Self-Reported Weather Sensitivity Stratifies Subjects with Chronic Pain: Is Weather Sensitivity Entirely Due to Confirmation Bias?

Shai N. Gozani, MD, PhD and Xuan Kong, PhD; NeuroMetrix Inc., Waltham, MA, USA

PURPOSE

Weather and chronic pain have long been thought to be related, with Hippocrates describing a connection in 400 BC. Weather is now reliably forecast and conveniently available on mobile platforms. If a relationship between weather and chronic pain exists, it may be possible to predict chronic pain changes to optimize pain control. These relationships may also inform travel and geographic preferences by people with chronic pain. Moreover, an understanding of the interplay between weather and chronic pain may advance scientific understanding and lead to novel therapeutic approaches.

Contemporary studies have evaluated the relationship between weather and various forms of chronic pain. A consistent finding is that people with chronic pain *believe* that weather influences their pain. By contrast, objective studies have been mixed. Some identified meaningful statistical and clinical associations, whereas others did not. One explanation for these discrepancies is that self-reported weather sensitivity is a manifestation of confirmation bias; namely the tendency to attribute worsening chronic pain to certain weather patterns while ignoring contradictory observations. Alternatively, scientific studies may have failed to uncover objective associations between weather and chronic pain for reasons such as small sample sizes, insensitive outcome measures, complex relationships, and incorrect quantification of the weather exposure.

The objective of this study was to compare chronic pain characteristics in those with and without self-reported weather sensitivity. The presence of substantial differences may indicate that confirmation bias, which is a ubiquitous psychological phenomenon, may not entirely explain the high prevalence of weather sensitivity.

METHODS

Study Design and Subject Selection. This cross-sectional study evaluated users of a wearable device to treat chronic pain (Quell®, NeuroMetrix, Waltham, MA) during a 9-month period (10/2016-6/2017). The device delivers high-frequency TENS and concurrently monitors sleep, activity and gait based on signals from an embedded tri-axial accelerometer. In this study, only the monitoring functions of the device were evaluated. A companion smartphone app also collects demographic data, relevant medical history, and chronic pain characteristics including weather sensitivity. Subjects self-reported as weather sensitive, insensitive or unsure. Weather sensitive subjects further identified triggering conditions among precipitation (rain or snow), cold temperature, hot temperature, humidity, cloudy and windy. Where multiple values were available during the study period (e.g., pain intensity), the median value was used. Inclusion criteria were (i) self-reported influence of weather on chronic pain, (ii) demographic and clinical data, and (iii) consent to use anonymized data for research.

Data Analysis. Forward stepwise multivariate logistic regression was used to develop a model that predicts weather sensitivity (i.e., sensitive or insensitive) from demographic and clinical variables (linear model without interactions). There were 44 potential predictive variables including age, gender, height, BMI, number of painful health conditions, 14 specific painful health conditions (e.g., arthritis, fibromyalgia, diabetes, CRPS), number of pain sites, 10 specific pain sites (e.g., legs, low back), chronic pain duration, pain pattern (e.g., worst pain in morning, worst pain at night), and frequency (e.g., daily, several times per week), pain intensity and interference with sleep, activity and mood on an 11-point NRS scale. At each iteration, the most significant variable (smallest *p* value) was added to the model. Only variables with $p<0.01$ were considered for inclusion. The model prediction was defined as the sum of the constant and the beta-coefficients corresponding to each variable identified by the logistic regression. The efficacy of the predictive model was assessed by the area under the receiver operating characteristic (ROC) curve. Analyses were performed using MATLAB R2016a (MathWorks, Natick, MA).

Table 1. Demographic and pain characteristics.

Characteristic	N=4979
Female: N (%)	2715 (54.5)
Age (yrs): mean (SD)	56.2 (14.2)
BMI (kg/m_2): mean (SD)	29.6 (6.8)
Duration of pain: N (%)	
<3 year	1612 (32.4)
>3 years	3358 (67.4)
Number of pain sites: mean (SD)	4.3 (2.4)
Distribution of pain: N (%)[a]	
Lower extremity	4720 (94.8)
Low back	3777 (75.9)
Upper extremity	2980 (59.9)
Head and neck	2426 (48.7)
Number of painful health conditions: mean (SD)	3.2 (1.9)
Painful health conditions: N (%)[a]	
Arthritis	2893 (58.1)
Back Injury	1902 (38.2)
Herniated Disc	1366 (27.4)
Spinal Stenosis	1231 (24.7)
Headache or Migraine	1148 (23.1)
Fibromyalgia	1106 (22.2)
Neck Injury	1081 (21.7)
Pain intensity: mean (SD)	5.8 (2.0)
Pain interference: mean (SD)	
Sleep	4.5 (2.8)
Activity	5.6 (2.5)
Mood	5.3 (2.7)

[a]More than one category per subject may apply.

Table 2. Weather sensitivity and triggering conditions.

Characteristic	N=4979
Weather Sensitive: N (%)	
No	1362 (27.4)
Yes	2499 (50.2)
Unsure	1168 (23.3)
Triggering Conditions: N (%)[a]	
Rain or snow	1871 (74.9)
Cold temperature	1684 (67.4)
Hot temperature	315 (12.6)
Humidity	745 (29.8)
Windy	211 (8.4)
Cloudy	295 (11.8)

[a]More than one category per subject may apply.

Table 3. Multivariate logistic regression model.

Predictor	OR (95%CI)
Age (yrs)	0.97 (0.97 - 0.98)
Female	2.03 (1.70 - 2.43)
BMI (kg/m^2)	1.02 (1.01 - 1.04)
Arthritis	2.94 (2.44 - 3.56)
Fibromyalgia	1.93 (1.48 - 2.53)
Back Injury	1.53 (1.28 - 1.84)
No. Pain Sites	1.19 (1.14 - 1.25)
Leg Pain	1.32 (1.08 - 1.61)
Duration > 3 Years	1.73 (1.44 - 2.08)
Worst pain in morning	1.56 (1.19 - 2.06)
Mood (NRS 0-10)	1.08 (1.04 - 1.11)

RESULTS

A total of 4979 device users met the inclusion criteria. Table 1 provides the demographic and pain characteristics of the study subjects. In general, the subjects were older adults with moderate to severe, multi-site pain of long-standing duration. Most subjects had several painful health conditions, with arthritis identified by over half of subjects (58.1%).

Table 2 summarizes self-reported weather sensitivity. About one-half of subjects (50.2%) were weather sensitive with the remaining subjects approximately evenly split between weather insensitive (27.4%) and unsure (23.3%). Subsequent analyses excluded unsure subjects, leaving 3811 subjects.

Table 3 shows the results of the multivariate logistic regression. There were 11 statistically significant independent variables that predicted weather sensitivity with $R^2=0.23$. Weather sensitive subjects were more likely to report arthritis, fibromyalgia or back injury. The two groups differed in their demographic features, certain pain characteristics including number of pains sites and duration, and pain interference with mood. Figure 1 shows a box plot that compares the distribution of model predictions for weather sensitive and insensitive cases. The area under the ROC curve for correctly classifying weather sensitivity based on the model predictions was 0.79 (95% CI 0.77-0.81).

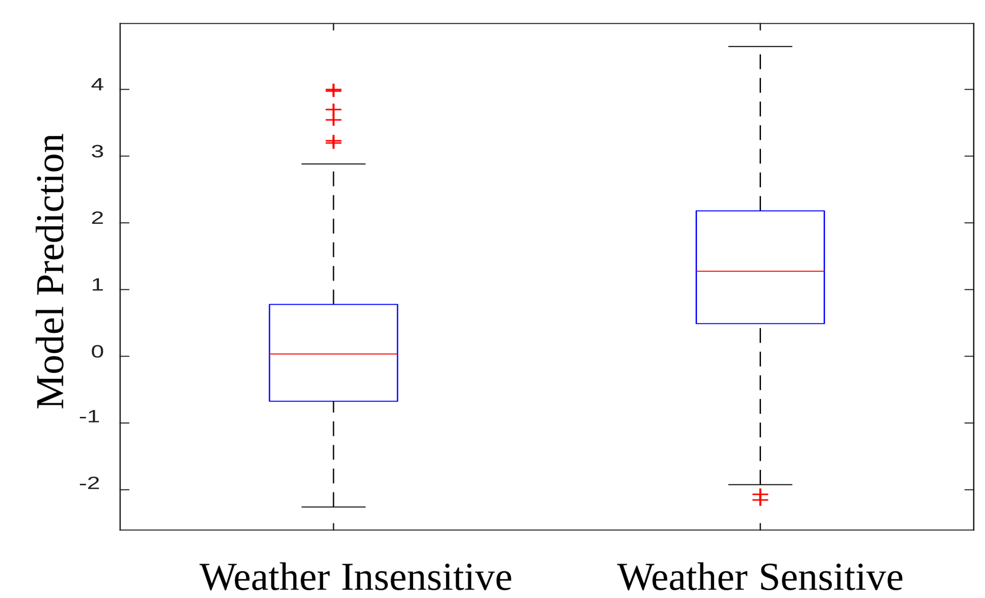

Figure 1. Box plot of weather sensitivity model predictions for subjects that self-reported as weather insensitive (left) and sensitive (right). Horizontal red line is median. Box shows intra-quartile range (IQR) and whiskers indicate 1.5 IQR below and above the 1st and 3rd quartiles. Outliers shown as '+'.

CONCLUSIONS

The multivariate logistic regression model in this study classified weather sensitivity in a large heterogeneous dataset with moderate accuracy. These results demonstrate that subjects with self-reported weather sensitivity express a different chronic pain phenotype than those who report weather insensitivity.

These results challenge the notion that self-reported weather sensitivity is entirely the product of confirmation bias, which is a ubiquitous and clinically undifferentiated psychological phenomenon. More specifically, it is difficult to explain why subjects with certain painful health conditions, such as arthritis and fibromyalgia, and specific pain characteristics would be particularly susceptible to a weather related confirmation bias. A more plausible explanation is that chronic pain attributes are directly or indirectly (e.g., through mood) influenced by weather variables, which amplifies the common perception of weather sensitivity. The challenge remains to quantitatively identify these associations, which are likely to be dynamic and complex.

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