Associations Between Emodiversity and Mental Health in University Students During the COVID-19 Pandemic

Keaghan M. Forster & Jessica P. Lougheed*

Department of Psychology, University of British Columbia Okanagan

Abstract

Emodiversity refers to the breadth and scope of emotions a person experiences day to day and may be uniquely related to mental health mean levels of positive and negative emotion. We examined the associations between positive and negative emodiversity, mean positive and negative emotion, and three mental health indicators: depressive symptoms, anxious symptoms, and overall wellbeing in a sample of undergraduate students ($N = 592$, 80% women, mode of age = 20 years) during different phases of lockdown during the COVID-19 pandemic. Participants completed a 14-day daily diary survey to assess their daily positive and negative emotions. Results indicated significant interactions between negative emodiversity and mean levels of negative mood in predicting symptoms of depression and anxiety and overall wellbeing. Specifically, for individuals who reported greater mean levels of negative mood, low negative emodiversity was associated with greater depressive and anxious symptoms and lower wellbeing. Results for positive emodiversity were not significant. These associations did not differ across changing pandemic restrictions. Results suggest that rigidity in negative emotions in daily life (i.e., high levels of negative emotion with low diversity in negative emotion states) are an important feature of mental health and wellbeing among university students.

Keywords: Emotion variability, emodiversity, mental health, internalizing symptoms, wellbeing, emerging adulthood.

Introduction

It is well-established that high levels of negative emotion and low levels of positive emotion are related to mental health problems (Frederickson & Joiner, 2002; Lyubomirsky et al., 2005; Watson et al., 1988), but mean emotion levels reflect only one aspect of emotion-related processes that are associated with mental health. Emodiversity refers to the breadth and scope of emotions that a person experiences day to day (Benson et al., 2018; Quoidbach et al., 2014; 2018). Whereas emotion variability represents the tendency for one's emotion to vary over time, emodiversity represents how broadly a person's emotion can vary. We investigated the associations between positive and negative emodiversity, their interactions with mean positive and negative emotion, and three mental health indicators: depressive symptoms, anxious symptoms, and overall wellbeing.

We examined the associations between emodiversity and mental health in undergraduate students, whose contexts are associated with several stressors and put them at risk for mental health difficulties. Undergraduate students are typically young adults between the ages of 17 or 18 through 25 years of age who tend to experience a period of instability as they navigate developing identities, career goals, and relationships (Tanner et al., 2009). Young adults under age 30 years tend to encounter the most frequent stressors in daily life compared to older stages of adulthood (Almeida et al., 2023). A meta-analysis of

35 studies showed that nearly one third of university students have experienced depression (Sarokjani et al., 2013). More recently, a study of two national surveys in the US showed that anxiety, depression, suicidal ideation, suicide attempts, and self-harm have all been on the rise in university students from 2007 to 2018 (Duffy et al., 2019). For example, the prevalence of depressive and anxious symptoms increased from 8.6% to 21.1% (2007 to 2017-2018) and from 6.3% to 11.7% (2007 to 2017-2018), respectively (Duffy et al., 2019). With these trends rising over the last decade, it is possible that these rates may have continued to change in recent years as a result of the COVID-19 pandemic. A recent study showed that college students in the US reported higher rates of anxiety and perceived stress at the beginning of the COVID-19 pandemic in April 2020 compared to July 2020 (Hoyt et al., 2021). Considering the increased prevalence of mental health difficulties in the undergraduate population (Howard et al., 2010), it is important to look more closely at factors related to their mental health such as emodiversity in daily life. These factors are especially important to consider if the quickly changing context of the COVID-19 pandemic may have played a role in the experience of stress and mental health challenges.

The onset of the COVID-19 pandemic brought with it new types of stressors as governments brought in lockdown and social distancing measures, requiring communities to reduce in-person social contact (Ernst et al., 2022). Many households pivoted to remote or hybrid work configurations for the first time, with varying degrees of ease of transition, while others continued in-person work facing greater risk of COVID-19 transmission. Fears about the virus infecting oneself and their loved ones emerged for many (Wang et al., 2022). Many universities and colleges in North America pivoted to online learning for the first time, which required both instructors and students to quickly adapt to unfamiliar classroom methods. The rapid shift in daily life resulted in exposure to new and more frequent stressors, and university students' concerns related to COVID-19 were associated with their emotional experiences in different ways (Calma-Birling & Zelazo, 2022). For example, university students reported increased concerns that the COVID-19 pandemic could create more conflicts with parents, which in turn was associated with feeling less supported and happy. Concerns regarding the pandemic's impact on taking online courses were associated with greater feelings of frustration. Concerns about oneself and loved ones getting sick were associated with greater feelings of worry. It is likely that daily life in the pandemic influenced several aspects of emotion- and emotion-related experiences, including emodiversity.

Emodiversity and Mental Health

Emodiversity is one of several concepts that captures the breadth or range of emotions that one may experience. To illustrate emodiversity in the current study, Figure 1 shows examples of individuals with various combinations of high and low levels of positive and negative emodiversity from data we collected as part of the current study. For these plots, each spoke represents a specific emotion the participants reported on daily for several days, the spoke length represents the frequency the emotion was experienced across the reporting period, and the colour represents the proportion of days the emotion was reported to be experienced with varying levels of frequency through the day. As shown in Figure 1, there is heterogeneity in positive and negative emodiversity—some individuals show high diversity in positive emotion but not negative emotion (Figure 1, Panel A), high diversity in both positive and negative emotion (Figure 1, Panel B), high diversity in negative emotion but not positive emotion (Figure 1, Panel C), and low diversity in both positive and negative emotion (Figure 1, Panel D).

Figure 1. Emotion Ecosystems of Four Participants
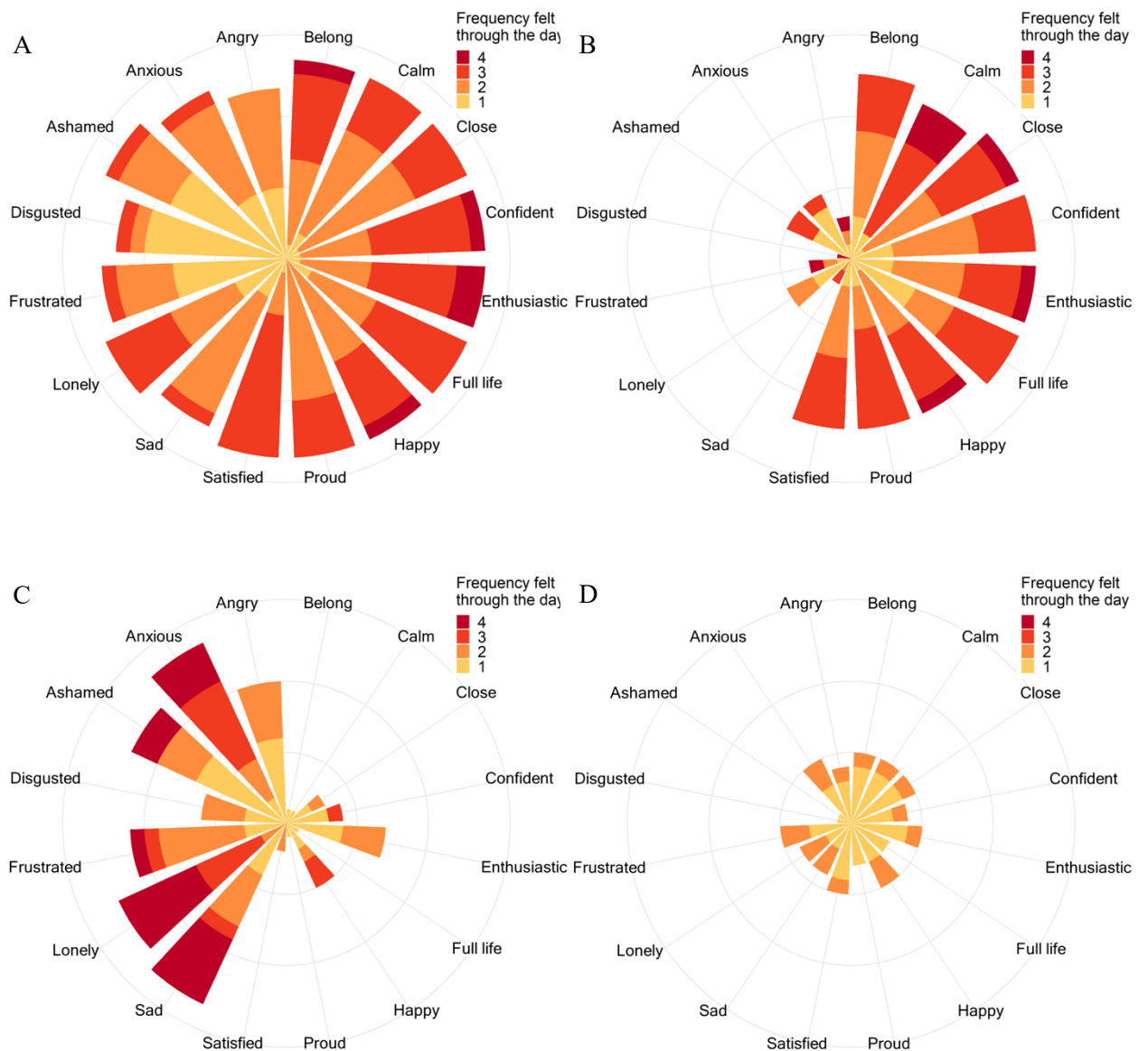
Note. These plots show positive and negative emotion data for four different participants from the current study. The plots show participants with: high positive emodiversity and low negative emodiversity (Panel A), high positive and negative emodiversity (Panel B), low positive emodiversity and high negative emodiversity (Panel C), and low positive emodiversity and low negative emodiversity (Panel D).

Research to date on emodiversity suggests that it is associated with both mental and physical health (Benson et al., 2018; Quoidbach et al., 2014). In the first examination of emotion-related diversity metrics, Quoidbach and colleagues (2014) assessed positive, negative, and total emodiversity from a one-time report of participants' tendencies to experience different emotions. They found that positive, negative, and total emotional diversity were each positively associated with positive mental and physical health, above and beyond the variance accounted for by mean emotion levels. Another study derived emodiversity measures from participants' self-reported emotions experienced during a 30-day daily diary study (Benson et al., 2018). Positive emodiversity was not associated with self-reported

physical health when mean levels of positive emotion were controlled for, but negative emodiversity was associated with self-reported physical health above and beyond the effect of mean levels of negative emodiversity. Specifically, greater negative emodiversity was associated with better physical health among individuals who also had high mean levels of negative emotion (Benson et al., 2018). Emodiversity has also shown associations with biomarkers of physical health, such as in one study that showed that greater positive emodiversity is associated with lower systemic inflammation (Ong et al., 2018).

The associations between emodiversity and mental health may vary by clinical status and other contextual factors. The results described above came from studies that used non-clinical samples. A recent study showed that individuals who had experienced clinically significant depression in their lifetime reported greater negative emodiversity and lower positive emodiversity compared to individuals who had never experienced depression, although positive emodiversity in individuals with a clinical history was adaptive when it was observed (Werner-Seidler et al., 2020). In addition, a study using a nationally representative non-clinical sample showed that greater positive emodiversity was associated with lower anxious and depressive symptoms, whereas greater negative emodiversity was associated with greater anxious and depressive symptoms (Urban-Wojcik et al., 2020). Thus, although earlier research indicated that both mental and physical health are associated with greater positive and negative emodiversity (e.g., Quoidbach et al., 2014; Benson et al., 2018), more recent research findings point to the importance of examining whether these associations differ according to individual differences and the broader context (Werner-Seidler et al., 2020).

Although a growing body of literature has examined emodiversity as it relates to depressive and anxious symptoms, less is known about whether it relates to positive aspects of mental health such as wellbeing. Focusing on both mental health difficulties and positive aspects of mental health provides a more complete picture regarding whether and when emodiversity is related to mental health. Wellbeing is multidimensional and different conceptualizations exist in the current literature (Butler & Kern, 2016). Seligman (2011) proposes five pillars to wellbeing which include positive emotion or affect, engagement, relationships, meaning, and accomplishment (PERMA) in his PERMA theory of wellbeing. Butler and Kern (2016) also emphasized the importance of not only the presence of positive affect but the lack of negative affect in wellbeing. Emodiversity, in addition to emotional valence, could be an important feature of overall wellbeing and recent research points to open questions regarding in what ways and for whom emodiversity is specifically associated with wellbeing (Urban-Wojcik et al., 2020).

The Current Study

We explored the associations between positive and negative emodiversity, and mean levels of positive and negative emotion, in predicting three mental health indicators: depression, anxiety, and overall wellbeing in undergraduate students during the COVID-19 pandemic. Our three primary research questions were:

(1a) Are positive and negative emodiversity associated with depressive symptoms? and (1b) Do the associations between positive and negative emodiversity and depressive symptoms vary by mean levels of positive and negative emotion, respectively?

(2a) Are positive and negative emodiversity associated with anxious symptoms? and (2b) Do the associations between positive and negative emodiversity and anxious symptoms vary by mean levels of positive and negative emotion, respectively?

(3a) Are positive and negative emodiversity associated with overall wellbeing? and (3b) Do the associations between positive and negative emodiversity and overall wellbeing vary by mean levels of positive and negative emotion, respectively?

Given the lack of research to date specifically on emodiversity and how it relates to mental health in the context of the COVID-19 pandemic, and emerging research indicating that greater emodiversity is not uniformly associated with better mental health (Urban-Wojcik et al., 2020; Werner-Seidler et al.,

2020), these research questions are exploratory. We predicted that positive and negative emodiversity will be associated with each mental health indicator (depressive symptoms, anxious symptoms, and wellbeing), although we did not hypothesize the specific direction of effects. We predicted that mean positive emotion will be negatively associated with depressive and anxious symptoms, but positively associated with overall wellbeing. We also predicted that mean negative emotion will be positively associated with depressive and anxious symptoms, but negatively associated with overall wellbeing. Lastly, we predicted there will be significant interactions between mean positive emotion and positive emodiversity, and between mean negative emotion and negative emodiversity as predictors of depressive symptoms, anxious symptoms, and overall wellbeing.

Method

Participants and Procedure

Participants were 930 undergraduate students recruited from the Department of Psychology research participant pool at a university in western Canada. This study received approval by the university Behavioural Research Ethics Board prior to data collection. Data collection occurred between February, 2021 and March, 2022. The full sample consisted of four cohorts based on the academic term when the data were collected (see specific details below in Measures). The sample size, along with the mode for gender, of each cohort can be found in Table 1. Participants' age ranged from 17 to 30+ years (mode = 20) in the full sample with similar breakdowns for each cohort (see Table 1). Participant ethnicities were: White (59%), Asian (19%), East Asian (8%), Multiple Ethnicities (7%), Black (4%), Hispanic (2%), and Indigenous (1%). Participants also reported their sexual orientation: Heterosexual (80%), Bisexual (10%), Asexual (4%), Pansexual (2%), Lesbian (2%), Gay (0.3%), and Other (2%). Lastly, 85% of participants indicated that they were domestic students, whereas 14% indicated they were international students. The modes of each demographic variable for all four cohorts are shown in Table 1.

Participants were recruited via the Department of Psychology SONA system, which is an online portal for students to sign up for and participate in studies for course credit. In Part 1 of the procedure, participants completed questionnaires through the online survey software Qualtrics. These questionnaires included a demographics survey; the Sadness questionnaire of the NIH Toolbox (Slotkin et al., 2012); the Emotional Distress (Anxiety) scale from the PROMIS item bank, short-form (Cella et al., 2010); and the PERMA profiler questionnaire of well-being (Butler & Kern, 2016). After completing Part 1 of the study, participants were automatically assigned 0.5 courses credits via the Department of Psychology SONA system and emailed instructions on how to complete Part 2.

In Part 2, participants completed a 14-day daily diary via a mobile app called ExpiWell (Tay, 2020). ExpiWell was used to send daily surveys to participants' phones at the end of each day at 8:00 pm, as well as a follow-up notification 20 minutes later if no action was taken. Participants had until 11:59 pm each night to complete the daily survey. The daily survey participants completed was the Your Feelings questionnaire to assess daily emotion (adapted from Charles et al., 2019). After completing the 14-day daily diary protocol, participants received either 1.0 credit for completing 8 or more daily diaries or 0.5 credit for completing 7 or fewer daily diaries.

Of the original 930 students who signed up to participate, 49 did not provide the needed ID variable in Part 2 of this study and were therefore excluded because we were not able to match their demographic data to their daily diary data. Of these 881 participants, an additional 289 were excluded due to the data requirements for calculating key variables (details in next section), which resulted in a total of 592 participants (477 women) in the analytic sample.

We collected data over four academic terms, resulting in four cohorts in the sample. For Cohort 1, data collection occurred between February and March 2021 when all courses at the university were held online, and the province had strict lockdown guidelines. For Cohort 2, data collection occurred between May and June 2021, after the provincial government had loosened many lockdown restrictions. Data

collection for Cohort 3 occurred between October and November 2022 after COVID-19 vaccines had achieved high uptake in the province and the university was operating in a hybrid online and in-person format. Lastly, data collection for Cohort 4 occurred between February and March 2022, shortly after the university returned to in-person instruction after a temporary move online during the surge of Omicron-related COVID-19 infections. Given the variations between cohorts and pandemic context (and possible seasonality effects), we controlled for cohort in analyses via a series of dummy variables with Cohort 1 (full lockdown) as the reference group. Thus, Cohort 2 was coded as (0, 1, 0, 0), Cohort 3 was coded as (0, 0, 1, 0) and Cohort 4 was coded as (0, 0, 0, 1).

Table 1. Participant demographic information of full sample and separate cohorts

	Cohort 1			Cohort 2			Cohort 3			Cohort 4			Full sample		
n	179			96			160			157			592		
	Mo (%)	Min.	Max	*Mo (%)*	Min.	Max	*Mo (%)*	Min.	Max	*Mo (%)*	Min.	Max	*Mo (%)*	Min.	Max
Age	19 (24.6)	17	30+	20 (39.6)	18	30+	19 (23.3)	17	30+	18 (29.7)	18	30+	20 (23.5)	17	30+
	Mode (%)			*Mode (%)*			*Mode (%)*			*Mode (%)*			*Mode (%)*		
Gender	Women (79.3)			Women (86.5)			Women (82.5)			Women (76.4)			Women (80.6)		
Ethnicity	White (61.5)			White (52.1)			White (66.9)			White (52.2)			White (59.0)		
Sexual Orientation	Heterosexual (82.3)			Heterosexual (81.3)			Heterosexual (82.5)			Heterosexual (75.2)			Heterosexual (80.4)		
Student status	Domestic (85.5)			Domestic (86.5)			Domestic (85.6)			Domestic (82.2)			Domestic (84.8)		

Measures

Depressive Symptoms

The NIH Sadness Scale consists of 8 questions related to the affective symptoms of depression and asks the participants how often they felt a certain way (e.g., "*I felt worthless*", "*I felt depressed*") in the last 7 days (Slotkin et al., 2012). Participants rated their responses on a 5-point Likert scale from 1-5 (1 = *never*, 2 = *rarely*, 3 = *sometimes*, 4 = *often*, 5 = *always*). The mean scores from this scale were used to represent depressive symptoms with higher scores representing a higher level of depressive symptoms. The reliability for this measure was good across all cohorts ($\alpha = .94$ for Cohort 1, $\alpha = .95$ for Cohort 2, $\alpha = .94$ for Cohort 3, $\alpha = .93$ for Cohort 4).

Anxious Symptoms

The Emotional Distress (Anxiety) scale from the PROMIS item bank (short-form) consists of 8 questions and asks the participants how often they felt a certain way (e.g., "*I felt fearful*", "*My worries overwhelmed me*") in the last 7 days (Cella et al., 2010). Participants rated their responses on a 5-point Likert scale from 1-5 (1 = *never*, 2 = *rarely*, 3 = *sometimes*, 4 = *often*, 5 = *always*). The mean score from this scale was used to represent anxious symptoms and higher scores represent a higher level of anxious symptoms. The reliability for this measure was good across all cohorts ($\alpha = .94$ for Cohort 1, $\alpha = .94$ for Cohort 2, $\alpha = .93$ for Cohort 3, $\alpha = .91$ for Cohort 4).

Overall Wellbeing

The PERMA profiler (Butler & Kern, 2016) consists of 23 questions that map onto several subscales: positive emotion (e.g., "*In general, how often do you feel joyful?*"), negative emotion (e.g., "*In general, how often do you feel anxious?*"), engagement (e.g., "*How often do you lose track of time while doing something you enjoy?*"), relationships (e.g., "*To what extent do you receive help and support from others when you need it?*"), meaning (e.g., "*To what extent do you generally feel you have a direction in your life?*"), accomplishment (e.g., "*How often are you able to handle your responsibilities?*"), health (e.g., "*Compared to others of your same age and sex, how is your health?*"), and single questions related to both loneliness ("*How lonely do you feel in your daily life?*") and happiness ("*Taking all things together, how happy would you say you are?*"). Overall wellbeing is calculated from the combination of the positive emotion, engagement, relationships, meaning and accomplishment subscales, and the single happiness item (Butler & Kern, 2016). The mean score is taken from these subscales to represent overall wellbeing with higher scores reflecting a higher level of wellbeing. Participants rated their responses on an 11-point Likert scale (0 = *Never, Not at all or Terrible* to 10 = *Always, Completely, or Excellent*). The reliability for this measure was good across all cohorts (α = .94 for Cohort 1, α = .93 for Cohort 2, α = .93 for Cohort 3, α = .93 for Cohort 4).

Daily Positive and Negative Emotions

In Part 2 of the study, daily emotion was assessed using the Your Feelings questionnaire, a daily diary measure adapted from the National Study of Daily Experience (adapted from Charles et al., 2019). Participants recorded the feelings they felt (selected from the 16 feelings the questionnaire provided) and the frequency they felt them on a scale from 0 to 4 (0 = *None of The Time*, 1 = *A Little of The Time*, 2 = *Some of The Time*, 3 = *Most of The Time*, 4 = *All of The Time*). The positively-valenced emotion items were *enthusiastic*, *happy*, *satisfied*, *confident*, *calm*, *like you belong*, *close to others*, *proud*, and *full of life*. The negatively-valenced items were *sad*, *angry*, *anxious*, *frustrated*, *disgusted*, *lonely*, and *ashamed*. We calculated the within- and between-person reliabilities of positive and negative daily emotions using the guidelines by Bolger and Laurenceau (2013). The results indicate whether within-person differences in change over time are reliable, with interpretation being similar to Chronbach's alpha. Positive emotion showed good within-person (range .86 to .88) reliability across all cohorts. Negative emotion showed good within-person (range .73 to .77) reliability across all cohorts.

Positive and Negative Emodiversity

We calculated positive and negative emodiversity via the Gini coefficient (Gini, 1912) using the approach described by Benson and colleagues (2018). We selected the Gini coefficient as opposed to other metrics such as Shannon's entropy or Simpson's index (Shannon, 1948; Simpson, 1949) as the Gini coefficient produces the most normal distributions of these metrics when applied to intensive longitudinal data on emotion (Benson et al., 2018). We calculated emotion variability separately for positive and negative emodiversity, as well as total emodiversity. Following Benson et al. (2018) and as seen in Equation 1, c_{ij} is the count of each individual's (i) reported emotion experienced within $j = 1$ to m number of emotion categories, indexed in non-decreasing order ($c_{ij} <= c_{ij+1}$). Emodiversity scores range from 0 to 1, with scores closer to 1 indicating a more diverse emotion "ecosystem".

Equation 1.
$$\text{Gini} = 1 - \left(\left(\frac{2 \sum_{j=1}^{m} j c_{ij}}{m \sum_{j=1}^{m} c_{ij}} \right) - \frac{m+1}{m} \right)$$

Mean Levels of Positive and Negative Emotion

Mean levels of positive and negative emotion were calculated from the positive and negative daily emotion data. A participant's mean positive emotion was calculated by taking the mean of all positive emotion items reported across all days of Part 2 of the study. Mean negative emotion was calculated by taking the mean of all negative emotion items across all days of Part 2 of the study.

Age Group

Participants reported their age as one of several categories ranging from 17 to 30+. Age was categorized into two groups for analysis: young adult student (those aged 17 to 24 years) and mature student (those aged 25 to 30+ years). We included age group as a control variable given that previous research has found age differences in emodiversity among broad portions of adulthood (Benson et al., 2018).

Gender

Participants identified their gender among several response options: man, woman, genderqueer, genderfluid, trans man, trans woman, self-described or other. We collapsed these groups into two categories for analysis given the low numbers of individuals who identified as neither men nor women: (1) those who identified as men, and (2) those who identified as women and other genders. We chose this grouping given that disparities in mental health variables tend to be strongest between men and other genders (e.g., Hoyt et al., 2021).

Missing Data

In line with recommendations from Benson and colleagues (2018), we calculated the positive and negative emodiversity metrics only for cases that reported at least six days of daily diary data. In our sample, 276 participants did not report on at least 6 days of Part 2 and were thus excluded from analyses. We used listwise deletion for any cases who did not report on the three mental health variables or the predictor variables. A total of 34 participants were excluded due to missing data on these variables.

Deviations from Preregistration

This project was preregistered. Data and code associated with this project are available here. There were several deviations from the preregistration, as several data collection and analytic choices were updated since the preregistration. First, we collected a fourth and final cohort of data that was not anticipated at the time of preregistration. Second, we included interactions between emodiversity and mean levels of positive and negative emotion (rather than only controlling for main effects of mean levels of emotion) in our regression models to allow us to examine the results for emodiversity in the context of mean levels of emotion, in line with previous research (Benson et al., 2018). Third, we added additional covariates to control for that were not preregistered: Gender and age group.

Results

We inspected descriptive statistics of all variables prior to analysis. Variable means, standard deviations, and bivariate correlations can be found in Table 2. Before using listwise deletion on participants with missing data, we ran t-tests on the outcome and predictor variables between cases with and without missing data. None of the t-tests were significant (all ps > .05); therefore, individuals with missing data who were therefore excluded via listwise deletion did not differ significantly from cases without missing data on outcome or predictor variables.

Table 2. Variable means, standard deviations, and bivariate correlations

	1	2	3	4	5	6	7	M (SD)
1. Positive emodiversity	-	-	-	-	-	-	-	0.84 (0.10)
2. Negative emodiversity	.14*	-	-	-	-	-	-	0.66 (0.14)
3. Mean positive emotion	.67*	-.16*	-	-	-	-	-	1.72 (.67)
4. Mean negative emotion	-.13	.65*	-.45*	-	-	-	-	0.85 (.47)
5. Depressive symptoms	-.03*	.34*	-.54*	.56*	-	-	-	2.62 (0.93)
6. Anxious symptoms	-.19*	.33*	-.39*	.54*	.75*	-	-	2.83 (0.91)
7. Overall wellbeing	.41*	-.24*	.66*	-.46*	-.67*	-.43*	-	6.44 (1.52)

We tested our hypotheses with three regression models. For Model 1, depressive symptoms were the outcome variable, for Model 2, anxious symptoms were the outcome, and for Model 3, overall wellbeing was the outcome variable. The predictors in all three models included the main effects of positive and negative emodiversity and mean levels of positive and negative emotion. We included interaction terms between negative emodiversity and mean negative emotion, and between positive emodiversity and mean positive emotion in all three models to examine whether the associations between emodiversity and mental health varies by mean emotion levels. Cohort, age group, and gender were included as covariates. All continuous predictor variables were mean centered before analysis. An *a priori* power analysis was conducted for an 11-predictor, non-directional multiple regression model with an α of .05 and assuming a medium effect size of .15 to obtain power = 0.95. The result indicated we would need a sample size of at least 178, which was exceeded.

Prior to analyzing the data, we checked the data to see if they met the assumptions associated with multiple regression. The collinearity of each model was tested to ensure multicollinearity was not an issue; this assumption was met in Model 1 (Positive Emodiversity, Tolerance = .28, VIF = 3.60; Negative Emodiversity, Tolerance = .44, VIF = 2.27; Mean Positive Emotion, Tolerance = .36, VIF = 2.75; Mean Negative Emotion, Tolerance = .34, VIF = 2.93), Model 2 (Positive Emodiversity, Tolerance = .28, VIF = 3.60; Negative Emodiversity, Tolerance = .44, VIF = 2.27; Mean Positive Emotion, Tolerance = .36, VIF = 2.75; Mean Negative Emotion, Tolerance = .34, VIF = 2.93), and Model 3 (Positive Emodiversity, Tolerance = .28, VIF = 3.60; Negative Emodiversity, Tolerance = .44, VIF = 2.27; Mean Positive Emotion, Tolerance = .36, VIF = 2.75; Mean Negative Emotion, Tolerance = .34, VIF = 2.93). We assessed the assumption of independence of residuals with the Durbin-Watson test and found this assumption was met for Model 1 (Durbin-Watson value = 1.86), Model 2 (Durbin-Watson value = 1.99), and Model 3 (Durbin-Watson value = 1.87). We assessed the assumptions of linearity, homoscedasticity, and randomness by inspecting the plots of fitted values against standardized residuals for each model and finding that none of these assumptions were violated. Lastly, we inspected Q-Q plots and histograms of the residuals for each model and confirmed the assumption of normally distributed residuals was not violated.

The summary for all model parameters for each model can be found in Table 3. For Model 1, the predictors significantly predicted depressive symptoms, $F(11, 558) = 36.23$, p < .001, $R^2 = .42$. The adjusted R^2 value of .40 indicated that about 40% of the variance in depressive symptoms was accounted for by model predictors. Contrary to expectations, the main effects of positive and negative emodiversity were not significantly associated with depressive symptoms. However, mean levels of positive and negative emotion were associated with depressive symptoms in the expected directions, with lower levels of mean positive emotion being associated with higher depressive symptoms, and higher mean levels of negative emotion being associated with higher depressive symptoms. There was a significant interaction between negative emodiversity and mean level of negative emotion. Follow up simple slopes analysis using the *emtrends* function of the *emmeans* package in R (Lenth, 2022) showed that at high levels of mean negative emotion (1 *SD* above the sample mean), there was a significant,

negative association between negative emodiversity and depressive symptoms. Specifically, a one-unit increase in negative emodiversity was associated with a 1.70 unit decrease (95% *CI* [-2.56, -0.84]) in depressive symptoms (see Figure 2A). In other words, depressive symptoms were greatest in the context of low negative emodiversity and high mean negative emotion. The interaction between positive emodiversity and mean levels of positive emotion was not significant. Regarding covariates, there were no significant differences between Cohort 2 versus Cohort 1, Cohort 3 versus Cohort 1, and Cohort 4 versus Cohort 1 on depressive symptoms, and age group was not associated with depressive symptoms. Gender was significantly associated with depressive symptoms, with those who identified as men reporting fewer depressive symptoms than those who identified as women or other genders.

For Model 2, the predictors significantly predicted anxious symptoms $F(11, 558) = 30.00$, p < .001, R^2 =.36. The adjusted R^2 value of .36 indicates that more than one third of the variance in anxious symptoms was accounted for by model predictors. Contrary to expectations, the main effect of positive emodiversity was not associated with anxious symptoms, but in line with expectations, lower levels of negative emodiversity were significantly associated with anxious symptoms. Contrary to expectations, mean levels of positive emotion were not associated with anxious symptoms, but as expected, higher mean levels of negative emotion were associated with greater anxious symptoms. The interaction between negative emodiversity and mean negative emotion was significant. Follow up simple slopes analysis showed that at high levels of mean negative emotion (1 *SD* above the sample mean), there was a significant, negative association between negative emodiversity and anxious symptoms. Specifically, a one-unit increase in negative emodiversity was associated with a 2.24-unit decrease (95% *CI* [-3.10, -1.39]) in anxious symptoms (see Figure 2B). In other words, anxious symptoms were greatest in the context of low negative emodiversity and high mean negative emotion. The interaction between positive emodiversity and mean positive emotion was not significant. Cohort comparisons to Cohort 1 and age group did not predict anxious symptoms. Gender significantly predicted anxious symptoms, with participants who identified as men reporting less anxious symptoms than those who identified women or the other genders.

For Model 3, the predictors significantly predicted overall wellbeing, $F(11, 558) = 46.55$, p < .001, R^2 =.48. The adjusted R^2 value of .48 indicates that almost half of the variance in overall wellbeing was accounted for by model predictors. Positive emodiversity did not predict wellbeing, but greater negative emodiversity significantly predicted lower wellbeing. Contrary to expectations, mean levels of positive emotion did not predict wellbeing, whereas greater levels of mean negative emotion were associated with lower wellbeing in line with expectations. The interaction between negative emodiversity and mean levels of negative emotion was significant. Follow up simple slopes analysis showed that at low levels of mean negative emotion (-1 *SD* from sample mean), the association between negative emodiversity and overall well-being was not significant (a one-unit increase in negative emodiversity was associated with a 0.89 unit increase in wellbeing, 95% *CI* [-0.22, 2.00]. In contrast, at high levels of mean negative emotion (+1 *SD* from the sample mean), negative emodiversity was positively associated with overall wellbeing, with a one-unit increase in negative emodiversity being associated with a 2.02 unit increase in wellbeing (95% *CI* [0.47, 3.57]; see Figure 2C). In other words, overall wellbeing was lowest in the context of high mean negative emotion and low negative emodiversity. The interaction between positive emodiversity and mean levels of positive emotion was not significant. Participants in Cohort 4 reported lower levels of wellbeing than Cohort 1, but otherwise, cohort comparisons to Cohort 1 were not significant. Age and gender groups did not significantly predict overall wellbeing.

Table 3. Summary of Model Parameters for Each Model

	Predictor Variables and Covariates	B	SE	β	t	p
Model 1 (Depressive Symptoms)	Positive Emodiversity	.43	.54	.05	.79	.428
	Negative Emodiversity	.06	.32	.01	.19	.848
	Positive Mean Emotion	-.50	.08	-.35	-6.6	<.001
	Negative Mean Emotion	.84	.11	.42	7.5	<.001
	Negative Emodiversity x mean Negative Emotion	-1.11	.46	-.09	-2.41	.016
	Positive Emodiversity x mean Positive Emotion	.39	.42	.04	.92	.359
	Cohort 1 vs. Cohort 2	-.07	.09	-.03	-.72	.474
	Cohort 1 vs. Cohort 3	.03	.08	-.02	.42	.673
	Cohort 1 vs. Cohort 4	.09	.08	.04	1.1	.281
	Young Adult vs. Mature Adult	.08	.13	-.02	.65	.519
	Men vs. Women and Other	.20	.08	-.08	2.4	.018
Model 2 (Anxious Symptoms)	Positive Emodiversity	.24	.56	-.03	.43	.670
	Negative Emodiversity	-.62	.33	-.09	-1.85	.015
	Positive Mean Emotion	-.19	.08	-.14	-2.44	.064
	Negative Mean Emotion	1.2	.12	.59	10.34	<.001
	Negative Emodiversity x mean Negative Emotion	-2.51	.48	-.20	-5.23	<.001
	Positive Emodiversity x mean Positive Emotion	-.08	.44	-.01	-.18	.854
	Cohort 1 vs. Cohort 2	-.04	.10	-.01	-.38	.708
	Cohort 1 vs. Cohort 3	.06	.08	.03	.70	.487
	Cohort 1 vs. Cohort 4	.08	.08	.04	1.00	.318
	Young Adult vs. Mature Adult	.14	.13	.04	1.09	.275
	Men vs. Women and Other	.08	.09	.15	4.34	<.001
Model 3 (Overall Wellbeing)	Positive Emodiversity	-.17	.84	-.01	-.21	.838
	Negative Emodiversity	-.82	.50	-.08	-1.64	<.001
	Positive Mean Emotion	1.41	.12	.61	11.94	.102
	Negative Mean Emotion	-.37	.18	-.11	-2.12	.034
	Negative Emodiversity x mean Negative Emotion	-1.75	.72	-.09	-2.42	.016
	Positive Emodiversity x mean Positive Emotion	-.52	.66	-.03	-.78	.435
	Cohort 1 vs. Cohort 2	-.24	.15	-.06	-1.64	.102
	Cohort 1 vs. Cohort 3	-.13	.12	-.04	-1.06	.288
	Cohort 1 vs. Cohort 4	-.26	.13	-.08	-2.07	.039
	Young Adult vs. Mature Adult	.33	.20	.05	-1.64	.102
	Men vs. Women and Other	-.05	.13	-.01	.37	.714

Figure 2. Interactions between Mean Negative Emotion and Negative Emodiversity in Predicting Mental Health and Wellbeing
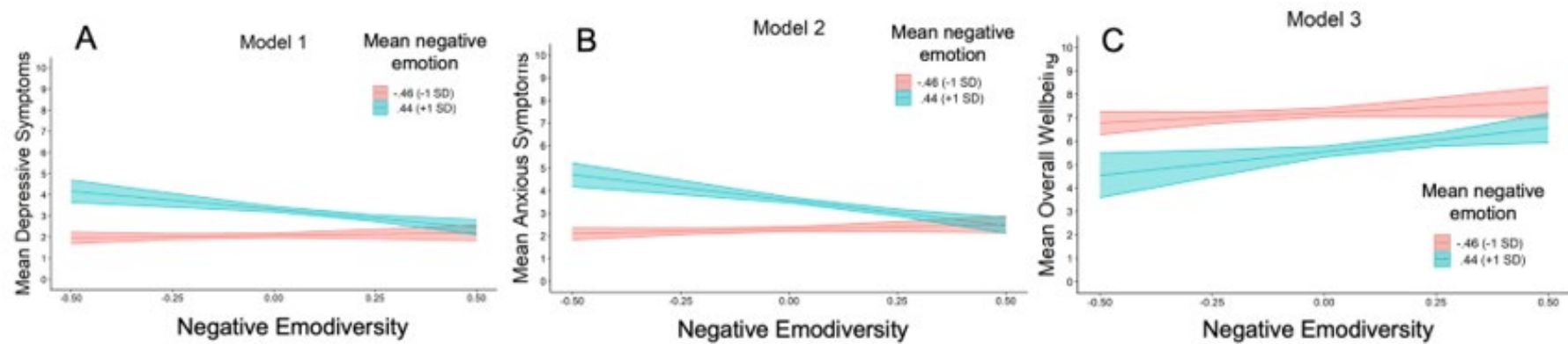
Note. Regions around the regression lines show the 95% confidence intervals

Discussion

The aim of this study was to examine the associations between emotion in daily life and mental health in undergraduate students during the COVID-19 pandemic. Specifically, we examined the associations between mean levels of positive and negative emotion, and positive and negative emodiversity, in predicting depressive symptoms, anxious symptoms, and overall wellbeing. We observed associations between mean levels of positive and negative emotion and depressive in the expected directions, with greater symptoms being associated with greater mean levels of negative emotion and lower mean levels of positive emotion. Greater anxious symptoms were associated with greater mean levels of negative emotion but were not associated with mean levels of positive emotion. Greater overall wellbeing as associated with lower mean levels of negative emotion but was not associated with mean levels of positive emotion. These results were partially in line with our expectations that mental health difficulties would be associated with greater negative and lesser positive emotion, and that wellbeing would be associated with greater positive and lesser negative emotion.

The associations between positive and negative emodiversity and mental health were mixed. Positive emodiversity was not associated with depressive symptoms, anxious symptoms, or overall wellbeing. Negative emodiversity was not associated with depressive symptoms, but it was associated with lower anxious symptoms and lower wellbeing. Significant interactions between negative emodiversity and mean levels of negative emotion in predicting all three aspects of mental health indicate the importance of contextualizing both aspects of daily emotion (mean levels and diversity) with respect to each other. Specifically, for depressive and anxious symptoms, we observed greater symptoms in the context of high mean levels of negative emotion and low emodiversity. These results might reflect rigidity in negative emotion among those experiencing higher levels of internalizing symptoms—as shown in other studies, both depression and anxiety are associated with the tendency to experience prolonged negative emotion states (Kashdan & Rottenberg, 2010; Panaite et al., 2020), and internalizing disorders have been characterized by difficulties adjusting emotion- and emotion-related processes to changes in daily context (i.e., context insensitivity; Kashdan & Rottenberg, 2010).

In predicting overall wellbeing, we observed no association between negative emodiversity and overall wellbeing for individuals who reported relatively low mean levels of negative emotion. In contrast, for individuals who reported relatively high mean levels of negative emotion, lower negative emodiversity was associated with lower overall wellbeing. Individuals experiencing high levels of negative emotion in daily life that are also not diverse with respect to the type of negative emotion may be experiencing rigidity in negative emotion which could explain the association with lower wellbeing. These results are in line our findings for depressive and anxious symptoms.

Although not central to our research questions, we examined the associations between daily emotion and mental health while controlling for several variables. Our results suggested that undergraduate student mental health and wellbeing did not vary much during the period of the COVID-19 pandemic examined in the current study. We found that students who participated during Cohort 4 (shortly after returning to in-person classes again after a sudden but temporary pivot to online learning during the early parts of the local Omicron surge) had significantly lower wellbeing than students who participated during Cohort 1 (during the period of provincial lockdown and fully remote learning contexts at the university). It is possible that students who participated in Cohort 4 reported lower wellbeing due to the uncertainty of that academic term, which contrasts Cohort 1 when students had more certainty about the lockdowns and the university's committed plan to remote learning for the entire academic year. In another recent study using the same sample (Lougheed et al., 2023), we observed that students generally did not differ across cohorts in their likelihood of reporting different types of daily stressors (e.g., interpersonal conflicts, school/work stressors, financial stressors), which may partly explain our lack of differences in anxious and depressive symptoms across the cohorts. We did not have access to data from before the onset of the COVID-19 pandemic and we know now that the 1.5 years during which data were collected likely corresponded to the middle parts of the pandemic, even though each cohort

experienced unique circumstances with respect to provincial and university regulations and their impact on work, academic, and social lives. It would be interesting to examine if the associations we observed between mean levels of emotion, emodiversity, and mental health and wellbeing are similar when students are not experiencing pandemic conditions.

In line with previous research (Hoyt et al., 2021), we found that participants who identified as men reported lower depressive and anxious symptoms than participants who identified as women and other genders. We did not observe gender differences on wellbeing. It is important to examine gender difference within groups of individuals who identity beyond the gender binary (e.g., nonbinary, genderqueer, agender identities, etc.). In the current study, our low cell sizes for these groups precluded us from these nuanced examinations of gender identity.

Limitations and Future Directions

Although there are several strengths of this study (e.g., large sample size, daily diary method that reduces recall bias), there are several limitations to keep in mind when interpreting the results of this study. The first is that the sample consisted solely of undergraduate students. It is important to examine specific factors in daily life that relate to the mental health of this specific population (Hoyt et al., 2021), but we cannot assume that our results generalize to the public. Second, our sample consisted of students who predominately (~80%) identified as women. This figure is representative of students enrolled in courses that offer course credit for study participation, but it precluded us from making comparisons between multiple gender identities given the small cell sizes. Third, we did not know where participants were located in each cohort in order to protect participant anonymity and confidentiality. However, this means that we had to rely on the cohort of participation as a proxy for pandemic context. While cohort of participant is a reliable indicator of university-specific lockdowns and restrictions, we do not have more nuanced data regarding what participants might have been experiencing locally that may have influenced their daily emotions.

Conclusion

Taken together, our results suggest that both mean levels of emotion and negative emodiversity play a role in mental health and wellbeing. Building on previous research (Benson et al., 2018; Quoidbach et al., 2014), we found that low negative emodiversity in the context of high mean levels of negative emotion in daily life was associated with greater depressive and anxious symptoms, and lower wellbeing, in undergraduate students during the COVID-19 pandemic. Our results add to the growing body of research demonstrating that individual differences and context likely play a role in how specifically emodiversity is related to mental health and wellbeing (Werner-Seidler et al., 2020; Urban-Wojcik et al., 2022). It is important to continue examining emodiversity in daily life—especially with respect to contextual factors (e.g., pandemic) and individual differences (clinical status)—to obtain a richer picture of the various landscapes of emotion that relate to mental health and wellbeing.

Additional Information

Conflict of Interest

The authors report there are no competing interests to declare.

Ethical approval

This project was reviewed and approved by the University of British Columbia Behavioural Research Ethics Board (Protocol #H20-03001).

Data Availability

Data and code associated with this project are available here.

Author CRediT Statement

JPL conceptualized and designed the project. JPL supervised all data collection procedures. JPL and KF conceptualized the research questions, hypotheses, and analytic models. KF led data analysis with supervision from JPL. KF led manuscript preparation. JPL led revisions. Both authors contributed to manuscript writing and revisions, and to the approval of the final version submitted for publication.

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