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## ARTICLE

# Need satisfaction in daily well-being: Both social and solitude contexts contribute to well-being

Mark Adams  | Netta Weinstein

School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK

## Correspondence

Mark Adams, School of Psychology and Clinical Language Sciences, University of Reading, PO Box 238, Reading RG6 6AL, UK.  
Email: [m.a.adams@reading.ac.uk](mailto:m.a.adams@reading.ac.uk)

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## Abstract

Daily need satisfaction for relatedness (social connection), autonomy (volitional self-congruent action), and competence (self-efficacy) fosters well-being, but those findings primarily reflect experiences during social interactions. A three-week daily diary study ( $N = 178$ ) explored psychological need satisfaction in two key everyday contexts: solitude and social. Holding constant the benefits of need-satisfying social contexts, autonomy satisfaction during solitude was key to peaceful affect, whereas competence satisfaction during solitude contributed to lower loneliness; both psychological needs in solitude contributed to evaluating the day as more satisfying. Relatedness-deficiency in solitude did not contribute to loneliness; instead, those who were relatedness-deficient in social interactions felt lonely. Further, need satisfaction in solitude compensated for deficient needs in social contexts, reducing loneliness (autonomy and relatedness) and increasing day satisfaction (all needs) when social contexts failed to satisfy needs. Findings suggest daily solitude can shape daily well-being and further attention is needed to understand and ultimately improve everyday solitude.

## KEYWORDS

loneliness, psychological need satisfaction, self-determination theory, solitude, well-being

## INTRODUCTION

According to self-determination theory, people feel well-being when their life experiences satisfy their basic psychological needs. Empirical evidence supports this view, showing that when people experience satisfaction of the specific needs for *autonomy* (the sense they can be volitional and self-congruent),

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*relatedness* (the feeling of being close and connected to others), and *competence* (the experience of being effective in pursuing important goals), they benefit from various well-being indicators (Chen et al., 2015; Tang et al., 2020). These benefits are commonly observed at a *general* level or within specific life domains (e.g., Lataster et al., 2022; Milyavskaya et al., 2013). Digging deeper, those broad benefits are comprised of a series of brief periods of time, each with distinct time-specific effects on well-being (Reis et al., 2000).

Indeed, targeted observations analysed *within* days consistently show that daily psychological need satisfaction influences daily well-being, even accounting for individual differences. Studies testing both trait and state levels show comparable effect sizes linking need satisfaction and well-being ranging from  $\beta = .13$  to  $.18$  for trait, and  $\beta = .15$  to  $.31$  for daily levels, respectively, even when accounting for well-being from the previous day (Sheldon et al., 1996). Similarly, Reis et al. (2000) found that autonomy, relatedness, and competence need satisfaction within a given day and each contributes to the day's well-being in terms of positive affect. These studies suggest that each of the three psychological need satisfactions contributes to daily well-being on that day, with comparable effects as when examining these links at the individual-difference level.

Such experiences of need satisfaction are contingent on the events of the day. For example, on days in which individuals conceal more from others, they experience reduced psychological need satisfaction as well as lower ratings of life satisfaction and vitality (Uysal et al., 2010). On days when athletes receive greater autonomy support from their parents, they experience greater need satisfaction, resulting in more positive emotions, self-esteem, and vitality (Gagne, 2003). Similarly, on days when individuals are autonomously prosocial, they experience greater psychological need satisfaction, along with reports of increased satisfaction and happiness (Mojza et al., 2011). Further, Reis et al. (2000) found that social experiences that involved non-argumentative interactions, as well as a sense of fun and feeling understood, were particularly important in fulfilling relatedness needs at the day level. Together, this research, in line with a broader focus linking social contexts to psychological need satisfaction (Sheldon & Bettencourt, 2002), offers extensive evidence that everyday need satisfaction and its corresponding well-being depends on enriching social contexts.

## Well-being in solitude

In the current paper, we argue that *solitude* contexts (i.e., time spent alone and not interacting with others face-to-face or virtually; Lay et al., 2018) can also satisfy basic psychological needs and foster daily well-being. We focus on three well-being indicators that have been observed to be characteristic of positive experiences within solitude as well as social time: peaceful affect, loneliness, and day satisfaction.

The first of these has received the most attention within the context of solitude experiences. For example, qualitative work and theory to date consistently identify that solitude has the potential to evoke a peaceful mood (Buchholz, 1999; Koch, 1990; Thomas, 2021), characterized by low-arousal positive affect that can be differentiated from high-arousal feelings such as excitement or happiness (Kensinger & Schacter, 2006; Russell, 1980). This is reflected in findings from a large multinational survey that reported 'being in solitude' as a top source of relaxation (Hammond & Lewis, 2016), as well as empirical evidence indicating that solitude provides low-arousal affect benefits (Long & Averill, 2003; Weinstein et al., 2021). In-depth analyses of diary data indicate that low-arousal positive (peaceful) affect is typical of solitude for some but not others (Lay et al., 2019), suggesting solitude may, but does not always, contribute to feeling peaceful.

While peaceful affect reflects the beneficial contributions of solitude to well-being, potential well-being costs associated with time spent in solitude have focused on loneliness (Matias et al., 2011; Pauly et al., 2017). Although children and adults can differentiate between solitude, isolation, and loneliness when queried (Galanaki, 2004; Hipson et al., 2021), it has often been thought that the more time one spends in solitude, the more isolated they are and the lonelier they feel (see review; see Coplan et al., 2021). These perspectives raise an intriguing question: – which qualities of solitude time contribute to global

feelings of loneliness, and does solitude time contribute to loneliness in equal or greater proportions than comparable experiences during social time?

Alongside these affective outcomes, we evaluate a cognitive outcome: day satisfaction, which has been modelled repeatedly as an outcome of basic psychological needs in *social contexts* (Reis et al., 2000; Weinstein & Ryan, 2010) as an evaluation indicative of subjective well-being. Just like the social interaction literature, which highlights that only certain social conditions satisfy daily need satisfaction and well-being, solitude's contributions may come from those moments alone when people experience greater psychological need satisfaction for autonomy, relatedness, and competence.

Although this topic has received little direct exploration, it is plausible that solitude contributes to need satisfaction in a similar manner to social contexts. Solitude provides a space free from external pressures, which might foster a sense of autonomy by aligning an individual's actions with their authentic selves. Solitude may also provide an opportunity for introspection, enabling individuals to cultivate a deeper sense of self-connection and further satisfy autonomy (see also Weinstein et al., 2023). Similarly, it may promote feeling competent when allowing individuals to engage in activities that they find optimally challenging and personally rewarding. Finally, although individuals are separated from others during solitude, taking time to reflect on social connections and interactions can help establish a sense of relatedness even in the absence of others, satisfying the relatedness need. Indirect evidence that psychological needs can be satisfied in solitude comes from research on activities undertaken in solitude, primarily in the realm of hobbies. For example, leisure crafters have been shown to shape their psychological need satisfaction and fulfilment through their hobby (Petrou & Bakker, 2016), while hobby musicians have been shown to experience more psychological need satisfaction and subsequent positive affect on the days they produce music (Koehler & Neubauer, 2020). Building on this nascent literature, it is reasonable to believe that psychological needs can be experienced similarly in either context (Hypothesis 1, or H1, below) and that need satisfaction experienced in each context contributes to daily well-being (H2 below).

In addition to testing relations between solitude as well as social psychological need satisfaction and daily well-being, we were inspired by work that examines psychological need satisfaction across life's domains to test how those contexts interact. For example, a foundational study in this area (Milyavskaya et al., 2009) identified the benefits for young people's positive affect of having need satisfaction balanced *across* different domains of daily life. In a subsequent study, researchers examined adults' *compensatory interactions* between need satisfaction at work and at home and found that competence need satisfaction at home was especially important for well-being when individuals did not feel a sense of competence at work (Hewett et al., 2017). In other words, this research suggests the protective benefits of one domain over the other. Contrary to their predictions, the researchers did not find such compensatory effects for autonomy and relatedness need satisfaction; in these cases, independent experiences in each domain were more important than their relation to one another.

Compensatory interactions may also occur in the context of solitude and social daily experiences. Specifically, it may be that experiencing psychological need satisfaction in one domain compensates for its absence in another (H3, below). For example, individuals who experience little psychological need satisfaction when they are with others may depend more on the psychological need satisfaction they experience when alone; such a phenomenon may inform research demonstrating that individuals with conflictual social relationships benefit from being alone (Birditt et al., 2019; Choi et al., 2023) and the body of work showing that those who have less functional social relationships prefer solitude (Rubin et al., 2014). On the other hand, having a strong and supportive social network may act as a buffer for those who experience solitude more negatively, potentially counterbalancing the adverse impact of time spent alone. For example, the presence of close and supportive connections has been associated with a reduction in various negative aspects of solitude, including low-arousal negative affect (Koch, 1994; Pauly et al., 2018), loneliness (Masi et al., 2011), and symptoms of depression (Kuczynski et al., 2022). As such, the relationship between psychological need satisfaction and well-being may be based on the dynamic interplay between these needs across different contexts.

## Current research

In the current research, we explore three hypotheses (H) that reflect the relative contributions of need satisfaction in both social and solitude contexts to daily well-being:

- H1 Given there is reason to believe psychological need satisfaction could be experienced in solitude as well as social contexts, we anticipated that psychological need satisfaction for autonomy, relatedness, and competence would be experienced similarly in social and solitude contexts.
- H2 We also expected that psychological need satisfactions for autonomy, relatedness, and competence in each of two daily contexts (either social or solitude) independently would contribute to a peaceful daily mood, lower loneliness, and greater day satisfaction.
- H3 Finally, we hypothesized that psychological need satisfactions in each of two daily contexts (either social or solitude) will have a compensatory effect when predicting daily peaceful mood, lower loneliness, and greater day satisfaction, such that the costs of deficits in one are compensated for the presence in the other.

We also set out to test one research question (RQ):

- RQ1 Do psychological need satisfactions in each of two daily contexts (either social or solitude) account *disproportionally*, relative to the other, for a daily peaceful mood, lower loneliness, and greater day satisfaction? That is, does one context (social or solitude) matter more for shaping daily well-being than another?

## METHOD

### Participants and recruitment

We recruited 178 English-speaking adults (95 women, 1 non-binary or genderqueer, 79 men, and three did not answer) from the United Kingdom and the United States. The mean age of participants was 47 years (IQR: 39–53). Participants were recruited via Prolific and compensated up to £60 (\$72) each for taking part, in full or partially, as a function of the number of days completed. Demographic characteristics are found in Table 1. Our sample allowed us to achieve 2967 data points, which exceeds the minimum number of data points (1600–1700) recommended for mixed effect models with no clear prior effect size (Brysbaert & Stevens, 2018; Meteyard & Davies, 2020; Nezlek, 2020). These measures were collected as part of a larger project focused on hours spent in solitude daily, motivation for solitude, and corresponding well-being (Weinstein, Vuorre, et al., 2023); no two relations are tested twice across the two studies. Data, measures, and scripts for the current project are available on the open science framework: (<https://osf.io/6jce9/>). A priori power analysis from the previous project using the “simr” package (version 1.0.5) in R suggested that a sample size of 150 participants with 21 observations per participant allowed more than 80% power to detect significant fixed effects at .05 alpha levels. To ensure this power analysis applied to the data in the current study, we conducted an additional post-hoc sensitivity analysis following guidelines by Murayama et al. (2022), using  $t = 3.07^1$  and 21 observations. Results suggested an ideal minimum sample size of 151 to achieve 80% power to detect fixed effects at .05 alpha levels.

<sup>1</sup>We used the value of autonomy in social contexts, a conservative  $t$ -value lower than the average of the six  $t$ -values from our models ( $M = 3.69$ ). See Table 4 for details.

TABLE 1 Descriptive statistics for participant demographic characteristics.

	Proportion of participants who selected this response
Gender (N=173)	
Male	.46
Female	.54
Non-binary	.01
Ethnicity (N=173)	
Asian	.04
South Asian	.10
African/Black	.11
Middle Eastern	.01
Hispanic	.01
White/Caucasian	.69
Other	.05
Education (N=173)	
Some Secondary	.01
Completed Secondary School	.08
Vocational or Similar	.14
Some university but no degree	.08
University bachelor's degree	.42
Graduate or professional degree	.28
Employment (N=171)	
Working full-time	.53
Working part-time	.26
Unemployed and looking for work	.04
Homemaker or stay-at-home parent	.04
Student	.02
Retired	.06
Other	.04

Procedure

All participants completed an initiation session, a baseline questionnaire, and up to 21 daily diaries. The initial session was delivered via Teams and was designed to increase adherence across 3 weeks and vet individuals' age and eligibility (namely, that participants were adult English speakers living in the United States or the United Kingdom). During this session, participants also completed a baseline survey consisting of a battery of demographic and trait-level questions and received verbal instructions on how to complete their upcoming daily diaries. Following this, a 21-day diary study using a fixed-interval design with participants receiving emailed survey reminders each evening (i.e., between 20:00 and 24:00) containing a link to the Qualtrics survey. This daily survey incorporated the Day Reconstruction Method (DRM; Kahneman et al., 2004), a technique that has been used successfully to improve recall of events of the previous day (Diener & Tay, 2014). Here, we adapted the wording of the DRM for the purpose of recalling earlier events and activities from the same day. Participants were asked to spend at least 3 min (enforced via the timing question in Qualtrics) thinking back over their day before reconstructing events of the day using the DRM recall prompts (e.g., to recall what they were doing, who they were with, and how they were feeling or what they were thinking at the time of each new event). After

completing the DRM procedure with the events of the day salient to them, participants completed the study measures described below.

## Measures

### Treatment of all outcome measures

All outcome measures were paired with a scale ranging from 0 (*not at all*) to 6 (*extremely*) unless noted otherwise for consistency across the survey.

## Independent variables

### Psychological need satisfaction in solitude and social contexts

Daily need satisfaction was assessed using the basic psychological needs scale (La Guardia et al., 2000). This scale consists of nine items, split into three subscales (autonomy, competence, and relatedness need satisfactions). For our purposes, we reference-shifted these scales to fit both contexts of solitude and social interaction by changing the wording of the question. Following guidance by Lay et al. (2018) for solitude contexts, the prompt was, “When you were alone (not interacting with anyone in-person or over technology), how true were these statements for you...”. while for social contexts, it was “When you were interacting (interacting with others in-person or over technology), how true were these statements for you?”. This ensured that we were able to record separate need satisfactions for each context.

Specifically, autonomy need satisfaction was measured using the three-item subscale of the basic psychological need scale (La Guardia et al., 2000), including “I felt free to be who I am”, and “I felt controlled or pressured to be certain ways” ( $\alpha = .92$ ,  $\alpha = .93$ , for solitude and social contexts, respectively). Competence need satisfaction was measured using the three-item subscale of the basic psychological need scale (La Guardia et al., 2000), including “I felt confident that I can do things well...” ( $\alpha s = .96$  for both solitude and social contexts). Relatedness need satisfaction was measured using the three-item subscale of the basic psychological need scale (La Guardia et al., 2000), including “I felt connected with people who care for me, and for whom I care.” ( $\alpha s = .96$  for both solitude and social contexts).

## Dependent variables

### Peaceful affect

We assessed daily peaceful affect using a composite measure that combined four items of daily affect. Participants were asked to “Please rate how you felt today” for each state (calm, relaxed, at-ease, and peaceful) on a 100-point scale (0 = *Not at all*, to 100 = *Very much*) (e.g., Lay et al., 2018). Internal consistency of our composite peaceful affect measure yielded a Cronbach's  $\alpha = .96$ .

### Loneliness

We selected a single-item measure of loneliness since this was more suitable for administering daily over the course of the 21-day period. This direct measure, “I felt lonely today”, provided a face-valid way of assessing feelings of loneliness that day (Shiovitz-Ezra & Ayalon, 2012) and was more appealing and less burdensome on participants (Victor et al., 2005) over repeated exposures than more involved alternatives such as the UCLA Loneliness Scale.



Day satisfaction

Day satisfaction is a cognitive evaluation of the day derived from life satisfaction, but one that is appropriate for capturing day-level variations (Przybylski et al., 2021; Sagioglou & Greitemeyer, 2014; Weinstein & Ryan, 2010). Participants were asked: “How was your day?”, on a scale ranging from 0 = *Very Bad* to 6 = *Very Good*. This brief method for assessing satisfaction produces similar results to multi-item measures in past research (Cheung & Lucas, 2014).

RESULTS

Preliminary tests

At the day-level, correlation analyses (Table 2, below the diagonal) showed large effects for links between psychological need satisfactions within solitude ( $r_s = .57$  to  $.77$ ) and social contexts ( $r_s = .73$  to  $.86$ ) on any particular day and large correlations across both solitude and social contexts ( $r_s = .61$  to  $.79$ ). Examining them separately, each psychological need in both social and solitude contexts is related to our three indicators of everyday well-being with broadly moderate effects (relations of psychological need satisfactions in solitude contexts,  $r_s = .34$  to  $.42$ , and social contexts  $r_s = .39$  to  $.45$ , with peaceful affect; in solitude contexts,  $r_s = -.23$  to  $-.32$ , and social contexts  $r_s = -.26$  to  $-.29$ , with loneliness; and in solitude contexts,  $r_s = .39$  to  $.49$ , and social contexts  $r_s = .43$  to  $.51$ , with day satisfaction).

At the individual level, correlation analyses (Table 2, above the diagonal) showed a similar pattern, with autonomy, relatedness, and competence showing large effects in relation to one another within solitude ( $r_s = .68$  to  $.89$ ) and social contexts ( $r_s = .73$  to  $.91$ ). Examining each separately, each psychological need in both social and solitude contexts related to our three indicators of everyday well-being relations of psychological need satisfactions in solitude contexts,  $r_s = .50$  to  $.61$ , and social contexts  $r_s = .49$  to  $.63$ , with peaceful affect; in solitude contexts,  $r_s = -.38$  to  $-.43$ , and social contexts  $r_s = -.42$  to  $-.49$ , with loneliness; in solitude contexts,  $r_s = .51$  to  $.67$ , and social contexts  $r_s = .54$  to  $.68$ , with day satisfaction.

TABLE 2 Correlations between study variables at the day level (below diagonal) and person level (above diagonal).

	1	2	3	4	5	6	7	8	9
Solitude Context									
1. Autonomy	-	.78***	.89***	.88***	.65***	.82***	.61***	-.38***	.65***
2. Relatedness	.57***	-	.68***	.76***	.85***	.67***	.50***	-.42***	.51***
3. Competence	.77***	.57***	-	.81***	.61***	.91***	.60***	-.43***	.67***
Social Context									
4. Autonomy	.67***	.51***	.63***	-	.79***	.91***	.63***	-.42***	.68***
5. Relatedness	.47***	.61***	.48***	.64***	-	.73***	.49***	-.49***	.54***
6. Competence	.59***	.49***	.71***	.79***	.61***	-	.57***	-.45***	.67***
Outcomes									
7. Peaceful Affect	.42***	.34***	.41***	.45***	.39***	.45***	-	-.38***	.69***
8. Loneliness	-.28***	-.23***	-.32***	-.29***	-.26***	-.30***	-.23***	-	-.50***
9. Day Satisfaction	.46***	.39***	.49***	.51***	.43***	.50***	.58***	-.41***	-

Note: \*\*\* Correlations are significant at  $p < .001$ . Lower triangle shows within-person (i.e., day level) correlations. Upper triangle in italics shows the between-person (i.e., person-level) correlations.

## Analysis plan for primary models

We used multilevel modelling (R lme4 package; Bates, Mächler, Bolker, & Walker, 2015) to account for the hierarchical data structure (daily diaries nested within people). Following the recommendations of Bolger and Laurenceau (2013), we included both within and between-person components in our models where possible (see tables for full model descriptions) to allow for a clearer interpretation of the effects at different levels (Bryk & Raudenbush, 1992). All models were initially fitted with a maximal random effects structure. However, due to issues of singular fit, we dropped these random effects in an effort to reduce the complexity of the models. As such, we retain only the random intercept model, following the guidelines set out by Barr et al. (2013).

## Multi-collinearity

We conducted checks for multi-collinearity given the large correlations observed between our need satisfaction predictors. Variance Inflation Factors (VIFs) were calculated for a model containing each of our three needs (autonomy, relatedness, and competence) in two contexts (social and solitude). We included both within-person and between-person versions of each, for a total of twelve predictors entered simultaneously. The results of this can be seen in Figure 1 (Panel a).

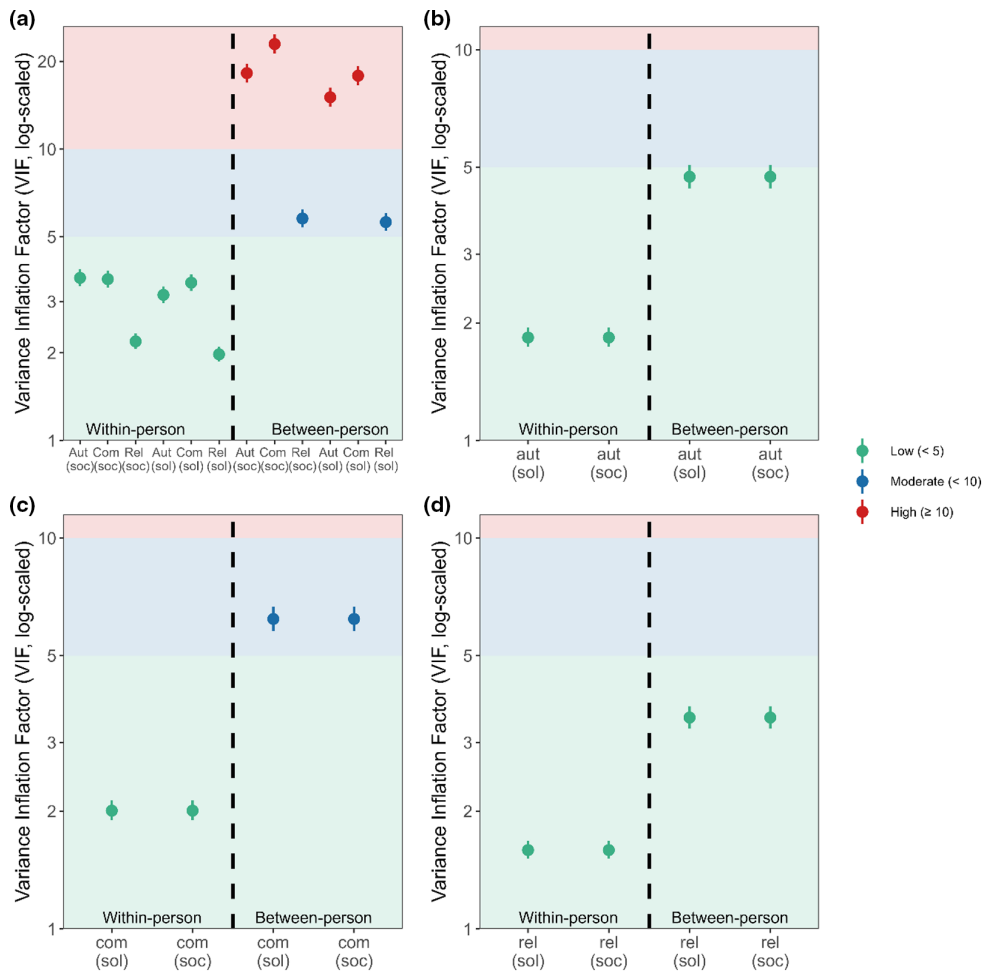
Results indicated VIF scores of less than five for all within-person centred predictors, indicating low collinearity (James et al., 2021) at the within-person level. In contrast, the between-person averages showed VIF scores greater than five, ranging from 5.62 for relatedness in solitude to 22.93 for competence in social contexts. These results indicate moderate to high collinearity, warranting caution in the interpretation of these effects.

We then created three separate multi-level models, each incorporating within-person-centred predictors as well as between-person averages for each need. The results of VIFs from these separate models are found in Figure 1 (Panels b–d) and indicate that when entered separately, both within-person and between-person predictors exhibited low collinearity for autonomy and relatedness need satisfaction (i.e., all VIFs < 5). However, the VIF values for between-person competence in both social and solitude contexts remained “moderate”, with VIF values ranging between 5 and 10 (James et al., 2021).

In light of these findings, we included both within-person deviations (Table 3) and between-person averages in our fixed effect models (Table 4). Each psychological need was modelled separately, yet simultaneously, for two contexts (solitude and social). We explore the implications of this collinearity among some of the between-person variables on the interpretation of our findings in the Discussion section.

## Does context elicit need satisfaction to similar degrees?

In the absence of evidence to the contrary and with likely mechanisms for psychological need satisfaction in both contexts, we hypothesized (H1) that psychological need satisfactions for autonomy, relatedness, and competence are experienced *similarly* in social and solitude contexts. To examine this, we defined two-level mixed effect models to test for within-person (i.e., day to day) differences between the two contexts (social and solitude) for each of the three needs (autonomy, relatedness, and competence). Each model included a random effects structure with daily observations nested within individuals and context (social, solitude) included as a random slope (see supplemental materials on OSF for full table of results). Results showed that context significantly predicted autonomy ( $b = -0.09$ , 95% CI  $[-0.16, -0.02]$ ,  $p = .014$ ), with individuals reporting greater autonomy in social ( $M = 5.20$ ,  $SD = 1.40$ , CIs  $[5.14, 5.25]$ ) compared to solitude ( $M = 5.11$ ,  $SD = 1.45$ , CIs  $[5.05, 5.16]$ ) contexts. Likewise, context significantly predicted relatedness need satisfaction ( $b = -0.39$ , 95% CI  $[-0.49, -0.28]$ ,  $p < .001$ ), with greater relatedness reported in social contexts ( $M = 5.62$ ,  $SD = 1.35$ , 95% CI  $[5.56, 5.68]$ ) compared to solitude ( $M = 5.22$ ,  $SD = 1.59$ , 95% CI  $[5.16, 5.28]$ )



**FIGURE 1** Variance Inflation Factors (VIF) for model predictors. Plots showing variance inflation factors (VIFs). X-axis shows the predictor (autonomy, relatedness, and competence) with the dashed line separating social and solitude contexts. Panel a shows VIFs for a model containing both within-person deviations and between person averages entered simultaneously. Panels b–d show VIFs for separate autonomy, competence, and relatedness models, respectively. Green, blue, and red datapoints indicate low, moderate, and high collinearity respectively.

contexts. However, context did not predict competence ( $b = -0.01$ , 95% CI  $[-0.07, 0.06]$ ,  $p = .988$ ), indicating no significant differences between the social ( $M = 5.40$ ,  $SD = 1.39$ , CIs  $[5.35, 5.46]$ ) or solitude contexts ( $M = 5.39$ ,  $SD = 1.42$ , CIs  $[5.34, 5.45]$ ). Taken together, these results suggest that, against our expectations, they would be similar across contexts. Context *does* play a significant role for both *autonomy* and *relatedness* needs, with both being higher during time spent in social interaction when compared to time spent in solitude. However, both contexts appeared to elicit *competence* need satisfaction similarly.

### Do psychological needs in both social and solitude contexts contribute to daily well-being?

To examine H2, we investigated how psychological need satisfactions (for autonomy, competence, and relatedness) in the two different contexts (social and solitude) contribute to daily well-being outcomes

TABLE 3 Within-person fixed effects for multilevel models predicting well-being.

	Peaceful affect			Loneliness			Day satisfaction		
	Est <sup>a</sup>	95% CI	<i>p</i>	Est <sup>a</sup>	95% CI	<i>p</i>	Est <sup>a</sup>	95% CI	<i>p</i>
Within-person									
Autonomy (soc)	1.94	0.70–3.17	<b>.002</b>	−0.06	−0.14–0.01	.107	0.17	0.10–0.24	<b>&lt;.001</b>
Competence (soc)	3.11	1.80–4.42	<b>&lt;.001</b>	−0.08	−0.16–0.00	.059	0.16	0.08–0.23	<b>&lt;.001</b>
Relatedness (soc)	2.37	1.30–3.44	<b>&lt;.001</b>	−0.10	−0.17–−0.03	<b>.004</b>	0.14	0.08–0.21	<b>&lt;.001</b>
Autonomy (sol)	2.81	1.71–3.91	<b>&lt;.001</b>	−0.03	−0.10–0.03	.320	0.08	0.02–0.14	<b>.010</b>
Competence (sol)	0.85	−0.42–2.12	.187	−0.18	−0.26–−0.10	<b>&lt;.001</b>	0.21	0.13–0.28	<b>&lt;.001</b>
Relatedness (sol)	0.49	−0.46–1.44	.314	−0.01	−0.07–0.05	.739	0.04	−0.02–0.09	.163
Within-person random effects (all needs simultaneous)									
σ <sup>2</sup>	232.85			0.91			0.76		
τ <sub>00</sub>	404.10			0.89			0.67		
ICC	0.63			0.49			0.47		
Marg R <sup>2</sup> / Cond R <sup>2</sup>	.10/.67			.06/.53			.12/.57		

Note: Bolded estimates are significant at  $p < .05$ . We entered within-person predictors simultaneously for each of the three outcome models (i.e., three total models).  $\sigma^2$  denotes the residual variance, and  $\tau_{00}$  represents the variance of the random intercept for the grouping factor (ID\_Num). ICC represents the Intraclass Correlation Coefficients for the models. Marginal/Conditional  $R^2$  represents the proportion of variance that can be attributed to the fixed effects alone and to both fixed and random effects, respectively.

Abbreviations: Soc, need within social contexts; Sol, need within solitude contexts.

<sup>a</sup>Coefficients are unstandardized.

(peaceful affect, loneliness, and day satisfaction). We conducted various two-level random-intercept models, with daily observations nested within individuals, and structured our models in two phases. Initially, we conducted three simultaneous models (one for each well-being outcome) to capture within-person variations at Level 1.

At this level, autonomy, competence, and relatedness scores from both solitude and social contexts were simultaneously entered to capture daily fluctuations in need satisfaction. At Level 2, to avoid issues of multicollinearity (see Figure 1), we conducted separate models – three for each psychological need (autonomy, competence, and relatedness). These models incorporated between-person means, representing each individual's average level of need satisfaction across all Level-1 observations, allowing us to examine how individual differences in average need satisfaction contribute to overall well-being across the study period. Each model included a random effects structure with daily observations nested within individuals to account for inter-individual variability. The results of these analyses can be seen in Tables 3 and 4.

### Day-level effects on well-being

#### Independent effects within social contexts

During daily social contexts, experiencing higher than usual levels of all three need satisfactions was associated with greater peaceful affect: autonomy ( $b = 1.94$ , 95% CI [0.70, 3.17],  $p = .002$ ), competence

TABLE 4 Between-person fixed effects for multilevel models predicting well-being.

	Peaceful affect			Loneliness			Day satisfaction		
	Est <sup>a</sup>	95% CI	<i>p</i>	Est <sup>a</sup>	95% CI	<i>p</i>	Est <sup>a</sup>	95% CI	<i>p</i>
Autonomy									
Autonomy (soc)	8.38	3.68–13.09	<b>&lt;.001</b>	−0.35	−0.62–−0.08	<b>.012</b>	0.28	0.09–0.47	<b>.004</b>
Autonomy (sol)	4.18	−0.39–8.75	.073	−0.05	−0.31–0.21	.710	0.29	0.11–0.48	<b>.002</b>
Random effects (autonomy)									
σ <sup>2</sup>	240.80			0.93			0.81		
τ <sub>00</sub>	226.54			0.72			0.30		
ICC	0.48			0.44			0.27		
Marg R <sup>2</sup> /Cond R <sup>2</sup>	.34/.66			.14/.52			.37/.54		
Competence									
Competence (soc)	2.74	−2.84–8.33	.335	−0.29	−0.59–0.01	.057	0.20	−0.02–0.41	.074
Competence (sol)	8.53	3.11–13.96	<b>.002</b>	−0.13	−0.42–0.17	.395	0.35	0.14–0.56	<b>.001</b>
Random effects (competence)									
σ <sup>2</sup>	244.19			0.92			0.80		
τ <sub>00</sub>	251.56			0.70			0.32		
ICC	0.51			0.43			0.29		
Marg R <sup>2</sup> /Cond R <sup>2</sup>	.30/.66			.16/.52			.37/.55		
Relatedness									
Relatedness (soc)	5.03	0.69–9.36	<b>.023</b>	−0.46	−0.67–−0.25	<b>&lt;.001</b>	0.29	0.12–0.47	<b>.001</b>
Relatedness (sol)	4.39	0.78–7.99	<b>.017</b>	−0.00	−0.17–0.17	.998	0.14	−0.01–0.28	.070
Random effects (relatedness)									
σ <sup>2</sup>	260.11			0.96			0.90		
τ <sub>00</sub>	279.99			0.62			0.42		
ICC	0.52			0.39			0.32		
Marg R <sup>2</sup> /Cond R <sup>2</sup>	.23/.63			.169/.49			.25/.49		

Note: Bolded estimates are significant at  $p < .05$ . We entered between-person averages entered separately for each need and outcome (i.e., nine total models).  $\sigma^2$  denotes the residual variance, and  $\tau_{00}$  represents the variance of the random intercept for the grouping factor (ID\_Num). ICC represents the Intraclass Correlation Coefficients for the models. Marginal/Conditional  $R^2$  represents the proportion of variance that can be attributed to the fixed effects alone and to both fixed and random effects, respectively.

Abbreviations: Soc, need within social contexts; Sol, need within solitude contexts.

<sup>a</sup>Coefficients are unstandardized.

( $b = 3.11$ , 95% CI [1.80, 4.42],  $p < .001$ ), and relatedness ( $b = 2.37$ , 95% CI [1.30, 3.44],  $p < .001$ ). Likewise, all three psychological needs were associated with greater day satisfaction: autonomy ( $b = 0.17$ , 95% CI [0.10, 0.24],  $p < .001$ ), competence ( $b = 0.16$ , 95% CI [0.08, 0.23],  $p < .001$ ), and relatedness ( $b = 0.14$ , 95% CI [0.08, 0.21],  $p < .001$ ). Only relatedness was linked to lower loneliness ( $b = -0.10$ , 95% CI [−0.17, −0.03],  $p = .004$ ), with neither autonomy nor competence showing significant associations (both  $p$ -values  $> .05$ ). This suggests that while autonomy and competence do not independently contribute to

feelings of loneliness, individuals who experience feelings of closeness and connection that exceed their typical levels during social interactions are likely to feel less lonely.

## Independent effects within solitude contexts

Results regarding psychological need satisfaction in solitude were mixed. Only autonomy was found to have significant positive associations with daily peaceful affect ( $b = 2.81$ , 95% CI [1.71, 3.91],  $p < .001$ ), suggesting that higher-than-usual feelings of autonomy in solitude drive a daily peaceful mood. Neither competence ( $b = 0.86$ , 95% CI [-0.41, 2.13],  $p = .185$ ) nor relatedness ( $b = 0.49$ , 95% CI [-0.46, 1.44],  $p = .314$ ) reached statistical significance. Predicting day satisfaction, both autonomy ( $b = 0.08$ , 95% CI [0.02, 0.14],  $p = .011$ ) and competence ( $b = 0.21$ , 95% CI [0.13, 0.28],  $p < .001$ ) showed positive associations. There was no effect of relatedness ( $b = 0.04$ , 95% CI [-0.02, 0.09],  $p = .163$ ), suggesting that deviations from typical daily levels of these needs in solitude do not alter feelings of tranquillity and peacefulness.

Finally, predicting loneliness, only competence need satisfaction was shown to be significant ( $b = -0.18$ , 95% CI [-0.26, -0.10],  $p < .001$ ), suggesting experiencing a sense of mastery above one's typical daily level in solitude activities helps to mitigate feelings of loneliness. Surprisingly, relatedness during solitude was found not to be associated with loneliness ( $b = -0.01$ , 95% CI [-0.07, 0.05],  $p = .739$ ). This suggests that feelings of connection, even when above one's typical levels in solitude, do not influence one's perceptions of loneliness. In addition, autonomy need satisfaction during solitude did not relate to loneliness ( $b = -0.03$ , 95% CI [-0.10, 0.03],  $p = .322$ ), implying that deviations from typical levels of daily autonomy experienced during solitude do not have a significant impact on feelings of loneliness.

## Person-level effects on well-being

### Independent effects within social contexts

Examining the between-person effects in social contexts revealed that, consistent with the within-person results, both autonomy ( $b = 8.38$ , 95% CI [3.68, 13.09],  $p < .001$ ) and relatedness ( $b = 5.03$ , 95% CI [0.69, 9.36],  $p = .023$ ) were linked to greater peaceful affect. However, unlike the within-person results, no relationship was found between competence and peaceful affect ( $b = 2.74$ , 95% CI [-2.84, 8.33],  $p = .335$ ). This pattern was observed across the remaining outcomes, with a significant positive association observed between autonomy and day satisfaction ( $b = 0.28$ , 95% CI [0.09, 0.47],  $p = .004$ ) and between relatedness and day satisfaction ( $b = 0.29$ , 95% CI [0.12, 0.47],  $p = .001$ ). A negative association was observed between loneliness and both autonomy ( $b = -0.35$ , 95% CI [-0.62, -0.08],  $p = .012$ ) and relatedness ( $b = -0.46$ , 95% CI [-0.67, -0.25],  $p < .001$ ). Meanwhile, no associations were observed between competence and either day satisfaction ( $b = 0.20$ , 95% CI [-0.02, 0.41],  $p = .074$ ) or loneliness ( $b = -0.29$ , 95% CI [-0.59, 0.01],  $p = .057$ ) in social contexts.

### Independent effects within solitude contexts

Within solitude contexts, person-level autonomy only exhibited a significant relationship with day satisfaction ( $b = 0.29$ , 95% CI [0.11, 0.48],  $p = .002$ ). Competence, however, was significantly positively associated with both peaceful affect ( $b = 8.53$ , 95% CI [3.11, 13.96],  $p = 0.02$ ) and day satisfaction ( $b = 0.35$ , 95% CI [0.14, 0.56],  $p < .001$ ). Relatedness was found to have a significant negative association only with peaceful affect ( $b = 4.39$ , 95% CI [0.78, 7.99],  $p = .017$ ). No other significant associations were found for needs in solitude contexts ( $p > .05$  for all remaining outcomes).

Do need satisfactions in one context compensate for their absence in the other?

To explore whether there is a compensatory effect in needs satisfactions between the two contexts (social and solitude) (H3), we examined the interactions of each of the three need satisfactions, with each need in solitude modelled as a moderator with its counterpart in social contexts. We included both within-person (Figures 2 and 4) and between-person (Figures 3 and 5) predictors in each model. The results are presented in Tables 4 and 5.

Day-Level interactions with Well-Being

For autonomy, significant interactions between social and solitude contexts were observed for loneliness ( $b = 0.06$ , 95% CI [0.03, 0.09],  $p < .001$ ) and day satisfaction ( $b = -0.04$ , 95% CI [-0.07, -0.02],  $p < .001$ ). These results show that on days where individuals experience lower than usual levels of autonomy in social contexts, having higher than usual autonomy in solitude was associated with a reduction in loneliness and an increase in day satisfaction. However, no interaction between social and solitude contexts for peaceful daily affect was observed ( $b = -0.29$ , 95% CI [-0.74, 0.16],  $p = .202$ ).

Regarding competence, only the interaction between social and solitude contexts for day satisfaction was significant ( $b = -0.04$ , 95% CI [-0.06, -0.01],  $p = .009$ ). This indicates that on days where individuals experienced lower than usual competence levels in social contexts, reporting higher competence in solitude was associated with greater day satisfaction, suggesting that solitude may compensate for deficits in social competence satisfaction. The interactions for peaceful daily affect ( $b = -0.03$ , 95% CI [-0.44, 0.49],  $p = .906$ ) and loneliness ( $b = 0.01$ , 95% CI [-0.02, 0.04],  $p = .543$ ) were not significant, suggesting no further compensatory effects between the two contexts in relation to competence.

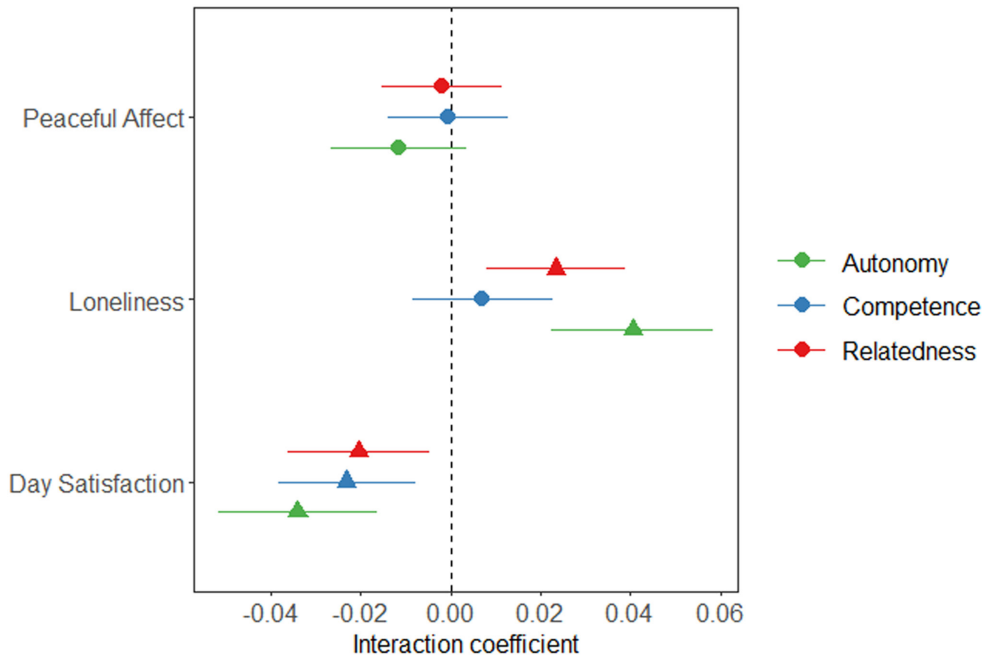
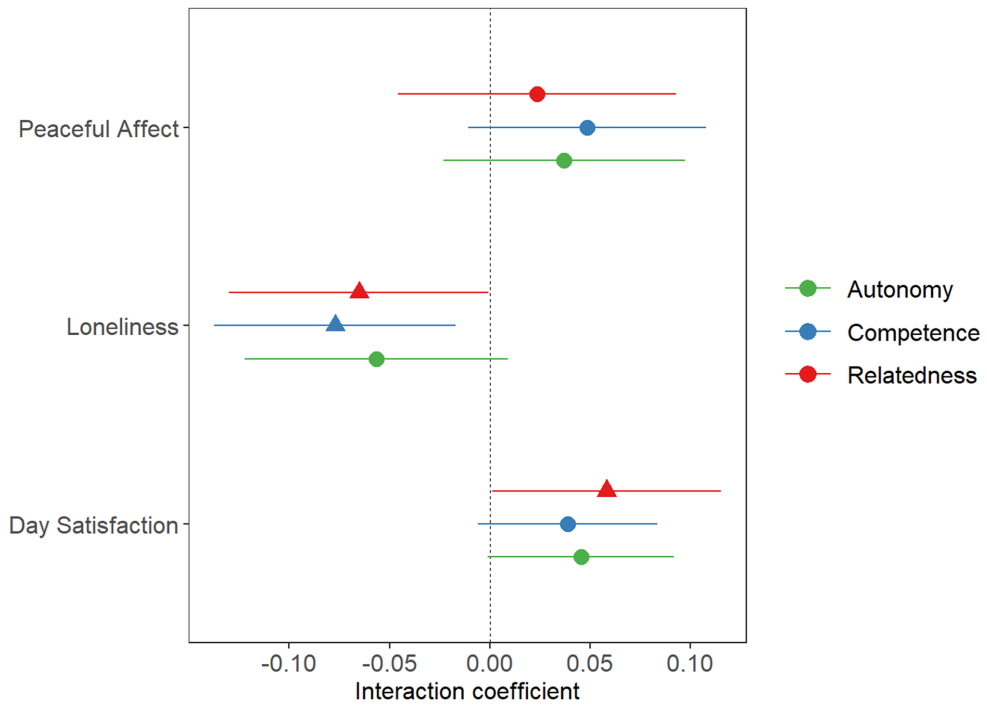
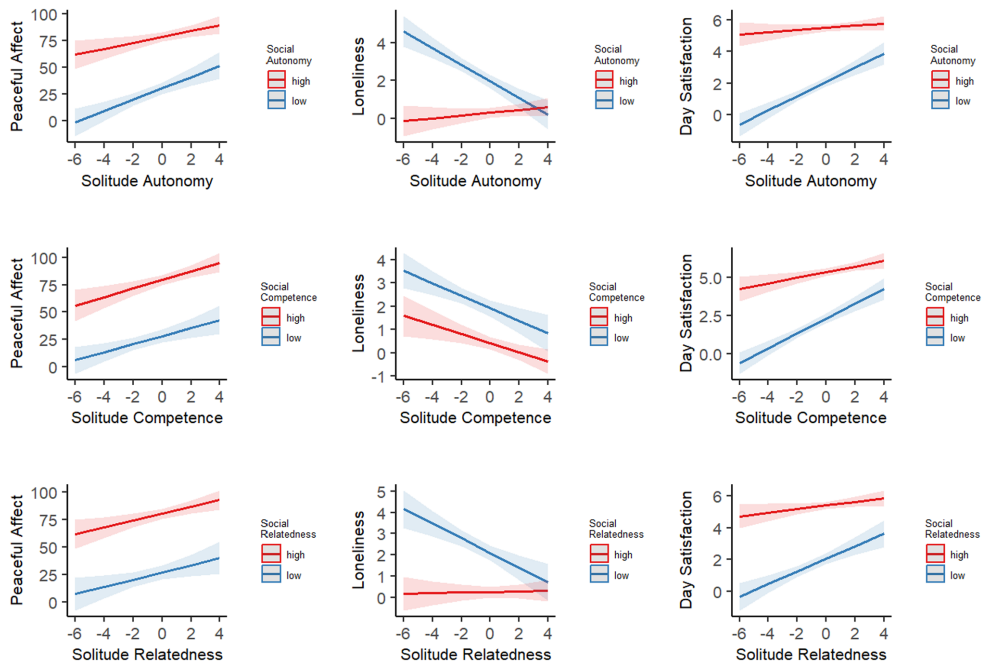


FIGURE 2 Interaction effects indicating magnitude of needs in social and solitude contexts (within-person). Estimated means of outcome (peaceful, lonely, and day satisfaction) as a function of psychological need satisfaction (autonomy, competence, and relatedness) in each of two contexts (solitude, social) with a 95% CI. Triangles indicate significant coefficients.

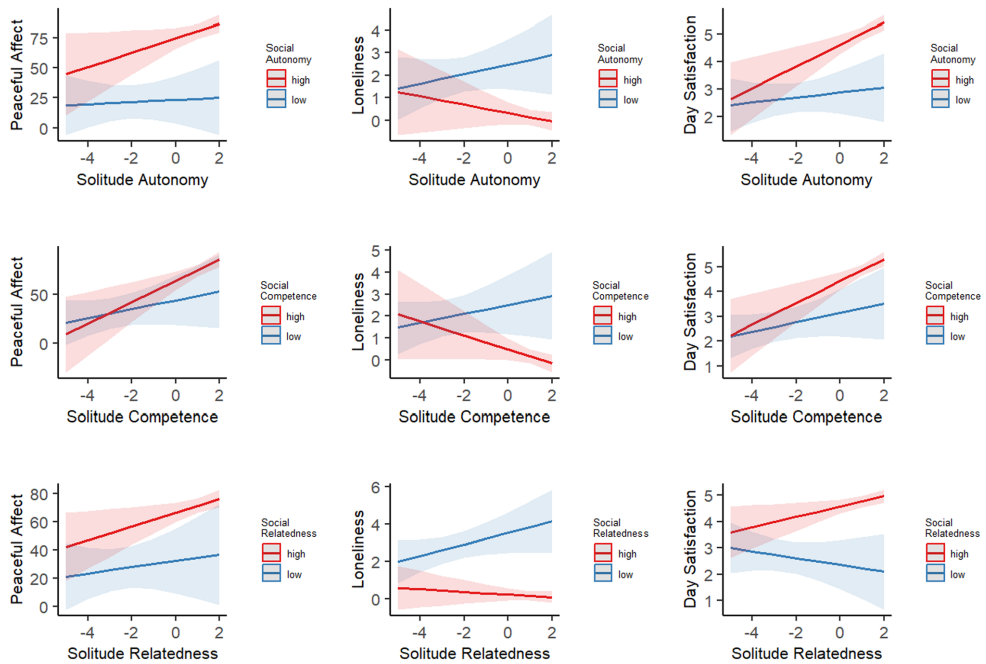


**FIGURE 3** Interaction effects indicating magnitude of needs in social and solitude contexts (between-person). Estimated means of outcome (peaceful, lonely, and day satisfaction) as a function of psychological need satisfaction (autonomy, competence, and relatedness) in each of two contexts (solitude, social) with a 95% CI. Triangles indicate significant coefficients.



**FIGURE 4** Within-person interaction effects of needs in social and solitude contexts. Columns represent outcomes (peaceful affect, loneliness, and day satisfaction), rows represent needs satisfaction (autonomy, competence, relatedness). X-axes represents solitude need satisfaction. Red lines indicate high (+1 SD) social need satisfaction, blue lines indicate low (-1 SD) social need satisfaction with a 95% confidence intervals. Needs satisfaction scores are centred within individuals.





**FIGURE 5** Between-person interaction effects of needs in social and solitude contexts. Columns represent outcomes (peaceful affect, loneliness, and day satisfaction), rows represent needs satisfaction (autonomy, competence, relatedness). X-axes represents solitude need satisfaction. Red lines indicate high (+1 *SD*) social need satisfaction, blue lines indicate low (−1 *SD*) social need satisfaction with a 95% confidence intervals. Needs satisfaction scores are between-person averages.

For relatedness, the interaction between social and solitude contexts for loneliness ( $b = 0.04$ , 95% CI [0.01, 0.07],  $p = .007$ ) and day satisfaction ( $b = -0.03$ , 95% CI [−0.06, −0.01],  $p = .026$ ) also suggested a potential compensatory role of solitude. Specifically, on days when individuals feel less connected than usual in social situations, feeling more connected in solitude was associated with a reduction in levels of loneliness and an increase in day satisfaction.

## Person-level interactions with well-being

At the individual level, results for autonomy revealed no significant interactions (all  $p$ -values  $> .05$ ), indicating no compensatory mechanisms in effect.

The results for competence at the individual level showed a single significant interaction for loneliness ( $b = -0.09$ , 95% CI [−0.15, −0.02],  $p = .012$ ). The results show that for individuals with lower-than-average social competence, those who reported higher-than-average solitude competence experienced a significant reduction in loneliness. The interactions for peaceful daily affect ( $b = 1.06$ , 95% CI [−0.23, −2.34],  $p = .108$ ) and day satisfaction ( $b = -0.04$ , 95% CI [−0.01, 0.09],  $p = .087$ ) were not significant, suggesting no further compensatory effects.

Finally, the results for relatedness at the individual level revealed significant interaction effects for loneliness ( $b = -0.06$ , 95% CI [−0.13, −0.01],  $p = .048$ ) and day satisfaction ( $b = 0.05$ , 95% CI [0.00, 0.10],  $p = .045$ ). This indicates that individuals with lower-than-average levels of relatedness in social contexts who report higher-than-average feelings of connectedness in solitude experienced a significant decrease in loneliness and a significant increase in day satisfaction. However, the interaction with peaceful daily affect was not significant ( $b = 0.44$ , 95% CI [−0.86, 1.74],  $p = .506$ ), indicating no compensatory mechanism. Taken together, these results appear to show the potential for solitude to ameliorate the negative effects of low needs satisfaction in social contexts and boost overall well-being (Table 5).

TABLE 5 Compensatory interaction effects for social × solitude contexts predicting well-being.

Parameter	Peaceful affect			Loneliness			Day satisfaction		
	Est <sup>a</sup>	95% CI	p	Est <sup>a</sup>	95% CI	p	Est <sup>a</sup>	95% CI	p
Within-person									
Autonomy (soc) × Autonomy (sol)	−0.29	−0.74–0.16	.202	0.06	0.03–0.09	<b>&lt;.001</b>	−0.04	−0.07–−0.02	<b>.001</b>
Competence (soc) × Competence (sol)	0.03	−0.44–0.49	.906	0.01	−0.02– 0.04	.543	−0.04	−0.06–−0.01	<b>.009</b>
Relatedness (soc) × Relatedness (sol)	−0.02	−0.50–0.46	.936	0.04	0.01–0.07	<b>.007</b>	−0.03	−0.06–−0.01	<b>.026</b>
Between-person									
Autonomy (soc) × Autonomy (sol)	0.86	−0.53–2.26	.226	−0.07	−0.15– 0.01	.091	0.05	−0.00–0.11	.056
Competence (soc) × Competence (sol)	1.06	−0.23–2.34	.108	−0.09	−0.15– −0.02	<b>.012</b>	0.04	−0.01–0.09	.087
Relatedness (soc) × Relatedness (sol)	0.44	−0.86–1.74	.506	−0.06	−0.13– −0.00	<b>.048</b>	0.05	0.00–0.11	<b>.045</b>
Random Effects (Aut)									
σ <sup>2</sup>	240.79			0.92			0.81		
τ <sub>00</sub>	224.92			0.70			0.30		
ICC	0.48			0.43			0.27		
Marg R <sup>2</sup> /Cond R <sup>2</sup>	.34/.66			.15/.52			.38/.55		
Random Effects (Com)									
σ <sup>2</sup>	244.27			0.92			0.80		
τ <sub>00</sub>	249.46			0.67			0.31		
ICC	0.51			0.42			0.28		
Marg R <sup>2</sup> /Cond R <sup>2</sup>	.31/.66			.18/.52			.38/.55		
Random Effects (Rel)									
σ <sup>2</sup>	260.19			0.95			0.90		
τ <sub>00</sub>	281.46			0.60			0.41		
ICC	0.52			0.39			0.31		
Marg R <sup>2</sup> /Cond R <sup>2</sup>	.23/.63			.18/.50			.26/.50		

Note: Models for autonomy, competence, and relatedness were entered separately. For each model, we entered both within-person deviations and between-person averages for both social (soc) and solitude (sol) contexts. Bolded estimates are significant at  $p < .05$ .  $\sigma^2$  denotes the residual variance, and  $\tau_{00}$  represents the variance of the random intercept for the grouping factor (ID\_Num). ICC represents the Intraclass Correlation Coefficients. Marginal/Conditional  $R^2$  represents the proportion of variance that can be attributed to the fixed effects alone and to both the fixed and random effects collectively.

Abbreviations: Soc, need within social contexts; Sol, need within solitude contexts.

<sup>a</sup>Coefficients are unstandardized.

Research question 1: Do psychological need satisfactions in each of two daily contexts (either social or solitude) contribute *disproportionally*, relative to the other, towards daily peaceful mood, lower loneliness, and greater day satisfaction?

Visual inspection of the within-person effect sizes in Figure 6 shows that the error bars (95% confidence intervals for the standardized beta estimates) clearly do not overlap in four cases (autonomy – day satisfaction, competence – peaceful affect, relatedness – peaceful affect, and relatedness – day satisfaction). Predicting peaceful affect, the effect size for competence is ~1.5 times larger in social contexts ( $b = .20$ ) than solitude ( $b = .13$ ), and the effect size for relatedness is ~1.64 times larger in social contexts ( $b = .18$ ) than solitude ( $b = .11$ ). Within day satisfaction, the effect size for autonomy is ~1.69 times larger in the social context ( $b = .27$ ) than in solitude ( $b = .16$ ), with the effect size for relatedness ~1.52 times larger in social contexts ( $b = .23$ ) compared to solitude ( $b = .15$ ). Similarly, visual inspection of the between-person effect sizes (Figure 7) shows only one instance (Relatedness – loneliness) where error bars clearly do not overlap. Predicting loneliness, the effect size for relatedness in social contexts ( $b = -.043$ ) is ~27 times larger than in solitude ( $b = .016$ ).

To test this, we conducted separate  $t$ -tests for each of our nine models, applying a Bonferroni correction to account for familywise error (i.e., a corrected  $\alpha$  level of .00556).

Results for the within-person effect sizes indicated a significantly stronger influence of social contexts compared to solitude contexts in four of our models: autonomy need ( $t(2538) = 4.07, p < .001$ ) and relatedness need ( $t(2538) = 3.20, p = .001$ ) predicting day satisfaction, competence need ( $t(2538) = 3.03, p = .002$ ), and relatedness need ( $t(2538) = 3.58, p < .001$ ) predicting peaceful affect. Likewise, comparison of the between-person effect sizes revealed only a single significant predictor, with relatedness in social contexts having a significantly stronger influence compared to solitude contexts ( $t(2538) = 3.57, p < .001$ ).

DISCUSSION

The current study tested the contributions of everyday psychological need satisfactions on daily well-being, focusing on three fundamental psychological needs: autonomy (self-congruent and volitional

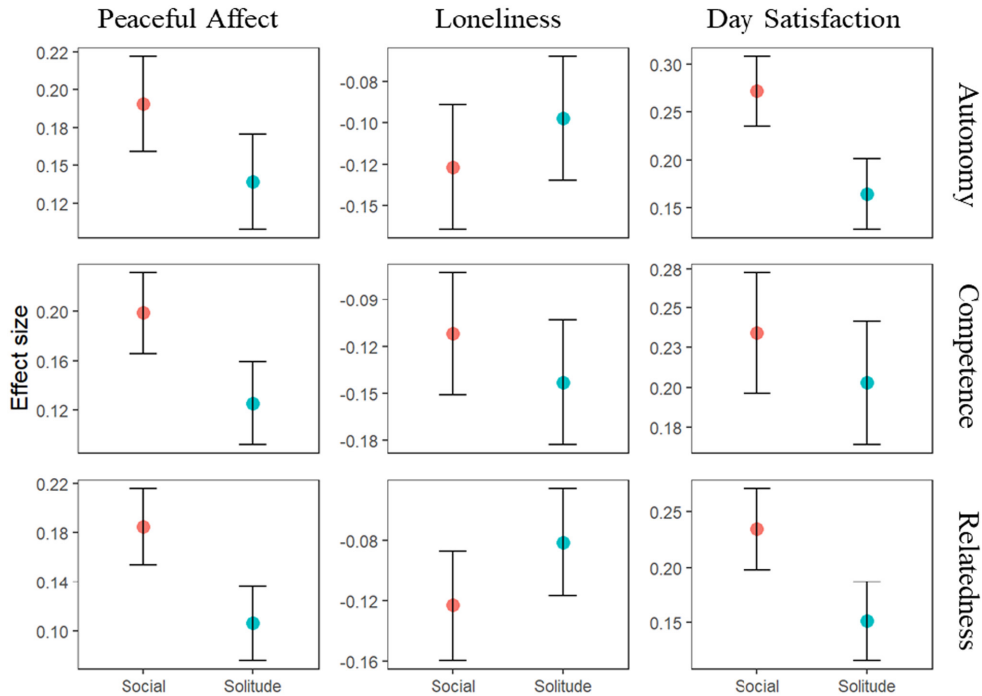
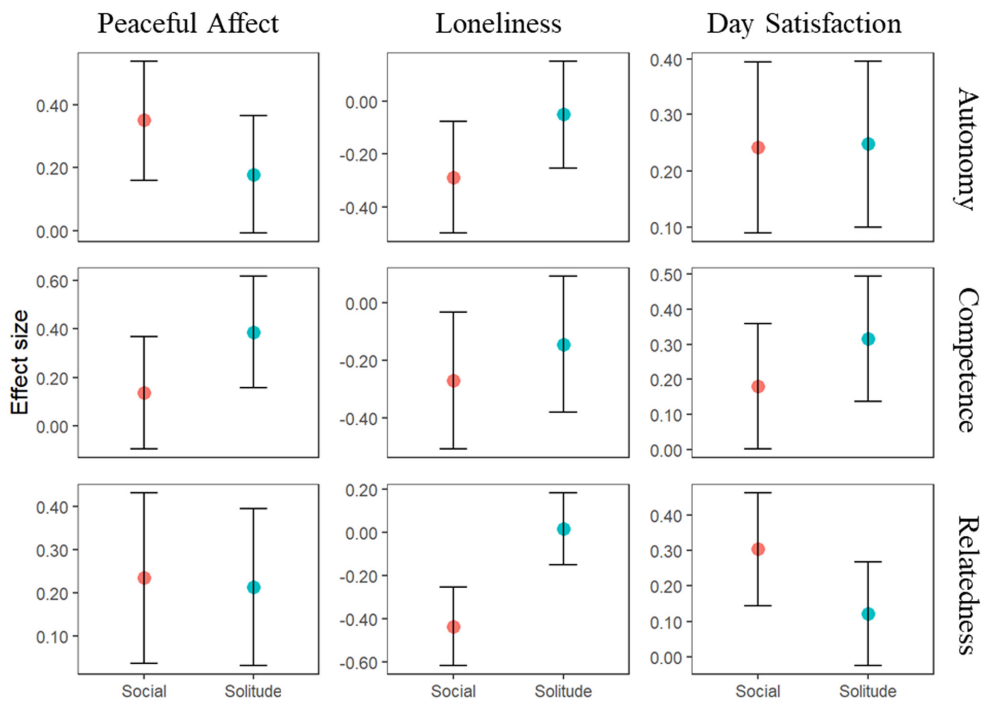


FIGURE 6 Within -person effect sizes (standardized betas) for two contexts (social and solitude). Data points represent the standard beta for both social and solitude contexts for each of our nine models. Error bars represent 95% confidence intervals of the standard beta estimate.



**FIGURE 7** Between-person effect sizes (standardized betas) for two contexts (social and solitude). Data points represent the standard beta for both social and solitude contexts for each of our nine models. Error bars represent 95% confidence intervals of the standard beta estimate.

experience and action), relatedness (feeling interpersonally connected), and competence (feeling effective in pursuing activities and goals). It extends previous research linking needs satisfaction and daily well-being (Reis et al., 2000; Sheldon & Bettencourt, 2002) by examining these psychological needs in two distinct everyday contexts: social interactions and solitude. Our primary focus was to investigate how each daily need satisfaction experienced within each context – social and solitude – benefits the day's well-being and to explore the potential for compensatory interactions that influence our daily well-being, asking, can need satisfaction in one context compensate for its deficit in the other?

Analyses comparing psychological need satisfactions in social and solitude settings revealed, unsurprisingly, that the relatedness need was more likely to be satisfied in social contexts compared to solitude, with a large effect size. However, what is notable is that even in solitude, relatedness need satisfaction remained relatively high, with participants averaging a rating of approximately 5.0 on a 6.0-point scale. Despite the absence of social interaction, individuals still experienced a meaningful sense of connection, suggesting they carried both the mental representations and affective aspects of socializing with them into solitude. These findings support theoretical expectations of the existence and power of connection during time spent alone, particularly from an attachment perspective (Mikulincer, 1995), and challenge previous views that conflated solitude and isolation, treating them as conceptually interchangeable (Constantian, 1981; Holmes, 1986).

Perhaps more surprisingly, we found autonomy need satisfaction to be lower in solitude than in social contexts. This stands in contrast with previous qualitative analyses suggesting that solitude offers a particular *opportunity* for autonomy need satisfaction by freeing individuals from social demands and allowing them space to engage in genuinely valued and enjoyable activities (Weinstein et al., 2021; Weinstein, Nguyen, & Hansen, 2023). It may have been that, while the opportunity was present, our participants may not have fully utilized solitude time in the service of satisfying their own autonomy. Indeed, previous work has identified that many individuals do not optimize their leisure time for rewarding activities (Beard & Ragheb, 1980; Csikszentmihalyi & LeFevre, 1989). Findings suggest that

efforts may be needed to inspire autonomous action during solitude time, for example, through targeted self-reflection and planning activities that help individuals select personally meaningful and rewarding actions (or inactions) during their daily solitude moments. Future conceptual and applied work is needed to develop such interventions.

To understand the contributions of daily solitude as well as social psychological need satisfaction, we focused our efforts on three key indicators of daily well-being that are sensitive to both contexts: peaceful affect, a sensitive indicator of the potential well-being contributions that solitude can make as a context for rejuvenation, deactivation, and relaxation (Roberts & Cunningham, 1990); loneliness, an indicator of disrupted relationships and detrimental alone time (Perlman & Peplau, 1981); and day satisfaction, a cognitive evaluation of a successful day (Przybylski et al., 2021). Some need satisfaction effects were observed consistently across well-being indicators, whereas others were specific to certain indicators but not others.

Across most indicators, psychological need satisfaction experienced in social contexts emerged as a significant contributor to daily well-being. At the day level, all three psychological need satisfactions independently contributed to the corresponding day's experiences of peaceful affect and day satisfaction, while only relatedness drove relations with lower loneliness. However, at the person-level, social-context-specific autonomy and relatedness, but not competence, drove relations across well-being indicators. These findings were observed even with tests for each need separately, but simultaneously modelling both social and solitude contexts, to address multicollinearity at the person level. In all, our results suggested that daily need satisfaction experienced specifically within social interactions contribute to daily well-being. This set of findings conceptually replicated previous research suggesting that daily relational experiences influence wellness through psychological need satisfaction (Reis et al., 2000). Moreover, the results align with studies of close relationships that suggest individuals feel a greater sense of well-being, including higher positive affect and lower negative affect, when their needs for autonomy, relatedness, and competence are met by their partners and close friends (Demir & Özdemir, 2010; Guardia & Patrick, 2008; Patrick et al., 2007).

Within solitude contexts, specific psychological need satisfactions played dominant roles in conservative models, accounting for all three psychological need satisfactions at the day level. For instance, only solitudinal autonomy need satisfaction related to greater daily peaceful affect when accounting for autonomy need satisfaction experienced in social contexts and the other psychological need satisfactions in both contexts. This result, highlighting the robust nature of solitudinal autonomy satisfaction, suggests that individuals who feel choiceful and able to act authentically and pursue their own volitional actions in solitude feel more peaceful throughout the day. Presumably, autonomy-satisfying solitude can contribute to a day's global well-being. This builds on previous mixed-method findings that suggest autonomy-driven solitude is often the most peaceful (Weinstein et al., 2021), as well as quantitative studies emphasizing the importance of chosen versus unchosen activities for enjoying solitude (Tse et al., 2022). Yet those existing studies had not addressed whether the benefits of solitude would extend to overall mood across the day when accounting for contributions made by social interactions on that day.

Daily solitude has the potential to foster a sense of peace and calm (Koch, 1994; Nguyen et al., 2018), reflecting the essential role of solitude as a rejuvenating experience that prepares individuals for subsequent social interactions (Littman-Ovadia, 2019). The current suggests that if solitude is to actualize this potential for peaceful mood, autonomy need satisfaction; finding agentic and authentic experiences free from pressure during one's solitude time – is key. Moreover, the current results suggested that the benefit of autonomy need satisfaction for daily well-being extends beyond feeling peaceful; it also contributed to a broad evaluation of the day as satisfying, suggesting more global well-being benefits (Przybylski et al., 2021).

Our findings also showed that competence need satisfaction made independent contributions (to those of social contexts) that resulted in lessened loneliness. This finding parallels previous work suggesting that when individuals feel competent in their actions (i.e., self-efficacy), they feel they can shape important and rewarding aspects of their lives that bridge goals and outcomes, and as a result, they feel

less lonely (Lawton et al., 1999). It also builds on indirect evidence found in research on hobbies, which shows that meaningful and fun hobbies protect against loneliness by creating a sense of fulfilment (Arslantaş et al., 2015). As was the case for autonomy need satisfaction, the benefits of competence need satisfaction extend beyond feelings of reduced loneliness to another dimension of well-being. Participants in our study who experienced a greater sense of competence during solitude reported not only a reduction in loneliness but an increased sense of satisfaction with their day.

Results at the person-level – examining individual differences in the tendency to experience daily need satisfaction in solitude – were inconsistent with the day-level effects we observed. These models, holding constant each psychological need's counterpart experienced across the diary period (e.g., testing competence in solitude while holding constant competence in social contexts), indicated inconsistent relations of needs across well-being indicators. For example, although we identified autonomy satisfaction as a robust correlate of both peaceful affect and day satisfaction experienced on that day, individual tendencies to experience the autonomy need across days were correlated with day satisfaction but not peaceful affect at the person level. Interestingly, examining need satisfaction correlates with loneliness across time suggested that no experiences, which we tested, in solitude contributed to overall loneliness – across broader spans of time, only social contexts seemed to contribute to feeling lonely. Such a finding suggests that there is a meaningful distinction to be made between solitude contexts and isolation as well as loneliness. This is consistent with lay individuals' understanding of solitude (Galanaki, 2004; Hipson et al., 2021) and stands in contrast with studies that conflate solitude and loneliness (see review Coplan et al., 2021).

Regarding potential compensatory effects between the two contexts, our study hints at the multifaceted nature of the interplay between psychological need satisfaction in social and solitude contexts, revealing significant compensatory effects for some, but not all, outcomes. It was evident from our results that solitude has the capacity to compensate for deficits in both autonomy and relatedness need satisfactions experienced in social settings, resulting in reduced loneliness and increased day satisfaction that were on par with having experienced these psychological need satisfactions in social contexts. This finding informs self-determination theory's (Deci & Ryan, 2000) views, which identify both autonomy and relatedness as fundamental psychological needs that must be satisfied (in at least one context) for well-being to occur. Yet our study suggested that psychological need satisfaction in only one of the two contexts (social or solitude) was necessary for attaining the most well-being benefits.

In asking the question of the context-specific contributions of need satisfaction to global well-being, we suggest researchers may, in the future, differentiate between need satisfaction – the active fulfilment of psychological needs, and need frustration – the active undermining of psychological needs. The two forms of needs experienced by the environment may offer added explanatory power in predicting well-being (Chen et al., 2015; Vansteenkiste & Ryan, 2013). For example, it may have been that autonomy or relatedness need satisfaction was frustrated in social settings when individuals felt pressure and demands from others or if they felt rejected, excluded, or judged by others (Bucher et al., 2019; Wei et al., 2005). Such actively frustrating experiences may result in boundary conditions for compensatory effects of solitude; they may indeed lead to solitude that is itself needlessly frustrating and/or incapable of lifting mood for a broadly beneficial day. These questions would be fascinating to ask in future work.

Solitude may have also facilitated a sense of self-connection (Thomas, 2021; Weinstein et al., 2021), perhaps compensating for any deficits in both autonomy and relatedness that were absent from social interactions. It is also plausible that in solitude, individuals reflect on and appreciate their existing connections or envision past connections (Weinstein, 2014). In those cases, solitude may have offered individuals a space where they could reclaim a sense of agency and interpersonal connection, at least in memory, with more supportive individuals, freeing them from a reliance on the current social context and thereby diminishing loneliness and increasing their sense of day satisfaction. This inward focus on relationships, despite the absence of social contact, may be a key factor in helping to reduce feelings of loneliness.

Competence, on the other hand, appeared to only have compensatory effects in enhancing day satisfaction. Solitude provides an opportunity to take on activities that are optimally challenging and



intrinsically motivated (Weinstein et al., 2023), reinforcing personal achievements (Long & Averill, 2003), and enhancing daily satisfaction (Ryan & Deci, 2017). In our data, those individuals who did not experience such competence in social contexts felt more satisfied in their day when solitude provided them those opportunities.

It is also noteworthy that the compensatory effects of solitude on peaceful affect did not reach significance across any of the three psychological needs. Rather, it is particularly autonomy needs satisfaction in solitude that contributed to a peaceful mood across the day. Future research may benefit from investigating the underlying mechanisms by which solitude nurtures this peaceful effect, and whether there are specific solitude activities that tease apart this beneficial impact.

## Limitations and future directions

It is important to consider our findings in light of the following limitations: First, our sample was relatively high-functioning and normative. In more extreme situations, such as when individuals live in conflictual or adverse social environments, solitudinal need satisfaction may become a more significant driver of peace and calm (Birditt et al., 2019). Similarly, individuals who cannot access satisfying social spaces, perhaps because of physical restrictions to their mobility or community access constraints, may benefit more from need satisfaction in solitude (Merchant et al., 2020). Although we consider the fairly broad adult sample a strength of the research for generalizing to a wider population, it limits potential generalization to more specialized populations, who are particularly in need of solitude-enhancing interventions.

Second, although the current study highlights that solitude need satisfaction contributes to well-being, we do not know *why* psychological need satisfaction was experienced. The mechanisms underlying the satisfaction of needs in social contexts are well understood (Chen et al., 2015; Ryan & Deci, 2017; Sheldon & Bettencourt, 2002). However, it is yet to be determined whether the underlying mechanisms in solitude mirror those in social contexts or operate through distinct processes. Further research is required to explore what activities or experiences drive the fulfilment of psychological needs in solitary contexts.

Third, we do not know the role that technology plays in social and solitudinal activities. In the current study, we focused only on social and solitude contexts. However, the predominant use of technology in modern life oftens blurs the boundary between social and solitude time (Halfmann et al., 2021). There is evidence to suggest that computer-mediated communication is an important everyday and daily life context that contributes to well-being under ideal conditions (Halfmann et al., 2021) and may further impact psychological need satisfaction (Ang et al., 2014; Halfmann & Rieger, 2019; Hull et al., 2016). Future studies may wish to examine the contribution of three contexts (social, solitude, and solitude with connectivity) to shed light on how needs may be satisfied in the context of modern life.

## Conclusion

In all, this study emphasizes that psychological need satisfaction experienced in both social contexts and solitude contexts contribute to daily well-being. Solitude is often neglected in models that associate well-being with interpersonal interactions, but here, we observed that it contributes independently to well-being outcomes typically considered to be benefits of successful social interactions. Contrary to previous views that conflated solitude with isolation, solitude instead emerges as a crucial part of an individual's day that serves to nurture autonomy, competence, and even relatedness. Importantly, when social needs are unfulfilled, individuals may turn to solitude to derive restorative benefits and offset the deficits experienced in social situations. As such, solitude may act as a means to ensure the balance of our psychological needs is met and contribute to an overall sense of well-being in daily life.

## AUTHOR CONTRIBUTIONS

**Mark Adams:** Conceptualization; methodology; data curation; investigation; writing – original draft; formal analysis; writing – review and editing.

**Netta Weinstein:** Conceptualization; methodology; data curation; investigation; formal analysis; writing – original draft; writing – review and editing.

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## CONFLICT OF INTEREST STATEMENT

The author(s) declare no conflicts of interest with respect to the research, authorship, and/or publication of this article.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the OSF page: <https://osf.io/6jce9/>.

## ORCID

Mark Adams  <https://orcid.org/0000-0001-8626-9227>

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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