Daily and momentary sensation-seeking and urgency in young adults: Associations with risk-taking and sleep

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Author Disclosure Statement

No conflicting financial interests exist.

Citation Diversity Statement

Recent work in several fields of science has identified a bias in citation practices such that papers from women and other minorities are under-cited relative to the number of such papers in the field (Bertolero et al., 2020; Caplar et al., 2017; Chakravartty et al., 2018; Dion et al., 2018; Dworkin et al., 2020; Fulvio et al., 2020; Maliniak et al., 2013; Mitchell et al., 2013; Wang et al., 2020). Here we sought to proactively consider choosing references that reflect the diversity of the field in thought, form of contribution, gender, race, ethnicity, and other factors. First, we obtained the predicted gender of the first and last author of each reference by using databases

that store the probability of a first name being carried by a woman (Dworkin et al., 2020; Zhou et al., 2020). By this measure (and excluding self-citations to the first and last authors of our current paper), our references contain 18.75% woman(first)/woman(last), 17.19% man/woman, 32.39% woman/man, and 31.67% man/man. This method is limited in that a) names, pronouns, and social media profiles used to construct the databases may not, in every case, be indicative of gender identity and b) it cannot account for intersex, non-binary, or transgender people. We look forward to future work that could help us to better understand how to support equitable practices in science.

Transparency and Openness Statement

The analysis code (https://osf.io/shvm7/?view_only=8d1efadc2a2e43b8836e81e310ab1261) and raw data/materials (https://osf.io/shvm7/?view_only=8d1efadc2a2e43b8836e81e310ab1261) used in this manuscript are openly available. No aspects of the study were pre-registered.

Abstract

Fluctuations in sensation-seeking may affect risk-taking, necessitating a consideration of these fluctuations as well as their antecedents. In 21-day daily diary data (*n*=78 participants; mean age=21.18, *SD*=1.75; 80.77% women), days of higher than usual sensation-seeking are also days of higher than usual risk-taking and are more likely to be alcohol use days than days of lower than usual sensation-seeking. On average, outcomes of risky behavior are rated positively. In 6-times a day experience-sampling data from the same participants over the same 21 days, we examine sleep as potential antecedent of fluctuations in sensation-seeking. We find that sensation-seeking peaks higher and earlier following nights of higher than usual sleep quality relative to days following average and lower than usual sleep quality. Together, findings suggest that seeking out novel experiences in daily life without rash decision-making leads to positive outcomes in young adulthood and positive risk-seeking may be supported by sleep quality.

Keywords: sensation-seeking; impulsivity; risk; ecological momentary assessment; daily diary

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Young adulthood is characterized by high levels of risk-taking (Claxton & van Dulmen, 2013; Krieger et al., 2018; Li et al., 2016). Risk-taking is often rightfully considered as having the potential for harmful consequences (Casey et al., 2008; Ernst et al., 2006; Steinberg et al., 2008). The positive side of risk-taking, whereby such behaviors afford one the opportunity to explore and experiment with relationships and identity (Hansen & Breivik, 2001; Romer et al., 2017; Yoneda et al., 2019), are increasingly considered. Two traits implicated in risk-taking are sensation-seeking and urgency. Sensation-seeking describes the propensity to seek out new, varied, and highly stimulating experiences, with a disposition towards engaging in risk-taking for the sake of such experiences (Zuckerman, 1994). Urgency refers to the tendency to act rashly when experiencing intense affect (Whiteside & Lynam, 2001). These perspectives focus on characterizing individuals as "risky" and "not risky", neglecting the notion that the same person may experience more sensation-seeking and urgency and, as a result, take more risks on one day than the next (Griffin & Trull, 2020; Lydon-Staley et al., 2020). An open question is *what* predicts *when* an individual will take risks. Sleep varies from day-to-day and changes reward-related decision-making, impulse control, and the neural circuitry underlying these processes (Muzur et al., 2002; Muzur et al., 2002; Tononi & Cirelli, 2003; Yoo et al., 2007). In this context, sleep may alter the expression of sensation-seeking and urgency in daily life, with implications for risk-taking. In this study, we examine within-person associations between sensation-seeking, urgency, risk-taking, and sleep in daily life.

The vast majority of research has focused on the dangerous consequences (e.g., substance use) associated with impulsigenic traits and risk-taking. Yet, young adulthood is a period

characterized by exploring relationships, experimenting with possible life directions, and searching for identity. Thus, expressions of impulsigenic traits, especially sensation-seeking, may be advantageous and benefit well-being. Recently, Yoneda et al. (2019) identified three classes of youth based on developmental trajectories of sensation-seeking and impulsivity: 1) low sensation-seeking and low impulsivity, 2) moderate sensation-seeking and low impulsivity, and 3) high sensation-seeking and impulsivity. In young adulthood, individuals in the moderate sensation-seeking and low impulsivity class reported the highest income, good achievement, low financial strain, and higher levels of psychological well-being relative to their counterparts with low or high levels of both traits (Yoneda et al., 2019). To this end, sensation-seeking, if expressed in moderate-to-high levels in the absence of urgency, may foster positive life outcomes and well-being during young adulthood.

Substantial research has sought to describe between-person differences in sensation-seeking and urgency and their associations with risk-taking. Research has increasingly considered fluctuations in sensation-seeking and urgency in daily life (Fleeson, 2016; Nesselroade, 1991). Such research emphasizes that personality comprises both dynamic processes varying from moment to moment and traits describing how individuals typically act (Fleeson, 2016). Researchers are increasingly characterizing the expression of impulsigenic traits in daily life to understand their dynamics and reactivity to contextual factors. Emerging evidence suggests that impulsigenic states may be reliably measured in daily life (Halvorson et al., 2019; Sperry et al., 2018). Moreover, person-level aggregates of these states are moderately correlated with global trait measures, suggesting the validity of these measures. Further, person-level aggregates are associated with emotional and behavioral problems in a similar manner as global self-report trait measures, suggesting state and trait tendencies are related at the between-subjects

level (Halvorson et al., 2019; Sperry et al., 2018). This work demonstrates the feasibility of measuring impulsigenic states in naturalistic settings.

Additional work indicates that 55-60% of the variance in momentary impulsigenic states reflects between-person differences, indicating a substantial amount of left-over variance that represents moment-to-moment fluctuations within individuals (Halvorson et al., 2019), which in turn may have implications for fluctuation in risk-taking. Indeed, initial studies examining within-person associations between impulsigenic states and risk behavior find that risk-taking was higher than usual on days of higher than usual sensation-seeking, and days of higher than usual sensation-seeking were more likely to be days on which alcohol was consumed relative to days of lower than usual sensation-seeking (Lydon-Staley et al., 2020). Furthermore, the association of impulsigenic states with risk-taking can even be observed on shorter timescales. State difficulties with premeditation, and to a lesser extent, sensation-seeking were related to alcohol use in the moment (Griffin & Trull, 2020). Whereas greater state difficulties with premeditation related to greater odds of reporting the consumption of an alcoholic drink as well as a greater number of alcoholic drinks at a given moment, greater sensation-seeking in the past 15 minutes was related to having consumed more alcohol in the moment (Griffin & Trull, 2020).

In addition to providing insight into sensation-seeking and urgency in daily life, there is increasing need to examine the types of risks individuals take in daily life. Risk-taking is not limited to illegal or dangerous behaviors. Instead, risk-taking is characterized by the potential opportunity for both rewards and costs, variability in the potential outcomes, and uncertainty in the outcomes realized (Holton, 2004; Leigh, 1999). Consistent with this perspective, research has tended to focus on negative behaviors (often illegal and perceived as dangerous) with high reward and often dangerous public health consequences, such as substance use, tobacco use, and

unsafe sexual practices (Kann et al., 2018). However, other perspectives emphasize the positive behaviors—considered socially acceptable and constructive—related to risk-taking, such as adventure, creativity, and exploration (Hansen & Breivik, 2001; Do et al., 2017; Van Duijvenvoorde & Crone, 2013). Interestingly, sensation-seeking is related to higher rates of both positive and negative risk-taking (Fischer & Smith, 2004; Hansen & Breivik, 2001; Yoneda et al., 2019), whereas greater urgency is related to negative risk-taking (Wood et al., 2013; Yoneda et al., 2019). To this end, risk-taking in daily life is likely to consist of both positive and negative risks, with dangerous and illegal risk-taking behaviors being much rarer (Willoughby et al., 2014). Instead, risks in daily life, especially during the period of young adulthood that is characterized by substantial exploration, may be adaptive, benefit well-being, carry potential costs that are mild in severity, and be socially acceptable (Duell & Steinberg, 2019). To gain insight into the positive aspects of risk-taking that may be more prevalent in daily life than high-risk behaviors with catastrophic consequences, study designs providing insight into everyday risks are necessary. In a recent example of such work, of 2,490 self-reports of the day's riskiest behaviors in the course of daily life, less than 4% of risky behaviors were specific to substance use (i.e., alcohol and smoking risks) with less than 15% posing a threat to safety, health, or well-being (e.g., alcohol use, risky driving; Lydon-Staley et al., 2020). Accordingly, assessing behavior as individuals go about their daily lives will advance our understanding of the diversity of risk-taking in ecologically-valid contexts and elucidate how state sensation-seeking and urgency relate to both positive and negative risks.

As well as considering the potentially causal associations between sensation-seeking, urgency, and risk-taking, we extend previous work on momentary state sensation-seeking and urgency by examining within-person fluctuations in sleep as a moderator of sensation-seeking

and urgency. Our focus on sleep reflects the importance of sleep during young adulthood and its positive association with risky behaviors (DeMartini & Fucito, 2014; Kenney et al., 2012; Rossa et al., 2014). One way sleep is thought to affect engagement in risky behavior is by restoring cognitive control processes (Muzur et al., 2002; Tononi & Cirelli, 2003; Yoo et al., 2007), thus impacting impulsigenic states (Drummond et al., 2006) and changing reward-related decision-making (Muzur et al., 2002). Drummond et al. (2006), for example, observed that after two nights of sleep deprivation, impairments in inhibitory control (i.e., greater impulsivity) were observed in young adults, with a return to baseline levels following just one night of recovery sleep (Drummond et al., 2006). In this context, insufficient sleep may hinder executive function, leading to changes in impulse control and reward-related decision-making. However, research examining the associations among sensation-seeking, urgency, and sleep has mostly been restricted to laboratory studies, providing little insight into these relationships in daily life.

The Present Study

We extend understanding of the associations among sensation-seeking, urgency, sleep, and risk-taking in multiple ways. First, we aim to replicate recent findings that days of higher than usual sensation-seeking are days of higher than usual risk-taking and that days of higher than usual sensation-seeking are more likely to be days on which alcohol is consumed relative to days of lower than usual sensation-seeking (Lydon-Staley et al., 2020). Second, we examine the extent to which the daily sensation-seeking associations with alcohol use and risky behavior are independent from associations with daily urgency by measuring urgency at the daily level. Third, by having participants describe their everyday risk behaviors and asking participants to rate the extent to which the outcome of their riskiest behavior is positive and negative, we aim to gain insight into the types, and outcomes, of risks that are undertaken during the course of daily life.

Fourth, we complement the daily assessment of sensation-seeking and urgency with momentary measures and examine the extent to which sensation-seeking and urgency fluctuate throughout the course of a day. Fifth, we test the extent to which night-to-night fluctuations in sleep duration and quality are associated with momentary fluctuations in sensation-seeking and urgency.

Method

We used data from the Networks of Daily Experiences (NODE) study, an intensive longitudinal study designed to provide insight into day-to-day intraindividual variability across a range of domains of functioning. The variables used in the present study have not been reported on previously. All research was conducted in accordance with the Institutional Review Board (IRB) at the [redacted for review]. All data and code used in the present study is available at OSF.

Participants

A final sample of 78 young adults (M = 21.18 years, SD = 1.75, 63 women) participated in this study. Participants were recruited from the University of [redacted for review] and the surrounding university community through poster, Facebook, Craigslist, and university research site advertisements. Individuals were eligible if they met 5 criteria: 1) between the ages of 18 and 25 years of age; 2) having consistent home access to a desktop or laptop with internet; 3) owning a smartphone; 4) willing to complete a 2-hour laboratory visit; 5) willing to install a free app on their smartphone and computer. An initial sample of 80 participants was recruited; however, 2 participants were excluded for non-compliance with the daily diary and smartphone-based experience sampling protocol (i.e., 0 instances of the daily diary or experience-sampling data). Participants identified as African American/Black (20.5%), Asian-American (24.4%), Hispanic/Latino (9%), Multiracial (7.7%), Other (7.7%), and white (30.8%). Participants

identified as bisexual (6.4%), heterosexual (85.9%), multiple (3.8%), other (1.3%), queer (1.3%), and not disclosed (1.3%). Participants reported a yearly family income ranging from under $20,000 to $200,000 or more (*Modal income* = under $20,000 and $20,000 to $49,000). Participants' education spanned less than a high school degree (1.3%), high school degree (28.2%), some college with no degree (42.3%), bachelor's degree (26.9%), or master's degree (1.3%). Participants' employment spanned full-time student (48.7%), part-time student (24.4%), part-time worker (6.4%), full-time worker (9%), and unemployed (11.5%).

Procedure

Recruitment materials directed interested participants to a website with study information and an eligibility form. After confirming that participants met inclusion criteria, participants were contacted, and a laboratory session was scheduled during which they completed a consent form and baseline demographic and other questionnaires. At the visit they were oriented to a Qualtrics-based daily diary and a smartphone-based experience-sampling protocol using the LifeData application. An application (History Trends Unlimited) was also installed on participants' laptops for an internet browsing study component that we do not report on in the present study. Following the laboratory visit, participants completed 21 days of experience-sampling assessment consisting of a morning survey and five further surveys delivered throughout the day via Life Data. The morning survey was sent at participant-specific times elicited at the laboratory session to maximize completion of the morning survey, including the following times: 7AM (*n*= 1 participant chose this time), 8AM (*n*=51), 9AM (*n*=13), 10AM (*n*=10), 11:10AM (*n*=3). The morning survey came at the same time each day. The momentary surveys were distributed randomly throughout the day, with at least 30 minutes between each prompt. The median time of day for each momentary response was 8:42 am (morning survey or

momentary response 0), 11:27 am (momentary response 1), 12:42 pm (momentary response 2), 2:06 pm (momentary response 3), 3:36pm (momentary response 4), and 5:36pm (momentary response 5). The morning and momentary surveys were identical except that a question asking about the previous night's sleep in the morning survey that was not included in the momentary surveys.

Links to the end-of-day daily diary surveys were sent via email at 6:30pm every evening. Participants were instructed to complete the daily assessments before going to bed but were also informed that the survey closed at 10am the following day. Participants were instructed that the survey could be completed before 10am if they were unable to get to their computers in the evening, but that they should answer the questions as if they were being completed the previous evening. Participants were compensated with a payment card that could be used as a debit card. Participants were compensated after completing each study phase. Participants received $20 after completing the laboratory visit. For the daily and momentary assessment, completion was incentivized by making participant payment contingent on completion: completion of the daily survey and 4 of the six momentary prompts for 3, 4, 5, 6, and 7 days each week was compensated with $10, $15, $20, $25, and $33.33, respectively. At the end of the 21 days, participants completing 85% or more of the momentary surveys received a bonus $25. Continued participation through the daily assessment was further incentivized by using a raffle for which an iPad mini was the prize. Completion of all 7 surveys each week resulted in one entry into the raffle drawing. Data collection began in July 2019 and ended in March 2020 when laboratory visits were no longer possible due to COVID-19.

Measures

The present study used participants' reports of demographic characteristics and trait sensation-seeking and impulsivity from the laboratory session, their daily diary reports, and their momentary reports.

Trait Sensation-Seeking and Impulsivity. Trait sensation-seeking and impulsivity were measured using the Brief Sensation-Seeking Scale (BSSS; Hoyle et al., 2002) and the Urgency, Premeditation, Perseverance, and Sensation-Seeking Scale (UPPS; Whiteside & Lynam, 2001) during the baseline survey. The BSSS is an 8-item scale with items ranging from 1 ("Disagree Strongly") to 5 ("Strongly Agree"). Internal reliability of the BSSS was acceptable (Cronbach's α =0.76).

The UPPS is a 45-item scale made up of four subscales: premeditation, urgency, sensation-seeking, and perseverance. Items range from 1 ("Agree Strongly") to 4 ("Disagree Strongly") and were reverse coded, when appropriate, such that higher values on an item indicated higher impulsivity. Internal reliability of the subscales was good with Cronbach's α's = 0.82, 0.84, 0.84, 0.83 for premeditation, urgency, sensation-seeking, and perseverance, respectively.

Daily Sensation-Seeking. Day's sensation-seeking was measured using two items adapted from the Fun-Seeking subscale of the BIS/BAS scales (Carver & White, 1994) and the Excitement-Seeking subscale of the Revised Neuroticism, Extraversion, and Openness Personality Inventory (Costa & McCrae, 1992): "Today, I craved excitement" and "Today, I craved new experiences". Participants were instructed to rate how accurately the statement reflected how they behaved today on a scale from 1 ("Not at all") to 100 ("Very") in increments of 1. This measure was used in a previous study on daily sensation-seeking where it showed moderate correlations with two trait measures of sensation-seeking, the capacity to reliably

capture within-person change, and substantial within-person variation from one day to the next (Lydon-Staley et al., 2020). In the current data, the sensation-seeking scale exhibited reliable within-person change ($R_c = 0.87$). Intraclass correlation (ICC) analyses indicate that the sensation-seeking scale is composed of approximately equal parts within-person and between-person variance (ICC = 0.57).

Momentary Sensation-Seeking. Momentary sensation-seeking was measured using two items adapted from the daily scale: "Right now, I crave new excitement" and "Right now, I crave new experiences". Participants provided their responses on a sliding scale from 1 ("Not at all") to 100 ("Very") in increments of 1. Intraclass correlation analyses indicated that the proportion of variance associated with between-person variability in momentary sensation-seeking was 0.59.

Daily Urgency. Day's urgency was measured using two items adapted for daily use from the urgency subscale of the Urgency, Premeditation, Perseverance, and Sensation-Seeking Scale (UPPS; Whiteside & Lynam, 2001): "Today, I had trouble controlling my impulses" and "Today, I had trouble keeping my feelings under control". Participants provided their responses on a sliding scale from 1 ("Not at all") to 100 ("Very") in increments of 1. The sample-mean of day's urgency was 20.71 ($SD = 17.59$, $min = 1$, $max = 100$). We note that recent experience-sampling work has used similar scales to assess urgency (Feil et al., 2020; Sharpe et al., 2020; Sperry et al., 2018; Tomko et al., 2014). The urgency scale exhibits reliable within-person change ($R_c = 0.79$). ICC analyses indicate that the urgency scale is composed of a substantial proportion of within-person variance (ICC = 0.62).

Momentary Urgency. Momentary urgency was measured using two items adapted from the daily scale to assess experiences of urgency in the present moment: "Right now, I have trouble controlling my impulses" and "Right now, I have trouble keeping my feelings under

control". Participants provided their responses on a sliding scale from 1 ("Not at all") to 100 ("Very") in increments of 1. Intraclass correlation analyses indicated that the proportion of variance associated with between-person variability in momentary urgency was 0.63.

Daily Risk-Taking. Day's risk-taking was measured during the morning survey using two items: "Yesterday, I took more or less risks than I normally do" and "Yesterday, my behavior was more or less risky than usual". Participants provided their responses on a sliding scale from -50 ("Less than usual") to 50 ("More than usual") in increments of 1. Participants were instructed during the laboratory session that a score of -50 did not necessarily mean no risks, it meant much less risky behavior or much less frequent risk-taking than usual for them, and that a score of 0 would indicate a day of the same amount of risky behavior that is typical for them. This measure was used in a previous study on daily risk-taking (Lydon-Staley et al., 2020). The risk-taking scale exhibited reliable within-person change (R_c = 0.93). Intraclass correlation analyses indicated that the proportion of variance associated with between-person variability in risk-taking was 0.25.

Participants also reported on their riskiest behavior of the day in an open-ended response to the question in the morning survey based on the previous day: "What was the riskiest thing you did yesterday?". Participants were asked to report on *yesterday's* riskiest behavior in order to ensure risky behaviors that may have occurred following completion of the evening survey were captured. Participants then rated the outcome of the riskiest behavior according to two separate items using a scale from 1 ("Not at all") to 100 ("Very") in increments of 1: "The outcome of the riskiest thing you did yesterday was positive" and "The outcome of the riskiest thing you did yesterday was negative". The negative risk outcome score in the dataset ranged from 1 to 100 (M = 23.17, SD = 24.55). The positive risk outcome score in the dataset ranged from 1 to 100 (M =

70.04, *SD* = 26.37). Due to the high correlation between the positive risk outcome and negative risk outcome score ($r = -0.67$, $p < 0.001$), the negative risk outcome variable was reverse-coded such that low scores indicated more negative outcomes and averaged with the positive risk outcome variable to form a single risk outcome construct, where higher total scores indicate more positive/less negative outcomes.

Daily Alcohol Use. Alcohol consumption for the previous day was measured during each daily diary assessment using three items of the form, "Yesterday, how many of the following drinks did you consume?" followed with prompts and definitions of standard servings for beer (12 fl. oz.), wine (5 fl. oz.), and shots of liquor (1.5 fl. oz.). Responses were give on a 0, 1, 2, 3, 4, 5+ response scale for each beverage category and were summed to obtain the total servings of alcohol consumed the previous day (see Lydon et al., 2016; Lydon-Staley et al., 2020 for previous use of this item). Participants were asked to report on yesterday's alcohol use to ensure that alcohol use that may have occurred after completion of the evening survey was captured.

Night's Sleep. Night's sleep was measured at the morning session in the experience-sampling protocol by using items adapted from The Pittsburgh Sleep Quality Index (PSQI; (Buysse et al., 1989) that have been used in previous experience-sampling studies (Lydon et al., 2016). Typically used as a previous-month recall measure, two items were configured for daily assessment as previous-night recalls. Sleep duration was measured by a response to the question, "How many hours and minutes of sleep did you get last night (This may be different from number of hours spent in bed)?". A number wheel was displayed where the hours could be moved in one-hour increments and the minutes could be moved separately in one-minute increments. Sleep quality was measured by a response to the question, "Last night, how would you rate your sleep quality?" on a slider with anchors at 1 ("Very bad") and 100 ("Very good")

in increments of 1. Such single-item, daily self-report measures are more strongly correlated with actigraphy-based measures of sleep than retrospective, previous month reports (Lauderdale et al., 2008), are practical when measurements are taken frequently to reduce participant burden, and demonstrate favorable psychometric properties (Cappelleri et al., 2009).

Statistical Analysis

Associations between daily sensation-seeking, urgency, and risk-taking and alcohol use. We tested the extent to which sensation-seeking and urgency were associated with risk-taking using separate multilevel models. We parameterized the time-varying variables (day's sensation-seeking and day's urgency) to separate within-person and between-person associations by splitting predictors into time-invariant (between-person; e.g., usual sensation-seeking) and time-varying (within-person; e.g., day's sensation-seeking) components (see Bolger & Laurenceau, 2013). We slid forward the risk-taking variable by one day (as the question was phrased to measure previous day's risk-taking to ensure the capture of risk-taking that occurred after the survey) such that *day's sensation-seeking* and *day's urgency* represented sensation-seeking and urgency on a concurrent day to the reports of risk-taking. Social weekend was used to code for weekend days such as Thursday, Friday, and Saturday, which are considered days when alcohol use is most likely in young adults and college students (Finlay et al., 2012). We specified a random intercept and random slopes for day of study, weekend (when model convergence was possible), *daily sensation-seeking*, and *daily urgency*.

We tested the extent to which sensation-seeking and urgency was associated with alcohol use. We slid forward the alcohol use variable by one day (as the question was phrased to measure previous day's alcohol use to ensure the capture of alcohol use that occurred after the survey) such that *day's sensation-seeking* and *day's urgency* represented sensation-seeking and urgency

on a concurrent day to the reports of alcohol use. We then fit a multilevel hurdle model (Atkins et al., 2013) using glmmTMB (Brooks et al., 2017), specifying a truncated Poisson function. Multilevel hurdle models allow us to model the binary outcome of whether a behavior occurs and continuous information about the extent of a behavior (e.g., in this case, how many drinks). We regressed alcohol use on day's sensation-seeking, usual sensation-seeking, day's urgency, usual urgency, weekend (dummy coded such that Thursday, Friday, and Saturday were indicated by 1), and day of study (to account for time as a third variable). We also included *age* and *gender* as covariates. We specified random intercepts and random slopes for day of study, day's sensation-seeking, and day's urgency at both the zero and count levels of the model.

Using results from similar daily diary data (Lydon-Staley et al., 2020), we followed procedures for power analysis in intensive longitudinal studies (Bolger & Laurenceau, 2013) and find that with a sample of 78 participants with 21 days of data (the number of observations available in the previous dataset), a significant within-person association between risk-taking and sensation-seeking is observed in over 97% of 1,000 simulated samples. As such, the current sample of 78 participants should be adequately powered to detect within-person associations between sensation-seeking, urgency, and risk-taking. Statistical significance was evaluated at $\alpha = 0.05$.

The association between night's sleep and momentary sensation-seeking and urgency. We sought to advance extant evidence demonstrating day-to-day variability in impulsigenic states (Griffin & Trull, 2020; Halvorson et al., 2019; Sperry et al., 2018) by examining the extent to which these states fluctuate within-person over the course of a day. Multilevel growth models were used to describe typical trajectories of sensation-seeking and urgency in relation to time of day (the six prompts of the experience-sampling data). These

typical changes were investigated by testing which pattern of time of day-related change (linear, quadratic, or cubic) best explained the relationship between time of day and each of the measures (sensation-seeking and urgency). To test time-of-day effects, all mixed-models followed a formal model-fitting procedure which we document in the supplement. Once a base model was established, we then tested for effects of last night's sleep on the shape of change in sensation-seeking and urgency across the day, as also documented in the supplement.

Results

Out of a possible total of 1638 daily diary days (21 days × 78 participants), 1122 (68.5 %) were available. Out of a possible total of 9,828 momentary reports (6 reports/day × 78 participants × 21 days), 8346 (84.9%) were available. The number of daily diary days completed by participants ranged from 1 to 20 (M = 14.38, SD = 5.16). The number of study days completed was inversely related to the average of day's urgency (r = -0.23 [95% CI: -0.43 to -0.01], p = 0.04). Thus, number of days completed was included in the remaining models as a covariate. No other significant correlations for days completed and day's sensation-seeking, risk-taking, UPPS subscales, or BSSS emerged. The number of momentary reports completed by participants ranged from 11 to 168 (M = 105.65, SD = 27.52).[1] The number of momentary reports was unrelated to average momentary sensation-seeking, impulsivity, BSSS, or UPPS subscales ($r's \leq 0.16$, $p's \geq 0.09$). We provide descriptive statistics and correlations of the variables used in the analyses in Table 1.

Day's sensation-seeking is positively associated with day's risk-taking

We ran multilevel models to examine whether day's sensation-seeking was associated with risk-taking (see Table 2, Figure 1A). Days of higher than usual sensation-seeking are also

[1] One participant had 168 momentary reports because their phone broke part way through the study and they were permitted to restart the protocol when their phone was fixed.

days of higher than usual risk-taking ($b = 0.10, p = 0.007$). Risk-taking is higher on weekends relative to weekdays ($b = 2.98, p = 0.003$). At the between-person level, usual sensation-seeking is positively associated with risk-taking ($b = 0.16, p < 0.001$). Self-reported risk-taking is lower for participants self-reporting as man ($b = -6.16, p = 0.03$). Day of study and age are unrelated to risk-taking (p's ≥ 0.31).

Day's urgency is unrelated to day's risk-taking

We ran a multilevel model to examine whether day's urgency was associated with risk-taking (see Table 2, Figure 1B). Day's urgency is unrelated to risk-taking ($b = 0.02, p = 0.58$). Risk-taking is higher on weekends ($b = 3.09, p < 0.001$). Self-reported risk-taking is lower for participants self-reporting as man ($b = -6.58, p = 0.04$). Day of study, age, and usual urgency are unrelated to risk-taking (p's ≥ 0.21). Days of higher than usual sensation-seeking remain days of higher than usual risk-taking ($b = 0.10, p = 0.008$) when urgency was added to the multilevel model used to test the within-person association between sensation-seeking and risk-taking.

Day's sensation-seeking is positively associated with day's alcohol use

We ran a multilevel hurdle model to examine whether day's sensation-seeking and day's urgency were associated with day's alcohol use (see Table 3). The zero-inflation submodel of the hurdle model estimates the probability of an extra zero (no alcohol use) such that a positive contrast indicates a higher chance of no alcohol use. Days of higher than usual sensation-seeking are more likely to be days on which alcohol is used ($b = -0.01, p = 0.04$) and weekends are more likely to be alcohol use days relative to weekdays ($b = -0.86, p < 0.001$). There is no association between day's urgency and alcohol use ($b = 0.003, p = 0.59$). At the between-person level, individuals with higher than usual urgency are more likely to have more alcohol use days relative to individuals with lower than usual urgency ($b = -0.02, p = 0.03$). There is no association

between usual sensation-seeking, gender, or day of study and the probability of more or less alcohol use days (p's ≥ 0.07). Older participants are more likely to have more alcohol use days relative to younger participants ($b = -0.21$, $p = 0.04$).

The conditional submodel of the hurdle model estimates the positive count process, providing insight into variables that increase or decrease the likelihood of consuming more alcohol on alcohol-use days. Day's sensation-seeking and day's urgency are not associated with amount of alcohol consumed (b's ≤ 0.002, p's ≥ 0.59). Greater amounts of alcohol are consumed on weekend drinking days relative to weekday drinking days ($b = 0.31$, $p = 0.02$). Day of study is not associated with amount of alcohol consumed ($b = 0.02$, $p = 0.07$). At the between-person level, no association between usual sensation-seeking, usual urgency, age, gender, and alcohol use emerged (p's ≥ 0.47).

Risks in daily life have positive outcomes on average

Participants reported riskier behavior on days of higher than usual sensation-seeking. We conducted a content analysis to provide insight into the risks that participants engaged in during the daily protocol. The content analysis indicated highly idiosyncratic risks (e.g., "pushed rat carcasses into a freezer that was already full", "ate chicken that my boyfriend cooked", "walked in cemetery in sandals"). Yet, common themes emerged. These common themes included social, work, school, substance use, and transportation risks. Social risks included examples such as "talked to a stranger", "invited people over", and "went to a party." Work risks included "rushed through work", "got to work late", and "cancelled volunteering." School risks included "didn't finish my essay", "presenting/speaking in class", and "skipped class." Examples of substance use risks included "smoked weed", "getting drunk alone", and "mixed alcohol with drugs." Transportation risks included "jaywalking", "drove around late at night", and "taking the bus

home alone late at night." All risk reports are available to be examined at OSF. Notably, the reported outcome of these risky behaviors is mostly positive (M = 73.4, SD = 23.3). We ran repeated measures correlations to examine the association between day's sensation-seeking and day's urgency with day's risk outcome. Day's sensation-seeking shows a positive correlation with day's risk outcome (r = 0.10, p < 0.001 [95% CI: 0.04 to 016]). Day's urgency shows no correlation with day's risk outcome (r = 0.01, p = 0.78 [95% CI: -0.05 to 0.07]).

Consistency and change in sensation-seeking and urgency throughout the day and associations with sleep

We next move from the daily level to a finer time scale by examining the momentary reports of sensation-seeking and urgency. Using multilevel growth models, we tested, for each measure separately, whether time of day (momentary response)[2] showed a linear, quadratic, or cubic relationship with sensation-seeking and urgency, and how sleep (duration and quality) impacted change in sensation-seeking and urgency throughout the day (see Supplemental Material).

Sensation-seeking. Momentary sensation-seeking throughout the day was best explained by a cubic time-model. This model indicated a pattern in which sensation-seeking is stable in the morning, then rises steeply during the day and then stabilizes in the evening (see Figure S1A). Night's sleep duration shows no association with day's sensation-seeking (p = 0.65). However, the interaction of night's sleep quality with time (linear) is significant (b=-0.02, p = 0.005). A description of the models is displayed in Supplemental Tables 3 and 4. As shown in Figure 2, following nights of higher than usual sleep quality, sensation-seeking exhibits a higher peak slightly earlier in the day, with a second rise in sensation-seeking in the afternoon relative to following a night of average or low sleep quality. In addition to these within-person associations,

[2] Results similar to those reported here were obtained from analyses using minutes elapsed since first prompt as the time variable.

people with higher than average sleep quality across the 21 days show higher than usual sensation-seeking (b=0.35, p = 0.02). The interaction of sleep quality with time of day (b = -0.02, p = 0.004) and the between-person associations for sleep quality (b = 0.45, p = 0.006) remain significant after including night's and usual sleep duration in the model.

Urgency. Momentary urgency throughout the day was best explained by a linear time-model. This model indicated a slight monotonic increase in urgency across the day (see Figure S1B). We tested, for each measure separately, whether night's sleep duration and night's sleep quality affected the trajectories of urgency across the day. Night's sleep duration shows no association with day's urgency (b=3.07, p = 0.16). Following nights of higher than usual sleep quality, urgency is higher (b =0.27, p = 0.04). Urgency is lower than usual following nights of higher than usual sleep quality (b=-0.26, p = 0.04), but night's sleep quality does not moderate the shape of change in urgency throughout the day (b = 0.003, p = 0.50). In addition to these within-person associations, people with higher than average sleep quality across the 21 days exhibit lower than usual urgency (b=-0.27, p = 0.04). However, these associations do not remain following inclusion of night's sleep duration and usual sleep duration in the model (p's $\geq$ 0.12). A description of the models is displayed in Supplemental Tables 3 and 4.

Discussion

We measured naturalistic daily and momentary fluctuations in sensation-seeking and urgency over the course of 21 days and tested within-person associations between sensation-seeking, urgency, and both self-defined risky behavior and alcohol use. Consistent with the hypothesized role for state sensation-seeking in promoting risky behavior, days of higher than usual sensation-seeking were also days of higher than usual risk-taking. These findings replicate prior work examining within-person associations between sensation-seeking, alcohol use, and

self-reported risk-taking (Lydon-Staley et al., 2020). This study extends this work by examining the distinct within-person associations between sensation-seeking and both self-reported risk-taking and alcohol use, independent of urgency. Day's urgency was unrelated to day's risk-taking and days of higher than usual sensation-seeking were associated with risk-taking and alcohol use independent of urgency. Thus, sensation-seeking's within-person association with alcohol was specific to normative engagement with alcohol use during young adulthood (World Health Organization, 2019) rather than heavy alcohol consumption that poses a more serious threat to well-being (NSDUH, 2018). Although urgency showed no within-person association with self-reported risk-taking or alcohol use, a between-person association between urgency and alcohol use was observed. Participants exhibiting greater levels of urgency throughout the 21-day protocol consumed more alcohol than participants with lower levels of urgency on days when they drank alcohol. These findings support prior between-person work highlighting impulsigenic traits as predictors of excessive amounts of alcohol, with urgency accounting for alcohol-related problems and heavy drinking, but not alcohol use in young adults (Magid & Colder, 2007; Pedersen et al., 2019).

By having participants rate the outcome of the riskiest behavior they reported each day, we additionally provide insight into the types and outcomes of risks undertaken during the course of daily life by young adults. Overall, risks in daily life had positive outcomes on average. Content analysis revealed highly idiosyncratic risks, with common themes emerging consistent with prior work in this area (Lydon-Staley et al., 2020): social, work, school, substance use, and transportation risks. Day's sensation-seeking—not day's urgency—showed a positive correlation with day's risk outcome, such that the outcomes of risks were more positive than usual on days when sensation-seeking was higher than usual. This association between sensation-seeking and

risk outcome further supports the hypothesized role of sensation-seeking in supporting positive risk-taking (Duell & Steinberg, 2019; Lydon-Staley et al., 2020; Yoneda et al., 2019). These findings also point towards the role of sensation-seeking in supporting adaptive and exploratory risk-taking propensities during young adulthood, often with positive outcomes (Hansen & Breivik, 2001; Romer et al., 2017; Yoneda et al., 2019). To this end, sensation-seeking as the propensity to seek out novel experiences does not necessarily mean these experiences will always consist of negative risk behaviors that are dangerous and imperil wellbeing. Although sensation-seeking may be important during the early phase of risk-taking, leading one to seek out novel experiences such as alcohol use, the factors underlying heavy alcohol use or continued engagement in risky behavior with negative outcomes may indeed be separate from sensation-seeking. These findings provide further support that relying exclusively on experimenter-defined risky behaviors (i.e., alcohol use) may fail to capture the majority of risks young adults take in daily life.

We complemented the daily assessment of sensation-seeking and urgency by leveraging fine-grained, temporal data collected within-day to examine the extent to which sensation-seeking and urgency fluctuate throughout the course of a day. Sensation-seeking throughout the day was best explained by a cubic-time model, indicating an emergent pattern in which sensation-seeking is stable in the morning (8:42-11:27am), rises steeply during the day (12:42-2:06pm), and stabilizes in the evening (3:36-5:35pm). The pattern of urgency throughout the day was best explained by a linear time-model, indicating a slight monotonic increase in urgency throughout the day. This finding is consistent with evidence demonstrating that urgency increased from the beginning of the day to the end of the day in a sample of heavy drinkers (Jones et al., 2018) and adds to perspectives that consider sensation-seeking and urgency as

dynamic states that vary not just from day to day but also from moment to moment (Halvorson et al., 2019; Lydon-Staley et al., 2020; Lydon-Staley & Bassett, 2018; Sperry et al., 2016, 2018).

Finally, we tested the extent to which momentary trajectories of sensation-seeking and urgency over the course of the day were related to fluctuations in sleep duration and quality. Sleep quality impacted day's sensation-seeking, such that following nights of higher than usual sleep quality, sensation-seeking exhibited a higher peak slightly earlier in the day, with a second rise in sensation-seeking in the afternoon relative to following nights of average or low sleep quality. Further, at the between-person level, people with higher than average sleep quality across the 21 days exhibited higher than usual sensation-seeking. The positive association between sensation-seeking and sleep quality may render engagement in risk-taking more likely for people with high average levels of sleep quality and on days following high relative to low sleep quality. However, we note that the outcomes of the risks taken in the present study were largely positive, suggesting that high sleep quality may facilitate exploratory risk behaviors that positively impact well-being. Furthermore, these sleep-related changes in reward-related decision-making occur such that peak levels of sensation-seeking happen earlier in the day when positive pursuits (e.g., exploration, creativity) are more likely than negative health-risk behaviors (e.g., drinking). Thus, sleep quality may contribute to positive risk-taking by not only restoring cognitive control processes (Muzur et al., 2002), but also by allowing for sensation-seeking to peak during the day—instead of the evening—when impulse control is less likely to be depleted.

In contrast to sensation-seeking, there was no evidence that the trajectory of urgency throughout the day was related to previous night's sleep. These findings do not replicate extant evidence observing the influence of sleep duration on impulsigenic traits (Drummond et al., 2006). The lack of an association between sleep and urgency in the present study may reflect

differences in study setting. Previous work taking place in the laboratory provides insight into what can happen when sleep duration is artificially curtailed. The present study captured naturalistic fluctuations in sleep as participants went about their daily lives, providing ecological validity to the current findings. Further, the average night's sleep duration in the present sample (M = 7.05, SD = 1.66 hours) falls within the recommended range of 7-9 hours for adults (Ross et al., 2020). The effects of low sleep duration and quality on urgency in daily life may be more readily apparent in populations less likely to achieve adequate hours of sleep, such as healthcare practitioners or individuals with psychopathology. Nonetheless, these findings point toward the important role that sleep plays in processes underlying reward-related decision-making and risk-taking.

Limitations

The study findings should be considered in light of the study's strengths and limitations. Our use of daily and momentary reports allowed us to capture naturally occurring fluctuations in sensation-seeking, urgency, and risky behavior during life as it is lived (Bolger et al., 2003). Our measures of sleep duration and sleep quality are based on single item self-reports. Although these measures are more strongly correlated with actigraphy-based measures of sleep than retrospective, previous month reports (Lauderdale et al., 2008), poor sleepers tend to underestimate total sleep time and the number of awakenings relative to polysomnography measures (Carskadon et al., 1976). These easy to administer measurements that also reduce participant burden may fail to capture other factors likely to influence sleep quality, such as the frequency of disturbing thoughts and nightmares, the duration awake prior to sleep onset, and the frequency of awakenings. Our measures of sensation-seeking and urgency are based on two items, respectively, thereby potentially not capturing the full breadth of each construct. Indeed,

sensation-seeking is sometimes comprised of facets of thrill and adventure-seeking, experience seeking, disinhibition, and boredom susceptibility. Similarly, urgency is sometimes comprised of facets of negative urgency and positive urgency (Smith et al., 2007). Longer daily and momentary scales measuring impulsigenic states will allow for the capture of the subcomponents of each construct and an examination of the factor structure at the within-person level. However, such designs are complicated by the need for scales that are short and reduce participant burden, especially at the momentary level. Despite these limitations, the day's and momentary sensation-seeking and urgency scales are capable of reliably capturing within-person change and show satisfactory convergent and discriminant validity with trait scales while being short enough (two-items) to be readily accommodated in experience-sampling protocols to measure sensation-seeking as distinct from urgency.

Conclusions

Overall, our findings contribute to a growing body of research demonstrating that sensation-seeking, if indulged in appropriate circumstances, may be adaptive and foster positive life outcomes during young adulthood (Hansen & Breivik, 2001; Romer et al., 2017; Yoneda et al., 2019). The tendency to seek out novel experiences may be particularly important during young adulthood—marked by profound exploration and experimentation with relationships, life direction, and identity. Indeed, reported risks taken in daily life had positive outcomes on average. Although days of higher than usual sensation-seeking were days of higher than usual risk-taking, such a finding does not necessarily mean that increased engagement in riskier behavior led to the experience of negative outcomes. A positive correlation between day's sensation-seeking and day's risk outcome suggests that, instead, states of sensation-seeking supported the pursuit of novel experiences, which often led to self-reported positive outcomes.

Seeking out novel experiences without rash decision-making (high urgency) in daily life may be important for finding one's way into adulthood, supporting the search for identity, and contributing to young adults' health and well-being. Furthermore, sleep quality may contribute to positive risk-taking by modulating sensation-seeking to peaks earlier in the day—when positive pursuits (e.g., exploration, creativity) rather than negative health-risk behaviors (e.g., alcohol consumption) are more likely to occur and when cognitive control resources are less likely to be depleted.

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Table 1. Correlations and descriptive statistics of key study variables in the daily diary and momentary time series.

Variable	***M***	***SD***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Day's sensation-seeking[a]	52.49	23.40												
2. Day's risk-taking[a]	48.87	9.60	.35**											
3. Day's urgency[a]	20.71	17.59	.04	.04										
4. Momentary sensation-seeking[b]	55.40	20.71	.94**	.32**	.09									
5. Momentary urgency[b]	22.72	18.56	-.01	.03	.86**	.08								
6. BSSS	3.29	0.75	.34**	.14	.08	.30**	.08							
7. UPPS premeditation	1.85	0.41	-.09	-.02	.19	-.01	.16	.37**						
8. UPPS urgency	2.19	0.50	-.11	-.13	.47**	-.09	.40**	.19	.29**					
9. UPPS sensation-seeking	2.75	0.57	.34**	.05	-.09	.30**	-.15	.67**	.23*	.09				
10. UPPS perseverance	1.94	0.48	-.12	.06	.16	-.06	.05	-.09	.34**	.15	-.27*			
11. Night's sleep duration[a]	7.00	0.91	.03	.03	-.16	-.01	-.19	-.27*	-.09	-.23*	-.09	-.19		
12. Night's sleep quality[a]	62.33	14.98	.28*	.03	-.13	.29*	-.19	.03	-.02	-.11	.16	-.33**	.47**	
13. Age	21.18	1.75	-.10	.05	.03	-.12	.06	.02	.06	.01	-.10	.06	-.10	-.33**

Note: BSSS = Brief Sensation-Seeking Scale; UPPS = Urgency, Premeditation, Perseverance, and Sensation-Seeking Scale; SS = sensation-seeking; PREM = premeditation; PERS = perseverance; URGE = urgency. $N = 78$. * indicates $p < 0.05$. ** indicates $p < 0.01$. [a] Calculated using intraindividual mean of daily time series. [b] Calculated using the intraindividual mean of the momentary time series.

Table 2. Results of the multilevel models examining associations of day's sensation-seeking and urgency with day's risk-taking.

Effect	Estimate	Standard error	*p*	*d*	Confidence interval	
					Lower	Upper
Sensation-seeking						
Fixed effects						
Intercept	-2.14	1.25	0.09		-4.60	0.32
Day of study	-0.12	0.12	0.31	-0.06	-0.35	0.11
Gender man	-6.16*	2.83	0.03	-0.51	-11.80	-0.53
Weekend	2.98*	1.01	0.003	0.19	1.01	4.96
Age	0.12	0.63	0.85	0.04	1.01	4.96
Day's sensation-seeking	0.10*	0.04	0.007	0.17	0.03	0.17
Usual sensation-seeking	0.16**	0.05	< 0.001	0.84	0.07	0.25
Random effects						
Intercept	8.24				6.45	10.51
Day of study	0.67				0.46	0.98
Day's sensation-seeking	0.14				0.06	0.30
Weekend	2.83				0.58	13.75
Urgency						
Fixed effects						
Intercept	-2.05	1.34	0.13		-4.68	0.59
Day of study	-0.15	0.12	0.21		-0.39	0.08
Gender man	-6.58*	3.07	0.04		-12.70	-0.46
Weekend	3.09**	0.96	< 0.001		1.22	4.97
Age	-0.16	0.68	0.82		-1.51	1.19
Day's urgency	0.02	0.03	0.58		-0.05	0.09
Usual urgency	0.02	0.07	0.74		-0.11	0.15
Random effects						
Intercept	8.89				7.30	11.06
Day of study	0.68				0.47	0.97
Day's urgency	0.09				0.02	0.34

Note. * $p < 0.05$, ** $p < 0.001$

Table 3. Results of multilevel hurdle model examining associations with alcohol use.

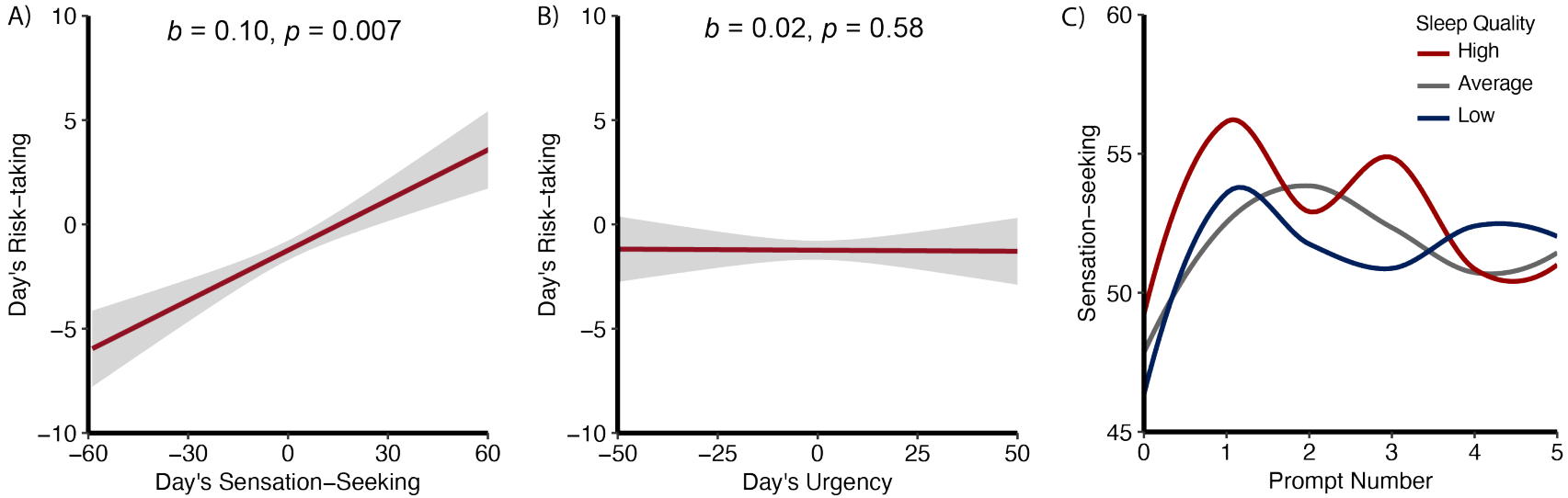
Effect	Estimate	Standard error	*p*
	Conditional submodel		
Fixed effects			
Intercept	0.51*	0.14	0.0004
Day of study	0.02	0.01	0.07
Weekend	0.31*	0.13	0.02
Age	-0.01	0.07	0.85
Gender man	0.10	0.30	0.97
Day's sensation-seeking	0.002	0.004	0.54
Usual sensation-seeking	-0.001	0.005	0.91
Day's urgency	-0.002	0.004	0.60
Usual urgency	0.004	0.005	0.47
Random effects	Variance		SD
Intercept	0.21		0.46
Day of study	< 0.001		< 0.001
Day's sensation-seeking	0.005		0.07
Day's urgency	0.06		0.25
Effect	Estimate	Standard error	*p*
	Zero-inflation submodel		
Fixed effects			
Intercept	2.57**	0.29	< 0.001
Day of study	0.002	0.02	0.92
Weekend	-0.86**	0.21	< 0.001
Age	-0.21*	0.11	0.04
Gender man	0.48	0.48	0.32
Day's sensation-seeking	-0.01*	0.006	0.04
Usual sensation-seeking	-0.01	0.008	0.07
Day's urgency	0.003	0.006	0.59
Usual urgency	-0.02*	0.10	0.03
Random effects	Variance		SD
Intercept	1.21		1.1
Day of study	0.21		0.46
Day's sensation-seeking	0.08		0.29
Day's urgency	< 0.001		0.002

Note. * $p < 0.05$, ** $p < 0.001$

Figure Captions

Figure 1. Graphic representation of the multilevel models showing the association of (A) day's sensation-seeking with day's risk-taking and (B) day's urgency with day's risk-taking. 95% confidence intervals are represented in gray. (C) Graphic representation of the multilevel growth model showing the interaction between last night's sleep quality (high, average, low) and sensation-seeking. Sleep quality was classified as high for values greater than the intraindividual maximum, low for values lower than the intraindividual minimum, and average for values in between the maximum and minimum.

Figure 1.


A)
b = 0.10, p = 0.007
Day's Risk−taking
Day's Sensation−Seeking
B)
b = 0.02, p = 0.58
Day's Risk−taking
Day's Urgency
C)
Sleep Quality
High
Average
Low
Sensation−seeking
Prompt Number