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Published in:
Current Research in Ecological and Social Psychology

DOI:
10.1016/j.cresp.2021.100012

Publication date:
2021

Current Research in Ecological and Social Psychology 2 (2021) 100012

Contents lists available at ScienceDirect

Current Research in Ecological and Social Psychology

journal homepage: www.elsevier.com/locate/cresp

Who is more prone to depression at higher latitudes? Islanders or mainlanders?

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ARTICLE INFO

Keywords:
Depression
Latitudinal gradient
Daylength variability
Islanders
Mainlanders

ABSTRACT

Across 195 countries, rates of depressive disorders in women and men are higher among islanders (relative to mainlanders) at more northern locations in the Northern Hemisphere and at more southern locations in the Southern Hemisphere. Our explanatory analyses show that the three-way interaction of greater daylength variability, being more of an islander, and adopting a more individualistic culture accounts for higher rates of depression in both genders. Differences in longitude, photoperiod, phase shift, disaster risk, economic poverty, income inequality, and urbanization level do not appear to account for the oppositely sloping north-south gradients of depression above and below the equator.

1. Introduction

"Depression is the leading cause of mental health-related disease burden globally, affecting an estimated 300 million people worldwide" (Herrman et al., 2019, p. e42). Depressed people can have many mental symptoms (e.g., feeling hopeless and helpless), disturbed patterns of individual behavior (e.g., problems with sleeping or working), and distorted social interactions (e.g., avoiding contact or creating conflict). These features of depression are thought to be similar across cultures (Haroz et al., 2017; Kesler and Bromet, 2013). Intriguingly, the Global Burden of Disease Network estimates that the share of the population with depression in 2017 was smallest near the equator (e.g., Colombia 2.20%, Peru 2.28%, Myanmar 2.30%) and largest near the poles (e.g., Sweden 4.49%, Finland 4.79%, Greenland 6.23%) (https://ourworldindata.org/grapher/share-with-depression). These estimates suggest the existence of higher rates of depression at higher latitudes. The same suggestion originates from the phenomenon of seasonal affective disorder—recurrent depression occurring more frequently with increasing seasonality at higher latitudes (Mersch et al., 1999; Rosen et al., 1989; Wehr and Rosenthal, 1989; Yang et al., 2010).

Traditionally, higher rates of depression at higher latitudes have been explained in terms of *photoperiod* (shorter periods between sunrise and sunset lead to more depressed people in winter; Lingjaerde et al., 1986; Potkin et al., 1986; Young et al., 1997) and *phase shift* (earlier dawns in winter make the biological clock run slower in people vulnerable to depression; Avery et al., 1997; Lewy et al., 1984; Rosenthal and Wehr, 1992). The common denominator of these well-documented theories is the link between shorter days and depression, validated by the efficacy of light therapy in treating seasonal depression (Golden et al., 2005; Oldham and Ciraulo, 2014). The present article is not about these biophysiological topics but seeks to supplement them by adding ecological and cultural context and content.

As discussed next, our supplementary understanding has three components: (1) the descriptive component unfolds the latitudinal gradients of depression in the Northern and Southern Hemisphere, (2) the mediation component explains why the main effect of greater daylength variability on higher rates of depression is expected to be mediated by higher cultural individualism, and (3) the modification component qualifies the latitudinal description of depression and uses cultural individualism to explain why islanders at higher latitudes are expected to be more prone to depression than mainlanders at higher latitudes.

1.1. Latitudinal gradients of depression

Latitudinal gradients in mindsets and practices can be described as unipolar equator-to-pole tendencies or bipolar pole-to-pole tendencies (Van de Vliert and Van Lange, 2019). Whereas the unipolar description of depression is more parsimonious, the bipolar description provides a more accurate, more informative, and more explanatory account of depression. The greater accuracy results from mapping depression along latitude in both the Northern and the Southern Hemisphere between the opposite poles. This bipolar description is more informative because it portrays reverse replication. It also exposes similarities and differences between the oppositely sloping latitudinal gradients of depression above

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https://doi.org/10.1016/j.cresp.2021.100012
Received 12 March 2021; Received in revised form 8 June 2021; Accepted 11 June 2021

and below the equator. So informative is the bipolar description that it even foreshadows how likely some explanations of depression might be.

Notably, it looks easier to explain oppositely sloping latitudinal gradients of depression in the Northern and Southern Hemisphere with global differences in daylength variability than with local differences in, for example, disaster risk (Tang et al., 2014) or urbanization level (Llorente et al., 2018; Probst et al., 2006). In addition, given that the Northern Hemisphere has more habitable landmasses in the northern direction than does the Southern Hemisphere in the southern direction, it makes sense to understand a comparatively steeper equator-to-pole gradient of depression towards the north pole in terms of greater variation in daylength variability. Finally, the daylength explanation seems more viable to the extent that there is a contrast between considerable increases of depression along latitude away from the equator in northern and southern directions (potential convergent validity) and no variation of depression along longitude east and west of the Greenwich meridian (potential discriminant validity).

Taken in total, the descriptive component, which foreshadows and anticipates the mediation and modification components of our theoretical framework, translates into Hypothesis 1: Rates of depression decrease from the south pole towards the equator and increase from the equator towards the north pole.

1.2. The path from daylength to depression

Greater daylength variability, with greater seasonal temperature variability and daily rain variability in its wake, requires continuous human intervention with nature, which encourages everyone to look after her- or himself and her or his loved ones (Hofstede, 2001). As a consequence, greater daylength variability at higher latitudes tends to elicit more individualism and less collectivism. By contrast, daylength stability, with seasonal temperature stability and daily rain stability in its wake, encourages everyone to value traditional rules and roles, including pre-existing group memberships and loyalties (Hofstede, 2001). Consequently, greater daylength stability at lower latitudes tends to elicit less individualism and more collectivism. In agreement with this line of reasoning, Hofstede (2001, p. 519) found a strong unipolar equator-to-pole association between geographical latitude and cultural individualism ($r = 0.79$, $n = 52$, $p < 0.001$).

A more accurate and more informative analysis of the pole-to-pole link between geographical latitude and cultural individualism showed that individualism decreases from the south pole towards the equator ($r = 0.50$, $n = 23$, $p < 0.01$) and increases from the equator towards the north pole ($r = 0.35$, $n = 122$, $p < 0.001$) (Van de Vliert and Van Lange, 2019, p. 870). Here, we explore the cumulative idea that the poleward increases in individualism lead to poleward increases in depression for the following reason: “Depressed patients in individualist cultures suffer more from guilt and are often unable to overcome the stress of personal decisions. Depressed patients in collectivist cultures can more often continue functioning because their social networks make the necessary decisions for them anyway” (Hofstede, 2001, p. 242; for details, see Draguns, 1997; Tanaka-Matsumi and Draguns, 1997).

Thus, the mediation component of our theoretical framework translates into latitude-related Hypothesis 2: Greater daylength variability is associated with higher cultural individualism which, in turn, is associated with higher rates of depression.

1.3. Islanders versus mainlanders

Hypothesis 2 implies that the same daylength variability at the same latitude affects individualism and depression to the same extent. However, if inhabitants of the same latitude differ in individualism versus collectivism (for whatever reason), they can be expected to also differ in their rates of depression. We concentrated on islands as a possible cause of cultural individualism and consequent depression because living on an island instead of in the mainland fits in our geographical frame, “determines a state of mind” (Beem, 1992, p. 86; Hay, 2006), and shapes personality (Camperio Ciani et al., 2007; Camperio Ciani and Capiluppi, 2011). Most importantly, building further on Hofstede’s (2001) latitudinal theory of culture, we argued that the relative isolation of islands makes islanders even more dependent on daylength and weather variabilities than mainlanders, thus eliciting relatively more individualism and less collectivism at higher latitudes.

Carefully treading on this untrodden territory, we translated the modification component of our theoretical framework into two further hypotheses. Hypothesis 3 is descriptive and qualifies Hypothesis 1: More so among islanders than among mainlanders, rates of depression decrease from the south pole towards the equator and increase from the equator towards the north pole. The topographical complication that many habitats are neither islands nor mainland is dealt with by analyzing degrees of islandness and then visualizing the results by breaking them down for 100% islanders, in-betweens (> 50% islandness), and mainlanders (< 50% islandness). Hypothesis 4 is explanatory and extends Hypothesis 2: In addition to or in interaction with greater daylength variability, being more of an islander is also associated with higher cultural individualism, which, in turn, is associated with higher rates of depression.

2. Data

2.1. Outcome variables: depression

The hypotheses were tested using the most recent country-level estimates of the Global Burden of Depression released by the Institute of Health Metrics and Evaluation (IHME; https://gbd2017.healthdata.org/gbd-compare). Based on medical, epidemiological data, surveys, and meta-regression modeling, the IHME estimates the share of the population suffering from depressive disorders, covering a spectrum of severity ranging from mild dysthymia to major depression. The estimates are age-standardized, assuming a constant age structure to allow comparisons across space and time. The latest year for which the IHME reported these data, broken down by country and gender, is 2017. The data, available for 195 countries, are geographically representative of all 234 independent countries and dependent territories on Earth (one-sample t-test against the known midrange values of all 234 territories: $t = 0.71$, $p = 0.48$ for absolute latitude; $t = 0.99$, $p = 0.32$ for longitude).

The gender breakdown allows replication tests of the hypotheses on women and men. The test on men is more conservative because the rates of reported major depression are lower for men than for women in every country on Earth (Andrade et al., 2003; Mersch et al., 1999; Weissman et al., 1996). As can be gathered from Table S1 of the Supplemental Material, the national percentages of depressed women (Mean = 4.06, SD = 0.82; Skewness = 0.83, SE = 0.17; Kurtosis = 1.99, SE = 0.35) and depressed men (Mean = 2.78, SD = 0.54; Skewness = 0.78, SE = 0.17; Kurtosis = 1.30, SE = 0.35) are approximately normally distributed variables. The test-retest reliability of the depression rates is high, both within countries across gender ($r = 0.79$, $n = 195$, $p < 0.001$), and between countries across time ($r = 0.95$, $n = 195$, $p < 0.001$ over the 27-year period from the first country estimates in 1990 to the last country estimates in 2017).

2.2. Mediation variable: individualism

Data on cultural individualism were not available for all 195 countries covered. To minimize missing data, a reverse-coded 178-country index of cultural collectivism (Van de Vliert, 2011) was used to represent cultural individualism. Specifically, cultural individualism was measured as the extent to which members of the nuclear family, relatives at large, and fellow nationals were treated in the same way as non-family members, non-relatives, and immigrants, respectively. The 178 scores in Table S1 indicate that individualism ranges from -2.39 in

Chad to 2.32 in Sweden (Mean = -0.24, SD = 0.73; Skewness = 0.96, SE = 0.18; Kurtosis = 1.70, SE = 0.36). The construct validity of this measure of individualism is reflected in a positive correlation with Hofstede's (2001) original measure of horizontal individualism versus vertical collectivism ($r = 0.83$, $n = 52$, $p < 0.001$; for the reconstruction of the original measure, see Van de Vliert, 2020).

To potentially qualify as a mediation variable between daylength variability and depression rates, this cross-national index of cultural individualism should vary along latitude and longitude in the same way as daylength variability does. As reported in Table S2, this is indeed the case. More in detail, northerners are more individualistic than southerners within the Northern Hemisphere ($r = 0.41$, $n = 140$, $p < 0.001$), whereas northerners are less individualistic than southerners within the Southern Hemisphere ($r = -0.35$, $n = 38$, $p < 0.03$). By contrast, the associations between longitude and individualism show that easterners are not more or less individualistic than westerners regardless of whether they reside east ($r = 0.10$, $n = 125$, $p = 0.28$) or west ($r = -0.01$, $n = 53$, $p = 0.97$) of the Greenwich meridian.

2.3. Geographical predictors

2.3.1. Latitude and longitude

The location of each country was retrieved from https://developers.google.com/public-data/docs/canonical/countries_csv. It was measured on the north-south coordinate of midrange latitude (negative below the equator and positive above it) and the east-west coordinate of midrange longitude (negative west of the Greenwich meridian and positive east of it). Because the Earth has north and south poles, latitude was treated as a bidirectional scale with the equator as a real and meaningful midpoint. Because the Earth has no east and west poles, longitude was treated as a unidirectional scale, with the Greenwich meridian as an imaginary and meaningless midpoint. We used the quadratic term of latitude (latitude-squared) to capture oppositely sloping latitudinal gradients in the Northern and Southern Hemispheres, and latitude-linear to control for confounding differences between the Hemispheres in habitable landmasses, terrain ruggedness, earthquakes, and more.

As also reported in Table S1, latitude ranged from -40.90 for New Zealand to 71.71 for Greenland (Mean = 18.90, SD = 23.99), and approximated a normal distribution (Skewness = -0.21, SE = 0.17; Kurtosis = -0.54, SE = 0.35). Longitude ranged from -175.20 for Tonga to 179.41 for Fiji (Mean = 17.77, SD = 68.09), and also approximated a normal distribution (Skewness = -0.16, SE = 0.17; Kurtosis = 0.36, SE = 0.35).

2.3.2. Islandness

The countries in our sample cover 42 islands, 39 landlocked territories, and 114 territories with water-border proportions somewhere between 100% and 0% (subdivisible in 35 countries with more water than land borders and 79 countries with more land than water borders) (Parker, 1997). These degrees of islandness pose some research problems. Notably, the dichotomy between islands and non-islands or between islands and landlocked territories throws away valuable information about the almost 100% islandness of, for example, Cuba (99%), Denmark (98%), United Kingdom (97%), Indonesia (95%), Greece (92%), South Korea (91%), and Qatar (90%). To test Hypotheses 3 and 4 as accurately as possible, we measured islandness at interval level as the degree to which a country has water borders rather than land borders (Parker, 1997). The country codes are reported in Table S1 (Mean = 0.45, SD = 0.39; Skewness = 0.34, SE = 0.17; Kurtosis = -1.46, SE = 0.35) (for insignificant zero-order correlations with latitude and longitude, see Table S2).

As yet another research problem, Australia and Greenland are so exceptionally large that their inhabitants may experience them as mainland rather than as an island. However, excluding them from the analyses has only negligible effects on the results. For that reason, Australia and Greenland were nevertheless coded as 100% islands.

2.4. Ecological predictors

2.4.1. Daylength variability

Links between photoperiod and depressive disorders (Lingjaerde et al., 1986; Potkin et al., 1986; Young et al., 1997) emphasize the possible importance of daylength to better understand the geography of depression. Based on each country's midrange latitude, the Chronology Unit of the University of Groningen has computed each country's daylength on 21 June and 21 December (Daan and Aschoff, 1975; Hut et al., 2013). We used the absolute difference between the two daylengths to represent daylength variability (Mean = 4.16, SD = 3.36; Skewness = 1.94, SE = 0.17; Kurtosis = 3.99, SE = 0.35). Daylength variability ($r = 0.99$, $n = 195$, $p < 0.001$) correlates almost perfectly with the longest day.

2.4.2. Disaster risk

Exposure to natural disasters such as earthquakes, violent storms, floods, and volcanic eruptions also leads to depression and related mental disorders (Tang et al., 2014). To take this influence into account, we borrowed a widely used cross-national measure from the United Nations (United Nations Development Programme, 2010): share of the population affected by natural disasters ($n = 178$).

2.4.3. Economic poverty

Poor populations tend to feel deprived and depressive (Llorente et al., 2018). National wealth was reversed to explore whether poverty might account for differences in depression. Economic poverty—measured with a time lag to allow causality to take hold—was represented by the average income per head in 2000, 2002, and 2004 ($n = 181$; United Nations Development Programme, 2002, 2004, 2006).

2.4.4. Income inequality

In wealthy countries, relatively poor people, surrounded by richer people, also tend to feel deprived and depressive (Llorente et al., 2018; Messias et al., 2011; Muramatsu, 2003). We therefore also controlled for the extent to which the distribution of income among individual households within a country deviates from a perfectly equal distribution. We retrieved the latest Gini coefficient released by the United Nations Development Programme (2019; $n = 151$) to avoid too many missing values.

2.4.5. Urbanization level

A final potentially confounding factor follows from the observation that depression is more prevalent in cities and other urban centers than in rural areas (Llorente et al., 2018; Probst et al., 2006). The percentage of a country's total population living in urban areas was taken from the C.I.A. World Factbook (https://www.cia.gov/library/publications/the-word.factbook/fields/349.html, retrieved 26 August 2018) ($n = 195$).

3. Methods

One hundred and ninety-five countries with known depression rates of women and men served as units of measurement and analysis (Table S1). We used SPSS 25.0 to regress depression rates on indicators of geography (latitude, longitude, islandness), habitat variability in daylength (with climate variability in its wake), and potential confounds (disaster risk, national wealth, urbanization). For reasons of comparability and comprehensibility, predictors were standardized. We report unstandardized regression coefficients based on heteroskedasticity-corrected standard errors, two-tailed significance tests, and 95% confidence intervals (Hayes, 2018). Data are available for inspection, reproduction, and secondary analysis from Table S1.

Table 1.
Prediction of islanders' and mainlanders' higher rates of depression at higher latitudes, broken down for women and men in 195 countries.

Predictors	Rates of depressed women			Rates of depressed men		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Latitude-linear (LALI)	0.10 (-0.01 to 0.22)	0.08 (-0.03 to 0.19)	0.08 (-0.03 to 0.20)	-0.07 (-0.15 to 0.01)	-0.08* (-0.15 to -0.01)	-0.09* (-0.17 to -0.02)
Latitude-squared (LASQ)	0.23*** (0.13 to 0.33)	0.17*** (0.07 to 0.27)	0.17*** (0.07 to 0.26)	0.09** (0.03 to 0.16)	0.07* (0.00 to 0.13)	0.07* (0.01 to 0.14)
Islandness (ISLA)	-0.05 (-0.16 to 0.06)	-0.22** (-0.35 to -0.08)	-0.21** (-0.36 to -0.07)	-0.05 (-0.12 to 0.03)	-0.11* (-0.21 to -0.02)	-0.10 (-0.19 to 0.00)
LALI x ISLA		0.26*** (0.15 to 0.36)	0.27*** (0.16 to 0.37)		0.15*** (0.07 to 0.22)	0.17*** (0.09 to 0.24)
LASQ x ISLA		0.18*** (0.08 to 0.27)	0.17*** (0.08 to 0.27)		0.07* (0.00 to 0.14)	0.06 (-0.00 to 0.13)
Longitude-linear (LOLI)			0.04 (-0.12 to 0.19)			0.15** (0.04 to 0.25)
ISLA x LOLI			0.04 (-0.09 to 0.18)			-0.06 (-0.15 to 0.03)
ΔR^2	0.11***	0.13***	0.01	0.06**	0.08***	0.04*
R^2	0.11***	0.24***	0.25***	0.06**	0.14***	0.18***

Shown are unstandardized regression coefficients with 95% confidence intervals between brackets (two-tailed tests). There is negligible multicollinearity (Variance inflation factors < 1.96), and there are no outliers (Cook's distances < 0.26).
* $p < 0.05$. ** $p < 0.01$. ***$p < 0.001$.

4. Descriptive results

4.1. Latitudinal gradients of depression

Table 1 reports that the rates of depressed women and men do not steadily increase or decrease from the south pole towards the north pole (see insignificant coefficients for "Latitude-linear" in Models 1 and 4). Instead, and in support of Hypothesis 1, depression rates are higher at higher latitudes for women and men (see significant positive coefficients for "Latitude-squared"). But that is only part of a much more complex story. Initially, islanders and mainlanders do not seem to differ in rates of depression (see insignificant coefficients for "Islandness" in Models 1 and 4). However, that first impression is then modified by the islanders' and mainlanders' latitudinal location (see Models 2 and 5). Due to their complexity, these interactive effects are difficult to understand without a visual breakdown of the results.

Fig. 1. displays the latitudinal distribution of depression rates, vertically broken down for islanders, in-betweens, and mainlanders; and horizontally further broken down for women and men. The two graphs at the top reveal that islanders have higher rates of depression at higher latitudes ($R^2 = 0.58$, $n = 42$, $p < 0.001$ for women; $R^2 = 0.27$, $p < 0.001$ for men). Despite the small subsample sizes, even the four simple slope tests tend to reach significance (Southern Hemisphere: $r = -0.68$, $n = 13$, $p < 0.01$ for women; $r = -0.56$, $n = 13$, $p < 0.05$ for men; Northern Hemisphere: $r = 0.65$, $n = 29$, $p < 0.001$ for women; $r = 0.34$, $n = 29$, $p = 0.07$ for men). The two graphs in the middle refer to 35 peninsulas and other countries with more water than land borders. At higher latitudes, inhabitants of these in-between countries tend to have higher rates of depressed women ($R^2 = 0.06$, $p = 0.03$) but not of depressed men ($R^2 = 0.01$, $p = 0.58$). The remaining mainlanders in the bottom graphs have a much less U-curved distribution of depression between the north and south poles. Although the total U-curve does reach significance for men, all simple slope tests are insignificant (Southern Hemisphere: $r = -0.17$, $n = 23$, $p = 0.43$ for women; $r = -0.03$, $n = 23$, $p = 0.89$ for men; Northern Hemisphere: $r = -0.11$, $n = 95$, $p = 0.29$ for women; $r = -0.20$, $n = 95$, $p = 0.06$ for men).

This detailed visualization of the complex interplay between latitude and islandness supports Hypothesis 3: More so among islanders than among mainlanders, rates of depression decrease from the south pole towards the equator and increase from the equator towards the north pole. Some shortcomings of these analyses are inherent to the widely varying physical size of the 195 sampled countries (ranging from 50 km^2 to 17100000 km^2). The smaller countries, being part of multi-country regions, tend to violate the assumption of independent observations. The larger countries, covering vast land areas (e.g., Australia, China, Greenland, Russia, and the United States), produce inaccurate overall measures of latitude, longitude, and islandness. To gauge the seriousness of these shortcomings, we repeated the hypothesis tests, assigning increasingly higher weights to more moderately sized countries. This weighting procedure yielded essentially the same results and inferences (Table S3).

In sum, we observed higher depression rates at higher latitudes in the Northern and Southern Hemisphere. Still, these tendencies were strong across island countries, weak across peninsula countries, and nonexistent across countries with more land than water borders. Although this geography of depression suggests links with daylength variability and cultural individualism, these explanatory associations are not yet demonstrated. Geographical support for the importance of daylength variability as an explanatory variable can be derived from the differential occurrence of depression rates along latitude and longitude (Section 4.2). Support for the modified indirect impact of daylength variability on depression rates is presented in Section 5.

4.2. Mapping depression along longitude

Variability in daylength—and thus in photoperiod, phase shift, seasonal temperatures, daily rainfall, plant growth, and animal life—vary in north-south rather than east-west directions (Diamond, 1997; Harcourt, 2015; Laitin et al., 2012; Van de Vliert and Van Lange, 2019). Consequently, if the daylength explanation put forward above is correct, one should expect the rates of depressed women and men to also vary along latitude (convergent validity) rather than longitude (discriminant validity). This is exactly what was observed. As also reported in Table 1, the rates of depressed women (Model 3; $\Delta R^2 = 0.01$, $p = 0.39$) and depressed men (Model 6; $\Delta R^2 = 0.04$, $p = 0.03$) are negligibly sensitive to the east-west location of the place of residence, regardless of whether on an island, on a peninsula or in the middle of the mainland.

At this point, three descriptive conclusions can be drawn. First, islanders and mainlanders do not seem to differ in depression rates if the habitat variability of their geographical location is not considered. Second, islanders and mainlanders residing at the same latitude in the East and the West, facing roughly the same habitat variability in daylength, tend to have roughly the same rates of depression. Third, compared to mainlanders, islanders in both the Northern and Southern Hemispheres are more prone to depression at higher latitudes with greater habitat variability in daylength (with climate variability in its wake).

5. Explanatory results

Although there can be little doubt about the existence of equator-to-pole increases in habitat variability Van de Vliert and Van Lange (2019), an open question is whether ecological and cultural factors can successfully predict rates of depression among islanders and mainlanders. To

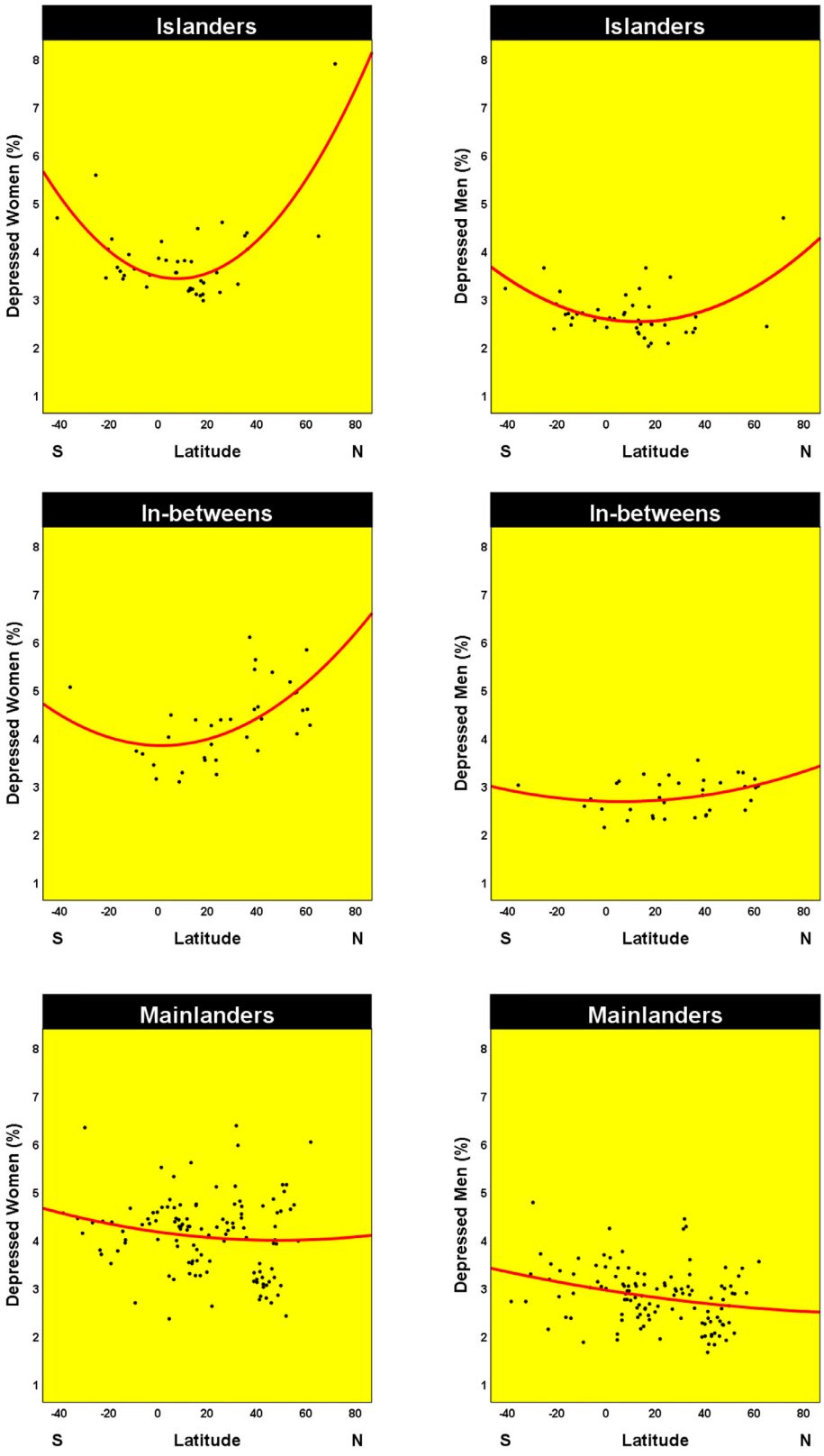

Fig. 1. Higher rates of depression at higher latitudes in the Northern and Southern Hemisphere. Shown at the top are equator-to-pole increases in depression for islanders ($R^2 = 0.58$, $p < 0.001$ for women; $R^2 = 0.27$, $p < 0.001$ for men). Shown in the middle are equator-to-pole gradients for in-betweens whose countries have more water than land borders ($R^2 = 0.34$, $p < 0.001$ for women; $R^2 = 0.11$, $p = 0.17$ for men). Shown at the bottom are negligible latitudinal differences in depression for mainlanders whose countries have more land than water borders ($R^2 = 0.02$, $p = 0.25$ for women; $R^2 = 0.08$, $p < 0.01$ for men).

what extent are daylength variability, islandness, and cultural individualism associated with the geography of depressive disorders? And to what extent are these presumably explanatory effects confounded with plausible alternative effects of disaster risk, economic poverty, income inequality, and urbanization level?

5.1. The path from daylength to depression

Greater daylength variability is linked to more depressive disorders in women ($r = 0.26$, $n = 195$, $p < 0.001$), but not in men ($r = 0.00$). A simple mediation analysis revealed no direct effect of daylength variability on the rates of depressed women ($b = 0.09$, $p = 0.24$, CI from -0.06

Table 2.
Interaction effects of daylength variability and islandness on rates of depressed women and men.

Predictors	Rates of depressed women		Rates of depressed men	
	Model 1 (n = 195)	Model 2 (n = 178)	Model 3 (n = 195)	Model 4 (n = 178)
Daylength variability (DAVA)	0.19 (-0.01 to 0.39)	0.11 (-0.13 to 0.36)	-0.04 (-0.22 to 0.14)	-0.09 (-0.30 to 0.11)
Islandness (ISLA)	-0.05 (-0.18 to 0.08)	0.04 (-0.13 to 0.21)	-0.06 (-0.20 to 0.08)	-0.05 (-0.21 to 0.12)
DAVA x ISLA	0.34** (0.10 to 0.58)	0.40** (0.13 to 0.68)	0.28** (0.06 to 0.51)	0.28* (0.04 to 0.52)
Cultural individualism (CUIN)		0.21* (0.00 to 0.42)		0.15 (-0.05 to 0.36)
DAVA x CUIN		0.12 (-0.00 to 0.25)		0.04 (-0.09 to 0.17)
ISLA x CUIN		0.08 (-0.10 to 0.26)		0.09 (-0.10 to 0.28)
DAVA x ISLA x CUIN		-0.32*** (-0.46 to 0.17)		-0.16* (-0.32 to -0.00)
R^2	0.20***	0.27***	0.08**	0.09*

Shown are unstandardized regression coefficients with 95% confidence intervals between brackets (two-tailed tests). There is negligible multicollinearity (Variance inflation factors < 2.71), and there are no outliers (Cook's distances < 0.18).
* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

to 0.25). Instead, a bootstrap confidence interval for the indirect effect through cultural individualism ($b = 0.12$) based on 5,000 bootstrap samples was entirely above zero (0.03 to 0.22). Disaster risk ($b = 0.01$, CI from -0.11 to 0.13), economic poverty ($b = -0.15$, CI from -0.34 to 0.04), income inequality ($b = 0.01$, CI from -0.01 to 0.04), and urbanization level ($b = 0.07$, CI from -0.08 to 0.21) did not have a confounding or additional effect. We inferred partial support for Hypothesis 2: in women, but not in men, greater daylength variability is associated with higher cultural individualism which, in turn, is associated with higher rates of depression. Moreover, to avoid reducing degrees of freedom unnecessarily (Atinc et al., 2012), we excluded the control variables from further analysis because of their negligible contribution to explaining the geography of depression.

5.2. Islanders versus mainlanders

Islanders exposed to daylength variability can have higher rates of depression than mainlanders exposed to the same daylength variability because the islanders are more individualistic than the mainlanders (main effect) or because their higher cultural individualism makes them more sensitive to daylength variability (interaction effect). Starting with the more complex explanation, we first tested whether islandness strengthens the effect of greater daylength variability on the outcome variable—rates of depression. The results in Table 2, model 1, show and a probe of the interaction effect confirms a more positive association between daylength variability and depression in women living on an island rather than in the mainland ($b = -0.15$, $p = 0.32$ at mean islandness -1SD, $b = 0.53$, $p < 0.01$ at mean islandness +1SD). Similarly, model 3 reveals a less negative association between daylength variability and depression in men living on an island rather than in the mainland ($b = -0.32$, $p < 0.05$ at mean islandness -1SD, $b = 0.24$, $p = 0.10$ at mean islandness +1SD). Both tendencies indicate that people coping with greater daylength variability are more depressive to the extent they are more of an islander.

In a second step, we tested whether islandness also strengthens the effect of daylength variability on the mediation variable—cultural individualism. This analysis revealed that daylength variability ($b = 0.46$, $n = 178$, $p < 0.001$, CI from 0.28 to 0.65), islandness ($b = 0.28$, $p < 0.001$, CI from 0.15 to 0.42), and their interaction ($b = 0.10$, $p = 0.29$, CI from -0.09 to 0.29) account for 30 percent of the variation in cultural individualism. Note that both main effects are significant, whereas the interaction effect is not. It tells that people exposed to higher daylength variability tend to be more individualistic irrespective of whether they are more or less of an islander, and that islanders tend to be more individualistic than mainlanders irrespective of the daylengths they are exposed to. Self-evidently, these additive effects of daylength variability and islandness on cultural individualism cannot explain the interaction effect of daylength variability and islandness on depression. What on Earth is going on?

A final analysis explored the possibility that cultural individualism, after having been shaped itself by daylength variability and by islandness, has in turn started to reinforce the interactive impact of daylength variability and islandness on depression. The findings in Table 2, models 2 and 4, result in two significant three-way interactions. Model 2 indicates negative associations between daylength variability and depression in, for example, collectivistic women living in the mainland rather than on an island ($b = -0.75$, $p < 0.001$ at mean individualism -1SD and mean islandness -1SD), and positive associations between daylength variability and depression in, for example, individualistic women living on an island rather than in the mainland ($b = 0.32$, $p < 0.05$ at mean individualism +1SD and mean islandness +1SD). Model 4 only indicates a negative association between daylength variability and depression in collectivistic men living on the mainland rather than on an island ($b = -0.59$, $p < 0.02$ at mean individualism -1SD and mean islandness -1SD). The results appear to provide empirical support for the proposition that depression peaks in individualistic islanders exposed to large seasonal variations in daylength.

6. Discussion

Nowhere in textbooks do we learn that the world's mental depression rates have a north-south rather than east-west distribution. Nor are we informed about the existence of a U-curve distribution of depression between the north and south poles. The present results help fill these gaps in our knowledge, highlighting the remarkable fact that the equator-to-pole increases in depression in the Northern and Southern Hemisphere are steeper for islanders than mainlanders. This tends to hold even for men, who have always had, and continue to have, lower rates of major depression than women in all countries on Earth (cf. Andrade et al., 2003; Mersch et al., 1999; Weissman et al., 1996). The two distinct generalizations—across hemispheres and genders—lend considerable credibility to the conclusion that islanders relative to mainlanders are more prone to depression at higher latitudes. This conclusion could be further strengthened by within-country replications.

Biogeographers will not be surprised by this finding as they have known for a long time about the special relationships between islands and illnesses (Harcourt, 2012, 2015). They speak of *island rules* to describe and explain how plants, animals, and humans on islands differ biologically from plants, animals, and humans on the mainland. One such rule is that infectious diseases in humans have flatter latitudinal gradients across island locations with sea climates than across mainland locations with continental climates (Cashdan, 2014). The new island rule developed here can be summarized as steeper equator-to-pole increases in rates of depression among islanders than among mainlanders. While it is hard to come up with an explanation for this geography

of depression, there are at least five reasons to believe in the existence of a worldwide ecology of depression modulated by habitat differences in daylength and islandness.

First, in common with the variability in daylength—and thus in photoperiod, phase shift, seasonal temperatures, daily rainfall, plant growth, and animal life—rates of depression fail to vary along the Earth's east-west axis, pointing to a latitude- rather than longitude-related explanation of depression. Second, among islanders, and especially so among individualistic female islanders, increases in daylength variability tend to go hand in hand with increases in rates of depression. Third, among mainlanders, and especially so among collectivistic mainlanders, increases in daylength variability tend to go hand in hand with decreases instead of increases in rates of depression. Fourth, photoperiod (Lingjaerde et al., 1986; Potkin et al., 1986; Young et al., 1997) and phase shift (Avery et al., 1997; Lewy et al., 1984; Rosenthal and Wehr, 1992) cannot account for the oppositely sloping latitudinal gradients of depression among islanders and mainlanders.

Finally, people who live at higher latitudes or on islands and clear peninsulas tend to have more individualistic cultures that make them more prone to depression (cf. Draguns, 1997; Hofstede, 2001; Tanaka-Matsumi and Draguns, 1997). Our reading of this finding is that individualistic cultures serve as double-edged swords. Daylength variability and islandness regularly disturb life and activities so that control has to be restored by using internal agency and creating internal structure (Friesen et al., 2014; Kay and Eibach, 2013; Whitson and Galinsky, 2008). On the one hand, these active control-restoring strategies in individualistic cultures leave the large majority of higher-latitude inhabitants and islanders more creative and happier in consequence (cf. Van de Vliert and Van Lange, 2019). On the other hand, one might speculate that a small minority of higher-latitude inhabitants and islanders may passively fall back on adopting overly simple and stable interpretations of the ordered environment that are unrelated to the control-reducing events (e.g., believing society is systematically divided into haves and have-nots; Landau et al., 2015). Future research may seek to show that this minority tends to use maladaptive control-restoring strategies associated with depressive feelings of hopelessness and helplessness rather than elated feelings of happiness.

These explanatory considerations should be read in the knowledge that the geography and ecology of depression cannot be convincingly studied in a controlled laboratory setting. Thus, cause and effect cannot be inferred, so that further investigations are needed to exclude rival explanations in terms of, for example, the greater exposure of higher-latitude inhabitants to insufficient ultraviolet radiation and cold stress. Mitigating this drawback is the almost axiomatic assumption that rates of depression in women and men cannot have caused widely different degrees of daylength variability and territorial water borders. Hence, there is a causal quality to our robust relationship: the only possible direction of impact is from daylength variability and islandness to depression. The same latitude-by-longitude design with nested islandness can be employed to explore the geography and ecology of, for example, treatment for depression (Smits and Huijts, 2015), control of neglected tropical diseases (Garchitorena et al., 2017), and disparities between islanders and mainlanders in healthy behaviors such as consumption of fruits/vegetables and abstinence of tobacco/alcohol use (Taylor et al., 2018).

That causation cannot be firmly established is not the only shortcoming of the proposed explanation of islanders' and mainlanders' rates of depression at higher latitudes. Additionally, the proposed mediating mechanism of the maladaptive control-restoring strategy of adopting overly simple and stable interpretations of the ordered environment (Landau et al., 2015) was not measured and analyzed. Mitigating this weakness is the complicating fact that a viable alternative theory should explain why the higher rates of depression at higher latitudes hold for islanders more than for mainlanders (Fig. 1). No alternative theory that we know of does so. The potentially confounding effects of disaster risk, economic poverty, income inequality, and urbanization level have been ruled out. As a result, this article provides novel evidence that brings global geography and ecology together to better understand why some populations are more depressive than others. Given the importance of depression for healthy human functioning, this is no small gap to fill.

Supplementary material

Additional supporting information may be found online in the Tables S1 to S5 of the supplementary material.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Evert Van de Vliert: Conceptualization, Formal analysis, Writing - original draft. **Peter J. Rentfrow:** Writing – review & editing.

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