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Research article

The effect of ultraviolet radiation on the incidence and severity of major mental illness using birth month, birth year, and sunspot data

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ABSTRACT

Background and objectives: The evaluation of the severity of patients afflicted with major mental illness (MMI) has been problematic because of confounding variables and genetic variability. There have been multiple studies that suggest several human diseases, especially schizophrenia, are predisposed to be born in certain months or seasons. This observation implied an epigenetic effect of sunlight, likely ultraviolet radiation (UVR), which is damaging to DNA, especially in an embryo. This paper outlines a method to evaluate the severity of schizophrenia (SZ), bipolar disorder (BPD), and schizoaffective disorder (SZ-AFF) using the month/year of birth of those affected compared to the month/year of birth of the general population (GP).

Relevance: Our previous research found that more intense UVR (equal to or greater than 90 sunspot number (SSN)) had a negative effect on the average human lifespan. Also, human birth rates vary in frequency by month of birth reflecting variables like availability of food, sunlight, and other unknown epigenetic factors. We wanted to see if the patient month of birth varied from the average birth months of the general population and if UVR has an epigenetic effect promoting these diseases.

Methods: We obtained the month and year of birth of 1,233 patients admitted over a 15-year period to Maine's largest state psychiatric hospital and counted the months of birth for each diagnosis of SZ, BPD, and SZ-AFF, and compared these results to the general population's birth months of 4,265,555 persons from U. S. Census Year 2006. The number of patients in each month was normalized to August and compared with the normalized birth months of the general population (GP). Plots of the normalized months were considered rates of change (e.g., derivatives) and their respective integrals gave domains of each mental illness relative to the GP. Normalizing the GP to unity was then related to the factor 1.28, e.g., 28% more entropy, deduced from the Sun's fractal dimension imprinted on biological organisms.

Results: The percent of patients meeting our criterion for severity: SZ = 27%; BPD = 26%; SZ-AFF = 100%.

Conclusions: High UVR intensity or a rapid increase in UVR in early gestation are likely epigenetic triggers of major mental illness. BPD is more epigenetically affected than SZ or SZ-AFF disorders. We found that 52% of 1,233 patients comprised the core function of a tertiary-care psychiatric hospital. Also, mental illness exacerbated when the median SSN doubled. This work also validates the Kraeplinian dichotomy.

What is new in this research: This paper offers a new paradigm for evaluating the severity of MMI and supports significant epigenetic effects from UVR.

1. Introduction

This paper offers a methodology to more objectively assess the severity of these three mental illnesses, schizophrenia (SZ), bipolar disorder (BPD) and schizoaffective disorder (SZ-AFF), using the intrinsic variation of solar radiation impressed on the epigenome-genome complex of all biological organisms. The literature on objectively assessing the severity of mental illness is not extensive [1]. Mainly noted are difficulties in defining severity of mental illness.

In the past two decades there have been many papers describing the effect of month and year of birth on the incidence of a variety of human diseases (see Table 1) [2]. Recently, a global meta-analysis reaffirmed that month of birth was associated with major mental disorders [3]. In addition, there is increasing interest in how environment affects the epigenome which controls the expression of the genetic library in DNA

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Table 1. List of publications involving MOB and various diseases.

CATEGORY	First Author (ref)	MOB	MOC	Comment
Lifespan/Life expectancy				
	Lerchl, A. [83]	Increased Oct–Dec	Jan–Mar	Decreased May–Jul
	Gavrilov, L. A. [84]	Increased Sep–Nov	Dec–Feb	centenarians
	Doblhammer, G. [85]	Autumn births	Jan–Mar	
	Lummaa, V. [86]	Nov–Mar, Jun	Feb–Jun, Sep	Fertility in 19th century
	Ueda, P. [87]	Mar–Apr	Jun–Jul	Increased cardiovascular mortality
	Ueda, P. [88]	Apr–May	Jul–Aug	Increased mortality in Sweden
	Abel, E. L. [89]	Increased Nov	Mar	Decreased in Jun
Multiple Sclerosis				
	Dobson, R. [90]	Apr–May	Jul–Aug	
	Pantavou, K. [91]	Mar–May	Jun–Aug	Meta-analysis
	Staples, J. [92]	Nov–Dec	1st -trimester Feb–Mar	(Southern Hemisphere) Higher incidence of MS
	Akhtar, S. [93]	Dec	Mar	Study in Kuwait
Celiac Disease	Capriati, T. [94]	Jun–Aug	Sep–Nov	? related to gluten/rotavirus
	Assa, A. [95]	May	Aug	Reduced risk: Dec- > Feb
Atopy				
	Nilsson, L. [96]	Sep–Feb	Dec–May	Less disease for those born in summer/spring
	Karachaliou, F.H. [97]	May–Aug	Aug–Nov	Study done in Greece
Asthma				
	Sargsyan, A. [98]	Oct–Dec	Jan–Mar	Pediatric patients
Autism				
	Lee, L. [99]	Mar, May, Sep	Jun, Aug, Nov	
	Lee, B. K. [100]	Sep–Nov	Dec–Feb	
	Shalev, H. [101]	Aug	Nov	
	Torrey, E. F. [27]	Mar	Jun	
ADHD				
	Sucksdorff, M. [102]		Nov–Mar	Low vitamin D in gestation
Diabetes mellitus type 1				
	Kahn, H. [103]	Apr–Jul	Jul–Oct	
Diabetes Mellitus Type 2				
	Grover, V. [104]	Oct is protective	Jan	African American cohort <18 yrs of age
Thyroiditis				
	Thvilum, M. [105]	Jun	Sep	Autoimmune hypothyroidism
	Kyrgios, I. [106]	Mar	Jun	Lowest in Nov
Colorectal cancer				
	Francis, N. [107]	Sep	Dec	
Narcolepsy				
	Dauvilliers, Y. [108]	Mar	Jun	Trough in Sep
Brain tumors				
	Brenner, A. [109]	Jan–Feb	Apr–May	
		Nov–Mar	Feb–Jun	Left-handedness increased risk
	Schmidt, L. [110]	Jan	Apr	ependymoma
Hodgkin's disease				
	Langagergaard, V. [111]	Mar	Jun	
Non-Hodgkin's lymphoma				
	Crump, C. [112]	Mar–Jun	Jun–Sep	Nadir in MOB Sep–Dec
Melanoma				
	Basta, N. [113]	Mar	Jun	Teenagers/young adults
	Lin, S–W. [114]			
IBS/Crohn's disease				
	Van Ranst, M. [115]	Apr, Aug	Jul, Nov	Fewer cases in MOB Jun
Depression				
	Schnittker, J. [49]	Apr–Aug	Jul–Nov	Aggravated by poor nutrition
	Torrey, E. F. [27]	Mar–May	Jun–Aug	

(*continued on next page*)

Table 1 (*continued*)

CATEGORY	First Author (ref)	MOB	MOC	Comment
Schizophrenia/BP disorder				
	Karlsson, H. [44]	Dec	Mar	Study from Sweden
	Davies, G. [116]	Jan–Mar	Apr–Jun	27 Northern Hemisphere sites
	Torrey, E. F. [27]	Dec–Mar	Mar–Jun	
Addison's disease	Pazderska, A. [117]	Dec	Mar	Trough in May
Malignant neoplasms	Stoupel, E. [118]	Jan–Apr	Apr–Jul	More males affected
Breast Cancer	Yuen, J. [119]	Jun	Sep	Study from Sweden

[4, 5]. In aquatic and terrestrial animals, as well as humans, many variables in the environment affect growth and development including temperature, food/nutrition, humidity, infections, gut microbiome, chemicals, ionizing radiation (radon, cosmic rays), and especially non-ionizing ultraviolet radiation (UVR) [6, 7, 8, 9]. Animal and plant life had to contend with genotoxic and mutagenic UVR from the Sun even after the formation of protective oxygen/ozone by stromatolites (cyanobacteria) in the pre-Cambrian Period [10, 11]. About 3% of ground-level solar radiation is UVR, of which about 95% lies in the UV-A (315–400 nm) spectrum and about 5% in the UV-B (280–315 nm) spectrum. Despite absorption by Earth's atmosphere, UVR is still a potent DNA/RNA mutagen, and over eons, organisms have developed efficient repair mechanisms to correct genotoxicity and maintain the integrity of DNA especially in meiotic organisms through the period of natural (sexual) selection [12, 13].

Since 1993, several reports have emerged postulating the adverse effects of higher intensity UVR on human longevity; namely, peaks of approximately 11-year solar cycles (MAX) were particularly able to shorten lifespan, presumably due to the damaging effects of UVR [14,15]. Using the mortality data of approximately 63 million persons, we found an average 8-year reduction in human lifespan, e.g., more diseases, when the sunspot number (SSN), a surrogate for solar intensity, was equal to or greater than 90 at birth, the average SSN being approximately 40, however, greater than or equal to 90 SSN occurs only about 11% of the time. ADDIN EN.CITE [16, 17]. The most damaging UVR occurs in the 3-year portion of an 11-year solar cycle called the solar MAX where the number of sunspots are at the highest (approximately 160) of the solar cycle. Although less compelling than findings during solar MAX, others primarily report changes in seasonal or monthly UVR that modulate the incidence of various diseases (see Table 1).

There is increasing evidence that light, likely in the UVR spectrum through a variety of mechanisms, affects the human embryo [17, 18, 19]. Other papers propose the importance of early-life events that affect the incidence of disease in adult individuals [20, 21, 22]. The epigenome of the fetus is most sensitive not only to a variety of environmental factors, but also to many maternal influences possibly even to sunlight; e.g., UVR striking the mother's skin where vitamin D metabolism among other metabolic factors may play a role [18, 23, 24]. There is recent evidence that the gut microbiome may foster MMI due to the absorption of small molecules it produces that affect the gut-brain axis [25]. Abnormal circadian rhythms may also play a role in the developing embryo as chronodisruption has been linked to depression later in adulthood [26].

Torrey et. al. reported in 1996 that persons afflicted with a major mental illness (MMI) like SZ or BPD were more likely born in late winter and early spring [27]. Since then, other human disorders had seasonal birth predilections implying that varying solar radiation might be an important factor. That schizophrenia has a 1% incidence world-wide also suggests a global effect, not exclusively related to diet/nutrition, humidity, or even latitude [28]. Hypotheses that implicate *Toxoplasmosis* or influenza in the incidence of schizophrenia are plausible but are not necessarily uniformly distributed world-wide; however, UVR affects epigenomes, at least of surface organisms, universally. UVR is not always unhealthy as sun exposure is linked to a reduced pediatric risk for multiple sclerosis [29]. There is also evidence that specific diseases are mitigated by UVR, but overall UVR is detrimental [30, 31, 32]. Adequate production/absorption by UVR of the hormone vitamin D is salutary for the human immune system, but too much UVR is detrimental to human lifespan [33, 34].

We acquired the month of birth (MOB) records in the 2006 U. S. Census and found that births are not uniformly distributed as more occur in the summer and early fall. The reason for this observation is not totally known except that many animals conceive in the fall and give birth in the spring and early summer probably due the evolutionary imperative of increased newborn survival in more favorable weather and better food supplies. In this paper we use the number of births by month in the general population as a baseline to compare with persons afflicted with major mental illnesses. The null Hypothesis tested here is that major mental illness is not related to month of birth or MAX or MIN.

Hypothesis #1: We hypothesize that the deviation of MOB of persons with MMI varies from that of the GP is a measure of the epigenetic effect of UVR at conception/early gestation, and evident at birth. We assume that the GP is, on average, ideally adapted to the UVR environment and alterations in MOB may be maladaptive due to varying effects of UVR at conception/gestation when ectodermal tissues are in formation.

The most complicated, problematic patients in mental health find their way into tertiary care facilities because their behaviors are the most unpredictable and therefore dangerous to self or others. Assessment of the severity of MMI has been problematic and this paper offers a methodology to be more objective in this process [35]. Using 18 years of admission data from our former state hospital (the Augusta Mental Health Institute, we found that 72% of patients had a single admission, but the remaining 28% comprised admissions 2 through 12 (see Figure 1) [36]. Even at a tertiary facility the staff could not successfully "cure" those who expressed so much complexity, risk, and disorganized behavior that they required more than a single admission. Some of our single admissions sought care in other hospitals, but they did not meet strict requirements for readmission to our tertiary-care facility.

Evident in everyday life are macroscopic examples of 28% less entropy, or fewer possible states, including physical and mental states necessary to match the variety of states in the environment. The prevalence in the US population with either a MMI or a substance abuse disorder was 28.5% in 20,291 adults in the National Institute of Mental Health Epidemiologic Catchment Area Program indicating that portion of the population in a less adaptive state relative to the environment [37]. Using the representation of biological evolution created by the late British mathematician John Conway's Game of Life (a cellular automaton) revealed that the exponent of its power law was exactly 1.28 even after 100 million mutations reflecting the challenges changing environments force on biological systems [38]. It is likely that organisms must maintain a variation of no less than 28% in their genome-epigenome complex to maintain survivability over the long term. In the plant world pruning more than 28% of the *living* portion of a tree or scrub can jeopardize its survival [39]. We humans require about 7 h of sleep in a 24-hour period (for adults about 28% of the day) to maintain good health

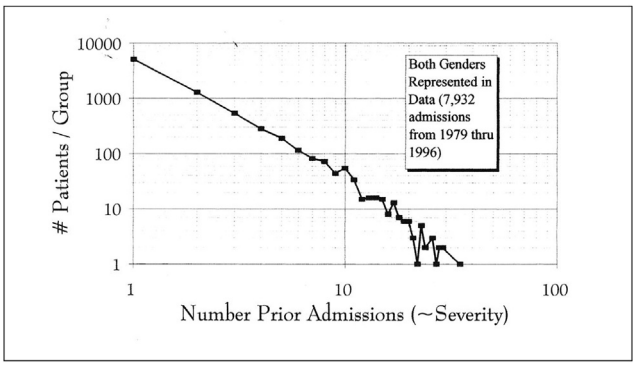

Figure 1. Number of prior admissions (severity) versus the number of patients per group (frequency); example of a power law. [36].

[40]. It probably is no accident that we also need 2 days out of a 7-day week (approximately 28%) for recreation. Note that *entropy is system dependent.* For example, entropy decreases with aging as there is less variation in heart rate, exercise tolerance, etc. (internal entropy)., but entropy increases rapidly at the time of death (external entropy).

Hypothesis #2: The more severe the mental disorder in our patients the larger the ratio of normalized birth month to the normalized (set to unity) birth month in the GP. That critical ratio is 1.28, above which indicates higher entropy relative to the environment (society), but internally (cerebrally) as in MMI, the ratio is less than 1.28 indicating lower entropy, e.g., fewer organized states available to match the environment.

The human brain is more complex than any machine invented by our species to date and is the most important organ for our survival. As such, the brain must be highly connected to our environment to preserve survival. It also manifests self-similarity on all scales like the branching of a tree, a property called "fractal", a term coined by the late mathematician Benoit Mandelbrot [41]. Recall that a one-dimensional object (e.g., a line) has a fractal dimension value of unity. The "rougher" or more irregular the line, the greater the fractal dimension and the more complex the object. Probably not coincidentally, the Sun is a dynamical system with a generalized fractal dimension based on 10.7 cm radio fluxes (in Solar Cycle 21) of 1.28 for periods of about a week, and 1.30 for periods longer than 272 days [42]. While beyond the scope of this article, the Rényi entropy and fractals are connected by a linear relation (e.g., $S_q = D_q \ln r$) [43]. If the fractal dimension approaches 2, a time series of radio fluxes becomes completely random [42].

The human brain has a fractal dimension of 1.60 (indicating more sulci; e.g., a cerebral cortex with more anatomical convolutions permitting more connections and probably higher intelligence) equal to approximately the square of the solar fractal dimension.

2. Methodology

2.1. The data

We obtained the admission data from the Riverview Psychiatric Center (Maine's largest state psychiatric hospital) since the incept of a new computer system in 2006. The birth records go back to year 1974 from the previous state hospital (Augusta Mental Health Institute) to 2003 (Riverview Psychiatric Center) as no one under the age of 18 was admitted and only individuals were selected, omitting multiple admissions of the same patient. We only required deidentified *birth month and birth year*. We also had the NOAA data base for sunspot activity averaged by month and year, a surrogate for solar energy output. (See Supplement 1 SSN and Supplement 2 SSN) A total of 1,233 patients were available for analysis, 445 for SZ (36% of total), 358 for BPD (29% of total), and 430 for SZ-AFF (35% of total). Of the SZ-AFF patients most were classified as "undifferentiated", but 98 (23%) of the 430 patients were classified "bipolar type". Only a few were classified "depressed type". We did not include patients with borderline or antisocial personality disorders as the primary diagnosis. No major depressive disorder diagnoses were included in this paper because most are successfully treated at primary and secondary psychiatric hospitals. We also acquired the MOB data for the year 2006 U. S. Census, N = 4,265,555, a year during a solar MIN, average SSN = 15, and serves as a good baseline for distribution of MOB with no sustained high UVR. Another author has used the GP as a baseline [44].

Table 2a. Number of patients by Month of Birth and Diagnosis at Riverview (MOB from years 1974–2003, collected from 2004 to present).

MOB	Schizophrenia	Bipolar Disorder	Schizoaffective Disorder	General population (2006)
Jan	40	28	40	340,297
Feb	29	27	37	319,235
Mar	47	34	51	356,786
Apr	40	32	31	329,809
May	48	25	49	355,437
Jun	29	37	37	358,251
Jul	36	23	40	367,934
Aug	33	30	31	387,798
Sep	38	37	42	374,711
Oct	33	28	37	367,354
Nov	26	28	33	351,832
Dec	46	29	42	356,111
Totals	**445 (36%)**	**358 (29%)**	**430 (35%)**	**4,265,555**
N ≥90 SSN	**185 (42%)**	**114 (32%)**	**189 (44%)**	**None ≥90 SSN**

The data were supplied in alphanumerical order, for example, Jan 1984, and were first sorted for year of birth (YOB) to match SSN with that month and year from the NOAA SSN data. Then each month was given a numeric value, for example, numeral 1 for January, numeral 2 for February, etc., and then sorted from 1 to 12 and each of the twelve months counted for the number of patients born in their respective months (see Tables 2a and 2b). The next step normalized each diagnosis to the month of August creating ratios to compare our data with the larger GP, also normalized to the month of August (see Tables 3a and 3b). We use the birth month/year data in the 2006 U. S. Census to serve as a reference because that population is *on average* adapted to the environment, and we hypothesize deviation from that average is maladaptive. We also calculated the average, median and standard deviation of SSN for the whole set for each diagnosis and for the separate greater than or equal to 90 SSN sets (see Table 4a, 4th column).

Using Excel and Tables 3a and 3b, we then created trend (goodness-of-fit) lines using third-degree polynomials for each of the three psychiatric diagnoses and for the GP (see Figure 2). We considered these trend lines to be *rate-of-change plots*, essentially derivatives. The trend line

Table 2b. Number of patients by Month of Birth for ≥90 SSN.

MOB	Schizophrenia	Bipolar disorder	Schizoaffective disorder
Jan	15	7	14
Feb	11	8	11
Mar	20	12	18
Apr	8	11	14
May	15	6	21
Jun	12	15	18
Jul	16	6	10
Aug	12	8	12
Sep	16	16	21
Oct	12	11	14
Nov	28	5	18
Dec	20	9	18
Totals	**185**	**114**	**189**

Table 3a. Normalized Month of Birth data from Table 2a.

MOB	Schizophrenia	Bipolar disorder	Schizoaffective disorder	General population
Jan	1.21	0.93	1.29	0.88
Feb	0.88	0.90	1.19	0.82
Mar	1.42	1.13	1.65	0.92
Apr	1.21	1.07	1.00	0.85
May	1.45	0.83	1.58	0.92
Jun	0.88	1.23	1.19	0.92
Jul	1.09	0.77	1.29	0.95
Aug	**1.00**	**1.00**	**1.00**	**1.00**
Sep	1.15	0.83	1.35	0.97
Oct	1.00	0.93	1.19	0.95
Nov	0.79	0.93	1.06	0.91
Dec	1.39	0.97	1.35	0.92

equations were then integrated for their total area under the curves (producing whole domains in the difference in MOB distribution from the GP for each diagnosis) for each monthly interval, (Jan–Feb, Feb–Mar, etc.). To check on accuracy, each of the 11 partitions added up within one-hundredth decimal accuracy to the total 1–12 integral for each diagnosis (See Tables 4a, 4b).

Dividing each of the 11 partition integrals in Table 4b by the respective GP integral, yielded the values in Table 4c, effectively normalizing to the GP. The plots in Figures 3, 4, and 5 (using data from Table 4c) give the severity of illness (extent of deviation from the GP) for the three diagnoses relative to a Y-axis value of 1.00, the reference to the GP. In this paper we use the average duration of human gestation to be 280 days, or 40 weeks, from the first day of a woman's last menstrual period. Therefore, we considered the month of conception (MOC) to be 10 months prior to MOB.

3. Results

3.1. Schizophrenia

Referring to Figure 3 created from the data in Table 4c:

Note that the full data set is below the critical severity level of 1.28 (Mar–Apr and Nov–Dec integrals are exactly 1.28). Looking at the greater than or equal to 90 SSN plot reveals essentially the same pattern but more severe illness in the late winter and early spring and an even higher peak during the November–December interval. Calculations of the most ill patients based upon the level above 1.28 in the greater than or equal to 90 SSN plot:

All >1.28 integral ratios in the SZ greater than or equal to 90 SSN set add up from January through May: 1.37 + 1.38 + 1.33 + 1.28 = 5.36,

Table 3b. Normalized MOB data for Diagnoses ≥90 SSN from Table 2b.

MOB	Schizophrenia ≥90 SSN	Bipolar disorder ≥90 SSN	Schizoaffective disorder ≥90 SSN
Jan	1.25	0.88	1.17
Feb	0.92	1.00	0.92
Mar	1.67	1.50	1.50
Apr	0.67	1.38	1.17
May	1.25	0.75	1.75
Jun	1.00	1.88	1.50
Jul	1.33	0.75	0.83
Aug	**1.00**	**1.00**	**1.00**
Sep	1.33	2.00	1.75
Oct	1.00	1.38	1.17
Nov	1.08	0.63	1.50
Dec	1.67	1.13	1.50

Table 4a. Data for all diagnoses and their ≥90 SSN subsets.

Diagnosis	Integral	Differential inflection(s) by month	average/median/ SD of SSN	ratio/gen pop Low high
Schizophrenia	**11.50**	4.0, 9.0	75/60/59	1.04 1.28
SZ ≥90 SSN	**12.65**	2.4, 7.8	141/137/35	1.13 1.57
Bipolar disorder	**10.28**	9.0	71/58/54	0.95 1.10
BPD ≥90 SSN	**13.35**	7.0	138/136/31	1.19 1.44
General population	**9.92**	1.5, 8.0	Average SSN = 15 (at Solar minimum)	1.00 1.00
SZ-AFF disorder	**14.04**	3.5, 9.0	78/65/59	1.27 1.57
SZ-AFF ≥90 SSN	**14.70**	4.5, 8.0	140/131/36	1.33 1.80

plus October–November and November–December: 1.33 + 1.57 = 2.90. Summing: 5.36 + 2.90 = 8.26 which is 8.26/12.65 = 0.65 (65%) of the total integral (in 2nd column of Table 4a).

Since there were 185 patients in the greater than or equal to 90 SSN set, 185 x 0.65 = **121 patients**.

121/445 total schizophrenic patients = 0.27 *or 27% of those afflicted with schizophrenia are more complicated and likely to have a longer length-of-stay (LOS).*

Referring to the second column in Table 4a, we take the ratio of the total integrals for the full 12 months of SZ greater than or equal to 90 SSN/SZ = 12.65/11.50 = 1.10. Therefore, there is 10% epigenetic component, leaving 90% genetic. We consider those born in greater than or equal to 90 SSN as influenced epigenetically.

3.2. Bipolar disorder

Referring again to Figure 4 created from Table 4c:

All >1.28 ratios are in the BPD greater than or equal to 90 SSN set except for January & February in that set: 1.19 and November–December: 1.35 Subtract (1.19 + 1.35 =) 2.54 from the total integral 13.35 or 10.81. This divided by the total integral (2nd column of Table 4a) for greater than or equal to 90 SSN: 10.81/13.35 = 0.81; 0.81 x 114 patients = **92 patients.** Of the total BPD patients, 92/358 = *26% of the BPD patients are more complicated and likely to have a longer LOS.* If we take the ratio of the total integrals for the full 12 months, BPD greater than or equal to 90 SSN/BPD = 13.35/10.28 = 1.30. Therefore, there is a 30% epigenetic component, three times that of schizophrenia, still leaving a substantial 70% genetic fraction.

3.3. Schizoaffective disorder

Referring to Figure 5 created from Table 4c:

All integrals are >1.28 for both SZ-AFF and the SZ-AFF greater than or equal to 90 SSN sets.

14.70/14.70 = 1.0 or 100% or all **430 patients** *are more complicated, probably with the longest LOS.* If we take the ratio of the total integrals for the full 12 months, SZ-AFF greater than or equal to 90 SSN/SZ-AFF = 14.70/14.04 = 1.05. Therefore, there is only a 5% epigenetic component suggesting that 95% of this disease is genetically canalized (according to Hallgrimsson, "canalization is the tendency for the development of a specific genotype to follow the same trajectory under different environments or different genetic backgrounds" [45].

To calculate the total of the most complex (e.g., physically as well as mentally) using the numbers in bold type above with the total number of patients being 1,233:

121 + 92 + 430 = 643 and 643/1233 = 0.52 *or 52% of our state hospital's population is significantly more ill, more expensive, and likely the main reason for the existence of a tertiary psychiatric care facility.*

An assessment of the total LOS in our hospital of thirty randomly selected patients for each diagnosis of SZ, BPD, and SZ-AFF disorder were as follows:

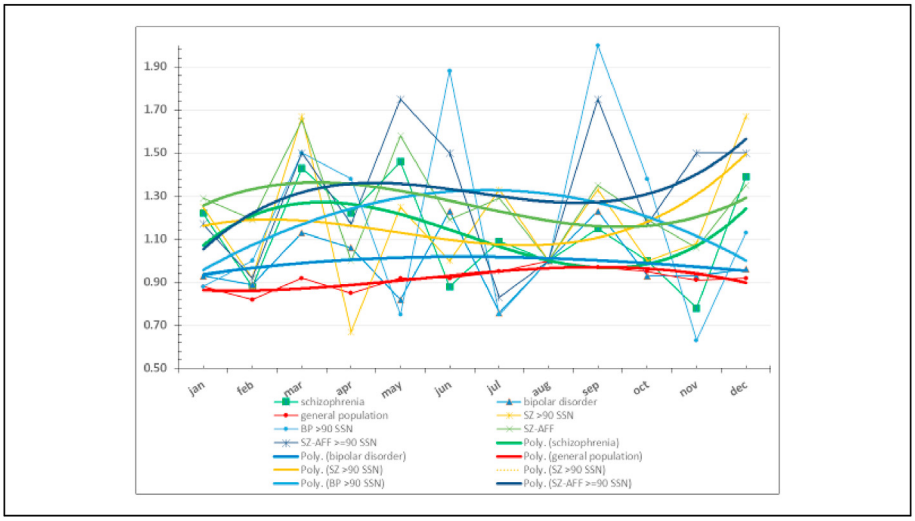

Figure 2. Trend lines by month of birth for patients with Schizophrenia, bipolar disorder, schizoaffective disorder and for the general population (2006 Census). Trend-line equations in Figure 2 (each subsequently integrated):
Schizophrenia: $y = 0.0023x^3 - 0.0449x^2 + 0.2442x + 0.7242$ ($R^2 = 0.1212$); N = 445
Schizophrenia ≥90 SSN: $y = 0.0017x^3 - 0.0257x^2 + 0.0924x + 1.0935$ ($R^2 = 0.159$); N = 170
Schizoaffective: $y = 0.0018x^3 - 0.0337x^2 + 0.1643x + 1.1241$ ($R^2 = 0.1286$); N = 430
Schizoaffective ≥90 SSN: $y = 0.0027x^3 - 0.052x^2 + 0.3061x + 0.7955$ ($R^2 = 0.1461$); N =189
Bipolar Disorder: $y = 9E\text{-}05x^3 - 0.0042x^2 + 0.0421x + 0.8976$ ($R^2 = 0.0339$); N = 358
Bipolar Disorder ≥90 SSN: $y = -6E\text{-}05x^3 - 0.0103x^2 + 0.1479x + 0.8195$ ($R^2 = 0.0827$); N = 114
General population (2006 census; N = 4,265,555): $y = -0.0006x^3 + 0.0089x^2 - 0.0249x + 0.8805$ ($R^2 = 0.6744$).

Schizophrenia: 10,279 days; Bipolar disorder: 13,591 days; Schizoaffective disorder: 22,769 days. (LOS includes a period of "convalescent status" outside the hospital for those patients with more severe symptoms and behaviors that require longer oversight).

If we assume that LOS is approximately proportional to severity of illness, the relative severity-of-illness estimates using the above LOSs: 1.32 (BPD patients are about 1/3 more ill than SZ patients); 2.22 (SZ-AFF patients are 2x more ill than SZ patients); 1.68 (SZ-AFF patients are about 2/3rds more ill than BPD patients).

Although SZ and BPD are nearly equal in complexity based on our severity metric, the SZ-AFF patients are clearly the most complicated.

Note in Table 4a (4^{th} column) that the median SSN for all three of the diseases studied here varies from 58 to 65 with the median equaling 60 (the average = 75, the SD = 55) (from the Supplement) from 1974 through 2002 (29 years) encompassing the birth years of our patients. The UVR dose for SZ greater than or equal to 90, 137/60 = 2.3 times greater than baseline; for BPD greater than or equal to 90 SSN, 136/58 = 2.3 times greater than baseline, and for SZ-AFF greater than or equal to 90 SSN, 131/65 = 2.0 times greater than baseline. *Therefore, epigenetic effects in these psychiatric diseases become more apparent when the baseline UVR doubles in intensity.* While infrared radiation is the most abundant electromagnetic radiation striking Earth as heat, according to quantum mechanics, UVR photons (mostly UV-A) have twice the energy of infrared photons and therefore our greater than or equal to 90 SSN set endures 4 times the potentially genotoxic energy compared to the less than 90 SSN set.

4. Discussion

There is significant difficulty quantifying the severity of psychiatric disease [46]. This paper offers a methodology to more objectively assess the severity of MMI based only on month and year of birth and SSN. While LOS is an indicator of the average severity of illness, our methodology parses out those patients whose epigenomes are especially affected by solar energy resulting in more severe mental illness. We were stimulated to look at MMI after 15 years of observation and noted that several patients, especially those with BPD, were born in solar cycle MAX. Our previous work demonstrated an epigenetic effect of UVR on average human lifespan and we were curious to see if a similar effect played a role in MMI. There are many potential external influences on our epigenome, a major one currently being the microbiome, and we have not ruled out an effect of circadian disruption (probably in the mother) which could alter the phenotypic expression of mental disorders. Our paper discusses one of these influences, e.g., UVR, which affects humans universally all over the world. In addition, confounding epigenetic influences are somewhat mitigated as 80% of our patients are comorbid for sexual/physical abuse, childhood malnutrition, substance abuse, and suicidal ideation.

One Hypothesis in this paper is that deviation of MOB from the average MOB distribution in the GP is a measure of the effect of UVR on the human epigenome at birth, but also at conception and early gestation [47]. ADDIN EN.CITE.

4.1. Schizophrenia

The peak MOB is known to be late winter and early spring, in February through April when MOC (10 months before birth) occurs in May, June and July around the summer solstice. What is not well-known, but seen in our data, is the peak MOB in November–December when MOC occurs at the spring equinox when UVR rapidly increases [44]. The embryonic/fetal central nervous system (CNS) is stimulated both from high-constant or rapidly-increasing UVR, apparently abetting schizophrenia with its known significant genetic loading. Environmental conditions at MOC are likely more important than at MOB because of the sensitivity of the embryo [48, 49].

Table 4b. Bimonthly integrals with totals.

Months Disease	Jan–Feb	Feb–Mar	Mar–Apr	Apr–May	May–Jun	Jun–Jul	Jul–Aug	Aug–Sep	Sep–Oct	Oct–Nov	Nov–Dec	Total
Schizophrenia	0.99	1.09	1.13	1.12	1.09	1.05	1.00	0.97	0.97	1.00	1.10	**11.51**
SZ ≥90 SSN	1.18	1.19	1.17	1.14	1.11	1.08	1.06	1.07	1.11	1.20	1.35	**12.66**
Bipolar	0.82	0.85	0.88	0.91	0.94	0.97	0.99	1.00	1.00	0.98	0.95	**10.29**
BPD ≥90 SSN	1.02	1.12	1.21	1.27	1.31	1.33	1.32	1.29	1.24	1.17	1.07	**13.35**
SZ-AFF	1.30	1.35	1.36	1.34	1.31	1.26	1.22	1.19	1.19	1.22	1.30	**14.04**
SZ-AFF ≥90 SSN	1.14	1.28	1.34	1.36	1.35	1.33	1.31	1.30	1.33	1.40	1.55	**14.69**
General population	0.86	0.86	0.88	0.89	0.91	0.93	0.94	0.94	0.93	0.90	0.86	**9.92**

Table 4c. Bimonthly integrals/integral of the general population.

Months Disease	Jan–Feb	Feb–Mar	Mar–Apr	Apr–May	May–Jun	Jun–Jul	Jul–Aug	Aug–Sep	Sep–Oct	Oct–Nov	Nov–Dec	Average
Schizophrenia	1.15	1.27	1.28	1.26	1.20	1.13	1.06	1.03	1.04	1.11	1.28	**1.16**
SZ ≥90 SSN	1.37	1.38	1.33	1.28	1.22	1.16	1.13	1.14	1.19	1.33	1.57	**1.28**
Bipolar	0.95	0.99	1.00	1.02	1.03	1.04	1.05	1.06	1.08	1.09	1.10	**1.04**
BPD ≥90 SSN	1.19	1.30	1.38	1.43	1.44	1.43	1.40	1.37	1.33	1.30	1.24	**1.35**
SZ-AFF	1.51	1.57	1.55	1.51	1.44	1.35	1.30	1.27	1.28	1.36	1.51	**1.42**
SZ-AFF ≥90 SSN	1.33	1.49	1.52	1.53	1.48	1.43	1.39	1.38	1.43	1.56	1.80	**1.49**

Although fewer in number, persons having the deficit (negative) symptom type of SZ, who express avolition and diminished emotion, are seen in Figure 3 as a birth nadir in months August and September [50]. This corresponds to MOC at the winter solstice when UVR is at its lowest. The low ratio reflects the lack of positive (paranoid, externally aggressive) symptoms in SZ perceived by society as more unpredictable states [51]. However, negative symptoms are more resistant to treatment, have more white matter brain changes, and have a higher incidence in relatives [52, 53, 54].

4.2. Bipolar disorder

The average severity level is 4% above the GP and the highest value is 10% in November–December. We hypothesize that this relatively low level of severity above the GP may indicate that genes involved in BPD may be selected for in milder forms of the disease because of the associated creativity, intelligence, and productivity [55, 56, 57, 58, 59, 60]. For BPD greater than or equal to 90 SSN the level of severity is at its maximum about 30% more severe than the full set. Epigenetic effects are particularly important in BPD [61].

Note that the greater than or equal to 90 SSN BPD set has a different shape than the full set. The peak falls in the months of May–Jun equivalent to the MOC at the autumnal equinox when UVR is rapidly decreasing and could abet the depression which characterizes the most common and disabling state of persons with BPD [62, 63]. This parallels the process of symptom onset in seasonal affective disorder (SAD) in which decreasing UVR evidently triggers the onset of depressive symptoms [64]. As seen in Figure 4, MOB effects in BPD are subtle and are only readily seen in only about one-third of the whole set with SSN greater than or equal to 90. Others have not been able to appreciate MOB effects when taking the whole BPD set [65].

4.3. Schizoaffective disorder

Since its inception as a diagnostic term in 1933 by Kasanin, it has caused consternation as it straddles the line between affective and psychotic disorders and challenges the Kraeplinian dichotomy paradigm [46, 66, 67, 68, 69, 70]. Figure 5 has the same general shape as schizophrenia in Figure 3 but is scaled to a higher ratio, e.g., more ill, and appears to give credence to the argument that SZ-AFF is more consistent with a primarily psychotic process than a mood disorder. This conclusion is supported by other researchers [71]. This is interesting because the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) says that the mood symptoms are "present for the majority of the total duration of the active and residual portions of the illness." In other words, the mood disorder component is emphasized over the psychotic component. Others suggest that psychotic and mood symptoms lie on a spectrum [46]. Our data suggest that the opposite is true; namely, the SZ-AFF is primarily a psychotic process as Figure 3 and Figure 5 more closely align with those of SZ than BPD. The different patterns observed between BPD compared to SZ and SZ-AFF also provide strong evidence in support of the Kraeplinian dichotomy, suggesting that there are two main categories of MMI, psychotic and mood [72]. The main reason for theorizing that SZ-AFF is a mood disorder is the response to lithium not seen in SZ [73]. Both the general and greater than or equal to 90 SSN sets are above the critical severity metric 1.28 and are the most ill psychiatric patients as corroborated by our LOS data.

4.4. The sun affects the epigenomes of surface organisms

After 3.8 billion years of biological evolution, it should not be surprising that the patterns of radiation from our variable Sun somehow affect the epigenomes of most, if not all, surface organisms. Our brain is

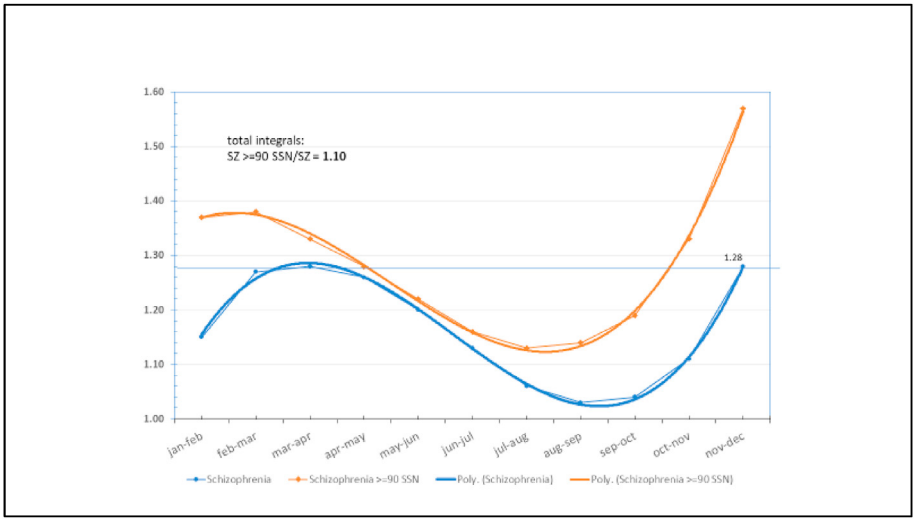

Figure 3. Schizophrenia- Bimonthly integrals normalized to the general population (1.00 on plot) Y-axis ≥ 1.28 being critically severe.

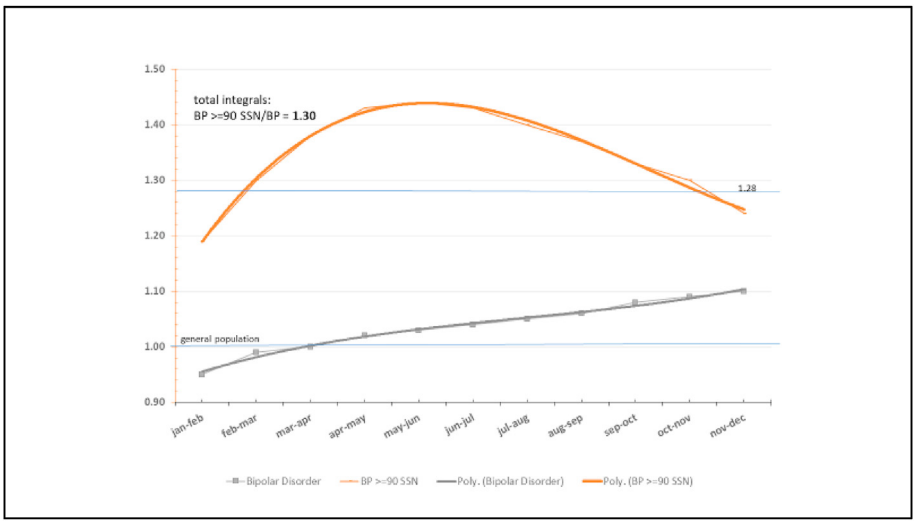

Figure 4. bipolar disorder- Bimonthly integrals normalized to the general population (1.00 on plot) Y-axis ≥ 1.28 being critically severe.

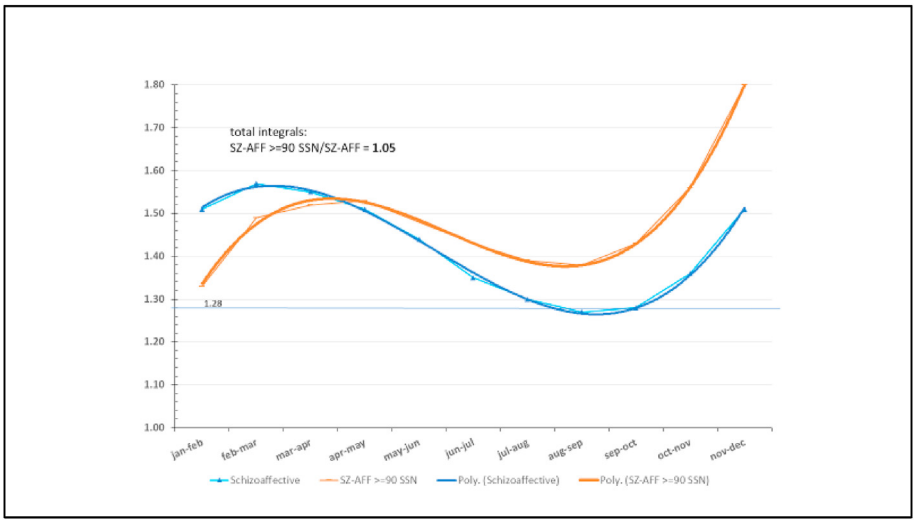

Figure 5. Schizoaffective disorder- Bimonthly integrals normalized to the general population (1.00 on plot) Y-axis ≥ 1.28 being critically severe.

the organ most responsible for human adaptability in an ever-changing environment. The fractal (self-similar at all scales) feature of solar radiation is manifest in the human brain as another fractal. e.g., 1.28 x 1.28 = 1.64, which is close to the reported 1.60 fractal dimension of the human brain [74]. We speculate that human dominance in the biological world may be in having a brain that effectively squares the solar fractal dimension of 1.28.

Solar physicists now predict that we may be entering a Grand Minimum when we perhaps will not see another Solar MAX for the next 50–100 years. However, lower doses of UVR may be beneficial to those with genetic loading for the psychiatric illnesses and with less of an epigenetic trigger to genetic loading, we may see less phenotypic expression of the psychiatric illnesses studied in this paper.

Of course, a most compelling question is how UVR affects the mother, which in turn, affects the embryo. Reptiles (e.g., chameleons), amphibians (e.g., frogs), and cephalopods (e.g., cuttlefish) have skin chromatophores that detect light and connect to the nervous system to improve survival [75]. The human embryo studied in artificial implantation procedures can be damaged by blue and long wavelength UV-A light [76]. More recently, in mice thermogenesis is enhanced by opsin-3-dependent adipocyte light sensing [77]. We hypothesize that T-lymphocytes circulating through the maternal skin, or cytokines triggered by UVR, carry information via the placenta to the fetal thymus [78]. Certainly, some mechanism must exist and is the subject of ongoing research [79]. In high, or rapidly increasing UVR, fetal ectoderm may be epigenetically "prewired" to future external environmental threats, and in persons with significant genetic loading for MMI, the developing CNS might be detrimentally overstimulated.

It is premature to prescribe recommendations about exposure to UVR during pregnancy, but we predict that altering UVR conditions at conception and early gestation would have a greater effect than similar exposures after puberty or in adulthood [80]. For example, if there is significant genetic loading, e.g., a schizophrenic family history, it might be advisable to avoid conception at the spring equinox (e.g., rapidly increasing UVR) or the summer solstice (highest UVR). The methodology used in this paper could be useful in identifying those who might become prodromal for MMI, an endeavor intensively studied over the past several years [81, 82].

5. Conclusions

Using Hypotheses #1 and #2 outlined in this paper, we conclude:

- High UVR intensity or a rapid increase in UVR promote expression of phenotypic SZ, BPD, and SZ-AFF disorders. Epigenetic effects in these genetically predisposed diseases become more apparent when the median SSN doubles, implying double UVR intensity.
- Epigenetic effects in BPD are 3 times greater than in SZ and 6 times greater than in SZ-AFF.
- SZ-AFF is least affected by high UVR, e.g., greater than or equal to 90 SSN, suggesting that this disorder is more canalized in the genome. The patients with this diagnosis are the most ill.
- Environmental UVR at MOC or early gestation is likely more important than MOB in influencing phenotypic expression of MMI, reflecting the sensitivity of the embryo.
- Using the increased entropy factor of 1.28 imposed by solar metabolism, we found that over half of our inpatients are especially unpredictable and expensive, supporting the need for tertiary psychiatric care.
- Our methodology validates the Kraeplinian dichotomy between psychosis and mood disorders.
- The mechanism of how maternal exposure to UVR affects the conceptus is yet to be determined, but such a mechanism must exist.

6. Limitations of the study

Despite 15 years of admissions, the study could benefit from a larger N by including similar patients from other state hospitals. Our patients were largely Caucasian and were the most ill in the state, not the average patient. Maine has moderate seasonal variation being at approximately 44° N latitude. The United Kingdom and Scandinavia are approximately 10° higher in latitude and it would be interesting to obtain data from these areas of greater variation and less UVR intensity.

7. Advantages of the study

We used simple calculations with readily available deidentified data. Patients were mostly from Maine, but many have come from other states and other countries averaging confounders like nutrition, temperature, and latitude. UVR affects the entire planet.

8. Future work

We would like to obtain data on major depressive disorder from secondary psychiatric facilities to compare severity of illness metrics with the plots in this paper. The acquisition of similar deidentified inpatient or outpatient data of psychiatric diseases, not usually seen in a tertiary psychiatric facility, could be instructive. We would also like to study multiple sclerosis, the quintessential autoimmune disease related to changing UVR/latitude.

Ethics approval and consent to participate

No data required consent as there were no identifiers. No specific human or animal subjects were required.

Declarations

Author contribution statement

George Edward Davis: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Matthew J. Davis: Contributed reagents, materials, analysis tools or data.

Walter E. Lowell: Analyzed and interpreted the data.

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Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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