial model without constraints fitted the data well, χ²(217) = 539.60, p < .001, CFI = .976, RMSEA = .035 (90% CI: .031, .039). Second, we constrained all the factor loadings of each latent variable to be equal across waves. The model also fitted the data well, χ²(229) = 557.40, p < .001, CFI = .976, RMSEA = .035 (90% CI: .031, .038). Thus, the assumption of invariance is tenable because the reduction in CFI was less than .01 when constrained are imposed (ΔCFI = .000; Cheung & Rensvold, 2002).

Finally, following Cole et al. (2005), we made the simplifying assumption of constraining autoregressive and cross-lagged paths to be invariant over time (i.e., T1 → T2 = T2 → T3). Our model showed good fit, χ²(233) = 562.54, p < .001, CFI = .976, RMSEA = .034 (90% CI: .031, .038), and there was no significant loss of fit when comparing with our previous model with loadings constrained, Δχ²(4) = 5.14, p = .273. Standardized factor loadings ranged from .675 to .968 (all p < .001). Structural parameters for our Study 2 cross-lagged panel model are reported in Table S2.

Prospective Relationships

Consistent with H3, BNS was a significant positive prospective predictor of positive affect, B = .09, [95% CI: .030, .150], p = .003, β_{T1→T2} = .111, β_{T2→T3} = .113, representing a large effect size (Orth et al., in press). Additionally, consistent with H4, positive affect was
also a significant positive prospective predictor of BNS, $B = .175$, [95% CI: .086, .265], $p < .001$, $\beta_{T1\rightarrow T2} = .130$, $\beta_{T2\rightarrow T3} = .126$, representing a large effect size.

**Contemporaneous Relationships**

Positive affect was significantly and positively correlated with BNS at T1 ($r = .662$ [95% CI: .621, .703], $p < .001$, representing a large effect size (Cohen, 1992) and these variables also showed large residual covariances at T2 ($r = .425$, [95% CI: .296, .555], $p < .001$) and at T3 ($r = .625$, [95% CI: .496, .754], $p < .001$).
Table S1

Unstandardized [and Standardized] Estimates of Structural Parameters from Cross-Lagged Path Model in Study 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>p</th>
<th>(95% CI)</th>
<th>Estimate</th>
<th>p</th>
<th>(95% CI)</th>
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</thead>
<tbody>
<tr>
<td><strong>Prospective relationships</strong></td>
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<tr>
<td><strong>Predictive paths</strong></td>
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<tr>
<td>BNS → PA</td>
<td>.112 [.156]</td>
<td>&lt;.001</td>
<td>(.047, .178)</td>
<td>.112 [.156]</td>
<td>&lt;.001</td>
<td>(.047, .188)</td>
</tr>
<tr>
<td>PA → BNS</td>
<td>.142 [.100]</td>
<td>.029</td>
<td>(.015, .269)</td>
<td>.142 [.100]</td>
<td>.029</td>
<td>(.015, .269)</td>
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<td><strong>Stability paths</strong></td>
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<tr>
<td>BNS → BNS</td>
<td>.638 [.626]</td>
<td>&lt;.001</td>
<td>(.549, .728)</td>
<td>.638 [.637]</td>
<td>&lt;.001</td>
<td>(.549, .728)</td>
</tr>
<tr>
<td>PA → PA</td>
<td>.639 [.636]</td>
<td>&lt;.001</td>
<td>(.540, .737)</td>
<td>.635 [.635]</td>
<td>&lt;.001</td>
<td>(.540, .737)</td>
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<tr>
<td><strong>Standardized contemporaneous relationships</strong></td>
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<tr>
<td>BNS with PA</td>
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<tr>
<td></td>
<td>.746</td>
<td>&lt;.001</td>
<td>(.706, .786)</td>
<td>.654 [.532]</td>
<td>&lt;.001</td>
<td>(.439, .625)</td>
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</table>

*Note.* BNS = basic needs satisfaction; PA = positive affect; standardized paths in square brackets for prospective associations. Only standardized contemporaneous relationships are reported.
### Table S2

*Unstandardized [and Standardized] Estimates of Structural Parameters from Cross-Lagged Path Model in Study 2*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>p</th>
<th>(95%CI)</th>
<th>Estimate</th>
<th>p</th>
<th>(95%CI)</th>
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</thead>
<tbody>
<tr>
<td><strong>Prospective relationships</strong></td>
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<tr>
<td><strong>Predictive paths</strong></td>
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</tr>
<tr>
<td>BNS → PA</td>
<td>.090 [.111]</td>
<td>.003</td>
<td>(.030, .150)</td>
<td>.090 [.113]</td>
<td>.003</td>
<td>(.030, .150)</td>
</tr>
<tr>
<td>PA → BNS</td>
<td>.175 [.130]</td>
<td>&lt;.001</td>
<td>(.086, .265)</td>
<td>.175 [.126]</td>
<td>&lt;.001</td>
<td>(.086, .265)</td>
</tr>
<tr>
<td><strong>Stability paths</strong></td>
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<td></td>
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</tr>
<tr>
<td>BNS → BNS</td>
<td>.808 [.765]</td>
<td>&lt;.001</td>
<td>(.742, .873)</td>
<td>.808 [.753]</td>
<td>&lt;.001</td>
<td>(.742, .873)</td>
</tr>
<tr>
<td>PA → PA</td>
<td>.814 [.782]</td>
<td>&lt;.001</td>
<td>(.730, .898)</td>
<td>.814 [.787]</td>
<td>&lt;.001</td>
<td>(.730, .898)</td>
</tr>
<tr>
<td><strong>Standardized contemporaneous relationships</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>BNS with PA</td>
<td>.662</td>
<td>&lt;.001</td>
<td>(.621, .703)</td>
<td>.425 (.625)</td>
<td>&lt;.001 (&lt;.001)</td>
<td>(.296, .555) (.496, .754)</td>
</tr>
</tbody>
</table>

*Note.* BNS = basic needs satisfaction; PA = positive affect; standardized paths in square brackets for prospective associations. Only standardized contemporaneous relationships are reported.
Figure S1

*Supplementary Hypotheses*