

# Some Like It Mild and Not Too Wet: The Influence of Weather on Subjective Well-Being

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**Abstract** More and more economists and politicians are advocating the use of comprehensive measures of well-being, on top of the usual national accounting measures, to assess the welfare of populations. Researchers using subjective well-being data should be aware of the potential biasing effects of the weather on their estimates. In this paper, the responsiveness of well-being to climate and transitory weather conditions is investigated by analyzing subjective well-being data collected in the Princeton Affect and Time Survey. General satisfaction questions about life in general, life at home, health and one's job, as well as questions concerning feelings intensities during specific episodes are studied. Women are much more responsive than men to the weather, and life satisfaction decreases with the amount of rain on the day of the interview. Low temperatures increase happiness and reduce tiredness and stress, raising net affect, and high temperatures reduce happiness, consistent with the fact that the survey was conducted in the summer. Methods to reduce the possible biases are suggested in the conclusion.

**Keywords** Subjective well-being · Life satisfaction · Happiness · Weather · Temperature · Precipitation

## 1 Introduction

Economists are increasingly interested in subjective well-being assessments. While psychologists have for many years studied happiness—its definition, its causes, its correlates, its social context and more (Kahneman et al. 1999; Argyle 2001; Strack et al. 1991)—it is rather recently that economists have departed from the sacrosanct focus on output growth to advocate for a more inclusive conception of well-being. As Frey and Stutzer

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summarized in their 2002 survey of the literature on happiness research: “It follows that economics is—or should be—about individual happiness (Frey and Stutzer 2002, p. 402).” In 2008, French President Nicolas Sarkozy commissioned a team of experts led by Nobel prize winners Joseph Stiglitz and Amartya Sen to identify the limits of GDP as a measure of economic performance and social progress. In their final report, they noted that “[m]easures of both objective and subjective well-being provide key information about people’s quality of life,” and followed by recommending that “[s]tatistical offices should incorporate questions to capture people’s life evaluations, hedonic experiences and priorities in their own survey (Stiglitz et al. 2009, p. 16).” One example of recent efforts to report on quality of life has been the OECD’s “Better Life Index,” which incorporates 11 measures including life satisfaction (Organisation for Economic Co-operation and Development 2011). The British magazine *The Economist* has surfed the trend and more than once proposed online debates about happiness on its website (The Economist 2011) or published articles on the issue.

In opposition to objective measures of well-being such as income, life expectancy, housing conditions and other observable factors, subjective measures rely on people’s own evaluations of their condition. It is generally accepted that there are many indicators of subjective well-being (SWB), each measuring a specific component that contributes to SWB in its own way (Krueger 2009; Bok 2010; Helliwell and Barrington-Leigh 2010). Satisfaction with life is one of the more common concepts and asks that people evaluate their lives “as a whole.” This will usually involve a cognitive process using a reflection and a judgment of their broad and continuing life circumstances. At the other end of the spectrum, positive and negative emotions reflect experienced happiness and relate to an individual’s affective state at a given moment. Such positive and negative affects are effectively measured as part of time-use surveys, or what Krueger et al. (2009) refer to as their approach of National Time Accounting (see also Helliwell and Barrington-Leigh 2010; Diener et al. 2009). In Krueger et al.’s own words, “National Time Accounting is a set of methods for measuring, categorizing, comparing, and analyzing the way people spend their time, across countries, over historical time, or between groups of people within a country at a given time. ... The methods we propose provide a means for evaluating different uses of time based on the population’s own evaluations of their emotional experiences, what we call *evaluated time use*, which can be used to develop a system of national time accounts” (Krueger et al. 2009, p. 11). The reliability of subjective well-being measures is a serious concern and as such has been extensively tested and reviewed in numerous studies (Bok 2010, chapter 2; Krueger et al. 2009; Helliwell and Barrington-Leigh 2010). Bok (2010, p. 39) concluded that “[a]ll in all ... careful researchers seem to measure happiness or dissatisfaction with enough accuracy to make the results useful for policy-makers.” However he added that “[i]t is true that a variety of transitory influences can affect people’s judgments about how happy or satisfied they are. Most of the time, however, these distortions are sufficiently random to cancel themselves out in surveys involving substantial numbers of people” (Bok 2010, p. 39).

One such transitory influence is the weather. Weather conditions affect mood and prosocial behavior. Cunningham (1979) found markedly increased tipping to restaurant waiters on sunny days and attributes the behavior to the impact of sunshine on mood. Beliefs about weather, whether they turn out to be accurate, also seem to influence mood, as Rind (1996) and Rind and Strohmetz (2001) found in their study of the impact of beliefs about weather on tipping. Smith (1979) documented the seasonal pattern of happiness and affect—but found no such pattern in life satisfaction. The existence of Seasonal Affective Disorder (SAD) as a mental health condition has long been recognized, with winter months associated with the highest level of seasonal depression (Oren and Rosenthal 1992). Keller

et al. (2005) and Denissen et al. (2008) both provide more recent examples of psychological studies linking mood to weather conditions. Economists have studied the effect of sunshine on stock market returns, suggesting that investors' good mood on sunny days influences their cognitive processes and trading decisions (Saunders 1993; Hirshleifer and Shumway 2003; Dowling and Lucey 2005; Goetzmann and Zhu 2003). While the link between meteorological conditions and affect is intuitive, the association with life satisfaction is less straightforward. If satisfaction with life is supposed to be an assessment of how good one's life is in general, should it vary depending on whether the sun is shining or not on the day the question is asked? Schwarz and Clore (1983) found that people reported significantly higher general happiness, life satisfaction, and content with current life on sunny vs. rainy days. However, when first primed about the weather, rainy-day subjects were better able to attribute the source of their sour mood to the weather conditions and reported the same average life satisfaction as they would on sunny days. Simonsohn (2007) found that prospective college students who visit a school on a cloudy day are more likely to enroll in that school and that university admission officers place greater relative importance on academics when reviewing applications on cloudier days. He argued that cloudier weather makes people place more weight on academic factors, and less on social factors and enjoyment, while making decisions about which college to enroll in.

This brings up a question: Are people consistently affected by weather conditions when they respond to subjective well-being surveys? If yes, researchers studying well-being need to know about the effects of such conditions and, depending on the purpose of the study, may want to control for current weather or use priming to tease out the weather effect. Rehdanz and Maddison (2005) looked at the issue using country-level data and found that higher mean temperatures in the summer months decrease happiness, while higher mean temperatures in the winter months increase it. Barrington-Leigh (2008) investigated the question using Canadian data on satisfaction with life. He found that after controlling for local climate expectations, recent cloud cover was significantly and negatively associated with satisfaction with life. Happiness did not appear to be correlated with his weather variables. He optimistically concludes that “[s]tatistical estimates which are not informed about the state of the weather produce the same inferences regarding the determinants of [satisfaction with life] as those which take weather’s influence into account” (Barrington-Leigh 2008, p. 26).

The present paper explores the relationship between weather, as characterized by temperature and precipitation variables, and subjective well-being in the United States, as measured by satisfaction with life and affective state. A unique dataset from 2006, the Princeton Affect and Time Survey (PATS), is used in conjunction with weather records. The influence of climate is also considered, although the exogeneity of climate is questionable. If people self-select into different climates based on the responsiveness of their well-being to weather conditions, then the climate becomes endogenous with respect to the model studied. Endogeneity, as opposed to exogeneity, indicates that climate is correlated with other factors, both observable (the other explanatory variables) and unobservable (the error term). This correlation with the error term results in a bias of the estimates of the impact of climate on SWB. The consequence is that we can no longer interpret the estimated effect of the climate as a causal one, which is what is of most interest. There is some evidence that it may be the case (Rappaport 2007).

This paper starts in Sect. 2 with a presentation of the framework by which weather might correlate with subjective well-being and the data used in the analysis. The models estimated in this study and the results are presented in Sect. 3. Section 4 offers a discussion and concludes.

## 2 Method

### 2.1 Weather as a Process Influencing Well-Being

Affect is the more direct and instantaneous facet of subjective well-being and is closely linked to mood and emotions. There can be positive affect (current mood: happy, interested) and negative affect (current mood: sad, depressed).<sup>1</sup> The exact channel through which weather changes affect is unclear however: sunny days could directly raise the feeling of happiness, for example by impacting mood (Cunningham 1979), but sunny days could also lead people to spend more time outside in social leisure activities, which provide more happiness than work. This second channel is suggested by Connolly (2008) who found that men spent an extra half an hour working on rainy days compared to sunny days, and falls in the line of Krueger et al.'s (2009) work which seeks to relate "experienced happiness" (an aggregation of affect measures over a certain period of time like a day) to how people spend their time. Keller et al. (2005) documented the mitigating effect of time spent indoors (thus away from the elements) and of the season. They found that time spent outdoors increased the strength of the relationship between weather and mood, and that the effect was strongest in the spring, after a long period of deprivation from pleasant outdoors weather.

A second constituent of SWB is satisfaction. Faced with the complex task of evaluating their life satisfaction, people will often resort to heuristics or readily available information (Schwarz and Strack 1991). Schwarz and Strack (1991, p. 63) noted: "In reality, however, individuals rarely retrieve all information that may be relevant to a judgment. Instead, they truncate the search process as soon as enough information has come to mind to form a judgment with sufficient subjective certainty [...] Hence, the judgment is based on the information that is most *accessible* at that point in time." The more global the concept to be evaluated (for example, when asked about life as a whole rather than satisfaction with job or health), the more likely the current affective state will be given informational value in shaping the judgment about well-being. Schwarz and Strack (1991) described two processes by which mood states may impact satisfaction reports. First, the mood can increase the accessibility of "mood-congruent information from memory," which means that one is more likely to recall positive events when in a happy mood, thus leading to a more positive evaluation of his or her life. Second, an individual can assume that his or her mood at the time of judgment is a "reasonable and parsimonious indicator" of general well-being. Whatever the psychological process, if weather shocks influence mood, then we can also expect them to have an impact on reports of life satisfaction, as was the case in Schwarz and Clore (1983).

### 2.2 Data

#### 2.2.1 Princeton Affect and Time Survey

The affective data come from the Princeton Affect and Time Survey (PATS). The PATS data are publicly available online [see Princeton Affect and Time Survey (2006)]. However

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<sup>1</sup> Neuroscientists studying the brain have found that various neurotransmitters (dopamine, noradrenaline, endorphins) activate "pleasure centers," and have asked what triggers the release of those neurotransmitters. Social contacts with friends, sexual activity, success, physical activity, eating and drinking, reading, listening to music and enjoying nature were all identified as causes of joy (Argyle and Martin 1991).

note that the geographical identifier that allowed the weather variables to be added to the dataset is not publicly available due to confidentiality reasons. The PATS was conducted by Gallup from May 4, 2006, to August 21, 2006, and collected information on time use and affect for 3,982 individuals as part of the Random Digit Sample, covering persons of age 15 and older living in the continental United States. The Random Digit Sample was nationally representative, and selected using an Equal Probability Selection Method. Each household was randomly assigned a day of the week, and once contacted, was asked about time use and affect for the previous day. The most recent birthday selection technique was used to designate a selected respondent among all household members 15 years of age or older. The survey was done over the telephone, using the same software used by the Bureau of Labor Statistics for data collection on the American Time Use Survey (ATUS) program. After the time-use module was collected, respondents were surveyed on their affect during three randomly selected 15-min intervals of their day, excluding time spent sleeping and grooming. The selection of episodes is thus proportional to time spent in the episode, and was done without replacement. Survey weights were designed to maximize the representativeness of the data.<sup>2</sup>

During the Affect Module, respondents were asked to rate the intensity of six different feelings as experienced during each selected episode, using a scale of 0 to 6, where 0 marks a low intensity and 6 a high intensity of the feeling. The survey covered the following feelings: happiness, tiredness, stress, sadness, interest, and pain. The ordering of the emotions in the questionnaire was randomly varied. Krueger et al. (2009) found that when asked about a negative feeling first, the responses about the following positive feelings were slightly lowered. Krueger et al. (2009, p. 36) explain that they chose a small number of feelings to save respondent time, and that they narrowed down the set of emotions to ask about based on a set of cognitive interviews done by the Gallup Organization. They also note that they avoided the use of compound adjectives to prevent confusion. A weakness of these affect measures, inherent to the way they were collected, is that they are retrospective of the previous day and not collected instantaneously, like they would be using an Experience Sampling Method or Ecological Momentary Assessment. However, such real-time studies are expensive, and Krueger et al. (2009, pp. 30–31) describe the PATS as an alternative way to collect affect measures that is based on a short recall period. Table 1 contains descriptive statistics for the feelings questions, as well as tabulations by intensity of feeling. Two variables measuring well-being are constructed from the answers to the feelings questions: net affect and the U-index (see Kahneman and Krueger (2006) for a presentation and discussion of net affect and the U-index as measurements of well-being.) The net affect is computed as follows:

$$\text{Net affect} = \text{happy} - \text{mean}(\text{stressed, sad, pain}) \quad (1)$$

The U-index relates to the percentage of time spent in an unpleasant state (U is for ‘unpleasant’), and is computed according to the following equation:

$$\text{U-index} = \begin{cases} 1 & \text{if } \max(\text{stressed, sad, in pain}) > \text{happy} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

The U-index is 1 when the most intense feeling is a negative one, and its use can be justified by the fact that most episodes of people’s days are pleasant, as can be seen in

<sup>2</sup> Summary statistics of the PATS sample are presented in an online appendix available as supplemental material.

**Table 1** Tabulations and summary statistics of feelings variables

Feeling or variable	Percentage in each category							Mean	SD	N
	Feeling intensity <sup>a</sup>									
	0	1	2	3	4	5	6			
<i>Panel A: Women</i>										
Happy	6.0	3.1	6.5	14.8	17.6	23.5	28.5	4.19	(1.73)	7,024
Interested	8.3	4.1	8.1	14.2	16.8	19.0	29.5	4.02	(1.88)	7,025
Tired	25.0	7.6	11.1	14.5	14.7	14.2	13.0	2.81	(2.12)	7,039
Stressed	48.7	11.2	11.6	9.1	7.1	6.1	6.2	1.58	(1.95)	7,038
Sad	76.8	7.1	4.8	3.9	2.6	1.9	2.9	0.66	(1.46)	7,037
In pain	73.2	5.1	4.4	4.7	4.3	4.2	4.1	0.91	(1.74)	7,038
Net affect <sup>b</sup>	–	–	–	–	–	–	–	3.14	(2.47)	7,012
U-index <sup>c</sup>	–	–	–	–	–	–	–	0.20	(0.40)	7,012
<i>Panel B: Men</i>										
Happy	4.9	2.4	7.5	19.5	20.5	22.6	22.6	4.06	(1.62)	4,316
Interested	5.9	3.9	8.3	16.1	19.2	22.3	24.4	4.03	(1.73)	4,319
Tired	26.2	10.2	14.1	15.7	14.4	11.6	7.8	2.48	(1.99)	4,322
Stressed	47.4	14.0	13.8	9.6	6.2	4.7	4.4	1.45	(1.79)	4,319
Sad	73.4	10.1	6.4	4.1	2.6	1.7	1.7	0.64	(1.33)	4,324
In pain	71.3	6.8	6.3	5.3	4.6	2.5	3.2	0.85	(1.61)	4,321
Net affect <sup>b</sup>	–	–	–	–	–	–	–	3.08	(2.24)	4,307
U-index <sup>c</sup>	–	–	–	–	–	–	–	0.18	(0.38)	4,307

Weighted by sample weights

<sup>a</sup> Feeling intensity questions are rated on a scale of 0 to 6, with 0 representing a low intensity, and 6 a high intensity

<sup>b</sup> Net affect is the intensity of happiness minus the average of stressed, sad, and pain

<sup>c</sup> The U-index is 1 if stressed, sad, or pain is greater than happy and 0 otherwise

Table 1, and that any dominant negative emotion will, by its salience, reflect the way people judge their mood during that episode.

At the end of the Affect Module, a set of questions about general well-being was included. Respondents were to rate their satisfaction about their life overall, their life at home, their health, and their job if they had one, on a scale of 1–4, where 1 meant “Not at all satisfied,” 2 “Not satisfied,” 3 “Satisfied,” and 4 “Very satisfied.” As can be seen in Table 2, which contains summary statistics and tabulations of the satisfaction questions, the majority of the people answered “Satisfied” or “Very satisfied” to these questions, with over 90 % of the responses in these two categories for the life satisfaction and home satisfaction questions, and 74 and 85 % for health and job satisfaction, respectively.

### 2.2.2 Weather Data

Data on the weather were added to the PATS data. The data on weather come from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric

**Table 2** Tabulations and summary statistics of satisfaction variables

	Percentage in each category <sup>a</sup>				Mean	SD	N
	Not at all satisfied	Not satisfied	Satisfied	Very satisfied			
<i>Panel A: Women area of satisfaction</i>							
Life	1.68	9.51	43.58	45.24	3.32	(0.71)	2,347
Home	1.28	7.91	43.47	47.34	3.37	(0.68)	2,349
Health	4.82	18.62	46.91	29.64	3.01	(0.82)	2,345
Job	2.35	13.13	53.07	31.45	3.14	(0.72)	1,062
<i>Panel B: Men area of satisfaction</i>							
Life	1.39	9.25	46.73	42.64	3.31	(0.69)	1,444
Home	1.18	5.81	42.21	50.80	3.43	(0.66)	1,445
Health	2.92	16.48	51.76	28.84	3.07	(0.75)	1,449
Job	2.46	14.00	51.82	31.71	3.13	(0.73)	879

Weighted by sample weights

<sup>a</sup> Satisfaction questions are rated on a scale of 1 to 4, with 1 meaning “Not at all satisfied,” and 4 meaning “Very satisfied”

Administration (NOAA) (see National Climatic Data Center (1971–2000), (2006a, b)). The daily summaries from over 8,000 weather stations located across the United States were used, corresponding to the data sets 3,200 and 3,210. The normal temperatures and precipitation levels come from the data set CLIM84, which is based on the weather from 1971 to 2000. Each respondent to the PATS was identified by his or her county of residence and matched to the average weather over all the weather stations in his or her county. Weather for the day of the interview and for the day of the diary (the day preceding the interview) was carefully identified. Because the PATS was conducted from May to August, snow is not significant to the study, so the elements used were temperature and precipitation. Table 3 contains tabulations and summary statistics for the precipitation and temperature variables. For the purpose of the analysis, both rain and temperature were broken down in categorical variables, for which the breakdown is shown in Table 3. Days since last dry day counts the number of days from the day of the interview since it last rained, and is equal to zero if there was precipitation on the day of the interview. This variable was meant to capture the effect of long rain spells, but its coefficient never came out statistically significant. While it is possible to look at the effect of both rain the day of the interview and the day of the diary (the day preceding the interview), the high day-to-day correlation for temperatures made it impossible to look at both the temperature of the interview day and of the diary day. Whenever temperature was included in regressions, temperature of the day of the interview was used when looking at satisfaction questions, and temperature of the day of the time-use diary (the day prior to the interview) when looking at feelings questions. The rationale was that for satisfaction questions, the previous day’s temperature should not matter, whereas when looking at feelings during specific episodes, it is the temperature at that time, and so on the diary day, that should matter. In any case, using either temperature did not change the results significantly, since the correlation between one day’s mean temperature and the previous day’s is 0.94, as can be seen in Table 3. In contrast, the same correlation for precipitation is 0.28.

**Table 3** Tabulations, summary statistics, and correlation matrix of weather variables

Precipitation	Percentage in each category					Mean	SD	Max.	
	Amount of precipitation (inches)								
	0	0–0.1	0.1–0.5	0.5–1	1 and above				
Day of interview <sup>a</sup>	59.4	19.2	14.5	5.2	1.8	0.106	(0.272)	3.73	
Day of diary <sup>a</sup>	60.3	19.7	13.4	4.4	2.2	0.101	(0.269)	3.40	
Days since last dry day <sup>b</sup>	–	–	–	–	–	1.274	(2.392)	23	
Daily normal <sup>c</sup>	–	–	–	–	–	0.109	(0.055)	0.31	
Temperature	Percentage in each category						Mean	SD	Max.
	Daily mean temperature (degrees F)								
	Under 50	50s	60s	70s	80s	90 and above			
Day of interview <sup>d</sup>	2.5	13.5	25.3	32.1	25.0	1.7	71.6	(10.7)	100.7
Day of diary <sup>d</sup>	1.9	14.4	24.7	33.8	23.4	1.8	71.6	(10.5)	101.9
Daily normal <sup>c</sup>	–	–	–	–	–	–	70.4	(8.3)	91.3

  

Correlation matrix	Temperature		Normal temp.	Precipitation		Normal prec.
	Int. day	Diary day		Int. day	Diary day	
Temperature, interview day	1					
Temperature, diary day	0.94	1				
Daily normal temp.	0.85	0.85	1			
Precipitation, interview day	–0.08	–0.01	–0.05	1		
Precipitation, diary day	–0.10	–0.04	–0.02	0.28	1	
Daily normal precipitation	–0.03	–0.03	0.09	0.19	0.17	1
Days since last dry day	–0.20	–0.15	–0.13	0.32	0.30	0.17

Weighted by sample weights

<sup>a</sup> Precipitation is measured in inches

<sup>b</sup> Days since last dry day counts the number of days since it last rained, and is equal to zero if the interview day is rainy

<sup>c</sup> Normals are daily normals (see Data section for details)

<sup>d</sup> Temperature is mean daily temperature (the average of the minimum and the maximum temperatures for the day), in degrees Fahrenheit

### 3 Results

#### 3.1 Models

After controlling for expected conditions, a given day’s temperature or precipitation level can reasonably be thought of as exogenous: an individual has no power over today’s cloudiness. On the other hand, in a model where households are mobile and can relocate, a locality’s climate is no longer exogenous. In fact, the decision to move to a certain area may be partly based on the climate. Rappaport (2007) observed that local population growth in the United States was highly correlated with warmer winter weather and cooler,



less humid summer weather. He argued that people were moving to areas with better weather, due to an increasing valuation of this factor's contribution to their quality of life, which was, in turn, due to rising real incomes. This renders tenuous the interpretation of the link between climate and SWB as causal. This interpretation is made even more difficult by the potential focusing illusion that can come into play. For example people generally think that they would be happier living in California when in fact studies have shown that they do not (Schkade and Kahneman 1998).

Assuming that a given day's weather is exogenous, the causal link between transitory weather (conditions the day of the interview) and well-being was estimated from the following econometric model:

$$SWB_{ijt} = \alpha + W'_{ijt}\gamma + N'_{ijt}\delta + X'_{ijt}\beta + \phi_j + \psi_t + u_{ijt}, \quad (3)$$

where  $SWB_{ijt}$  was the measure of interest for individual  $i$  in state  $j$  at time  $t$ , i.e. one of the four satisfaction variables (satisfaction with life, at home, with own health or at work), one the six affect variables (happy, interested, tired, stressed, sad, in pain) or one of the two measures constructed from the affect variables, the net affect and the U-index. The vector  $W$  contained the weather variables: precipitation dummies for the interview day and the diary day, temperature dummies for the interview or diary day, and a variable counting the number of days since last dry day. The vector  $N$  contained normal precipitation and temperature, to control for climate. The controls ( $X$ ) included a quadratic in age and education, marital status, race and hispanic ethnicity dummies. Household income was not used because too few respondents provided an answer. Tests showed that if household income was included in regressions, coefficient estimates did not change substantively but precision was lower. State ( $\phi_j$ ) and time ( $\psi_t$ ) fixed effects were included and  $u$  was the usual error term. In regressions where an affect measure was explained, day of week and activity fixed effects were also included. The model was estimated by ordinary least squares (OLS), with heteroskedasticity-robust standard errors clustered at the state or individual level to allow for intra-cluster correlations, and using the sampling weights provided with the data. For satisfaction variables, there was only one observation per person so the clustering is at the state level, whereas affect was observed for three different time-use episodes of a person's day, which made clustering possible at the individual level for affect variables. To try a model better suited with the particular form of the data (answers are on a scale of 1–4 or 0–6), ordered probits were estimated. However the results did not change significantly and so only OLS results are presented for ease of interpretation.

All the analyses were performed separately for men and women, and then jointly to test if the effects were statistically different for men and women. The two main result tables only present test results for the significance of the weather variables, and the reader should refer to the online appendix for complete results for all regressions used in this paper as well as for coefficient estimates for the control variables. Looking at the effect of temperature, the omitted category was that of mean temperature in the 70s, which is what the average was. This category was omitted to highlight the effect of extreme temperatures on feelings intensity. The same analysis was done using maximum temperature instead of mean temperature. The two were so highly correlated however (correlation over 0.95) that the results were the same, just shifted up by 10 degrees, which is the average difference between mean and maximum temperatures. Note that the analyses were also done using a specification with normal weather and deviations from normal weather, instead of levels of precipitation and temperature. The results did not change qualitatively, and are more easy to interpret in the format presented here.

**Table 4** Test results of significance of weather variables in feelings regressions

Test performed	Dependent variable: feeling							
	Happy	Interested	Tired	Stressed	Sad	In pain	Net affect	U-index
<i>Panel A: Women</i>								
Daily normal precipitation	0.806	0.714	0.710	0.829	0.374	0.978	0.924	0.484
Daily normal temperature	0.910	0.940	0.601	0.144	0.025	0.808	0.362	0.841
Days since last dry day	0.320	0.192	0.328	0.845	0.558	0.034	0.700	0.322
Precipitation on interview day	0.863	0.117	0.512	0.621	0.899	0.200	0.812	0.993
Precipitation on diary day	0.488	0.253	0.029	0.068	0.069	0.060	0.236	0.007
Temperature on diary day	0.010	0.979	0.017	0.005	0.172	0.429	0.016	0.031
<i>Panel B: Men</i>								
Daily normal precipitation	0.827	0.943	0.444	0.541	0.883	0.103	0.908	0.164
Daily normal temperature	0.797	0.341	0.460	0.742	0.404	0.299	0.863	0.583
Days since last dry day	0.578	0.534	0.814	0.940	0.988	0.131	0.856	0.528
Precipitation on int. day	0.159	0.888	0.374	0.277	0.097	0.798	0.573	0.767
Precipitation on diary day	0.235	0.197	0.498	0.994	0.220	0.218	0.507	0.717
Temperature on diary day	0.562	0.823	0.438	0.648	0.702	0.765	0.570	0.685
<i>Panel C: Tests of equality of effects for men and women</i>								
Daily normal precipitation	0.292	0.105	0.172	0.463	0.213	0.295	0.622	0.420
Daily normal temperature	0.826	0.891	0.149	0.084	0.250	0.827	0.624	0.611
Days since last dry day	0.942	0.203	0.610	0.936	0.847	0.910	0.929	0.933
Precipitation on interview day	0.647	0.361	0.429	0.289	0.461	0.364	0.967	0.957
Precipitation on diary day	0.285	0.040	0.581	0.547	0.237	0.453	0.513	0.386
Temperature on diary day	0.335	0.866	0.272	0.479	0.831	0.926	0.472	0.610

All values listed are  $p$ -values (Prob. > F) of the corresponding F-test of the (joint) significance of the variables listed. Each regression also includes controls for education, age and age squared, marital status, race, and hispanic ethnicity, with fixed effects for day of week, activity, month and state. Weighted by sample weights. The standard errors are clustered at the individual level

### 3.2 Affect

Examination of the analyses for women in Panel A of Table 4 reveals that temperature on diary day had a significant effect on the feelings happy, tired and stressed, as well as on the net affect and U-index. While not reported here (see online appendix for complete results), low temperatures increased positive affect and decreased negative ones: low temperatures raised happiness and high ones lowered it; lower temperatures decreased tiredness, stress, and to a lesser extent sadness; and relatively high temperatures marginally increased the intensity of sadness. All this lead to a rise in net affect for very low temperatures and a decrease for very high temperatures. Comparing the effect of the weather variables with other covariates helps to give an order of magnitude. Using coefficients for divorce [Argyle (1999) reported that “Marriage has often been found to be one the strongest correlates of happiness and well-being” (p. 359)], the effects of weather are large: a day with temperature above 90 (relative to one in the 70s) had a bigger effect on the net affect than being divorced or widowed (relative to being married), and a day under 50 had an effect

almost twice the size of that of being married (relative to being divorced), which was about half a standard deviation of the net affect. Since the PATS was conducted in summer months, this seems reasonable, and is also consistent with the evidence found by Rehdanz and Maddison (2005) and Keller et al. (2005).

When thinking about precipitation the prior was that precipitation on the day of the diary (that is, when the activity was taking place) was what would be important, not precipitation on the interview day. This was indeed true: whenever significant (for the feelings tired, stressed, sad and in pain and the U-index), it was rain on the diary day that mattered. What is surprising is the direction of the effects: more rain seemed to be linked with *less* tiredness, stress and sadness, though mostly for the higher levels of precipitation: the coefficients for precipitation more than 0 but less than 0.1 inch were of the expected sign, though not significant except for pain. Perhaps when asked about tiredness on rainy days, survey respondents attributed their tiredness to the rain and thus ‘factored out’ the rain in their answer.

The findings for men reported in Panel B are striking: none of the tests came out statistically significant at the usual levels of significance, except one that was marginally significant with a  $p$ -value of 0.097. Men do not appear to respond to weather shocks the same way women do. Panel C shows the tests of equality between men and women, where a low  $p$ -value means that equality was rejected. Looking at Panel C, most tests concluded that we could not reject the hypothesis that men and women behaved alike. This may be because men’s estimates were imprecise.

### 3.3 Satisfaction

The PATS data include four general satisfaction questions, relating to different spheres of life: life overall, life at home, health, and job satisfaction. Table 5 presents regression estimates for the effect of weather on life satisfaction for women. Column (1) of Table 5 is with month fixed effects while column (2) adds state fixed effects. The prior, and contrary to the feelings questions, was now that if rain has an effect on satisfaction levels, it would be the rain of the day of the interview, not of the diary day (the day before the interview, for which the time-use diary is collected). None of the rain dummies for the diary day were significant, but most of the ones for the interview day were, all reducing satisfaction level more or less monotonically (the omitted category was that of no rain at all). Further confirming the hypothesis, the F-statistics and their associated  $p$ -values presented at the bottom of the table showed that taken together, the rain dummies for the interview day were significant but not the ones for the diary day.

Turning to temperature, lower temperatures were associated with higher satisfaction (though the effects were not statistically significant) while higher temperatures negatively impacted life satisfaction, both statistically and substantively: a temperature in the 80s (compared to the 70s) decreased life satisfaction by about 2 standard deviations, and in the 90s by 2–3 standard deviations, depending if the state fixed effects were included or not. Moreover, the decrease in satisfaction linked to temperature in the 90s was of a similar size as the decrease due to being single (relative to being married). Taken together, however, the temperature dummies were only marginally statistically significant in the specification without state fixed effects, and not at all for that including state fixed effects.

Daily normal mean temperature had a positive but small impact on life satisfaction. Daily normal precipitation significantly decreased life satisfaction, with an extra standard deviation of normal rain reducing life satisfaction 5–10 % of a standard deviations. The biggest change in estimates between column (1) and column (2) (adding state fixed effects)

**Table 5** Regression results, effect of weather on life satisfaction, women

Independent variable	Dependent variable: Life satisfaction	
	(1)	(2)
Daily normal prec.	-0.827** (0.340)	-1.462** (0.698)
<i>Precipitation on interview day<sup>a</sup></i>		
0 < prec. < 0.1	-0.106** (0.050)	-0.094*
0.1 ≤ prec. < 0.5	-0.110* (0.061)	-0.100 (0.061)
0.5 ≤ prec. < 1	-0.170** (0.084)	-0.162* (0.090)
1 ≤ prec.	-0.332** (0.135)	-0.319** (0.149)
<i>Precipitation on diary day (day before interview)<sup>a</sup></i>		
0 < prec. < 0.1	0.011 (0.048)	-0.028 (0.049)
0.1 ≤ prec. < 0.5	-0.016 (0.055)	-0.043 (0.050)
0.5 ≤ prec. < 1	-0.002 (0.086)	-0.033 (0.091)
1 ≤ prec.	0.067 (0.130)	0.029 (0.130)
Days since last dry day	0.009 (0.009)	0.012 (0.009)
Daily normal temp.	0.012** (0.005)	0.010 (0.009)
<i>Temperature on interview day<sup>a</sup></i>		
Under 50	0.171 (0.156)	0.201 (0.162)
50s	0.032 (0.078)	0.021 (0.076)
60s	-0.025 (0.053)	-0.031 (0.050)
80s	-0.169*** (0.061)	-0.158** (0.065)
90 and above	-0.234*** (0.080)	-0.155 (0.107)
Constant	3.435*** (0.396)	3.668*** (0.642)
R-squared	0.104	0.132
Month fixed effects	x	x
State fixed effects		x
F-test prec. int. day <sup>b</sup>	5.826	4.392
Prob. > F prec. int. day	0.001	0.004
F-test prec. diary day <sup>b</sup>	0.116	0.341
Prob. > F prec. diary day	0.976	0.849
F-test temp. int. day <sup>b</sup>	1.985	1.486
Prob. > F temp. int. day	0.098	0.212

Clustered standard errors in parentheses (at state level). The regressions also include controls for education, age and age squared, marital status, race, and hispanic ethnicity. Weighted by sample weights. N = 2,062

<sup>a</sup> Precipitation is measured in inches, mean temperature in degrees Fahrenheit. Omitted categories are no rain and mean temperature in the 70s

<sup>b</sup> The F-tests are of the joint significance of the precipitation or temperature dummies

\*  $p < 0.1$ , \*\* $p < 0.05$ ,

\*\*\*  $p < 0.01$

**Table 6** Test results of significance of weather variables in satisfaction regressions

Test performed	Dependent variable: area of satisfaction			
	Life	Home	Health	Job
<i>Panel A: Women</i>				
Daily normal precipitation	0.042	0.083	0.845	0.175
Daily normal temperature	0.236	0.497	0.633	0.280
Days since last dry day	0.222	0.196	0.332	0.702
Precipitation on interview day	0.004	0.266	0.794	0.381
Precipitation on diary day	0.849	0.878	0.680	0.693
Temperature on interview day	0.212	0.044	0.121	0.710
<i>Panel B: Men</i>				
Daily normal precipitation	0.596	0.600	0.728	0.928
Daily normal temperature	0.615	0.356	0.923	0.229
Days since last dry day	0.829	0.843	0.949	0.112
Precipitation on interview day	0.694	0.885	0.210	0.472
Precipitation on diary day	0.177	0.731	0.256	0.162
Temperature on interview day	0.432	0.052	0.734	0.419
<i>Panel C: Tests of equality of effects for men and women</i>				
Daily normal precipitation	0.223	0.429	0.835	0.687
Daily normal temperature	0.315	0.141	0.532	0.414
Days since last dry day	0.476	0.488	0.682	0.227
Precipitation on interview day	0.012	0.621	0.869	0.695
Precipitation on diary day	0.088	0.782	0.519	0.214
Temperature on interview day	0.291	0.000	0.027	0.325

All values listed are  $p$ -values (Prob. > F) of the corresponding F-test of the (joint) significance of the variables listed. Each regression also includes controls for education, age and age squared, marital status, race, and hispanic ethnicity, with fixed effects for month and state. Weighted by sample weights. The standard errors are clustered at the state level

is for the coefficient on normal precipitation. This is not so surprising since the normal reflects the time of year and the geographical location of the individual. Changes in normal precipitation within state are likely to be smaller.

Table 6 is similar to Table 4 in showing test results for the joint significance of weather variables, but now for regressions (including month and state fixed effects) where areas of satisfaction were the dependent variables. Panel A reports the test results for women only, so the first column (Life) corresponds to the results from Table 5, column (2). Looking at the rest of Panel A, we observe that only one other relation appeared statistically significant ( $p$ -value < 0.05): that of the effect of temperature on home satisfaction. We see in Panel B the results for men, and conclude once again that none of the variables had an impact on men's satisfaction reports. The only group of variables that was jointly significant at a level under 10 % was again the one for the temperature on the interview day. For both men and women, the only temperature variable having a statistically significant impact was that for a temperature in the 80s, with a negative effect for women's home satisfaction and a positive effect for men's. No clear pattern emerged from the other temperature variables, even when not taking into account statistical significance. Panel C shows the results of tests of equality of effects between men and women: only for the effect of precipitation on

interview day on life satisfaction and the effect of temperature on home satisfaction were the effects different.

In conclusion, weather the day of the interview affected only women, with more rain and higher temperatures statistically and substantively decreasing life satisfaction, consistent with the affect results. Interestingly, the same patterns did not emerge when considering other aspects of satisfaction, which would support the hypothesis that women resorted to their weather-influenced mood as “reasonable and parsimonious indicator” only for the most global of evaluations (life vs. specific satisfaction). Men did not appear to let transient weather shocks influence their subjective satisfaction reports, which could be because of the weaker effect of weather on their mood that was found with the affect data. It could also be, as in Connolly (2008), that men responded more to the weather by modifying their activities, thus mitigating the effect on their subjective well-being.

#### 4 Discussion

In this paper, subjective well-being data from the Princeton Affect and Time Survey were supplemented by weather data to investigate the effect of precipitation and temperature, both transitory and average, on satisfaction levels and feelings intensities. Overall, women appear more responsive to environmental variables, showing lower life satisfaction on rainier days. The reasons for these gender differences are unclear and would be an interesting area for future research. Satisfaction in the specific areas of the PATS, home, health and job, is much less influenced by rain, consistent with the hypothesis that the more general the evaluation asked of the respondent, the more she will rely on current mood to construct her judgment. Temperatures have the greatest effect on the intensity of happiness, tiredness, and stress, and thus show up in the net affect and U-index results too. Low temperatures provide the biggest boost, which since the PATS was run in the summer months, from May to August, seems a reasonable finding. It would be interesting to compare this with results coming from data collected in the winter, to see if the effect is reversed, as suggested in Rehdanz and Maddison (2005) and Keller et al. (2005). There is some evidence that rain reduces tiredness and stress, which in turn reduces the U-index associated with heavy rain. The results for men are simply not robust enough for any clear conclusion to be drawn from this study on the responsiveness of men’s satisfaction levels and feelings to the weather, and suggest that they do not respond to weather shocks the same way women do.

The current study is subject to limitations worth noting. First the data only cover the United States, so the conclusions drawn here can only reasonably apply to the US or countries with similar climates and amenities. Second the survey was conducted over the summer months, making it difficult to extend the results to other seasons. Finally, while transitory weather shocks are arguably exogenous, normal conditions can be the result of a choice and as such a causal effect can not be determined with the type of data and analysis applied here. Hence the effect of the daily normals has to be interpreted carefully: there could be a selection bias if people move to certain areas because of the weather, a claim supported by Rappaport (2007). Nevertheless, the PATS data are interesting because of their large sample size and national representativeness.

If the past few years are any predictor of the direction future research in economics will take, then we can expect to see more studies incorporating subjective well-being data in their analysis. Knowing how such data are sensitive to elements like the temperature and amount of rain is important if researchers want to tease out the effect of transitory shocks to

the weather, to focus on other variables and circumstances of interest. This paper provides evidence that current conditions will matter more to women than to men, and that simply controlling for month and state will not be sufficient to control for fluctuations around normal conditions and day-to-day variations. If a researcher's data come from a year-round, country-wide survey, it could be reasonable to think that weather shocks are essentially random and would not bring significant bias one or way the other. But if SWB data are collected over a short period of time and in a specific location, one needs to be careful about interpretation of regression estimates, especially when making gender comparisons, since one conclusion we can draw from this study is that women's SWB is generally more affected by weather than men's.

One way to reduce bias would be to use a measure of "experienced happiness" (Krueger et al. 2009) that is aggregated over a longer period than a day, such as a week or more, or similarly to collect data using an Experience Sampling Method over more time. Another way to deal with this situation would be to include weather data in the analysis, which is reasonable especially if the survey is covering only a few days and/or locales. If weather shocks affect mood which affects life satisfaction, the problem may be seen as one of too much noise (weather shocks) for the amount of signal ('real' satisfaction). One way to reduce the noise would be to use priming about the weather in the questionnaire, that is inducing survey respondents not to rely on the meteorological condition as a "parsimonious indicator" of satisfaction, as Schwarz and Clore (1983) have shown. In surveys where adding a question comes with a premium, this may unfortunately not be possible, and the researcher will have to be careful about interpretation.

One question left unanswered by this study and for which the PATS could help, with its information on well-being and time use combined, is that of the transmission channel of the weather effects. Time-use data contain information on daily activities as well as their location (indoor vs. outdoor). These variables can mitigate the relationship between weather and mood (Keller et al. 2005) and their distribution also differs between men and women. Does the weather directly influence SWB, or is it mostly that weather affects activities, which then affect mood and SWB in general? Similarly, would a mediational model show that the effect of weather conditions on life satisfaction acts through their impact on affect? In this paper both satisfaction and affect are treated as dependent variables. It would be interesting to investigate if, and to what extent, the relationship between weather and satisfaction is mediated by affect. Answering these questions may also help shed light on the gender differences in responses to weather documented in this paper.

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