Highly Sensitive Adolescents:
The Relationship Between Weekly Life Events and Weekly Socioemotional Well-Being

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Declarations

Author's Contribution | S.I. conceived of the study, participated in its design and coordination, performed the statistical analyses, and drafted the manuscript.

Data Sharing Declaration | The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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Abstract

Recent research into Person x Environment interaction has supported the view that sensitivity to environmental influences is a *susceptibility* factor rather than a *vulnerability* factor. Given this perspective, this study examined the role of the adolescent's sensory-processing sensitivity in the context of weekly life events and weekly socioemotional well-being. In the study, 114 adolescents repeatedly self-reported their sensitivity, recent life events, and recent socioemotional well-being in four surveys at one-week intervals. The results suggested the shape of Sensitivity x Life Events interaction significantly varied from week to week, which is consistent with the vantage sensitivity and diathesis-stress framework. In specific weeks, adolescents with high sensitivity are more likely to benefit from positive events than those with low sensitivity. These sensitive adolescents can be described as developmentally *susceptibility* rather than *vulnerability*.

Keywords: highly sensitive person, highly sensitive child, sensory-processing sensitivity, differential susceptibility, vantage sensitivity

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People vary in their sensitivity to both positive and negative environmental influences. This means that some individuals are more susceptible to environmental stimuli than others. Such individual differences can be captured through the concept of *Environmental Sensitivity*, defined as the ability to process and register positive and negative environmental exposures or experiences (Greven et al., 2019; Pluess, 2015). Considering the recent elaborations on the theory of *Environmental Sensitivity* and the accumulation of a large body of knowledge on the field (Aron et al., 2012; Belsky et al., 2009; Belsky et al., 2007; Belsky & Pluess, 2009; Ellis et al., 2011; Greven et al., 2019; Pluess, 2015; Pluess & Belsky, 2013), there is no doubt today that the relationship between adolescents' experiences and developmental outcomes is moderated by their own sensitivity to environmental influences. To advance our understanding of *Environmental Sensitivity* in adolescence, the current study aims to provide new evidence on how the temperamental traits of *Environmental Sensitivit*y in adolescents can moderate the relationship between weekly life events and weekly socioemotional well-being, using repeated measurements at weekly intervals.

Individual Differences in Environmental Sensitivity

The key concept in this study is that individual differences in *Environmental Sensitivity* are not defined by any single factor, but by a variety of genes and temperamental/personality traits (Belsky & Pluess, 2009). For example, serotonin transporter gene polymorphisms (5-HTTLPR)[1] and serotonin receptor 2A gene (HTR2A) associated with the serotonergic system, and dopamine receptor D2 and D4 (DRD2, DRD4) and Catechol-O-Methyltransferase (COMT) genes associated with the dopaminergic system, have been studied as genetic markers of *Environmental Sensitivity* (Belsky et al., 2015; Chao, Chao, & Chen, 2019). Recent studies using genome-wide tests suggest that multiple sensitivity genes cumulatively contribute to individual differences in sensitivity, and that the effect of a single sensitivity gene is rather small (Keers et al., 2016). In addition, shyness, difficult temperament, and negative affectivity have been studied as the temperamental markers (Aron, Aron, & Jagiellowicz, 2012), while there has been growing interest in the concept of sensory-processing sensitivity (SPS; Aron & Aron, 1997; Greven et al.,

[1] I should also note that the role of 5-HTTLPR as a marker of differential susceptibility has been challenged in recent years due to several non-replications (e.g., Culverhouse et al., 2018).

2019).

SPS is a temperamental or personality trait of *Environmental Sensitivity*, and characterized by deeper processing of sensory information, a stronger emotional reaction, greater awareness of environmental stimulation, and ease of overstimulation, and can also be observed in several non-human species (Aron et al., 2012). Self-report measures like the Highly Sensitive Person Scale for adult (HSPS) and Highly Sensitive Child Scale (HSCS), have been translated into multiple languages and are widely used to measure SPS (Aron & Aron, 1997; Pluess et al., 2018; Pluess et al., 2020). Several studies using a factor analytic approach have demonstrated that the HSPS/HSCS consists of three factors (i.e. Ease of Excitation, Low Sensory Threshold, and Aesthetic Sensitivity): The Ease of Excitation (EOE) subscale refers to being easily overwhelmed by internal and external stimuli (e.g., getting nervous when someone is observing you or uncomfortable when you have a lot to do); the Low Sensory Threshold (LST) subscale represents a low threshold to unpleasant sensory arousal by sensory stimuli (e.g., being made uncomfortable by loud noises); the Aesthetic Sensitivity (AES) subscale is characterized by a high degree of artistic and aesthetic awareness (e.g., being deeply moved by good music and good food). EOE and LST are involved in variations in responsiveness to negative experiences, while AES reflects individual differences in response to positive experiences (Pluess et al., 2018). More recently, a bifactor model that assumes a general susceptibility factor has been supported (e.g., Iimura & Kibe, 2020; Lionetti et al., 2018; Pluess et al., 2018). Furthermore, Assary et al. (2020) reported that the heritability of *Environmental Sensitivity* as measured by the HSCS was 47% (95% CI = [0.30, 0.53]) in a sample of 2,868 adolescent twins; non-shared environmental effects and measurement error explained the remaining 53% (95% CI = [0.47, 0.59]) of the variation of sensitivity. This behavioral genetic finding can be interpreted as suggesting that individual differences in *Environmental Sensitivity* can be half explained by genetic influences (i.e., the proportion of individual differences in the study sample under specific conditions that are due to genetic variation) and half by environmental influences (e.g., Knafo et al., 2008; Rijsdijk & Sham, 2002).

Environmental Sensitivity and the Role of the Environment

In developmental science, the mechanism of interaction between *Environmental Sensitivity* and environmental influences (e.g., parenting and adversity) has been conceptualized within a traditional diathesis-stress model or dual-risk model (e.g., Belsky et al. 2007; Belsky &

Pluess, 2009). According to these models, *vulnerable* children or adolescents are more likely to be negatively affected by adverse experiences and to be at increased risk of developmental psychopathology. Indeed, studies of Gene x Environmental interaction (e.g. Caspi & Moffitt, 2006) and Child Temperament x Parenting interaction (e.g., Morrell & Murray, 2003), which examined the effects of interactions between vulnerability factors and negative environments on developmental outcomes, have provided a body of evidence to support the diathesis-stress/dual risk model. For example, Morrel and Murray (2003) showed that boys with high levels of emotional and behavioral dysregulation at 9 months predicted conduct disorder symptoms at 8 years of age later, mediated by hostile parenting. However, while the above traditional framework may seem plausible as a mechanism of Sensitivity x Environment interaction, it unfortunately fails to explain the positive developmental outcomes in a supportive environment (Pluess & Belsky, 2013; Pluess, 2017).

Importantly, the view of *vulnerability* in the diathesis-stress and dual-risk perspectives is now reconsidered by the differential susceptibility theory (Belsky, 1997; Belsky & Pluess, 2009) and the biological sensitivity to context theory (Boyce & Ellis, 2005) to be derived from an evolutionary reasoning. In these frameworks, susceptibility to environmental influence is interpreted as a *susceptibility* factor rather than a *vulnerability* or *risk* factor. Therefore, a highly sensitive person is not only more likely to be adversely affected by negative environments, but also likely to benefit disproportionality from supportive experiences (Pluess & Belsky, 2013). Indeed, there appears to be a growing number of studies supporting this theory. For example, Belsky et al. (2015) re-analyzed data from studies that reported interactions between candidate plasticity genes (e.g. 5-HTTLPR) and environments (e.g. parenting), and they obtained findings consistent with differential susceptibility theory in several developmental outcomes. In addition, the results of a meta-analysis by Van IJzendoorn et al. (2012) also indicated that Caucasian adolescents with the 5-HTTLPR s-allele, traditionally labeled as a *risk* gene polymorphism, are more likely to benefit from positive environments than their peers with l-allele. Furthermore, Rudolph et al. (2020) examined how brain activation (e.g., insula, dorsal anterior cingulate cortex) as a susceptibility factor moderates the relationship between the quality of the parent-child relationship and depressive symptoms, which supports a claim of differential susceptibility.

Recently, vantage sensitivity has been proposed as a third framework that is related to the differential susceptibility (Pluess & Belsky, 2013; Pluess, 2017). Vantage sensitivity is a concept that, in contrast to the diathesis-stress thinking, indicates the tendency of highly sensitive individuals to benefit from particularly positive experiences; this corresponds to the *bright side* of sensitivity in the differential susceptibility framework. Although there is still a paucity of evidence, some supportive findings have been reported in data from countries such as the United Kingdom, Italy, and Japan. Pluess and Boniwell (2015) conducted a school-based intervention, targeting adolescent girls in an at-risk population for depression in the United Kingdom, and they showed that only girls with a high SPS benefited from the intervention (i.e. decreased symptoms of depression). Nocentini, Menesini, and Pluess (2018) also reported that the effectiveness of the bullying prevention program was observed only in Italian adolescents with high SPS assigned to the intervention group. Furthermore, Iimura and Kibe (2020) investigated the role of SPS in high school transition and showed that, compared to Japanese adolescents with low SPS, peers with high SPS experienced an improvement in socioemotional well-being before and after the transition when they perceived the new school environment as supportive.

More recently, frameworks including the differential sensitivity theory, biological sensitivity to context theory, vantage sensitivity theory, and SPS discussed above have been integrated by leading researchers in this research area within the overarching umbrella framework of *Environmental Sensitivity* (Greven et al., 2019; Pluess, 2015; Pluess et al., 2020). The central notion of *Environmental Sensitivity* is that "individuals differ in how they perceive and process environmental features, with some being generally more and some generally less sensitive" (Pluess, 2015, pp. 1-2). As I have reviewed, evidence for *Environmental Sensitivity* is accumulating through a multifaceted approach that includes behavioral genetic (Assary et al., 2020), correlational (Iimura & Kibe, 2020), experimental (Pluess et al., 2020), interventional (Nocentini et al., 2018), and neurophysiological (Rudolph et al., 2020) studies. The present study reconsiders the relationship between adolescents' weekly current life events and weekly socioemotional well-being through a correlational approach using the HSCS, which measures the SPS, a temperamental marker of *Environmental Sensitivity*.

Sensitivity, Current Life Events, and Current Socioemotional Well-Being

Adolescence is a developmental stage characterized by biological growth and major social role transitions (Sawyer et al., 2018) and these dynamic changes sometimes lead to developmental psychopathology, including decreased self-regulation (Ng-Knight et al., 2016), heightened risk-taking (Romer, 2010), and increased depressive symptoms (Ge & Natsuaki, 2009). As suggested by the review described above, individual differences in *Environmental Sensitivity* may play a vital role in the daily socioemotional development of adolescents, although there is insufficient evidence. For example, several cross-sectional studies have reported bivariate associations between SPS and depression (Liss et al., 2008; Yano & Oishi, 2018), anxiety (Liss et al., 2008; Liss et al., 2005), alexithymia (Liss et al., 2008; Liss et al., 2005), and problems falling asleep (Boterberg & Warreyn, 2016; Grimen & Diseth, 2016) in adolescents.

In addition, there is substantial evidence that supports a close relationship between daily life events and socioemotional well-being (e.g., Kessler, 1997; Suh et al., 1996). For example, adolescents perceive interpersonal stress about friends and parents in their daily lives, cumulatively affecting their emotional and behavioral symptoms (e.g., Hampel & Petermann, 2006; Rudolph, 2002). In addition, stresses regarding adult responsibilities and academic performance are also unique to adolescence and should be associated with emotional states, including depression and anxiety (Moksnes et al., 2010).

Given these findings and a review of Sensitivity x Environmental interactions, it may be plausible to view adolescents with high SPS more likely than those with low SPS to change their current socioemotional well-being – both *for better* and *for worse* – depending on the quality of their current life events. The study most relevant to this hypothesis is that of Pluess et al. (2010). According to their study, individuals with the s-allele of 5-HTTLPR, a genetic marker of *Environmental Sensitivity*, increased current neuroticism when they experienced many recent negative life events, but decreased neuroticism when they experienced many positive life events: that is, the shape of the interaction between sensitivity and current life events was consistent with the differential susceptibility.

Overview of the Current Study

Does the adolescent's SPS, known as temperamental/personality trait of *Environmental Sensitivity*, moderate the relationship between current life events and current socioemotional well-being? If so, what shape of interaction do SPS and current life events exhibit? The aim of this study was to determine which models of diathesis-stress, differential susceptibility, and vantage sensitivity present an appropriate framework for describing current socioemotional well-being. If adolescents with high SPS experienced more of the effects of negative life events during the week and consistently showed lower socioemotional well-being compared to those with low SPS, this would support the diathesis-stress model (A in Figure 1). Alternatively, if adolescents with high SPS showed lower socioemotional well-being than those with low SPS when experiencing negative life events, while exhibiting higher well-being when experiencing positive life events, this would support the differential susceptibility model (B in Figure 1). Furthermore, if adolescents with high SPS always showed higher socioemotional well-being than those with low SPS to the extent that the quality of their current life events was positive, it would support the vantage sensitivity model (C in Figure 1). Considering the recent paradigm shift from diathesis-stress to differential susceptibility (i.e., the view that sensitivity is not a *vulnerability* but a *susceptibility*; Belsky & Pluess, 2009; Pluess, 2017), this study expected adolescents with high SPS to exhibit better socioemotional well-being when they experience positive life events compared with those with low SPS.

[Figure 1]

Method

Procedure and Participants

A paper-and-pencil questionnaire survey was conducted during the spring semester of 2020 at universities in urban Tokyo, Japan. Japanese students who fall into late adolescence (Sawyer et al., 2018) were recruited in class and participated in a one-month, four time point longitudinal survey at weekly intervals. At Week 1 (Time 1), 114 students (71 females; M_{age} =18.7 year, SD_{age} = 0.8 year) completed the questionnaire. At Week 2 (Time 2), one week after Time 1, 100 students (62 females; 12% attrition rate from Week 1) participated in the study. In Week 3, the participants were 105 students (67 females; 8% attrition rate from Week 1) (Time 3). At Week 4, the sample included 106 students (67 females; 7% attrition rate from Week 1). The institutional review board of [redacted] University approved all procedures in the current study.

Measure

Students completed the 11-item Japanese version of the Highly Sensitive Child Scale for adolescence (J-HSCS)[2], which was developed to measure SPS (Kibe & Hirano, 2019). As with the English scale (Pluess et al., 2018), previous studies have supported the bifactor structure of the J-HSCS, which includes three-subscales (i.e. Ease of Excitation, Low Sensory Threshold, and

[2] The data used in this study were measured as part of a psychology class assignment. In this class, students self-reported SPS, current life events, and socioemotional well-being across four time points in order to enhance their self-understanding. For this purpose, the SPS was measured at multiple time points, despite being a stable trait.

Aesthetic Sensitivity) plus a general sensitivity factor (Iimura & Kibe, 2020; Kibe & Hirano, 2019). Therefore, as with previous research (e.g., Pluess & Boniwell, 2015), the total mean score of the J-HSCS can be used to capture SPS. Total scores were also used in this study for analysis. Each item (e.g., *loud noises make me feel uncomfortable*, *I get nervous when I have to do a lot in little time*) was rated using a 7-point Likert-type scale, ranging from 1 (*not at all*) to 7 (*extremely*). The internal consistency of the 11 items was acceptable with Cronbach's α = 0.64 at Week 1, .0.78 at Week 2, 0.75 at Week 3, and 0.79 at Week 4.

Based on Pluess et al. (2010), students were asked to answer questions about two striking events they had experienced during the past week in an open-ended format. In this format, participants write in a box about two of their most memorable events. Then, the students evaluated the subjective positive or negative impact of each event on themselves. The instructional text was as follows: "Please write about two significant events in your daily life that you have experienced in the last week." Many students responded with daily life events related to academics (e.g., homework, examination) and interpersonal relationships (e.g., go on a date, dinner with friends, part-time job), rather than major life events such as bereavement or serious illness. These events were rated on a 7-point Likert-type, ranging from minus 3 (*this event had a very negative effect on me*) to plus 3 (*this event had a very positive effect on me*); zero represented no effect.

To measure students' socioemotional well-being at each occasion of measurement, we used the 5-item Japanese version of the World Health Organization's five-item Well-Being Index (WHO-5; Awata et al., 2007). Students rated their own socioemotional well-being status over the previous one week based on five items (e.g., *I felt cheerful and in good spirits*, *I felt calm and relaxed*) on a 6-point scale, ranging from 1 (*at no time*) to 6 (*all of the time*). The internal consistency of the scale was good with Cronbach's α = 0.78 at Week 1, .0.84 at Week 2, 0.85 at Week 3, and 0.90 at Week 4.

Data Analysis

First, to describe the overall picture of the current measures, several preliminary analyses were performed as follows: 1) calculating descriptive statistics including the means and standard deviations for all the variables; 2) computing autocorrelations and intra-class correlations (ICC) over 4 time points in each measure to determine the stability of key variables across waves; 3) bivariate correlations between all measures, and 4) testing the effect of time and gender on the means for each measure. With respect to the fourth prenatal analysis, I checked for gender differences in the mean score for SPS in the Japanese sample, as reported in previous studies (e.g., Pluess et al., 2018); if present, I controlled for them in the interaction analysis described next.

Widaman's Confirmatory and Competitive Approach

Next, to identify the optimal models of SPS x Life Event interactions, we performed a model selection-based on reparameterized regression analysis known as Widaman's confirmatory and competitive approach (Belsky & Widaman, 2018; Jolicoeur-Martineau et al., 2020; Widaman et al., 2012). To examine the interaction between SPS and Life Event for each week, we set up weekly statistical models, i.e. we analyzed four models. In addition, the trend of the interaction between SPS and events over a month was shown by performing an analysis using the mean score of over a month. In the series of analyses, socioemotional well-being was included as the dependent variable, the 19-item J-HSCS (i.e. SPS) was included as the moderator, and the life event and interaction term with SPS was included as the predictors.

Based on Widaman et al. (2012), we used a nonlinear regression program to estimate the parameters of the regression model. The equation for the re-parameterized regression model can be written as:

$$Y_{tn} = B_{0tn} + B_{1tn}(X_{1tn} - C_{tn}) + B_{3tn}\big((X_{1tn} - C_{tn})X_{2tn}\big) + E_{tn},$$

where Y_{tn} represents the dependent variable (i.e. socioemotional well-being) at Time n, X_{1tn} represents the environment predictor (i.e. life event) at Time n, X_{2tn} represents the sensitivity predictor (i.e. SPS) at Time n, C_{tn} is the point on X_{1tn} at which the slopes for the high-sensitivity group and low-sensitivity group cross, B_{0tn} stands for the intercept representing the Y_{tn} score on C_{tn} at Time n, B_{1tn} and B_{3tn} are the regression coefficients at Time n for, respectively. E_{tn} refers to a stochastic error term at Time n.

Figure 1 is a graph depicting the difference between differential susceptibility, diathesis-stress, and vantage sensitivity. As it shows, the position of C on X_1 distinguishes between models (Jolicoeur-Martineau et al., 2020; Widaman et al., 2012). If C is within the range of the values on X_1, observed in the current study, the model supports differential susceptibility (i.e., the middle part of Figure 1). If C is at or above the most positive values on X_1 in this study, the model is consistent with diathesis-stress (i.e. the upper part of Figure 1). In contrast, if C is at or below the lowest values on X_1, the model suggests vantage sensitivity (i.e. the lower part of Figure 1).

Additionally, the regression model described above can compare alternative models, such as a strong model and a weak model. The strong model fixes the slope for the non-sensitivity group at 0 (i.e., $B_1 = 0$), whereas the weak model does not impose such constraints on the slope for the non-sensitivity group (i.e., $B_1 \neq 0$).

Using the LEGIT package (Jolicoeur-Martineau et al., 2020), "GxE_interaction_test" function (Jolicoeur-Martineau et al., 2019), and "nls" functions of R statistical software, the current study compared six regression alternative models: strong differential susceptibility (Model 1a), weak differential susceptibility (Model 1b), strong diathesis-stress (Model 2a), weak diathesis-stress (Model 2b), strong vantage sensitivity (Model 3a), and weak vantage sensitivity (Model 3b). The optimal model was evaluated based on the Bayesian information criterion (BIC) and the Akaike information criterion (AIC): the lower the value, the better the model.

Additional Analysis

Finally, this study conducted an additional analysis to examine, from a different perspective, whether the findings supported by the above competitive model approach are robust. While the series of analyses above focused on cross-sectional relationships, this additional analysis examined predictive relationships. Specifically, we used Widaman's competitive approach to investigate how the SPS x Life Event interactions at one previous occasion (i.e. Time $n - 1$) explained socioemotional well-being at the next occasion (i.e. Time n).

Missing Data Analysis

Of the participants, 79% (n = 90) participated in the survey at all time points and 21% (n = 24) did not participate in at least one survey. With respect to baseline variables, students who participated in the survey at all time points had higher mean values for current life events ($t[109] = 3.64$, $p < .001$) and socioemotional well-being ($t[109] = 2.70$, $p = .008$) compared to those who dropped out. Little's missing completely at random (MCAR) test suggested that our longitudinal data, including J-HSCS, life event, and WHO-5, were not MCAR ($\chi^2 = 450.74$, $df = 190$, $p < .001$). Therefore, missing data in the current sample were handled with pairwise or listwise deletion. All analyses were conducted on R, version 3.4.4 (R Core Team, 2018) and its interface RStudio, version 1.2.5001. Our data will be shared in public repository (https://osf.io/xxxxxxxxxxx).

Results

Preliminary Analysis

Table 1 shows the means and standard deviations for all measurements over a month. The histogram of each variable can be seen in Open Science Framework (https://osf.io/ayf93/?view_only=fce70d7beb324c0b803f2eccbca7f27e).

[Table 1]

Autocorrelations and Intraclass Correlations

The autocorrelation coefficients between all time points were $r = .57 \sim .80$ ($p < .001$) for SPS, $r = .63 \sim .75$ ($p < .001$) for socioemotional well-being, and $r = .26 \sim .29$ ($p < .05$; Week 1 was not significantly correlated with Week 3 and Week 4: both $r = .15$) for Life Event. The ICC showed good test-retest stability with 0.70 ($p < .001$) for SPS, and moderate stability with 0.66 ($p < .001$) for socioemotional well-being. In contrast, the ICC for Life Event was small with 0.18 ($p < .001$), suggesting there was a relatively large intra-individual change.

Bivariate Correlations between Measures

Bivariate correlations between all measures are presented in Table 2. SPS showed a small negative or no correlation with socioemotional well-being. Also, SPS has no significant correlation with Life Events. Overall, life events were positively correlated with Socioemotional Well-being.

[Table 2]

Effects of Time and Gender

A two-factor mixed-design analysis of variance with SPS as the dependent variable and Gender × Time as the independent variable showed that neither the main effect nor the interaction effect was significant. When socioemotional well-being was used as the dependent variable, Gender × Time was significant ($F(3, 257) = 3.25$, $p = .024$), but no significant difference was found at any level in the post hoc analysis. When Life Event was used as the dependent variable, Gender × Time was significant ($F(3, 246) = 2.87$, $p = .037$), and post hoc analysis showed that only males had a significantly higher mean for Week 1 than Week 3 ($t = 3.08$, $df = 82$, adjust $p = .017$).

SPS x Life Event Interaction

Before performing the confirmatory competitive analysis, I performed a series of standard (i.e., exploratory) regression analyses using weekly and monthly data, including the main effects model and the interaction effects model. Detailed estimates are shown in the supplementary Table S1 ~ S5 on the OSF. According to these estimates, the F ratio when an interaction term is added exceeds 1 in the Week 2 and the entire month models, which sufficiently satisfies the criteria for proceeding to confirmatory competitive analysis (Belsky & Widaman, 2018). However, in the other week models (Weeks 1, 3, and 4), the F ratio was below 1. Although it may not be necessary to initiatively perform the confirmatory competitive analysis of these weeks, showing these findings may have some merit in capturing the differences between weeks and the overall picture of the current sample. Therefore, the current study presents the results of confirmatory competitive analysis in all weeks.

Week 1

As shown in Table 3, the smallest BIC and AIC supported the strong vantage sensitivity model (Model 2a; BIC = 277.54 and AIC = 269.41) as the best fit to explain SPS x Life Event interaction in Week 1. The crossover point in this model was the minimum value ($C = \min(X_1) = -3$) of the environmental variable (i.e., Life Event) observed in this study. The estimated score for socioemotional well-being on C was $B_0 = 2.12$ ($SE = 0.19$, $p < .001$). The slope for the low-sensitivity students (B_1) was fixed at 0.00. The interaction term was $B_3 = 0.03$ ($SE = 0.01$, $p < .001$). Figure 2 shows the different patterns in the relationship between life events and socioemotional well-being among highly sensitive (top 97.5%), middle sensitive (50%), and low sensitive (bottom 2.5%) adolescents.

[Table 3] [Figure 2]

Week 2

The strong diathesis-stress was selected as the model describing the optimal shape of SPS x Life Event interaction in Week 2 (Model 3a; BIC = 245.05 and AIC = 237.45; Table 4). As illustrated in Figure 2, the crossover point in this model was at the max end ($C = \max(X_1) = 3$) of the environmental variable. The intercept on the crossover point, B_0, was 3.36 ($SE = 0.14$, $p < .001$). The slope for the low-sensitivity students was stable ($B_1 = 0.00$) and the interaction term was significant ($B_3 = 0.04$, $SE = 0.01$, $p < .001$).

[Table 4]

Week 3

The smallest BIC and AIC proposed the strong diathesis-stress model (Model 3a; BIC = 275.73 and AIC = 267.85; Table 5). As shown in Figure 2, the crossover point was located at 3.00 on the life event and the intercept was 3.36 (SE = 0.15, p < .001) in this model. As in Week 2, only the highly sensitive students benefited from supportive life events (B_3 = 0.04, SE = 0.01, p < .001), whereas students with low sensitivity showed resistance to the quality of life events (B_1 = 0.00).

[Table 5]

Week 4

In Week 4, both BIC and AIC supported the weak vantage sensitivity model (Model 2b; BIC = 287.59 and AIC = 277.21; Table 6). The crossover point was -3.00 and the intercept was 2.20 (SE = 0.28, p < .001). The slope for students with low sensitivity was B_1 = 0.00; the interaction term was B_3 = -0.09 (SE = 0.03, p = .006). As depicted in Figure 2, this model can be seen as the contrastive effects of the model (Belsky et al., 2007) rather than the weak vantage sensitivity model. The theory of *Environmental Sensitivity* posits that highly sensitive individuals are more susceptible to both positive and negative environmental influences than others. On the contrary, the results suggest that highly sensitive adolescents are less susceptible to life events than those with low sensitivity. In addition, it differs significantly from the estimates of other weeks. Therefore, the robustness of this finding may be questionable. This certainty is discussed again in the additional analysis section.

[Table 6]

Entire Month

As shown in Table 7, analysis using one-month mean score for each variable supported the strong diathesis-stress model (Model 3a; BIC = 192.71 and AIC = 185.60)[3]. As can be seen in Figure 2, the point where the two regression lines cross was 3.00. The socioemotional well-being at C was 3.31 (SE = 0.18, p < .001). For students with low sensitivity, their regression line was parallel to the degree of life event (B_1 = 0.00). For students with high sensitivity, the one-month mean score for socioemotional well-being improved as the quality of life events was more

[3] From a longitudinal perspective, I explored whether the interaction between SPS and life events significantly predicted the intercept and slope of socioemotional well-being over one month, using a latent growth curve model (see Supplementary Figure S1). The results showed that the interaction between the centralized one-month mean SPS and life events significantly predicted the intercept of socioemotional well-being (b = 0.24, SE = 0.11, p = .034; see Supplementary Table S6). However, a simple slope test showed that no statistically significant effect could be detected in this sample for both the high (+1SD; b = 0.81, SE = 0.52, p = .119) and low (-1SD; b = -1.14, SE = 0.67, p = .091) SPS adolescents.

supportive (B_3 = 0.05, SE = 0.02, p = .002).

[Table 7] [Supplementary Figure S1] [Supplementary Table S6]

Additional Sensitivity Analysis

To examine whether the results of the above cross-sectional analysis are robust, we conducted an additional analysis based on a predictive perspective. Specifically, using the same Widaman's confirmatory approach, I tested which model best fitted the data when the SPS x Life Event interaction at Time $n - 1$ explained socioemotional well-being at Time n. As can be seen in Appendix Figure A, the series of additional analyses supported the finding that strong diathesis-stress was best fitted to the current data in all models predicting socioemotional well-being at Week 2 to 4. These results were consistent with the findings of Weeks 2 and 3 above, but not Week 4. Therefore, strong diathesis-stress may be a more appropriate model than the weak vantage sensitivity model in Week 4. Details of the estimated parameters are shown in supplementary Table S6~S8 on the OSF.

[Supplementary Table S7 – S9] [Appendix Figure A]

Discussion

Recent theoretical refinements have strengthened the view that *Environmental Sensitivity* is a *susceptibility* factor rather than a *vulnerability* factor in ontogenetic development (e.g. Belsky & Pluess, 2009). Based on this new perspective, the current study examined the role of SPS, a personality trait of *Environmental Sensitivity*, in the relationship between current life events and current socioemotional well-being in adolescents. The results based on Widaman's confirmatory approach suggested that the data including four time points fitted both the diathesis-stress model and the vantage sensitivity model. Specifically, this study revealed that adolescents with high SPS were more likely to be affected by not only negative life events but also positive ones, resulting in an increase in their socioemotional well-being. This result supports the view that SPS measured by the HSCS is a susceptibility factor.

"Dark Side" of Environmental Sensitivity

In Week 2 and 3, the SPS x Life Event interaction supported the strong version of diathesis-stress model. That is, as with the traditional view of sensitivity (Monroe & Simons, 1991), adolescent's SPS functioned as *vulnerability* when they experienced many negative life events. In contrast, low-sensitivity adolescents showed resilience regardless of the quality of life events. These findings are not surprising, given that the adolescent's SPS correlates positively with depression and anxiety (e.g. Liss et al., 2005; 2008). These results may simply reflect that the highly sensitive person was more likely to be overstimulated.

Regarding the mechanism, Greven et al. (2019) hypothesize that "greater depth of processing, in interaction with emotional reactivity, is the core underlying component, leading to greater awareness of subtleties and ease of overstimulation (p. 290)." Another possibility that SPS is associated with low socioemotional well-being may be the issue that the HSCS used to measure SPS is more likely to consist of items that are rather negatively phrased; thus, if there are many negative life events, it may be easier to show a negative association with socioemotional well-being.

In Week 4, although each information criterion suggested the weak version of the vantage sensitivity model, its shape of interaction was too different from ones in other weeks and the entire month. One possibility is that the solutions did not converge, and therefore, the results of additional sensitivity analyses may be more appropriate to interpret SPS x Life Event interaction in Week 4 (Figure A). In fact, an additional analysis suggested that the shape of the SPS x Life Event interaction in Week 4 supported the strong diathesis-stress model as well as the results of Week 2, Week 3, and the entire month. Other possible interpretations imply that the mechanisms of interaction between SPS and everyday life events may be more complex than the researchers assumed. As can be inferred from the various interaction shapes reported in recent Person x Environment interaction studies (see Belsky et al., 2015; Belsky et al., 2021), the significant dynamics of adaptation to environmental influences can be observed in highly sensitive individuals. This possibility has been more recently described as "differential, differential susceptibility," suggesting that individuals who are susceptible to one environment may be less susceptible to another (Belsky et al., 2021). In light of this fact, it is not surprising that different shapes of interactions (e.g., strong or weak versions of diathesis-stress, differential susceptibility, and vantage sensitivity) may be identified for each week, as the results of this study show.

"Bright Side" of Environmental Sensitivity

What is noteworthy about this study is *not* that adolescents' SPS negatively moderates the relationship between adverse environmental experiences and developmental outcomes discussed above. Rather, this study most notably provided evidence of the *bright side* of *Environmental Sensitivity*, namely, the vantage sensitivity. In contrast to Week 2 and 3, the SPS x

Life Event interaction in Week 1 supported the strong version of vantage sensitivity. In this model, only highly sensitive adolescents benefit from positive life events, whereas low sensitive adolescents remain stable under supportive environments and this is called vantage resistance (Pluess, 2017). What the finding suggests is that adolescent's SPS should be interpreted as a *susceptibility* rather than simply a *vulnerability*. In the context of this study, adolescents with high SPS were more likely to decrease their socioemotional well-being through negative life events and to improve well-being through supportive life events. Such a *for better* and *for worse* pattern was also confirmed in the daily level of SPS x Life Event interaction.

Much remains unclear about the neurobiological mechanisms of vantage sensitivity; however, it is possible that highly sensitive individuals more easily and deeply register positive life experiences in the central nervous system (Belsky & Pluess, 2009), thereby resulting in the higher socioemotional well-being score, including items such as *I have felt cheerful and in good spirits* and *I have felt calm and relaxed*, when they experienced many positive life events. Although research on vantage sensitivity is still limited, some studies have reported findings that assumed the benefits of such a "highly sensitive brain." In school context, for example, school-based intervention programs predicted subsequent positive developmental outcomes (e.g. decrease in depression and victimization) for children with high SPS (Nocentini et al., 2018; Pluess & Boniwel, 2015). In addition, positive changes in the school environment explained the subsequent increase in socioemotional well-being among highly sensitive adolescents (Iimura & Kibe, 2020). In the experimental context, fMRI (functional magnetic resonance imaging) studies found that, in comparison to that of clinical cases of sensory atypicality, SPS differs in response to reward processing of social stimuli, empathy, and the areas of self-control, which implies positive aspects of SPS in environmental interaction (Acevedo, Aron, Pospos, & Jessen, 2018). Given these findings, it may be important to consider individual differences in SPS for planning any positive intervention to promote the individual's daily level of socioemotional well-being.

Why is the Vantage Sensitivity Only Partially Supported?

Overall, the results of the monthly and additional analyses have supported the diathesis-stress model rather than the vantage sensitivity model. In other words, the results suggested the robustness of findings in Week 2 to 4 not only from a cross-sectional perspective but also from a predictive perspective. However, why did this study reveal only partial findings that support vantage sensitivity? One possible explanation for this is the nature of the scale used to measure adolescent's SPS. As noted in the most recent review (Greven et al., 2019), the HSP/HSC scale includes relatively fewer items that reflect the positive aspects of sensitivity (i.e., AES subscale) than those that reflect the negative aspects (i.e., EOE and LST subscales). Only the AES subscale corresponds to positive side of sensitivity, which consists of positively worded items (e.g., "some music can make me really happy", "I love nice tastes")[4]. Improvements in the scale may increase evidence supporting vantage sensitivity.

Finally, why did the shape of the interaction differ from week to week? In other words, why was vantage sensitivity supported at Week 1 and consistent with diathesis-stress at Weeks 2 to 4? Could this be the case? Given that high sensitivity or high developmental plasticity can be characterized as a life history strategy of "conditional adaptation" with an evolutionary background (e.g., Del Giudice, 2017; Ellis & Del Giudice, 2019), it is quite possible that different interaction shapes could be observed from week to week. The adaptive developmental plasticity exhibited by highly sensitive adolescents is "the outcome of structured interplay between the organism and its environment, shaped by natural selection to increase the capacity of individuals to track both their internal condition and their external environments and, integrating this information, to adjust the development of their phenotypes accordingly" (Ellis & Del Giudice, 2019, p. 114). The dynamics of conditional adaptation observed in the present study could have been confirmed by analyzing interactions over short intervals, such as in the experience sampling method. Another potential possibility, as discussed above, is that in this study, "differential, differential susceptibility" may have been observed according to weekly life events (Belsky et al., 2021). This suggests that the susceptible adolescents showed vantage sensitivity to a particular life event in a particular week while they showed diathesis-stress to another life event in another week.

Strengths and Limitations

The current study has the following methodological strengths: 1) enhancing ecological validity using short-term and multi-time point survey that are close to an experience sampling method; 2) enhancing the robustness of findings from both predictive and cross-sectional

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[4] Although not included in the aim of this study, I have examined the above possibilities. Specifically, the series of analysis of the SPS x Life Event interaction for each week shown in the results section was reanalyzed using only the AES subscale. The findings for all weeks supported the strong vantage sensitivity model. The detailed estimates can be seen in the Supplementary Table (Table S10 ~ S13). Given these results of reanalysis, it is not desirable to conclude that highly sensitive adolescents develop their own daily socioemotional well-being in the diathesis-stress manner.

analyses; and 3) utilizing Widaman's confirmatory competitive model testing, which maximizes statistical power by parameterizing the crossover point to allow for a direct comparison of alternative models. These strengths will contribute to enhancing the validity of the concept of *Environmental Sensitivity*.

Although this article presented the first evidence of vantage sensitivity in the context of the adolescent's daily life, several limitations need to be addressed for future advancement. First, all variables measured in this study rely on self-reporting. Several studies have reported that parental ratings of child susceptibility moderate environmental quality and developmental outcomes (e.g. Slagt, Dubas, Van Aken, Ellis, & Deković, 2018). Given these attempts to better interpret the findings of this study, it may be appropriate to consider whether using a multi-informant assessment is reproducible. Second, it is not desirable to over-generalize the findings of this study using Japanese data, as ethnic/cultural differences in *Environmental Sensitivity* remain unclear. Further elaboration of the sensitivity concept will require additional knowledge from Asian countries, including Japan, and international comparisons. Third, the findings of this study should not be overly generalized as it solely relies on data from university students in Tokyo. Forth, the quality of life events reported in this study were likely to be more positive and so lead to the findings supporting the vantage sensitivity. Relatedly, future research may need to develop and use it as more valid measures of both positive and negative current life events. Fifth, it may be possible to further understand the characteristics of sensitive adolescents by controlling for other environmental factors that are assumed to influence socioemotional well-being during adolescence. For example, in the research area of *Environmental Sensitivity*, the parent-child relationship and the school environment have been examined as important environmental factors related to socioemotional development. Finally, the results for Weeks 1, 3, and 4 should be interpreted as suggestive at best, as they do not strictly meet Widaman's criteria (F-ratio > 1). Also, as mentioned above, Widaman's approach has merit with respect to statistical power, but may have been underpowered due to the relatively small sample size of this study.

Conclusions

Are sensitive adolescents simply vulnerable? We may need to reconsider the diathesis-stress view of sensitivity. If we were to describe more accurately the highly sensitive adolescents, it is that they are more susceptible to environmental influences – *for better* and *for worse* – as a result of their own temperamental, physiological, and genetic makeup (Belsky et al., 2015). The current study provided an opportunity to reconsider the role of adolescents' temperamental marker of *Environmental Sensitivity* in the relationship between weekly life events and weekly socioemotional well-being. Adolescents with high sensitivity are more likely to be affected by recent positive life events than those with low sensitivity. It may positively contribute to their current socioemotional well-being. Importantly, the shape of the Susceptibility × Life event interaction can vary widely from week to week.

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Table 1

Descriptive Statistics for Measures in Each Week and Entire Month

	Week 1 (Time 1)		Week 2 (Time 2)		Week 3 (Time 3)		Week 4 (Time 4)		Entire month	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Sensitivity	5.08	(0.73)	5.15	(0.76)	5.27	(0.77)	5.24	(0.78)	5.18	(0.68)
Well-being	2.84	(0.80)	2.96	(0.93)	2.93	(0.92)	2.89	(1.03)	2.91	(0.81)
Life event	1.03	(1.60)	0.75	(1.62)	0.73	(1.58)	0.92	(1.47)	0.86	(0.98)

Note. Sensitivity = Highly Sensitive Child Scale (i.e., sensory-processing sensitivity), Well-being = WHO-5 index (i.e., socioemotional well-being), Life event = Life events recent one week.

Table 2

Bivariate Correlations for All Measures

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Sensitivity W1	–													
2	Sensitivity W2	.75**	–												
3	Sensitivity W3	.69**	.75**	–											
4	Sensitivity W4	.57**	.77**	.81**	–										
5	Well-being W1	-.01	.03	-.16	-.22*	–									
6	Well-being W2	-.06	-.09	-.07	-.15	.63**	–								
7	Well-being W3	-.13	-.07	-.17	-.23*	.63**	.75**	–							
8	Well-being W4	-.07	-.06	-.10	-.18	.57**	.66**	.75**	–						
9	Life event W1	-.12	-.02	-.04	-.05	.34**	.22*	.31**	.10	–					
10	Life event W2	.02	-.08	-.05	-.07	.20	.31**	.27*	.19	.26*	–				
11	Life event W3	-.08	-.04	-.17	-.04	.15	.14	.35**	.30**	.15	.29**	–			
12	Life event W4	.04	.20	.13	.14	.22*	.21*	.16	.27**	.15	.24*	.26*	–		
13	Sensitivity 1M	.83**	.90**	.92**	.87**	-.14	-.11	-.16	-.06	-.08	-.04	-.10	.22*	–	
14	Well-being 1M	-.05	-.06	-.11	-.22*	.81**	.88**	.90**	.87**	.20	.27*	.21	.19	-.13	–
15	Life event 1M	-.01	.03	-.01	.00	.31**	.33**	.33**	.22*	.55**	.73**	.62**	.58**	.01	.33**

Note. Sensitivity = Highly Sensitive Child Scale (i.e., sensory-processing sensitivity), Well-being = WHO-5 index (i.e., socioemotional well-being), Life event = Life events recent one week, W1 = Week 1, W2 = Week 2, W3 = Week 3, W4 = Week 4, 1M = mean score of one month.

** $p < .01$, * $p < .05$

Table 3

Model Comparison of Sensitivity × Life Event Interactions at Week 1 (Time 1)

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**2.57**	**(0.54)**	<.001	1.45	(14.39)	.920	**3.09**	**(0.13)**	<.001	**3.13**	**(0.13)**	<.001	**2.12**	**(0.19)**	<.001	**2.06**	**(0.20)**	<.001
B_1	0.00	(−)[a]	*NA*	0.15	(0.33)	.657	0.00	(−)[a]	*NA*	0.23	(0.23)	.314	0.00	(−)[a]	*NA*	0.13	(0.13)	.324
C	-0.16	(3.11)	.959	-6.40	(80.34)	.937	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*
B_3	**0.03**	**(0.01)**	<.001	0.01	(0.06)	.923	**0.03**	**(0.01)**	<.001	-0.01	(0.04)	.801	**0.03**	**(0.01)**	<.001	0.01	(0.02)	.662
pseudo R^2		0.11			0.11			0.11			0.11			0.11			0.11	
BIC		281.44			285.95			277.71			281.38			277.54			281.24	
AIC		270.61			272.40			269.58			270.54			269.41			270.40	

Note. B_0 = intercept representing the estimated *Y* score (socioemotional well-being) on *C* (crossover point); B_1 = slope for the low sensitivity group; *C* = the point on X_1 (life event) at which the slopes for the high sensitivity group and low sensitivity group cross, B_3 = slope for the high sensitivity group; BIC = Bayesian information criterion; AIC = Akaike information criterion; Coeff. = coefficient; *SE* = standard error; *NA* = not available. Bold values are statistically significant parameters. The environment variables (X_{1tn}), life events, can range from -3 to +3.

[a] Parameter fixed at reported value (*SE* is not applicable).

Table 4

Model Comparison of Sensitivity × Life Event Interactions at Week 2 (Time 2)

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**3.24**	**(0.57)**	<.001	**3.02**	**(0.20)**	<.001	**3.36**	**(0.14)**	<.001	**3.33**	**(0.15)**	<.001	**2.33**	**(0.21)**	<.001	**2.26**	**(0.22)**	<.001
B_1	0.00	(—)[a]	*NA*	-0.39	(0.34)	.255	0.00	(—)[a]	*NA*	-0.10	(0.20)	.610	0.00	(—)[a]	*NA*	0.15	(0.15)	.325
C	2.32	(3.11)	.456	1.16	(1.07)	.283	3.00	(—)[a]	*NA*	3.00	(—)[a]	*NA*	-3.00	(—)[a]	*NA*	-3.00	(—)[a]	*NA*
B_3	**0.04**	**(0.01)**	<.001	0.11	(0.06)	.092	**0.04**	**(0.01)**	<.001	0.05	(0.04)	.147	**0.03**	**(0.01)**	.002	0.01	(0.03)	.840
pseudo R^2		0.13			0.14			0.13			0.13			0.10			0.11	
BIC		249.53			252.70			245.05			249.31			247.92			251.45	
AIC		239.40			240.04			237.45			239.18			240.32			241.32	

Note. See note in Table 3 for what the parameters and abbreviations mean.

Table 5

Model Comparison of Sensitivity × Life Event Interactions at Week 3 (Time 3)

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**3.72**	**(0.64)**	<.001	**3.27**	**(0.42)**	<.001	**3.36**	**(0.15)**	<.001	**3.31**	**(0.16)**	<.001	**2.29**	**(0.22)**	<.001	**2.17**	**(0.22)**	<.001
B_1	0.00	(−)[a]	*NA*	-0.24	(0.37)	.522	0.00	(−)[a]	*NA*	-0.21	(0.24)	.391	0.00	(−)[a]	*NA*	0.29	(0.16)	.072
C	5.09	(3.87)	.191	2.77	(2.32)	.236	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*
B_3	**0.04**	**(0.01)**	<.001	0.08	(0.07)	.247	**0.04**	**(0.01)**	<.001	0.07	(0.04)	.088	**0.03**	**(0.01)**	.003	-0.02	(0.03)	.538
pseudo R^2	0.14			0.14			0.13			0.14			0.09			0.12		
BIC	280.01			284.20			275.73			279.59			280.92			282.20		
AIC	269.51			271.08			267.85			269.09			273.04			271.70		

Note. See note in Table 3 for what the parameters and abbreviations mean.

Table 6

Model Comparison of Sensitivity × Life Event Interactions at Week 4 (Time 4)

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**4.74**	**(0.68)**	<.001	1.61	(2.22)	.470	**3.31**	**(0.18)**	<.001	**3.29**	**(0.18)**	<.001	**2.61**	**(0.27)**	<.001	**2.20**	**(0.28)**	<.001
B_1	0.00	(−)[a]	*NA*	0.46	(0.43)	.280	0.00	(−)[a]	*NA*	-0.28	(0.26)	.275	0.00	(−)[a]	*NA*	**0.64**	**(0.18)**	<.001
C	**10.78**	**(4.83)**	.028	-5.96	(10.97)	.588	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*
B_3	**0.04**	**(0.01)**	.010	-0.05	(0.08)	.525	**0.04**	**(0.01)**	.007	0.09	(0.05)	.071	0.01	(0.01)	.274	**-0.09**	**(0.03)**	.006
pseudo R^2	0.12			0.13			0.07			0.09			0.01			0.13		
BIC	288.60			291.97			288.73			292.09			295.08			287.59		
AIC	278.22			279.00			280.94			281.71			287.29			277.21		

Note. See note in Table 3 for what the parameters and abbreviations mean.

Table 7

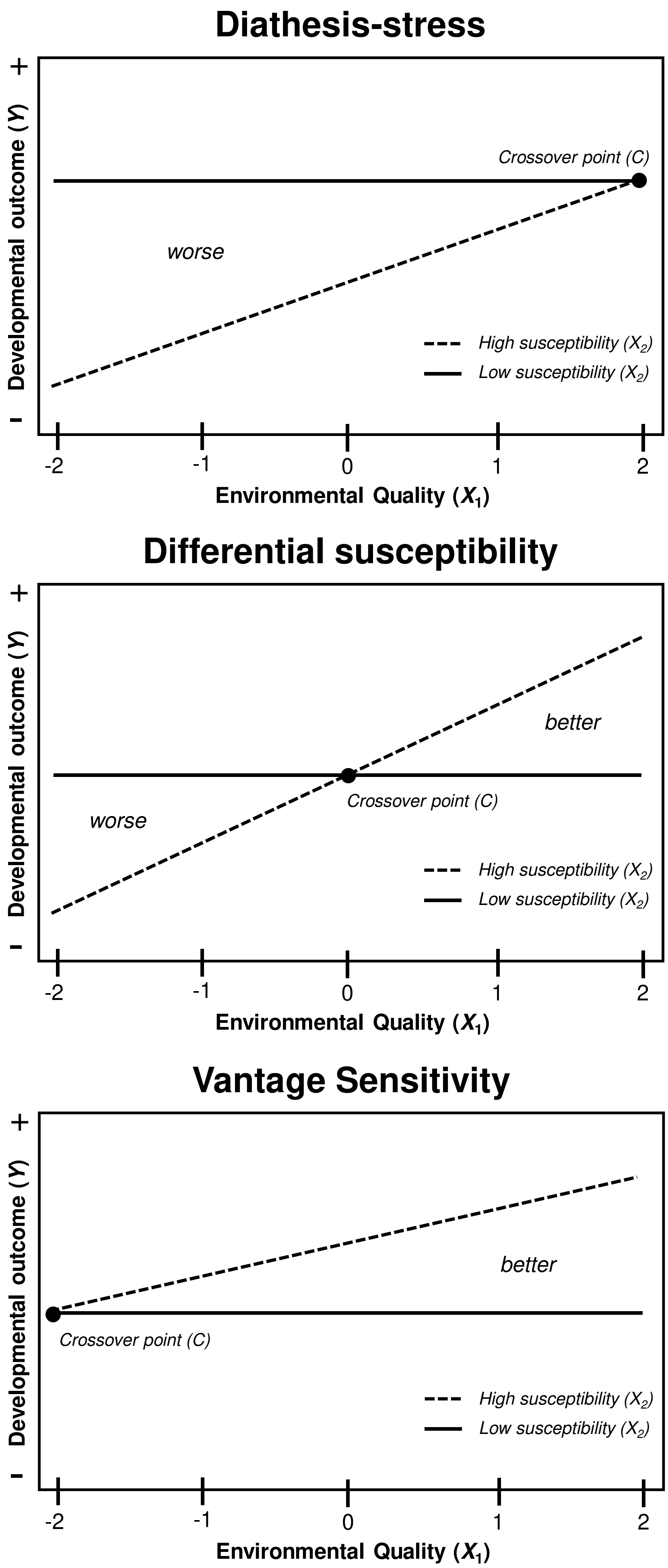
Model Comparison of Sensitivity × Life Event Interactions Over the Course of a Month

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**3.69**	**(0.67)**	<.001	**3.17**	**(0.30)**	<.001	**3.45**	**(0.19)**	<.001	**3.42**	**(0.20)**	<.001	**2.40**	**(0.22)**	<.001	**2.26**	**(0.24)**	<.001
B_1	0.00	(−)[a]	*NA*	-0.58	(0.66)	.380	0.00	(−)[a]	*NA*	**-0.25**	**(0.33)**	.455	0.00	(−)[a]	*NA*	0.39	(0.26)	.138
C	3.77	(2.63)	.155	1.91	(1.06)	.076	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*
B_3	**0.05**	**(0.02)**	.003	0.16	(0.12)	.200	**0.05**	**(0.02)**	.002	0.10	(0.06)	.115	**0.04**	**(0.02)**	.015	-0.02	(0.05)	.591
pseudo R^2	0.12			0.13			0.12			0.13			0.06			0.10		
BIC	196.95			200.50			192.71			196.49			196.73			198.79		
AIC	187.47			188.65			185.60			187.02			189.62			189.32		

Note. See note in Table 3 for what the parameters and abbreviations mean

Figure 1

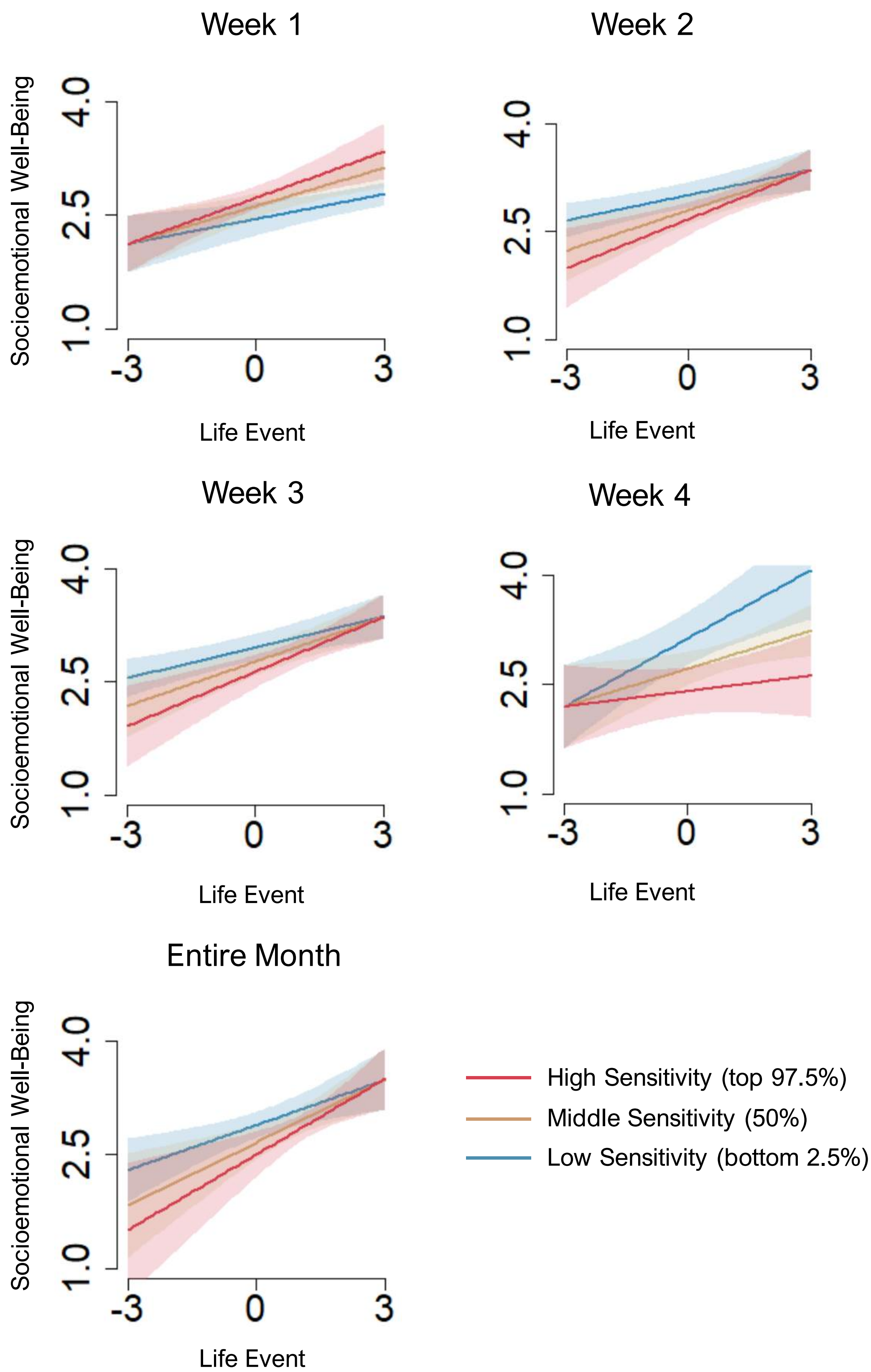
Graph Depicting the Difference between Diathesis-Stress, Differential Susceptibility, and Vantage Sensitivity



Note. X_1 represents the predictor of environmental measure; X_2 represents the moderator of the sensitivity measure; *Y* refers to the developmental outcome; and *C* is the point on X_1 at which the slope for the highly sensitive student and non-highly sensitivity student cross.

Figure 2

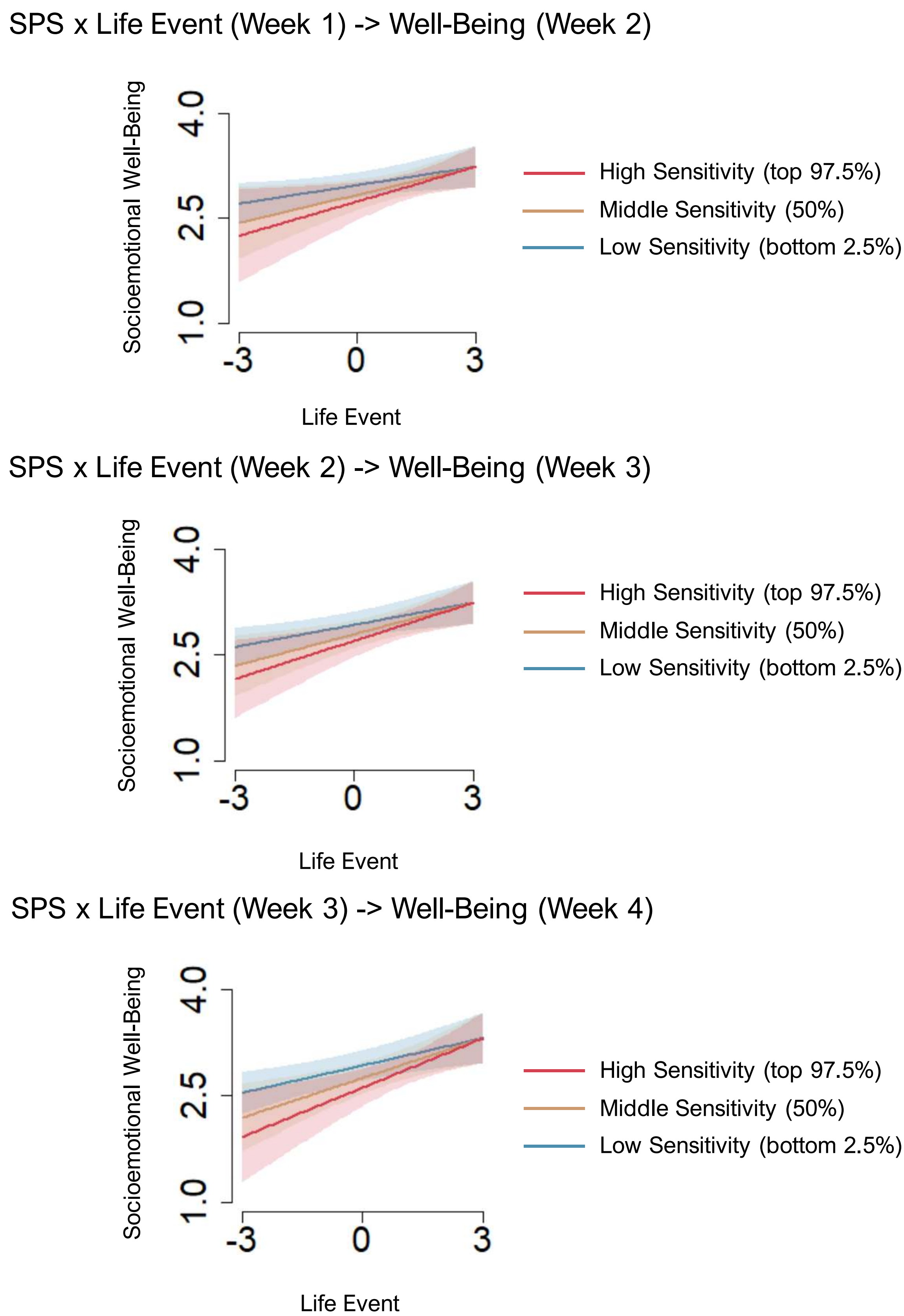
Sensory-Processing Sensitivity × Life Event Interactions



Appendix

Figure A

Additional Sensitivity Analysis from a Predictive Perspective



Supplementary Materials

Highly Sensitive Adolescents:

The Relationship Between Weekly Life Events and Weekly Socioemotional Well-Being

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Table S1

Standard Parameterized Regression for Socioemotional Well-being in Week 1

	Step 1 (Main effects model)		Step 2 (Interaction model)	
Parameter	Coeff. (*SE*)	*p*	Coeff. (*SE*)	*p*
B_0	2.84 (0.08)	<.001	2.84 (0.08)	<.001
B_1	0.14 (0.05)	.009	0.14 (0.05)	.011
B_2	0.08 (0.12)	.480	0.06 (0.12)	.613
B_3			0.04 (0.07)	.520
BIC	198.23		202.16	
AIC	188.75		190.31	
R^2	0.08		0.09	
F (df)	3.65 (2, 76)	.030	2.55 (3, 75)	.061
ΔR^2			0.01	
F (df)			0.41 (1, 75)	.520

Note. B_0 = intercept; B_1 = main effect of environment variable (i.e., life event); B_2 = main effect of sensitivity variable (i.e., sensory-processing sensitivity); B_3 = interaction effect of environment variable and sensitivity variable. BIC = Bayesian Information Criterion. AIC = Akaike Information Criterion. Coeff. = coefficient.

Table S2

Standard Parameterized Regression for Socioemotional Well-being in Week 2

	Step 1 (Main effects model)		Step 2 (Interaction model)	
Parameter	Coeff. (*SE*)	*p*	Coeff. (*SE*)	*p*
B_0	2.96 (0.09)	<.001	2.96 (0.09)	<.001
B_1	0.19 (0.06)	.002	0.16 (0.06)	.009
B_2	-0.09 (0.13)	.468	-0.07 (0.13)	.570
B_3			0.14 (0.08)	.104
BIC	218.62		220.20	
AIC	209.14		208.36	
R^2	0.12		0.15	
F (df)	5.43 (2, 76)	.006	4.59 (3, 75)	.005
ΔR^2			0.03	
F (df)			2.69 (1, 75)	.104

Note. B_0 = intercept; B_1 = main effect of environment variable (i.e., life event); B_2 = main effect of sensitivity variable (i.e., sensory-processing sensitivity); B_3 = interaction effect of environment variable and sensitivity variable. BIC = Bayesian Information Criterion. AIC = Akaike Information Criterion. Coeff. = coefficient.

Table S3

Standard Parameterized Regression for Socioemotional Well-being in Week 3

	Step 1 (Main effects model)		Step 2 (Interaction model)	
Parameter	Coeff. (*SE*)	*p*	Coeff. (*SE*)	*p*
B_0	2.93 (0.10)	<.001	2.94 (0.10)	<.001
B_1	0.09 (0.06)	.138	0.08 (0.06)	.199
B_2	-0.15 (0.13)	.251	-0.15 (0.13)	.260
B_3			0.06 (0.07)	.405
BIC	223.38		227.02	
AIC	213.90		215.17	
R^2	0.05		0.06	
F (df)	2.14 (2, 76)	.124	1.65 (3, 75)	.183
ΔR^2			0.01	
F (df)			0.70 (1, 75)	.405

Note. B_0 = intercept; B_1 = main effect of environment variable (i.e., life event); B_2 = main effect of sensitivity variable (i.e., sensory-processing sensitivity); B_3 = interaction effect of environment variable and sensitivity variable. BIC = Bayesian Information Criterion. AIC = Akaike Information Criterion. Coeff. = coefficient.

Table S4

Standard Parameterized Regression for Socioemotional Well-being in Week 4

	Step 1 (Main effects model)		Step 2 (Interaction model)	
Parameter	Coeff. (*SE*)	*p*	Coeff. (*SE*)	*p*
B_0	2.89 (0.11)	<.001	2.90 (0.11)	<.001
B_1	0.16 (0.07)	.035	0.16 (0.07)	.041
B_2	-0.35 (0.14)	.018	-0.36 (0.15)	.017
B_3			-0.04 (0.09)	.662
BIC	237.61		241.78	
AIC	228.13		229.93	
R^2	0.09		0.10	
F (df)	4.16 (2, 76)	.019	2.80 (3, 75)	.045
ΔR^2			0.01	
F (df)			0.19 (1, 75)	.662

Note. B_0 = intercept; B_1 = main effect of environment variable (i.e., life event); B_2 = main effect of sensitivity variable (i.e., sensory-processing sensitivity); B_3 = interaction effect of environment variable and sensitivity variable. BIC = Bayesian Information Criterion. AIC = Akaike Information Criterion. Coeff. = coefficient.

Table S5

Standard Parameterized Regression for Socioemotional Well-being in Entire Month

	Step 1 (Main effects model)		Step 2 (Interaction model)	
Parameter	Coeff. (*SE*)	*p*	Coeff. (*SE*)	*p*
B_0	2.90 (0.08)	<.001	2.90 (0.08)	<.001
B_1	0.26 (0.08)	.004	0.24 (0.08)	.006
B_2	-0.14 (0.12)	.279	-0.16 (0.13)	.202
B_3			0.15 (0.12)	.200
BIC	197.87		200.50	
AIC	188.39		188.65	
R^2	0.11		0.13	
F (df)	4.74 (2, 76)	.011	3.74 (3, 75)	.014
ΔR^2			0.01	
F (df)			1.66 (1, 75)	.200

Note. B_0 = intercept; B_1 = main effect of environment variable (i.e., life event); B_2 = main effect of sensitivity variable (i.e., sensory-processing sensitivity); B_3 = interaction effect of environment variable and sensitivity variable. BIC = Bayesian Information Criterion. AIC = Akaike Information Criterion. Coeff. = coefficient.

Table S6

Latent Growth Curve Model for Predicting Socioemotional Well-Being by Sensory-Processing Sensitivity, Life Events, and their Interaction

Parameter	*Coefficient*	*SE*	*p*
SPS ⇒ Intercept (Well-being)	-0.17	0.12	.155
Life event ⇒ Intercept (Well-being)	0.26	0.08	.001
SPS × Life event ⇒ Intercept (Well-being)	0.24	0.11	.034
SPS ⇒ Slope (Socioemotional Well-being)	-0.00	0.04	.980
Life event ⇒ Slope (Well-being)	-0.01	0.03	.777
SPS × Life event ⇒ Slope (Well-being)	-0.05	0.04	.175
Intercept (Well-being) ⇔ Slope (Well-being)	0.05	0.02	.024

Note. SPS = sensory-processing sensitivity. Simple slope test revealed that the effect of life events on the intercept for socioemotional well-being was not statistically significant for adolescents with low (-1*SD*; *b* = -1.14, SE = 0.67, *p* = .091) or high (+1*SD*; *b* = -0.81, *SE* = 0.52, *p* = .119) SPS.

Table S7

Model Predicting Socioemotional Well-being in Week 2 by Sensitivity x Life Event in Week 1

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**3.29**	**(0.63)**	<.001	[b]	([b])	.995	**3.23**	**(0.15)**	<.001	3.24	**(0.15)**	<.001	**2.55**	**(0.24)**	<.001	**2.43**	**(0.26)**	<.001
B_1	0.00	(−)[a]	*NA*	[b]	([b])	.735	0.00	(−)[a]	*NA*	0.05	(0.28)	.862	0.00	(−)[a]	*NA*	0.19	(0.15)	.197
C	3.46	(5.05)	.495	[b]	([b])	.994	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*
B_3	**0.03**	**(0.01)**	.033	[b]	([b])	.994	**0.03**	**(0.01)**	.026	0.02	(0.05)	.754	0.02	(0.01)	.066	-0.01	(0.03)	.680
pseudo R^2		0.05			0.05			0.05			0.05			0.04			0.05	
BIC		270.99			275.44			266.42			270.96			268.04			270.89	
AIC		260.69			262.57			258.69			260.67			260.31			260.59	

Note. B_0 = intercept representing the estimated Y score (socioemotional well-being) on C (crossover point); B_1 = slope for the low sensitivity group; C = the point on X_1 (life event) at which the slopes for the high sensitivity group and low sensitivity group cross, B_3 = slope for the high sensitivity group; BIC = Bayesian information criterion; AIC = Akaike Information Criterion; Coeff. = coefficient; *SE* = standard error; *NA* = not available. Bold values are statistically significant parameters. The environment variables (X_{1tn}), life events, can range from -3 to +3.

[a] Parameter fixed at reported value (*SE* is not applicable).

[b] Improper solutions (not converged)

Table S8

Model Predicting Socioemotional Well-being in Week 3 by Sensitivity x Life Event in Week 2

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**3.20**	**(0.66)**	<.001	**2.97**	**(0.18)**	<.001	**3.24**	**(0.15)**	<.001	**3.21**	**(0.16)**	<.001	**2.41**	**(0.22)**	<.001	**2.35**	**(0.23)**	<.001
B_1	0.00	(−)[a]	*NA*	-0.46	(0.44)	.305	0.00	(−)[a]	*NA*	-0.13	(0.25)	.599	0.00	(−)[a]	*NA*	0.13	(0.18)	.455
C	2.69	(4.52)	.553	1.18	(1.18)	.320	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*
B_3	**0.03**	**(0.01)**	**.007**	0.11	(0.08)	.174	**0.03**	**(0.01)**	.005	0.05	(0.05)	.254	**0.03**	**(0.01)**	.013	0.00	(0.03)	.925
pseudo R^2	0.09			0.10			0.09			0.09			0.07			0.08		
BIC	237.65			241.01			233.19			237.37			234.83			238.71		
AIC	227.79			228.68			225.79			227.50			227.43			228.85		

Note. See note in Table S1 for what the parameters and abbreviations mean.

Table S9

Model Predicting Socioemotional Well-being in Week 4 by Sensitivity x Life Event in Week 3

Parameter	Differential Susceptibility						Diathesis-Stress						Vantage Sensitivity					
	Strong: Model 1a			Weak: Model 1b			Strong: Model 2a			Weak: Model 2b			Strong: Model 3a			Weak: Model 3b		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
B_0	**3.27**	**(0.77)**	<.001	**3.19**	**(0.82)**	<.001	**3.31**	**(0.18)**	<.001	**3.31**	**(0.19)**	<.001	**2.22**	**(0.26)**	<.001	**2.13**	**(0.27)**	<.001
B_1	0.00	(−)[a]	*NA*	-0.05	(0.44)	.912	0.00	(−)[a]	*NA*	-0.01	(0.29)	.976	0.00	(−)[a]	*NA*	0.24	(0.19)	.218
C	2.57	(4.25)	.520	2.36	(4.38)	.591	-3.00	(−)[a]	*NA*	-3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*	3.00	(−)[a]	*NA*
B_3	**0.04**	**(0.01)**	**.004**	0.04	(0.08)	.576	**0.04**	**(0.01)**	.002	0.04	(0.05)	.459	**0.03**	**(0.01)**	.007	-0.01	(0.03)	.844
pseudo R^2	0.09			0.09			0.09			0.09			0.07			0.09		
BIC	298.61			303.17			294.04			298.61			296.14			299.14		
AIC	288.31			290.30			286.32			288.31			288.42			288.84		

Note. See note in Table S1 for what the parameters and abbreviations mean.

Table S10

SPS x Life Events Interaction using only Aesthetic Sensitivity Subscale in Week 1

Model	BIC	crossover	crossover 95%
Vantage sensitivity STRONG	274.76	-3	
E only	278.13	NA	
Diathesis-stress STRONG	278.78	3	
G + E only	279.01	NA	
Differential susceptibility STRONG	279.19	-5.12	(-6.06 / -4.17)
Vantage sensitivity WEAK	279.36	-3	
Diathesis-stress WEAK	279.79	3	
Differential susceptibility WEAK	283.72	69.19	(68.25 / 70.12)
Intercept only	288.42	NA	
G only	289.10	NA	

Table S11

SPS x Life Events Interaction using only Aesthetic Sensitivity Subscale in Week 2

Model	BIC	crossover	crossover 95%
Vantage sensitivity STRONG	252.19	-3	
E only	254.94	NA	
Diathesis-stress STRONG	255.57	3	
Vantage sensitivity WEAK	255.80	-3	
Differential susceptibility STRONG	256.63	-4.3	(-5.36 / -3.24)
G + E only	258.04	NA	
Differential susceptibility WEAK	259.16	-0.81	(-1.79 / 0.16)
Diathesis-stress WEAK	259.48	3	
Intercept only	270.32	NA	
G only	273.47	NA	

Table S12

SPS x Life Events Interaction using only Aesthetic Sensitivity Subscale in Week 3

Model	BIC	crossover	crossover 95%
Vantage sensitivity STRONG	277.63	-3	
E only	279.75	NA	
Diathesis-stress STRONG	280.26	3	
Vantage sensitivity WEAK	281.94	-3	
Differential susceptibility STRONG	282.26	-3.36	(-4.29 / -2.43)
G + E only	283.36	NA	
Differential susceptibility WEAK	284.38	-0.62	(-1.57 / 0.33)
Diathesis-stress WEAK	285.78	3	
Intercept only	293.05	NA	
G only	295.23	NA	

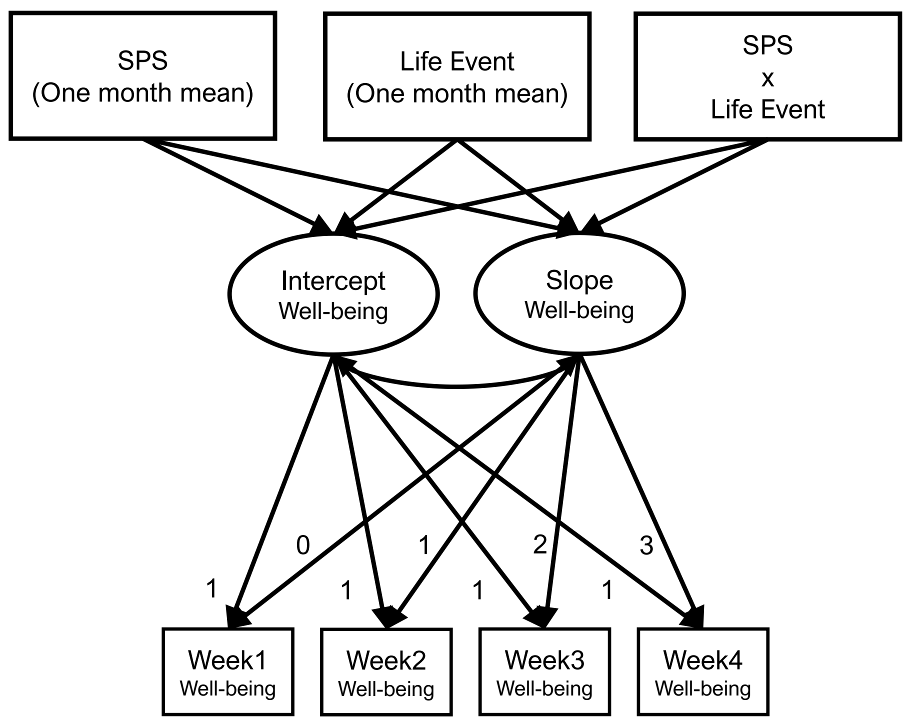
Table S13

SPS x Life Events Interaction using only Aesthetic Sensitivity Subscale in Week 4

Model	BIC	crossover	crossover 95%
Vantage sensitivity STRONG	290.38	-3	
Diathesis-stress STRONG	292.73	3	
Diathesis-stress WEAK	293.43	3	
G + E only	294.06	NA	
Differential susceptibility STRONG	294.64	-6.75	(-8.35 / -5.15)
Vantage sensitivity WEAK	294.98	-3	
Differential susceptibility WEAK	298.03	3.07	(1.71 / 4.43)
E only	303.51	NA	
G only	309.62	NA	
Intercept only	322.48	NA	

Figure S1

Latent Growth Curve Model for Predicting Socio-Emotional Well-being by Sensory-Processing Sensitivity x Life Events Interaction



Note. SPS = Sensory-Processing Sensitivity (one-month mean). SPS and life events were centralized and used in the analysis.