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Emodiversity and the Emotional Ecosystem

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Abstract

Bridging psychological research exploring emotional complexity and research in the natural sciences on the measurement of biodiversity, we introduce – and demonstrate the benefits of – emodiversity: the variety and relative abundance of the emotions that humans experience. Two cross-sectional studies across more than 37,000 respondents demonstrate that emodiversity is an independent predictor of mental and physical health – such as decreased depression and doctor’s visits – over and above mean levels of positive and negative emotion. These results remained robust after controlling for gender, age, and the five main dimensions of personality.

Emodiversity is a practically important and previously unidentified metric for assessing the health of the human emotional ecosystem.

Keywords: Emotion; Emotional Complexity; Diversity; Entropy; Mental Health; Physical Health

Emodiversity and the Emotional Ecosystem

Compare three individuals: Person A experiences three moments of joy in a given day, Person B experiences two moments of joy and one moment of contentment, and Person C experiences two moments of joy and one moment of anxiety. If we sum the number of positive emotions (joy and contentment) and subtract the number of negative emotions (anxiety), A and B would be equally happy, and happier than C. Indeed, decades of research on negative and positive affectivity suggests that high levels of positive emotion and low levels of negative emotion are an essential component of health and subjective well-being (DeNeve & Cooper, 1998; Diener, Suh, Lucas, & Smith, 1999; Fredrickson, 2001; Watson & Pennebaker, 1989). Is well-being simply the result of such simple arithmetic subtractions? We investigate whether not just the mean levels but also the diversity of emotions that people experience may have benefits for their well-being. We show that the *emodiversity* of A, B, and C's emotions – the variety and relative abundance of the emotions they experience – is an independent and integral component of the human emotional ecosystem, that predicts both mental and physical health.

Our notion of emodiversity builds on a large body of research highlighting the benefits of having a rich, authentic, and complex emotional life (Barrett, 2009; 2013; Barrett & Bliss-Moreau, 2009). Along with people's explicit knowledge of their own emotions (i.e., *emotional awareness*; Lane & Schwartz, 1987), the richness and complexity in people's self-reported experience of emotion is a primary aspect of the broad concept of *emotional complexity* (e.g., Lindquist & Barrett, 2008), which has been linked to adaptive emotion regulation and mental health in adulthood and old age (Helson & Wink, 1987; Labouvie-Vief & Medler, 2002; Ryan & Deci, 2001). While such complexity has been operationalized a variety of ways, these measures of

complexity may be grouped into two broad categories: measures of emotional granularity and measures of emotional covariation.

Emotional granularity is the degree to which a person can verbally characterize emotional experiences with precision (Barrett, 1998, 2004; Barrett, Gross, Christensen, & Benvenuto, 2001; Feldman, 1995; Tugade, Fredrickson, & Barrett, 2004). People high in emotional granularity tend to experience emotions in a discrete and differentiated fashion; that is, they experience one particular emotion rather than a mix of different emotions at a given time. Emotional granularity is determined by assessing the relatedness between one's emotion ratings over time using person-correlations (e.g., Barrett, 1998; Barrett et al., 2001; Feldman, 1995) or intraclass correlations (Tugade et al., 2004). *Emotional covariation* or dialecticism is a person's intraindividual correlation between positive and negative affect over time (e.g., Bagozzi, Wong, & Yi, 1999). A correlation near zero suggests that a person experiences positive and negative affect independently; a negative correlation suggests that they are experienced on a single continuum. Related research on *mixed emotions* demonstrates that people can experience pleasant and unpleasant emotions at the same time (Larsen, McGraw, & Cacioppo, 2001; Larsen & McGraw, 2011). The propensity to experience positive and negative affect independently has been linked to emotional complexity and is related to various indicators of adjustment (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Coifman, Bonanno, & Rafaeli, 2007; Larsen & Cutler, 1996; Reich, Zautra, & Davis, 2003).

Emotional granularity and emotional covariation measures capture important aspects of the complexity of one's emotional life. One question that remains unexplored, however, is whether the *diversity* of one's emotional life is beneficial for mental and physical health. Indeed, several researchers have argued that experiences

of specific, differentiated emotional states (e.g., anger, shame, and sadness) have more adaptive value than do global affective states (e.g., feeling bad), as specific emotions are less subject to misattribution errors (Keltner, Locke, & Audrain, 1993; Schwarz, 1990) and provide richer information regarding which specific strategy is more suited for dealing with an affective situation (Barrett et al., 2001; Barrett & Gross, 2001; Ciarrochi, Catuti, & Mayer, 2003). Moreover, flexibility in human biological and psychological processes is associated with adaptive mental functioning and enhanced resistance to disease (Kashdan & Rottenberg, 2010; Kleiger, Miller, Bigger Jr., & Moss, 1987; Mikolajczak et al., 2010). Drawing on this literature, we explored whether higher levels of emodiversity might translate into higher subjective and objective well-being.

We draw our operationalization of emodiversity from research in the natural sciences on the benefits of biodiversity (i.e., the variety and relative abundance of different types of organisms within an ecosystem), which has been shown to foster adaptive flexibility and promote ecosystem resilience (Danovaro et al., 2008; Elmqvist et al., 2003; Heller & Zavaleta, 2009; Potvin & Gotelli, 2008; Rammel & van den Bergh, 2003; Tilman, Reich, & Knops, 2006). We adapted the Shannon biodiversity index, which quantifies the number of species and the evenness of species in a biological ecosystem (Magurran, 2004; Shannon, 1948), to quantify emodiversity, or the richness (how many specific emotions are experienced) and evenness (the extent to which specific emotions are experienced in the same proportion) in the human emotional ecosystem.

In two studies, we explore a role for emodiversity as a predictor of both mental (Study 1) and physical health (Study 2). Both studies reveal beneficial effects for emodiversity of positive emotions, emodiversity of negative emotions, as well as

global emodiversity of both positive and negative emotions taken together. In addition, we control for other possible covariates of emodiversity – such as age and personality – to demonstrate a unique role for emodiversity in health.

Study 1

Method

Participants. We recruited 35,844 participants ($M_{age} = 38.8$, $SD = 13.8$; 79% female) as part of a large online survey on emotions and well-being. The opportunity to participate in this survey was advertised during the *France 2* television series “*Leurs Secrets du Bonheur*” – a French television program aired in the Fall of 2011. A link to the online survey was placed on the program website. A large majority of the sample was French (84.6%), though respondents from other francophone countries also participated (Belgium: 9.5%; Switzerland: 2.5%; African nations: 1.5%; Canada: 0.2%; Other: 1.7%). The surveys were administered in French.

Measures.

Emotion and emodiversity. We measured participants’ propensity to experience positive and negative emotions with a modified version of the French translation of the Differential Emotion Scale (mDES; Philippot, Schaefer, & Herbette, 2003). The scale comprises 18 items measuring 9 specific positive (alertness, amusement, awe, contentment, joy, gratitude, hope, love, and pride) and 9 specific negative (anger, sadness, embarrassment, fear, disgust, guilt, shame, contempt, and anxiety) emotional states. Each item consists of groups of three emotional adjectives (e.g., alertness = interested, concentrated, alert; anger = angry, irritated, mad) for which participants have to indicate how frequently they experience them on a five-point Likert-scale (from 0 “never” to 4 “most of the time”). Following standard procedures, we then

aggregated the 9 positive emotions and 9 negative emotions items into a mean positive emotion score and mean negative emotion score, respectively.

We also computed three emodiversity indexes (one for positive emotions, one for negative emotions, and a global one for all 18 emotions) using the following formula derived from Shannon's entropy:

$$\text{Emodiversity} = \sum_{i=1}^S (P_i \times \ln P_i)$$

where:

S = total number of emotions experienced (richness)

p_i = proportion of S made up of the i th emotions

Specifically, in order to compute emodiversity, we:

1. Divided the number of times an individual experienced emotion #1 by the total number of times she experienced all types of emotions. This gave us p_1 .
2. Multiplied this proportion by its natural log ($p_1 * \ln p_1$)
3. Repeated this for each specific emotions assessed.
4. Summed all the ($p_i * \ln p_i$) products and multiplied the total by -1.

High values are representative of more diverse emotional experiences. An individual experiencing only one type of emotion would have an emodiversity value of 0 because p_i would equal 1 and be multiplied by $\ln p_i$, which would equal 0. If *all* the emotions of the list were evenly experienced then emodiversity would be maximal. So the emodiversity value captures in a single index not only the number of emotions an individual experience (*richness*) but also the relative abundance of the different emotions that makes a person's emotional experience (*evenness*). Note that for individuals who reported experiencing no emotion (mean score = 0), emodiversity scores were manually set to 0 (as in this case, most statistical software are not able to compute an emodiversity score and will set the value to system missing). An example

of our emodiversity scoring procedure for a randomly selected respondent from Study 1 is provided in Table 1. Schematic representing prototypical respondents low and high in emodiversity can be found in Figure 1. An online emodiversity calculator and spreadsheets can be downloaded from www.emodiversity.com.

Depression. Depression was assessed with the Montgomery–Åsberg Depression Rating Scale – Self Rated (MADR-S; Meites, Deveney, Steele, Holmes, & Pizzagalli, 2008), a 9-item self-report scale that measures depressive symptoms (French translation: Bondolfi et al., 2010). Respondents rate their symptom severity on a 7-point scale ranging from 0 to 3, resulting in a total score ranging from 0 to 27. Higher scores indicate higher levels of depressive symptoms.

Additional measures. We collected other measures, including the Ten Item Personality Inventory (Gosling, Rentfrow, & Swann, 2003), a standard measure of the five primary personality traits (i.e., conscientiousness, agreeableness, emotional stability, openness to experience, and extraversion), as well as demographic information including age and gender. Other measures not the focus of the present paper were collected after these primary measures; a complete list of these variables is available from the authors upon request.

Results and Discussion

Gender, age, and descriptive statistics. Descriptive statistics and inter-correlations between the variables are presented in Table 2. Men were less depressed than women ($M_{men} = 5.88$, $SD_{men} = 0.42$; $M_{women} = 6.52$, $SD_{women} = 4.01$), $t(32123) = -11.42$, $p < .001$, $d = -0.16$, and experienced less negative emotion ($M_{men} = 1.00$, $SD_{men} = 0.76$; $M_{women} = 1.08$, $SD_{women} = 0.77$), $t(32123) = -7.03$, $p < .001$, $d = -0.10$, and less negative emodiversity ($M_{men} = 1.33$, $SD_{men} = 0.62$; $M_{women} = 1.36$, $SD_{women} = 0.59$), $t(32123) = -3.05$, $p < .001$, $d = -0.4$. Men also experienced more positive emotion

($M_{men} = 1.99$, $SD_{men} = 0.84$; $M_{women} = 1.87$, $SD_{women} = 0.88$), $t(32123) = 10.34$, $p < .001$, $d = 0.14$, and more positive emodiversity ($M_{men} = 1.95$, $SD_{men} = 0.38$; $M_{women} = 1.87$, $SD_{women} = 0.44$), $t(32123) = 13.12$, $p < .001$, $d = 0.19$. There were small but significant negative correlations between age and all three measures of emodiversity.

Positive emotion. We used a multiple regression model to investigate whether emodiversity of positive emotion was negatively related to depression independently of the mean level of positive emotion, and whether the effect of emodiversity varies depending on one's level of mean positive emotion. After centering positive emodiversity and mean positive emotion and computing the emodiversity-by-mean emotion interaction term (Aiken & West, 1991), the two predictors and the interaction were entered into a simultaneous regression model. Both greater positive emodiversity ($\beta = -.36$, $t = -20.14$, $r_{partial} = -.11$, $p < .0001$) and greater mean positive emotion ($\beta = -.40$, $t = -38.89$, $r_{partial} = -.21$, $p < .0001$) were independently associated with lower depression. The interaction between emodiversity and mean positive emotion was also significant ($\beta = -.14$, $t = -11.15$, $r_{partial} = -.06$, $p < .0001$), suggesting that the effect of emodiversity depended on the level of mean positive emotion. Simple slopes for the association between emodiversity and depression were tested for low (-1 SD below the mean) and high (+1 SD above the mean) levels of mean positive emotion. Each of the simple slope tests revealed a significant negative association between emodiversity and depression, but emodiversity was slightly more strongly negatively related to depression for high levels of mean positive emotion ($\beta = -.46$, $t = -17.54$, $r_{partial} = -.09$, $p < .0001$) than for lower levels of mean positive emotion ($\beta = -.13$, $t = -14.49$, $r_{partial} = -.08$, $p < .0001$). Figure 2 plots the simple slopes for the interaction.

To examine the robustness of these results, we conducted a similar multiple regression model controlling for age, gender, and the five-factor model of personality. Results indicated that greater positive emodiversity remained a significant negative predictor of depression ($\beta = -.27, t = -11.50, r_{\text{partial}} = -.09, p < .0001$) above and beyond the effects of mean positive emotion and the control variables. Finally, we tested for potential curvilinear relationships between positive emodiversity and depression. We found a statistically significant quadratic term for positive emodiversity ($\beta = -.05, t = -3.27, r_{\text{partial}} = -.02, p < .01$). However, both the magnitude of this effect and a visual examination of the regression curve suggest that the significance of this effect is due to our large sample size but that it has little practical significance (see Figure 2). The most conservative approach is therefore to consider the relationship between positive emodiversity and depression as linear.

Negative emotion. A similar multiple regression model was used to investigate whether the diversity of negative emotion people experience negatively predicts depression, independently of the mean level of negative emotion they experience, and whether the effect of emodiversity varies depending the level of mean negative emotion. Results indicated that greater negative emodiversity was associated with lower depression ($\beta = -.20, t = -16.74, r_{\text{partial}} = -.09, p < .0001$), whereas greater mean negative emotion was associated with higher depression ($\beta = .86, t = 76.49, r_{\text{partial}} = .38, p < .0001$). The interaction between emodiversity and mean negative emotion was also significant ($\beta = -.14, t = -19.60, r_{\text{partial}} = -.11, p < .0001$), suggesting that the effect of emodiversity depended on the level of mean negative emotion. Simple slopes for the association between emodiversity and depression were tested for low (-1 SD below the mean) and high (+1 SD above the mean) levels of mean negative emotion. Each of the simple slope tests revealed a significant negative

association between emodiversity and depression, but emodiversity was more strongly negatively related to depression for high levels of mean negative emotion ($\beta = -.33, t = -18.56, r_{\text{partial}} = -.10, p < .0001$) than for lower levels of mean negative emotion ($\beta = -.06, t = -8.34, r_{\text{partial}} = -.05, p < .0001$). Figure 2 plots the simple slopes for the interaction.

As with positive emotion, we conducted a multiple regression model controlling for age, gender, and the five-factor model of personality. Greater negative emodiversity remained a significant negative predictor of depression ($\beta = -.17, t = -10.98, r_{\text{partial}} = -.09, p < .0001$) above and beyond the effects of mean negative emotion and the control variables. Finally, we tested for potential curvilinear relationships between negative emodiversity and depression (Figure 2). The quadratic term for negative emodiversity was not significant ($\beta = -.01, t = -1.02, r_{\text{partial}} = -.01, p = .31$).

Global emodiversity. Taken together, these results suggest that a lack of diversity of both positive and negative emotional experiences is associated with poorer mental health. In fact, controlling for mean positive and mean negative emotion, positive and negative emodiversity were positively correlated ($r = .19, p < .0001$). As a result, we next computed the emodiversity index for all 18 emotions and entered this global emodiversity score into a regression predicting depression. We found that increased global emodiversity was associated with decreased depression ($\beta = -.07, t = -14.56, r_{\text{partial}} = -.08, p < .0001$) above and beyond the effect of controlling for mean positive emotion ($\beta = -.36, t = -72.14, r_{\text{partial}} = -.36, p < .0001$) and mean negative emotion ($\beta = .55, t = 112.37, r_{\text{partial}} = .52, p < .0001$). This effect held when controlling for personality, gender, and age ($\beta = -.10, t = -14.26, r_{\text{partial}} = -.11, p < .0001$). Finally, testing for curvilinear effects, we found a significant yet very small

quadratic relationship between overall emodiversity and depression ($\beta = -.02$, $t = -5.75$, $r_{\text{partial}} = -.03$, $p < .0001$). As with positive emodiversity, both the magnitude of this effect and a visual examination of the regression curve (Figure 2) again suggest that the relationship between global emodiversity and depression is best characterized as linear.

Study 1 provides initial evidence for the idea that the diversity of emotions that people experience plays a unique role in their mental health. Greater emodiversity, whether computed for positive emotions, negative emotions, or all emotions, was consistently linked to lower depression, independently of mean levels of positive and negative emotions. We note that the effect sizes of our emodiversity measures were small compared to mean positive and negative affect: emodiversity accounts for about 1% of the variance in depression. In addition, it is possible that the present results could be explained in part by the fact that non-depressed individuals are feeling different emotions than those typically associated with depression. Consequently, in Study 2, we explored whether emodiversity also predicted objective physical health and contrasted the effect size of emodiversity with other well-known predictors of health.

Study 2

Method

Participants. Respondents were recruited by a government-run health insurance service in Belgium. A sample of 10,000 members 18 years of age and older – representative of the Belgian adult population with regard to gender, age, language, socioeconomic status and geographical distribution – was extracted from the member database to receive the survey by mail. Surveys were administered in French or Dutch depending on respondents' language. A total of 13.1% of respondents answered ($N =$

1310) from which we removed 37 individuals whose score on objective health indicators were 4 *S.D.* above or below the mean, leaving a final sample of 1,273 participants ($M_{age} = 51.04$, $SD = 16.2$; 58% female).

Measures.

Emotion and emodiversity. We measured participants' propensity to experience 10 specific positive (interest, content, joy, enthusiasm, pride, happiness, awe, serenity, gratitude, and amusement) and 10 specific negative (anxiety, anger, guilt, upset, jealousy, shame, nervousness, irritation, sadness, and fear) on a five-point Likert-scale (from 0 "never" to 4 "most of the time"). We then computed mean positive emotion, mean negative emotion, positive emodiversity, negative emodiversity, and global emodiversity scores following the same procedure as in Study 1.

Objective health. We obtained three objective health indicators from the health insurance service for each respondent over the last 11 years: (1) the mean number of visits to family doctors per year, (2) the mean number of days spent in hospitals per year, and (3) the mean Defined Daily Dose (DDD) – a typical indicator of medication consumption based on the average maintenance dose per day. The DDD provide a fixed unit of measurement independent of price and dosage form (e.g., tablet strength) enabling researchers to assess trends in drug consumption and to perform comparisons between population groups (Wertheimer, 1986). In addition to these three indicators of (poor) health, we also obtained the average costs (in euros) to the Belgian Social Security of these expenses for each participant per year (i.e., doctor-related costs, hospitalization-related costs, and prescription drugs-related costs).

Comparative health-related behaviors. In order to compare the magnitude of the benefits of emodiversity on health to other well-known health-related behavior, participants indicated the extent to which they were eating healthily, exercising, and smoking cigarettes. Specifically, participants were asked to complete (1) a 4-item healthy diet questionnaire (“*I try to vary my alimentation*”, “*I try not to eat fatty food*”, “*I try not to eat salty food and snacks*”, and “*I stay away from sweets and sodas*”), (2) a 3-item sport/exercise questionnaire (“*I exercise for at least 30 minutes three times a week*”, “*I practice yoga, Pilates, or stretching for at least 30 minutes three times a week*”, “*I practice leisure activities that help me stay in good shape such as gardening, golf, etc.*”), and (3) a 1-item smoking questionnaire (“*I smoke more than two cigarettes a day*”). All items were scored on a 3-point scale from 1 (almost never) to 3 (almost always).

Results and Discussion

Gender, age, and descriptive statistics. Descriptive statistics and inter-correlations between the variables are presented in Table 3. Women were found to experience more negative emotion on average ($M_{men} = 1.15$, $SD_{men} = 0.54$; $M_{women} = 1.29$, $SD_{women} = 0.60$), $t(1199) = 4.48$, $p < .001$, $d = .25$, and very slightly more negative emodiversity ($M_{men} = 1.92$, $SD_{men} = 0.42$; $M_{women} = 1.96$, $SD_{women} = 0.33$), $t(943) = 2.10$, $p = .04$, $d = .11$. No other significant gender differences were found. As in Study 1, we observed small but significant negative correlations between age and negative emodiversity and global emodiversity. Controlling for age and gender did not change the following pattern of results. Therefore, for parsimony, we will only report the analyses without these covariates. The distributions of the emodiversity scores were negatively skewed. Following statistical guidelines, a reciprocal

transformation was performed to correct skew (Howell, 2013; Osborne, 2008). Note that analyses using the non-transformed variables yielded similar results¹.

Positive emodiversity and objective health. Positive emodiversity, mean positive emotion, and their interaction were entered into a series of regressions predicting the mean number of visits to family doctors per year, the mean number of days spent in hospitals per year, the mean DDD and their respective costs to the Belgian Social Security. Results from these regression showed that positive emodiversity was negatively related to visits to the doctor ($\beta = -.29, t = -4.18, r_{\text{partial}} = -.12, p < .0001$), doctor's related costs to the Belgian Social Security ($\beta = -.32, t = -4.60, r_{\text{partial}} = -.13, p < .0001$), hospital related costs to the Social Security ($\beta = -.14, t = -1.98, r_{\text{partial}} = -.06, p < .05$), and mean DDD of medication ($\beta = -.24, t = -3.37, r_{\text{partial}} = -.10, p < .001$) over and above mean positive emotion. Positive emodiversity was also negatively related to days spent at the hospital ($\beta = -.13, t = -1.84, r_{\text{partial}} = -.05, p = .07$) and medication related costs to the Social Security ($\beta = -.12, t = -1.77, r_{\text{partial}} = -.05, p = .08$), although these relationships were only marginally significant.

In contrast, mean positive emotion was not significantly related to visits to the doctor ($\beta = .01, t = 0.33, r_{\text{partial}} = .01, p = .74$), doctor's related costs to the Social Security ($\beta = .01, t = 0.24, r_{\text{partial}} = .01, p = .81$), days spent at the hospital ($\beta = -.05, t = -1.23, r_{\text{partial}} = -.04, p = .22$), hospital related costs to the Social Security ($\beta = -.05, t = -1.21, r_{\text{partial}} = -.04, p = .23$), mean DDD of medication ($\beta = .03, t = 0.66, r_{\text{partial}} = .02, p = .51$), and medication related costs to the Social Security ($\beta = -.06, t = -1.46, r_{\text{partial}} = -.04, p = .15$).

The positive emodiversity * mean positive emotion interaction was significant for visits to the doctor ($\beta = -.22, t = -3.55, r_{\text{partial}} = -.10, p < .001$), doctor related costs for Social Security ($\beta = -.22, t = -3.66, r_{\text{partial}} = -.11, p < .001$), and mean DDD ($\beta = -$

.17, $t = -2.71$, $r_{\text{partial}} = -.08$, $p < .001$). Simple slope analyses at low (-1 SD) and high values (+1 SD) of mean positive emotion for each of these significant interactions revealed that positive emodiversity was slightly more strongly related to doctor's visits for high levels of mean positive emotion ($\beta = -.29$, $t = -4.18$, $r_{\text{partial}} = -.12$, $p < .001$) than for lower levels of mean positive emotion ($\beta = -.15$, $t = -3.56$, $r_{\text{partial}} = -.10$, $p < .001$). Likewise, positive emodiversity was slightly more strongly related to doctor's related costs to the Belgian Social Security for high levels of mean positive emotion ($\beta = -.32$, $t = -4.60$, $r_{\text{partial}} = -.13$, $p < .001$) than for lower levels of mean positive emotion ($\beta = -.18$, $t = -4.15$, $r_{\text{partial}} = -.12$, $p < .001$). Finally, positive emodiversity was slightly more strongly related to mean DDD for high levels of mean positive emotion ($\beta = -.24$, $t = -3.37$, $r_{\text{partial}} = -.10$, $p < .01$) than for lower levels of mean positive emotion ($\beta = -.13$, $t = -3.00$, $r_{\text{partial}} = -.09$, $p < .01$).

Negative emodiversity and objective health. Negative emodiversity, mean negative emotion, and their interaction were entered into a series of regressions predicting the mean number of visits to family doctors per year, the mean number of days spent in hospitals per year, the mean DDD and their respective costs to the Belgian Social Security. Results showed that negative emodiversity was negatively related to visits to the doctor ($\beta = -.12$, $t = -2.55$, $r_{\text{partial}} = -.07$, $p = .01$), doctor's related costs to the Social Security ($\beta = -.14$, $t = -3.11$, $r_{\text{partial}} = -.09$, $p < .001$), days spent at the hospital ($\beta = -.10$, $t = -2.24$, $r_{\text{partial}} = -.06$, $p < .05$), hospital related costs to the Social Security ($\beta = -.10$, $t = -2.13$, $r_{\text{partial}} = -.06$, $p < .05$), mean DDD ($\beta = -.22$, $t = -4.65$, $r_{\text{partial}} = -.13$, $p < .001$), and medication related costs to the Social Security ($\beta = -.20$, $t = -4.31$, $r_{\text{partial}} = -.12$, $p < .001$) over and above mean negative emotion.

In contrast, mean negative emotion was significantly positively related to visits to the doctor ($\beta = .19$, $t = 4.67$, $r_{\text{partial}} = .13$, $p < .001$), doctor's related costs to

the Social Security ($\beta = .22, t = 5.31, r_{\text{partial}} = .15, p < .001$), days spent at the hospital ($\beta = .22, t = 5.19, r_{\text{partial}} = .15, p < .001$), hospital related costs to the Social Security ($\beta = .11, t = 2.62, r_{\text{partial}} = .08, p < .01$), mean DDD ($\beta = .22, t = 5.27, r_{\text{partial}} = .15, p < .001$), and medication related costs to the Social Security ($\beta = .23, t = 5.71, r_{\text{partial}} = .16, p < .001$). None of the negative emodiversity * mean negative emotion interactions were significant.

Global emodiversity and objective health. Global emodiversity scores were entered into regressions predicting each health outcome, controlling for mean positive emotion and mean negative emotion. Global emodiversity was significantly negatively related to visits to the doctor ($\beta = -.13, t = -3.30, r_{\text{partial}} = -.10, p = .001$), doctor's related costs to the Social Security ($\beta = -.16, t = -4.04, r_{\text{partial}} = -.12, p < .001$), days spent at the hospital ($\beta = -.14, t = -3.35, r_{\text{partial}} = -.10, p = .001$), hospital related costs to the Social Security ($\beta = -.10, t = -2.48, r_{\text{partial}} = -.07, p = .01$), mean DDD ($\beta = -.17, t = -4.06, r_{\text{partial}} = -.12, p < .001$), and medication related costs to the Social Security ($\beta = -.14, t = -3.39, r_{\text{partial}} = -.10, p = .001$) over and above mean positive emotion and mean negative emotion.

Comparative health-related behaviors. In order to compare the magnitude of the benefits of emodiversity on health to other health-related behaviors, we examined the correlations between exercising, eating healthily, and smoking cigarettes, and our different health outcomes. Exercising was significantly negatively related to visits to the doctor ($r = -.11, p < .001$), doctor-related costs to the Social Security ($r = -.12, p < .001$), days spent at the hospital ($r = -.08, p < .001$), hospital related costs to the Social Security ($r = -.15, p < .001$), mean DDD ($r = -.15, p < .001$), and medication related costs to the Social Security ($r = -.14, p < .001$). Eating healthily was positively related to visits to the doctor ($r = .12, p < .001$), doctor-related costs to the Belgian Social

Security ($r = .12, p < .001$), and mean DDD ($r = .05, p < .05$). Smoking was not significantly related to any health indicators (all r 's $< .04$). The average effect sizes across the three (poor) health indicators were $r = -.11$ for exercising, $r = .05$ for healthy diet, and $r = -.03$ for smoking. In contrast, the average effect sizes across the three (poor) health variables were $r = -.09$ for positive emodiversity, $r = -.09$ for negative emodiversity, and $r = -.11$ for global emodiversity. We note that unlike mental health – for which mean positive and negative affectivity were much stronger predictors than emodiversity – the average effect sizes of emodiversity across the three physical health variables were larger than mean positive emotion ($r = .00$) and only slightly smaller than mean negative emotion ($r = -.14$), respectively.

Whereas Study 1 demonstrated the benefits of emodiversity for mental health, Study 2 provides evidence that the diversity of emotions that people experience is linked to their objective physical health, independently of their mean levels of emotion. The size of these effects was nontrivial: emodiversity was a similar or stronger predictor of physical health than mean levels of affect, eating healthily, not smoking, and exercising frequently.

General Discussion

Drawing from research methods in natural sciences used to quantify the biodiversity of ecosystems, the present research provides the first evidence for the notion that emodiversity – the variety and relative abundance of the emotions that humans experience – might play a unique role in human well-being. Emodiversity, whether positive, negative, or global, was associated with better mental and physical health across two large cross-sectional studies of over 37,000 respondents. In both studies, this association was best characterized as linear and the benefits of emodiversity did not seem to level off at very high levels. In addition, although the

positive relationship between emodiversity and mental and physical health was sometimes slightly stronger for people experiencing high levels of mean emotion, this association remained significant for low levels of mean emotion. Finally, our findings remained robust after controlling for gender, age, and the five primary dimensions of personality.

Although the cross-sectional nature of this design precludes causal inferences, our findings dovetail with an emerging literature showing that a complete understanding of the impact of emotions on well-being requires more than an understanding of mere overall levels. For example, fluctuation around one's average level of emotion (e.g., standard deviation) has been shown to be related to psychological-health above and beyond mean levels of emotions, while too much variability can be maladaptive (e.g., Gruber, Kogan, Quoidbach, & Mauss, 2013; Trull et al., 2008). Likewise, measures of emotion differentiation derived from traditional mood scales have been shown to correlate negatively with depression (Demiralp et al., 2012).

Why could emodiversity be beneficial for mental and physical health?

Although our data cannot tell us the underlying reasons emodiversity is positively associated with mental and physical health, several possibilities seem plausible. As noted in the introduction, experiencing many different specific emotional states (e.g., anger, shame, and sadness) may have more adaptive value than experiencing fewer and/or more global states (e.g., feeling bad), as these specific emotions provide richer information about which behavior in one's repertoire is more suited for dealing with a given affective situation (Barrett et al., 2001; Barrett & Gross, 2001; Ciarrochi et al., 2003). Second, reporting a wide variety of emotions might also be a sign of a self-aware and authentic life; such emotional self-awareness and authenticity have been

repeatedly linked to health and well-being (e.g., Schutte, Malouff, Thorsteinsson, Bhullar, & Rooke, 2007; Wood, Linley, Maltby, Baliouisis, & Joseph, 2008).

Finally, an intriguing possibility could be that, as with research suggesting that biodiversity increases resilience to negative events because a single predator cannot wipe out an entire ecosystem, emodiversity may prevent specific emotions – in particular detrimental ones such as acute stress, anger or sadness – from dominating the emotional ecosystem (see e.g., McEwen, 2004). For instance, the experience of prolonged sadness might lead to depression but the joint experience of sadness and anger – although unpleasant – might prevent individuals from completely withdrawing from their environment. The same biodiversity analogy could be applied to positive emotion. Humans are notoriously quick to adapt to repeated exposure to a given positive emotional experience (Frederick & Loewenstein, 1999); positive experiences that are diverse may be more resistant to such extinction. While these hypotheses must be investigated in future research, we note their accordance with personality research showing that highly self-complex individuals (i.e., people with many distinct self-aspects) are less vulnerable to swings in affect and self-appraisals in response to life events than individuals with limited self-aspects (Linville, 1985; Ryan, LaGuardia, & Rawsthorne, 2005).

Beyond investigating the underlying mechanisms of emodiversity, future research is also needed to better understand individual differences in emodiversity. First, a more comprehensive examination of gender and developmental differences in emodiversity is warranted. Our research demonstrates small gender differences, with men showing slightly lower levels of negative emodiversity, a finding that dovetails with previous research showing that men tend to be lower in emotional awareness (Barrett, Lane, Sechrest, & Schwartz, 2000). Likewise, age was negatively related to

our different measures of emodiversity, aligning with recent research showing that depending on the manner in which emotional complexity is defined and measured, younger adults can sometimes display a more complex emotional life than older adults (Ready, Carvalho, & Weinberger, 2008).

Future research should also explore how emodiversity relates to and interacts with existing measures of emotional functioning, such as emotion variability (e.g., Gruber et al., 2013), emotional intelligence (Salovey & Mayer, 1989), and emotion regulation (e.g., Gross & Thompson, 2007). In particular, further research is needed to assess the relationship between emodiversity and emotional granularity (Barrett, 1998; 2004), two constructs that derive from the shared idea that people can range from having few distinct emotional experiences to having many diverse experiences, and that a rich emotional life is broadly beneficial. However, whereas emotional granularity is high when people report feeling a limited number of discrete emotions at a given point in time, emodiversity is high when people report experiencing a wide and even range of emotions in general. We suggest that high emotional granularity may be a pre-requisite for high emodiversity: individuals must be able to finely differentiate the nuances between different emotional states to have a truly diverse emotional life.

While future research is needed to document the precise pathway by which emodiversity improves outcomes and interacts with other existing measures of emotional complexity, our results taken together support the notion that emodiversity is a significant and previously unidentified metric for assessing the health of the human emotional ecosystem.

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Endnotes

¹ Results from regression analyses with covariates and from regression analyses using the non-transformed variables can be downloaded from www.emodiversity.com

Table 1

Example of computation of emodiversity with the 18 emotions of the mDES used in Study 1.

Emotion	Score	P_i	$\ln P_i$	$(P_i * \ln P_i)$
Alertness	3	0.09	-2.43	-0.21
Amusement	1	0.03	-3.53	-0.10
Anger	2	0.06	-2.83	-0.17
Anxiety	3	0.09	-2.43	-0.21
Awe	2	0.06	-2.83	-0.17
Contempt	1	0.03	-3.53	-0.10
Contentment	0	0.00		
Disgust	0	0.00		
Embarrassment	1	0.03	-3.53	-0.10
Fear	4	0.12	-2.14	-0.25
Gratitude	1	0.03	-3.53	-0.10
Guilt	2	0.06	-2.83	-0.17
Joy	0	0.00		
Hope	2	0.06	-2.83	-0.17
Love	4	0.12	-2.14	-0.25
Pride	3	0.09	-2.43	-0.21
Sadness	3	0.09	-2.43	-0.21
Shame	2	0.06	-2.83	-0.17
SUM EMOTION	34			
EMODIVERSITY				2.61

Table 2

Correlations Among and Descriptive Statistics for Study 1 Variables

	Min	Max	<i>M</i>	<i>S.D.</i>	1	2	3	4	5	6	7	8	9	10	11	12
1 Mean Positive Emotion	0	4	1.89	0.88	--											
2 Mean Negative Emotion	0	4	1.07	0.77	-.42**	--										
3 Positive Emodiversity	0	2.20	1.89	0.44	.75**	-.38**	--									
4 Negative Emodiversity	0	2.20	1.36	0.60	-.34**	.79**	-.23**	--								
5 Global Emodiversity	0	2.89	2.39	0.25	.38**	.37**	.61**	.57**	--							
6 Depression	0	27	6.40	4.10	-.62**	.68**	-.54**	.54**	.00	--						
7 Age	15	90	38.76	13.86	-.06**	-.14**	-.05**	-.17**	-.16**	-.03**	--					
8 Extraversion	2	20	10.79	3.84	.40**	-.20**	.30**	-.17**	.12**	-.31**	-.04**	--				
9 Conscientiousness	2	20	15.02	3.55	.18**	-.25**	.12**	-.24**	-.11**	-.29**	.09**	.06**	--			
10 Neuroticism	2	20	11.82	4.42	-.48**	.56**	-.38**	.49**	.07**	.59**	-.09**	-.15**	-.20**	--		
11 Openness	2	20	13.04	3.85	.31**	-.13**	.23**	-.11**	.10**	-.21**	-.03**	.32**	.07**	-.16**	--	
12 Agreeableness	2	20	13.91	3.30	.34**	-.38**	.24**	-.35**	-.08**	-.35**	.12**	.10**	.22**	-.39**	.18**	--

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3

Correlations Among and Descriptive Statistics for Study 2 Variables

	Min	Max	<i>M</i>	<i>S.D.</i>	1	2	3	4	5	6	7	8	9	10	11	12
1 Mean Positive Emotion	0	4	2.57	0.67	--											
2 Mean Negative Emotion	0	3.8	1.23	0.58	-.35**	--										
3 Positive Emodiversity	0	2.30	2.22	0.17	.55**	-.07**	--									
4 Negative Emodiversity	0	2.30	1.94	0.37	-.12**	.61**	.24**	--								
5 Global Emodiversity	0	2.99	2.75	0.21	.08**	.53**	.69**	.79**	--							
6 Age	18	80	51.04	16.20	-.06*	-.14**	-.05	-.15**	-.11**	--						
7 Doctor's visits	0	22.27	5.23	3.67	-.09**	.12**	-.05	-.01	-.01	.26**	--					
8 Doctor costs for SS	0	331.91	73.71	54.09	-.11**	.13**	-.07*	-.03	-.03	.30**	.97**	--				
9 Days spent hospitalized	0	27.60	0.80	2.33	-.08**	.14**	-.04	.00	.01	.11**	.28**	.30**	--			
10 Hospital costs for SS	0	3717.76	253.56	487.78	-.08**	.05	-.04	-.07*	-.04	.24**	.42**	.44**	.66**	--		
11 Mean DDD	0	15761.99	1449.22	2395.01	-.08**	.07*	-.03	-.04	-.02	.36**	.43**	.48**	.30**	.39**	--	
12 Prescription drugs costs for SS	0	23409.79	849.57	1821.54	-.12**	.10**	-.05	-.01	-.01	.28**	.39**	.44**	.36**	.34**	.77**	--

Note: * $p < .05$, ** $p < .01$, *** $p < .001$. SS = Social Security; DDD = Defined Daily Dose.

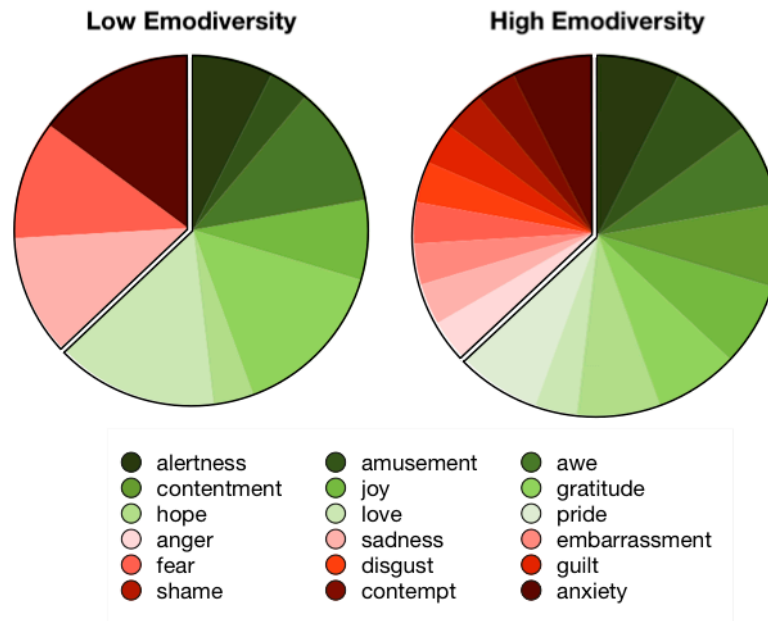


Figure 1. Schematic representing prototypical respondents low and high in global emodiversity, respectively. Selected respondents have identical mean levels of positive (green) and negative (red) emotion – matching the sample means (Positive Emotion = 1.89; Negative Emotion = 1.11) – but varied widely in emodiversity.

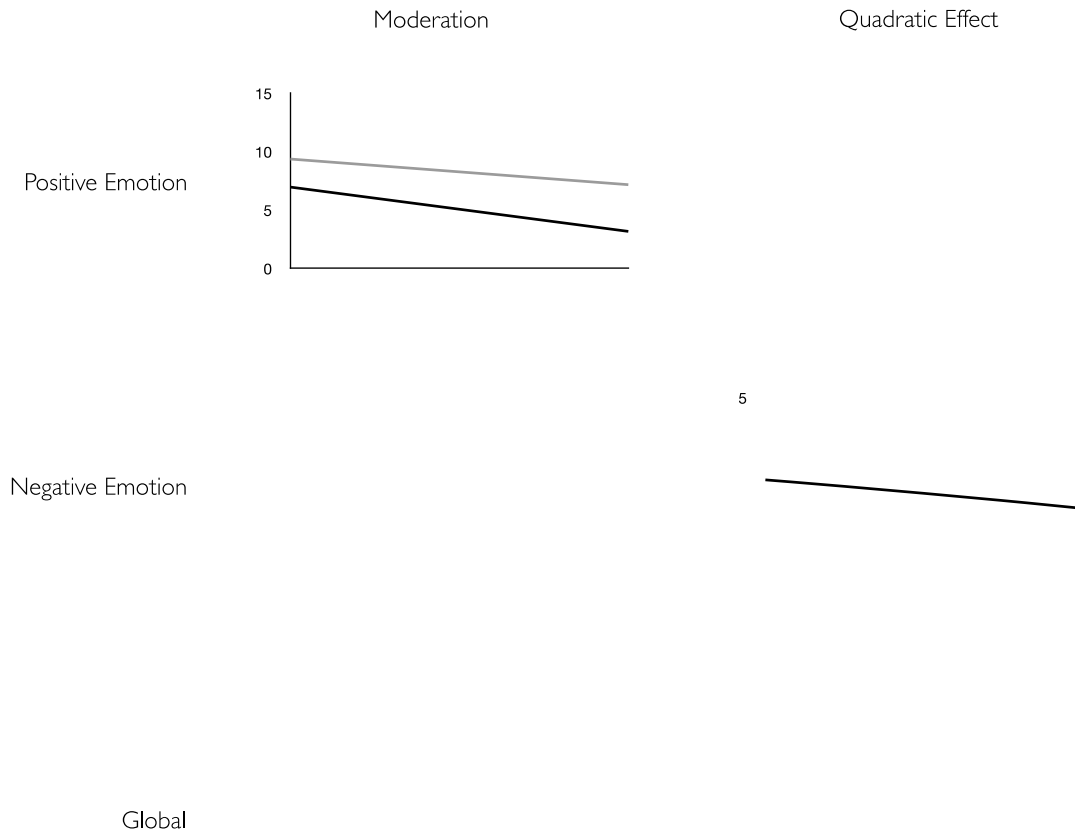


Figure 2. Conditional and quadratic effects for positive, negative, and global emotion diversity.