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Affective Normative Data for English Weather Words

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Abstract: The research in this article examines the emotional associations people have to common weather words and to selected terms that appear in weather communications (e.g., severe thunderstorm warning). A sample of 420 university students provided ratings for each term along four dimensions: 1. Valence (unhappy vs. happy), 2. Arousal (calm vs. excited), 3. Dominance (in control/dominant vs. controlled/passive), and 4. Surprise (unsurprising/predictable vs. surprising/unpredictable). The results of this research provide descriptive statistical data for the 141 weather words along the four dimensions. The author also examined the correlations of the four dimensions across the terms and observed a high degree of association between the rated arousal and surprise characteristics of terms. In addition, the results revealed the clustering of weather words according to shared similarities across the four affective dimensions (illustrating affective-based synonymy). The results of the research are significant because they reveal a deeper understanding of the subjective and emotional experiences of the atmosphere that people may have when describing the weather of a place. Similarly, the normative data from this research may be used in the analysis of weather- or climate-based communications to characterize the emotional significance or impact of a message.

Keywords: affect; biometeorology; emotion; climate; communication; lexicon; linguistics; weather

1. Introduction

Many meteorological, biometeorological, and climatic products for end users are made available in the form of texts or narratives. Local weather forecasts may consist of several sentences that combine both verbal descriptive terms along with quantitative values for forecasted variables [1]. An example from the National Weather Service in the United States may be:

Sunny and clear today with a high of 76. Partly cloudy in the late afternoon with a 10% chance of widely scattered thunderstorms. Mostly cloudy tonight with a 30% chance of rain. Low 69.

Similar types of text products exist from the weather services in Australia, Canada, and the United Kingdom [2–4]. Biometeorological information about pollen, ozone, and other air-quality indicators along with ultraviolet radiation also are available in a combination of textual and graphical formats [5,6]. Lengthier narratives with different types of weather descriptors appear in weather forecast discussions [7]. Weather, climatic, and biometeorological information also is portrayed narratively in the form of weather and climate summaries for a place [8]. Such narratives of the weather have existed since the early days in the history of meteorology, either in the form of *if-then* propositions used to forecast the weather or as a way to summarize past weather events [9,10].

Researchers within biometeorology have focused their efforts on the development of lexical descriptors to communicate perceived thermal sensations [11–15]. Most of this research has attempted to anchor verbal descriptors of thermal sensation (e.g., warm, hot, humid) to particular physical meteorological conditions. One challenge encountered with this approach has been that people living in different cultural, geographical, or climatic regions use the same or similar descriptors in referring to very different measurements of temperature and humidity [11,14,16].

Descriptive words and phrases, used in combination with quantitative information in a forecast or climate summary, help users to develop fuller meanings and greater understandings of the weather [1,17,18]. Within the cognitive frame of a forecast, a phrase such as: overcast, windy, with rain can easily convey the nature or character of the day's weather given the semantic relationships among the terms [19–21]. Furthermore, meteorologists use descriptive terms to explain the development and evolution of weather systems and to provide recommendations to prepare for severe or extreme weather [7,22].

Several researchers have documented the need for using descriptive terms and phrases in ways that produce the intended meanings in those who consume forecast products [1,17]. When particular terms, phrases, or quantities are used (e.g., in the probability of precipitation), what meanings do weather consumers infer [23]? Descriptive words and phrases that adequately convey the meanings of weather and climate forecasts are essential in creating effective communications about the atmosphere to citizens and stakeholders [24,25]. With global climate disruption, it also becomes important to examine communications across cultures to find the best method of conveying information about weather and climate events [26–28].

Brunskill [11] studied the meanings of common terms that broadcasters in selected regions of the United States used, especially in conveying temperature information. Before this, Stewart [18] examined the semantic structure of 153 weather and climate terms. With few exceptions, researchers have explored the denotative (semantic) features of weather terms and focused correspondingly less on the connotative (emotional) associations [12,13]. The exploration of emotion-related features of weather and climate words is significant because this could reveal peoples' emotional responses to particular weather phenomena and also the relationships that exist among the terms within a psych-emotional field.

Psychologists and linguists have examined the emotional characteristics that people associate with English language words in general [20,29,30]. Although it is possible to associate particular words with one or more discrete emotions (e.g., happiness, anger, disgust, etc.), the more frequent approach in this area has involved rating words along three dimensions that are fundamental constituents of the discrete emotions [30]. These affective dimensions involve: 1. Valence (unhappy versus happy), 2. Arousal (calm versus excited), and 3. Dominance (controlled/passive versus in control/dominant) [29,30]. These dimensions are fundamental in that they relate to basic, primary evaluations of experiences as: 1. good or bad, 2. something that demands heightened sensitivity and preparedness to respond, and 3. Something that the person can control or will be controlled by. An example of this methodological approach exists in the Affective Norms of English Words (ANEW) that provides peoples' ratings on common English words using the three affective dimensions [29].

The author has three aims in this article, the first of which is to provide normative statistical information for 141 weather and climate terms and phrases on the dimensions of valence, arousal, dominance and surprise based upon a sample of research participants. The second aim is to assess the degree of interrelationship between the affective dimensions for these weather words and phrases. That is, within a weather lexicon, to what extent does valence (goodness/badness) relate to the degree of arousal and dominance? The author's third aim is to examine the way that weather and climate terms cluster together with respect to their ratings on emotional dimensions. What terms are similar with respect to their associated emotional dimensions and thus may exhibit some degree of emotional synonymy?

In pursuing these aims, the present research extends the work of Stewart [18] by establishing the affective properties of weather and climate terms whose semantic relations were previously documented. This research also supplements the ANEW lexicon by examining specific words and phrases that may be found within communications about weather and climate [29]. Finally, the results of this project may be useful to forecasters and others within atmospheric science who could benefit from knowing the emotional properties of weather and climate terms for the purposes of effective communication with weather consumers.

2. Materials and Methods

2.1. Materials

The materials for this research included 141 English language words and phrases that were descriptive of some aspect of weather or climate, many of which investigated previously for their semantic relationships (see Table 1) [18]. There were 42 nouns and 99 adjectives. The words were descriptive of individual weather variables such as wind (breezy, windy, blustery), temperature (hot, warm, cool, cold), precipitation (rainy, snowy, drizzle), sky conditions (clear, overcast, cloudy), humidity (muggy, moist, humid, dry, arid), and the overall weather (sunny, calm, fair, summery), among other weather or climate descriptors. The phrases consisted of two- and three-word combinations such as: severe thunderstorm, flood watch, winter storm watch. Among these phrases, there were 12 bigrams and 6 trigrams.

Table 1. Descriptive statistics for weather words rated on valence, arousal, dominance, and surprise.

Term	Valence		Arousal		Dominance		Surprise		Cluster [3]
	Mean [2]	SD	Mean	SD	Mean	SD	Mean	SD	
1. Airy	7.33	1.69	4.04	2.67	6.44	1.84	3.76	1.98	1
2. Arctic	3.32	2.34	5.42	2.35	3.14	2.15	6.27	2.15	2
3. Arid	4.17	1.91	3.70	1.81	4.92	1.93	4.15	2.06	3
4. Bad (weather)	2.74	1.76	5.53	2.05	3.14	1.77	5.14	2.28	2
5. Balmy	6.05	2.07	4.50	2.03	5.73	2.12	4.28	1.91	1
6. Bleak	3.07	1.78	3.51	1.89	4.02	1.91	4.24	2.07	3
7. Blizzard (*n*) [1]	4.06	2.37	6.64	2.01	3.19	2.01	7.59	1.88	2
8. Blustery	4.22	1.86	5.41	1.69	4.12	1.77	5.87	1.94	2
9. Bone-chilling	2.44	2.02	4.96	2.56	3.94	2.44	5.88	2.37	2
10. Breezy	5.66	1.98	4.81	2.04	5.00	1.89	4.65	1.91	1
11. Bright	7.99	1.43	5.32	2.75	6.75	1.97	4.04	2.31	1
12. Brilliant	7.50	1.73	5.97	2.42	6.60	2.03	5.07	2.19	1
13. Brisk	6.67	2.11	5.06	2.40	6.07	2.10	4.55	2.11	1
14. Calm	7.39	1.65	2.68	2.44	6.56	2.38	2.92	1.93	1
15. Chilly	4.41	2.17	4.27	2.14	4.60	1.86	4.47	1.97	3
16. Clear	7.77	1.54	4.17	2.79	6.92	1.92	3.76	2.53	1
17. Cloudy	4.70	1.79	3.16	1.63	5.01	1.74	3.30	1.75	3
18. Cold	4.43	2.36	4.30	2.33	4.46	2.21	4.63	2.48	3
19. Comfortable	7.85	1.57	4.04	2.90	7.01	2.27	3.81	2.23	1
20. Cool	6.55	1.84	4.54	2.27	6.02	1.84	4.16	1.91	1
21. Crisp	6.77	1.92	4.80	2.34	6.12	1.96	4.70	2.09	1
22. Damp	3.81	1.50	3.52	1.64	4.19	1.72	3.48	1.56	3
23. Dark	4.05	2.11	4.45	2.19	3.88	2.24	4.40	2.12	3
24. Depressing	2.28	1.61	3.11	2.11	3.21	2.15	4.02	2.13	3
25. Dim	4.21	1.63	3.36	1.67	4.56	1.79	4.17	1.80	3
26. Dismal	3.06	1.89	3.43	1.99	4.16	2.12	3.78	1.87	3
27. Drab	3.33	1.69	2.93	1.68	4.20	2.08	3.51	1.77	3
28. Dreary	3.17	2.02	3.03	1.76	3.83	2.04	3.50	1.78	3
29. Drizzle (*n*)	4.52	1.55	3.44	1.85	4.99	1.87	3.31	1.72	3
30. Drizzly	4.63	2.04	3.38	1.74	4.83	1.70	3.63	1.61	3
31. Drought (*n*)	2.59	1.52	4.32	2.02	3.10	1.79	5.18	2.35	2
32. Dry	4.85	1.79	3.65	1.70	5.13	1.89	4.23	1.90	3
33. Dull	3.64	1.77	2.59	1.70	4.51	2.04	3.13	1.60	3
34. Dusty	3.41	1.64	4.29	1.87	4.04	1.69	5.74	2.14	3
35. Fair	6.69	1.71	3.44	2.30	6.16	2.05	3.53	1.97	1
36. Fall (*n*)	7.86	1.72	6.02	2.75	6.75	2.06	3.94	2.25	1
37. Fine	7.41	1.95	4.50	2.60	6.75	2.21	4.08	2.33	1
38. Flash Flood (*n*)	2.64	1.71	6.03	2.23	2.96	2.13	7.07	2.10	2
39. Flash Flood Warning (n)	2.80	1.62	5.93	2.18	3.36	2.08	6.43	2.17	2
40. Flood (*n*)	2.36	1.44	5.76	2.23	2.87	1.93	6.40	2.30	2

Table 1. *Cont.*

Term	Valence		Arousal		Dominance		Surprise		Cluster [3]
	Mean [2]	SD	Mean	SD	Mean	SD	Mean	SD	
41. Flood Warning (*n*)	2.59	1.45	5.85	2.25	3.02	2.07	6.62	2.04	2
42. Fog (*n*)	4.00	1.82	3.89	2.17	3.83	1.65	4.49	2.18	3
43. Foggy	4.15	1.58	4.38	1.98	3.95	1.87	4.95	1.90	3
44. Freeze (*n*)	3.62	2.34	4.67	2.39	3.65	2.05	5.69	2.48	2
45. Freeze Warning (*n*)	3.64	2.16	5.31	2.16	3.89	1.82	5.77	2.21	2
46. Freezing	3.42	2.19	4.52	2.28	4.19	2.18	5.05	2.35	3
47. Freezing Rain (*n*)	3.30	1.68	5.27	1.67	3.45	1.65	5.93	1.92	2
48. Fresh	6.65	1.98	4.42	2.56	6.07	2.26	4.36	2.28	1
49. Frigid	3.37	2.11	4.38	2.16	3.86	2.02	5.12	2.13	3
50. Frost	4.49	2.09	4.91	2.04	4.49	1.95	5.27	2.11	3
51. Frosty	4.64	2.01	4.72	1.88	4.27	1.73	5.13	2.11	3
52. Frozen	3.89	1.95	4.93	2.06	3.94	2.07	5.57	2.08	2
53. Gloomy	2.89	1.84	2.83	1.81	4.02	2.19	3.67	1.85	3
54. Good (weather)	8.36	1.35	5.22	3.02	7.31	1.74	4.18	2.31	1
55. Gray	3.69	1.97	2.84	1.77	4.52	2.05	3.64	1.87	3
56. Gusty	4.28	1.77	4.86	1.99	4.10	1.86	5.21	1.89	3
57. Hail (*n*)	2.93	1.66	5.97	1.93	3.04	1.86	6.49	2.04	2
58. Harsh	2.63	1.51	5.65	2.00	3.24	2.00	5.88	2.14	2
59. Hazy	3.31	1.56	4.10	1.93	3.75	1.93	4.92	1.93	3
60. Hot	4.83	2.26	4.87	2.04	5.30	2.14	3.99	2.18	3
61. Humid	3.02	1.82	3.35	1.89	4.31	2.29	3.09	1.94	3
62. Hurricane (*n*)	2.21	1.59	6.91	2.25	2.45	2.03	7.17	2.21	2
63. Hurricane Warning (*n*)	2.40	1.61	6.92	2.25	2.74	2.21	7.59	1.87	2
64. Hurricane Watch (*n*)	2.74	1.81	6.62	2.28	2.90	2.28	7.10	2.08	2
65. Ice Storm (*n*)	3.40	2.09	6.07	1.92	3.04	1.76	6.75	2.20	2
66. Ice Storm Warning (*n*)	3.26	1.94	6.13	2.18	3.19	1.93	7.11	1.96	2
67. Icy	3.71	1.84	5.18	2.07	3.31	1.75	5.80	2.20	2
68. Inclement	3.42	1.75	4.57	2.15	4.13	1.72	4.72	2.17	3
69. Mild	6.36	1.84	4.22	2.38	6.10	2.02	3.94	2.07	1
70. Misty	4.54	1.50	3.30	1.51	4.86	1.71	4.03	1.74	3
71. Moist	4.11	1.80	3.64	1.92	4.86	1.98	3.92	1.95	3
72. Muggy	2.74	1.86	3.55	2.07	3.95	2.07	3.58	1.86	3
73. Nippy	4.82	2.13	4.37	2.09	5.22	2.15	4.59	2.05	3
74. Overcast	4.52	1.91	3.1	1.84	4.71	2.22	3.53	1.89	3
75. Parched	2.85	1.66	4.19	2.06	3.64	2.08	4.75	2.03	3
76. Partly Cloudy	6.09	1.65	3.45	2.08	6.06	1.86	3.33	1.83	1
77. Precipitation (*n*)	5.03	1.73	4.40	1.80	5.05	1.68	4.44	1.72	3
78. Predictable	6.20	1.78	3.39	2.25	6.48	2.13	3.23	2.30	1
79. Rain (*n*)	4.76	2.12	3.93	2.02	4.71	1.81	3.91	2.06	3
80. Rainfall (*n*)	5.18	2.21	3.68	2.03	5.13	1.97	3.80	1.82	3
81. Rainy	4.92	2.17	4.05	1.96	4.91	2.04	3.92	1.82	3
82. Raw	3.28	1.78	3.48	1.87	3.87	1.73	4.38	1.98	3
83. Rough	3.06	1.67	5.44	2.24	3.27	1.80	5.54	2.15	2
84. Scorching	2.93	2.10	4.70	2.34	4.16	2.19	4.65	2.35	3
85. Searing	2.74	2.08	4.93	2.51	3.43	2.11	5.17	2.73	2
86. Serene	8.10	1.43	3.28	2.72	6.88	2.26	3.79	2.43	1
87. Severe	2.84	1.62	6.42	2.15	3.12	1.84	6.69	2.06	2
88. Severe Thunderstorm (*n*)	3.63	2.01	5.96	2.10	3.38	2.02	6.09	2.23	2
89. Severe Thunderstorm Warning (*n*)	3.56	1.97	6.51	1.80	3.51	2.09	6.33	2.04	2
90. Severe Thunderstorm Watch (*n*)	3.47	2.02	6.00	2.11	3.44	1.99	6.20	1.98	2
91. Shower (*n*)	4.82	1.99	4.23	1.91	4.64	1.82	4.70	1.87	3
92. Showery	4.52	1.85	3.87	1.94	4.49	1.89	4.17	1.91	3
93. Sizzling	3.30	2.24	5.25	2.28	3.88	2.17	5.04	2.52	2
94. Sleet (*n*)	3.86	1.89	4.99	1.93	3.93	1.80	5.84	2.10	2
95. Sloppy	2.84	1.89	3.94	2.09	3.61	1.94	4.65	1.97	3

Table 1. *Cont.*

Term	Valence		Arousal		Dominance		Surprise		Cluster [3]
	Mean [2]	SD	Mean	SD	Mean	SD	Mean	SD	
96. Smoggy	2.64	1.56	4.36	2.10	3.35	1.78	5.08	2.16	3
97. Smoky	3.02	1.68	5.14	2.18	3.70	2.02	6.27	2.14	2
98. Snow (*n*)	7.27	1.72	6.70	2.18	4.88	1.78	7.02	1.97	1
99. Snowy	6.79	1.79	6.07	2.04	4.82	2.09	6.86	1.95	1
100. Soaking	2.87	1.80	4.37	1.93	3.61	1.81	4.97	1.99	3
101. Soggy	3.21	1.75	3.50	1.85	3.90	2.06	4.07	2.10	3
102. Somber	3.31	1.71	2.94	1.89	4.09	2.04	3.64	1.98	3
103. Sopping	2.99	1.77	3.93	1.86	3.74	1.93	4.64	2.17	3
104. Spring (*n*)	7.48	1.60	5.74	2.28	6.33	1.96	4.05	2.12	1
105. Squally	3.93	1.73	5.46	1.93	3.90	1.70	5.68	1.96	2
106. Stable	6.56	1.71	3.23	2.14	6.44	2.11	3.50	2.16	1
107. Steamy	3.46	1.81	3.63	1.80	3.83	1.98	3.64	1.98	3
108. Stormy	4.19	2.17	5.50	2.13	3.94	2.05	5.34	2.21	2
109. Sultry	3.96	2.22	4.13	2.01	4.38	2.03	3.97	2.04	3
110. Summer (*n*)	7.45	2.04	5.80	2.90	7.06	1.98	3.85	2.62	1
111. Summery	7.31	1.70	5.62	2.55	6.46	1.85	4.10	2.36	1
112. Sunless	3.27	2.03	3.63	1.94	4.19	1.98	4.33	2.13	3
113. Sunny	8.04	1.52	5.08	2.92	6.75	2.11	4.14	2.26	1
114. Sunshine (*n*)	8.17	1.17	5.66	3.05	6.76	2.19	4.38	2.46	1
115. Sweltering	2.57	1.85	4.90	2.34	3.33	2.23	5.16	2.41	2
116. Temperate	6.13	1.67	3.81	1.99	5.94	1.80	3.67	1.83	1
117. Tempestuous	3.76	1.94	5.14	1.96	3.67	1.79	5.24	2.12	2
118. Threatening	2.76	1.78	6.34	2.15	2.93	1.90	6.76	2.07	2
119. Thunder (*n*)	4.56	2.31	5.62	2.11	4.15	2.04	5.53	2.16	2
120. Thundershower (*n*)	4.60	2.04	5.32	2.04	4.08	1.89	5.23	1.84	3
121. Thunderstorm (*n*)	4.76	2.33	5.21	2.40	3.94	2.10	5.27	2.38	3
122. Tornado (*n*)	2.22	1.73	7.11	2.26	2.28	1.93	7.41	2.10	2
123. Tornado Warning (*n*)	2.23	1.48	6.80	2.29	2.53	2.00	7.35	2.05	2
124. Tornado Watch (*n*)	2.63	1.61	6.42	2.03	2.92	2.02	6.59	2.05	2
125. Torrid	3.81	2.04	4.57	1.97	4.24	2.10	5.06	2.18	3
126. Turbulent	2.89	1.58	6.29	2.14	3.16	2.02	6.14	2.30	2
127. Unchanging	5.38	1.82	3.23	2.02	5.93	2.29	3.45	2.35	1
128. Unpredictable	3.45	1.71	5.72	1.95	2.89	1.89	6.24	2.22	2
129. Unsettled	3.79	1.47	4.39	1.97	3.63	1.77	4.71	2.08	3
130. Violent	2.29	1.78	6.42	2.55	2.85	2.27	7.04	2.35	2
131. Warm	7.34	1.70	4.62	2.66	6.57	1.94	3.69	2.30	1
132. Warning (*n*)	2.93	1.74	6.43	2.20	3.30	2.12	6.64	2.08	2
133. Watch (*n*)	3.61	1.54	5.63	1.82	3.67	1.78	5.74	2.08	2
134. Wet	3.86	1.68	3.62	2.00	4.29	2.00	3.66	2.01	3
135. Wild	3.40	2.09	6.10	2.23	3.07	1.80	6.01	2.10	2
136. Windy	4.75	1.89	5.15	1.82	4.24	1.87	5.00	2.17	3
137. Winter (*n*)	5.53	2.38	4.52	2.10	5.02	1.92	3.64	1.91	3
138. Winter Storm (*n*)	4.41	2.28	6.24	1.86	3.89	2.11	6.70	2.11	2
139. Winter Storm Warning (n)	4.11	2.34	6.18	2.28	3.36	1.83	6.78	2.29	2
140. Winter Storm Watch (n)	4.46	2.33	5.56	2.03	3.97	1.93	6.14	1.90	2
141. Wintry	5.13	2.04	4.91	1.91	4.71	1.75	5.09	1.98	3

Notes:[1] (*n*) beside a word in the first column indicates that it was presented as a noun. Otherwise, the words were presented as adjectives descriptive of the weather. [2] The number of respondents used in calculating the descriptive statistics ranged from 95 to 110. The differences in number were due to respondents being randomly assigned to respond to different words. [3] Cluster membership: 1 = Fair/Good Weather, 2 = Severe Weather, 3 = Ordinary Inclement Weather.

Research participants provided their ratings for each term using four nine-point rating scales. The scales were: 1. Valence (unhappy = 1 to happy = 9), 2. Arousal (calm = 1 to excited = 9), 3. Dominance (controlled/passive = 1 to in control/dominant = 9), and 4 Surprise (unsurprising = 1 to surprising = 9). The first three scales have been used successfully in previous affective research on general English language words [29,31]. The fourth dimension (Surprise) was added here for two

reasons, the first of which is research that suggested that an additional dimension may be needed to more fully capture the emotional nuances in stimuli such as words or pictures [32]. The second reason is that some weather events may develop over a long timeframe (e.g., drought), whereas other events are very "short-fused," and thus may be experienced as surprising (e.g., tornado). Each of the four rating dimensions were presented visually (online) and were anchored with verbal descriptors (e.g., Unhappy/Happy) at each endpoint. Furthermore, each of the nine rating points contained a small line drawing of manikin portraying a facial expression corresponding the point on the dimension. These self-assessment manikins (SAM's) are used regularly in providing dimensional ratings to lexical and pictorial stimuli within emotion research [29,31]. A sample rating page is provided in the supplemental online materials for this article.

2.2. Participants

The participants were 420 undergraduate students from a large public university in the southeastern United States. The participants ranged in age from 18 to 36 years (M = 20.77 years, SD = 1.59 years). The participants were primarily female (84.4%) and White (72%) with respect to race. The participants consisted of Black (9%), Latinx (5%), Asian (4%), and Other (10%). The participants were part of a research pool and completed the research to satisfy course requirements. All of the participants completed an informed consent to participate voluntarily in the research and could discontinue their participation at any time.

2.3. Procedure

The research procedure involved the participants first enrolling electronically for the project from among a number of possible research alternatives. The participants could enroll for the research and complete it individually on their computer or laptop at a time of their choosing. Although the study was online, participation was limited to the research pool (i.e., no snowball sampling or sharing of the web link to the survey was allowed as this was not part of the research pool procedures). Use of an online platform for research like this is common within psychology.

After completing the informed consent, the participants were directed to the Qualtrics online survey platform where they were provided with an overview and instructions on the rating task. The overview included a detailed description of each of the four dimensions (valence, arousal, dominance, and surprise) followed by three practice words to become familiar with the rating task. Next, the participants were provided with 35 randomly-selected terms of the 141 (see Table 1) for which to provide the four emotion ratings.

The choice of providing only about one-quarter of the 141 terms for the rating was meant to minimize participant fatigue and to keep them engaged with the task, which required approximately 20 min to complete. The words were accompanied by a parenthetical description of their use as a weather or climate term. In addition, the order of appearance of the four affective rating scales was randomized for each word to minimize possible order effects on participant's ratings. After completing the ratings task, the participants were shown a debriefing statement and then received research credit for their class. The research materials and procedure were reviewed and approved by the Institutional Review Board at the author's university (MOD00006951, parent protocol: STUDY00004476).

2.4. Data Analysis

The author used the R statistics package [33] to calculate the descriptive statistics (means, standard deviations) for each term on the four affective dimensions. The author also used R to calculate the Pearson correlations among the four dimensions based upon the mean ratings as given in Table 1. A K-means cluster analysis of the 141 weather words was conducted with the R statistics package to explore the naturally-occurring groups of words based upon peoples' ratings on the four affective dimensions [33]. The K-means approach was chosen for this analysis because it does not assume a hierarchical relationship among the words. This method of clustering is unsupervised and begins

with an initial specification (from the user) of the number of clusters. The algorithm initially sorts words into clusters based upon their minimum Euclidean distance from the cluster center. The analysis process iterates as the cluster centers evolve and words are moved between clusters to minimize their distance from the cluster center [34,35]. Cluster analysis has been used in projects like this one to explore their shared characteristics [20]. Three clusters were chosen because several tests suggested that this was the optimal number for the data based upon the NbClust package in R [36].

3. Results

3.1. Normative Descriptive Statistics for Weather Words

Table 1 shows the means and standard deviations of the 141 adjectives and noun phrases on the four affective dimensions (valence, arousal, dominance, and surprise); the terms are listed in alphabetical order. The Supplementary Materials for this article provides Table S1 in Excel format for use by other researchers.

Table 2 lists the five words that had the highest and lowest mean scores on each of the four dimensions. Words connoting bright and sunny conditions received the highest ratings on valence (happiness). Similarly, summer, serene, clear, and comfortable received the highest mean ratings for feelings of dominance or being in control. The words tornado, hurricane, and warnings for these received the lowest mean valence ratings (unhappiness). These same terms tornado and hurricane received the highest mean ratings for arousal (excitement) and surprise; they received the lowest mean ratings on dominance. That is, tornado and hurricane were associated with unhappy excitement and surprise that generated feelings of being passive or controlled. Calm, humid, cloudy, dull, and predictable received the lowest ratings for feeling surprised.

Table 2. Weather words with extreme ratings at each pole of valence, arousal, dominance, and surprise.

Valence			
Happy	**Mean**	**Unhappy**	**Mean**
Good (weather)	8.36	Violent	2.29
Sunshine	8.17	Depressing	2.28
Serene	8.10	Tornado Warning	2.23
Sunny	8.04	Tornado	2.22
Bright	7.99	Hurricane	2.21
Arousal			
Excited	**Mean**	**Unexcited**	**Mean**
Tornado	7.11	Drab	2.93
Hurricane Warning	6.92	Gray	2.84
Hurricane	6.91	Gloomy	2.83
Tornado Warning	6.80	Calm	2.68
Snow	6.70	Dull	2.59
Dominance			
In Control/Dominant	**Mean**	**Controlled/Passive**	**Mean**
Good (weather)	7.31	Violent	2.85
Summer	7.06	Hurricane Warning	2.74
Comfortable	7.01	Tornado Warning	2.53
Clear	6.92	Hurricane	2.45
Serene	6.88	Tornado	2.28
Surprise			
Surprised	**Mean**	**Unsurprised**	**Mean**
Blizzard	7.59	Cloudy	3.30
Hurricane Warning	7.59	Predictable	3.23
Tornado	7.41	Dull	3.13
Tornado Warning	7.35	Humid	3.09
Hurricane	7.17	Calm	2.92

Regarding differences in mean scores according to the participant gender, men (M = 4.75) reported a significantly higher mean value for feeling dominant or in control in responding the 141 terms than did women (M = 4.34), $p = 0.001$. No other statistically significant gender differences were observed on valence, arousal, or surprise.

3.2. Relationships among the Affective Dimensions

Table 3 shows the intercorrelations of valence, arousal, dominance, and surprise. Valence and dominance were associated positively, meaning that happiness was associated with feelings of being dominant or in control. The weather words associated mostly with this positive affect were those pertaining to sunny, clear, and bright conditions. Valence exhibited a negative association with surprise. Words conveying predictable and unchanging weather were also the ones that possessed higher happiness ratings. Arousal or excitement exhibited a negative relationship with feelings of dominance or being in control. Arousal also was highly correlated with surprise in that words conveying weather that was sudden or unexpected (e.g., tornado, severe thunderstorm) were also associated with becoming excited or stirred-up. Similarly, surprise exhibited a negative association with dominance. Words connoting sudden and unpredictable weather were also words associated with being controlled or powerless.

Table 3. Pearson correlations of valence, arousal, dominance, and surprise ratings.

Variable	Valence	Arousal	Dominance
Arousal	−0.13		
Dominance	0.94 *	−0.37 *	
Surprise	−0.46 *	0.87 *	−0.68 *

* $p < 0.0001$.

3.3. K-Means Cluster Analysis of Weather Words

The rightmost column of Table 1 shows the cluster membership for each weather word. Figure 1 also depicts cluster polygons in principal component space. The nature of the cluster composition was quite straightforward when inspecting the constituent words. The first cluster (31 words) consisted of fair, sunny, clear, comfortable, and good weather descriptors, among others (See Table 1). Of interest was the finding that snow and snowy were members of this cluster. The words in this cluster connoted conditions that were associated with happy arousal and feelings of being in control and not surprised.

The second cluster consisted of 49 words and phrases that were associated with severe weather conditions: bad, flood, harsh, severe, tornado, violent, and wild, among others. Weather events that possessed a watch or warning were included within this cluster. Within Figure 1, this cluster was located in a region that encompassing feeling surprised and controlled or passive. The third cluster consisted of 61 words that described ordinary or routine inclement weather. This cluster possessed both weather terms (e.g., cloudy, drizzly, rainy, and windy) and emotional adjectives associated with these conditions (e.g., depressing, dreary, gloomy, and somber).

A follow-up multivariate analysis of variance was performed to assess the distinctiveness of the cluster centroids (means) with respect to the four dimensions. This manova was statistically significant, $\Lambda_W = 0.076$, $F(8, 270) = 89.02$, $p < 0.0001$, which indicated that the three emotion clusters of weather words possessed different multivariate means. Furthermore, univariate analyses of variance indicated that all three clusters of words differed significantly from each other with respect to their mean values on valence, arousal, and dominance. For surprise, the severe weather cluster exhibited a significantly greater mean than did either the fair or inclement weather clusters ($p < 0.0001$ for all univariate analyses of variance).

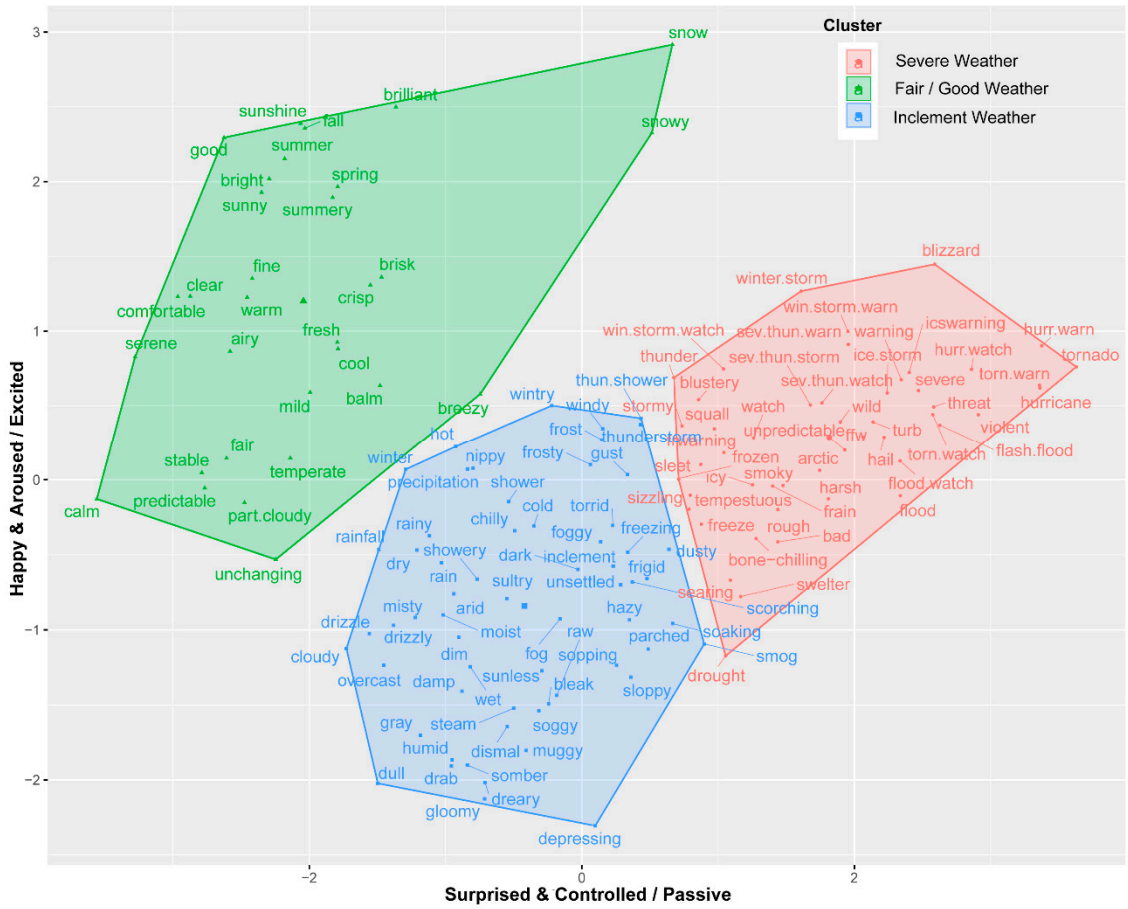

Figure 1. Weather word cluster membership in two-dimensional space. Note that some words have been abbreviated from their original form in Table 1.

There were 19 of the 141 words that could be used to describe the thermal environment. The cluster membership of these terms is instructive for biometeorological purposes because the terms may convey the emotional experiences people experienced previously or may anticipate in the future. In this regard, cool, mild, temperate, and warm were associated with the good weather cluster (1) of terms. The names of thermal conditions that people associated with inclement weather (cluster 2) included: chilly, cold, freezing, frigid, hot, humid, muggy, scorching, steamy, sultry, and torrid. Finally, thermally bad or severe (cluster 3) terms included: bone-chilling, searing, sizzling, and sweltering.

4. Discussion

Meteorological, biometeorological and climate communications utilize a range of common as well as specialized words and phrases. The present research extends our understanding of these words in at least two ways. First, it goes beyond the previous work on the semantic properties of weather and climate words to examine their emotional dimensions and affective connotations [18]. In Stewart's second-order factor analysis of these words, he found two factors that pertained to good and bad weather [18]. In addition to the lower valence (i.e., relative unhappiness) associated with ordinary inclement weather, the current project helps to explain what it is about bad weather that leads people to evaluate it as such. For the kinds of weather described by the terms that cluster as severe or threatening, people tend to feel more helpless, passive, and that they do not have control. Similarly, this type of weather often is associated with surprise and less predictability. Together, these features may demand action, adjustment, and coping, which some people may find challenging or, in some instances, bad.

Conversely, the result that good, sunny, and fair-weather words were associated with happiness and feeling more in control or dominant is consistent with prior research [37]. Furthermore, the results

of this research imply that the increased ability to be in control or autonomous to pursue outdoor activities may be one of the features that make sunny, clear, and fair weather something that is good. In this regard, it was interesting to observe that men in the sample expressed higher levels of dominance in response to the weather words overall compared to women. Snow and snowy were the only precipitation terms to be clustered with good weather. This result may have occurred because people have feelings of nostalgia or sentimentality about their early lives evoked by a winter snowfall [38]. Similarly, the positive associations with snow may have emerged from the possibilities that it affords for pursuing winter sports.

Second, this research is additive to previous efforts to evaluate the sentiments or attitudes that people have expressed in weather texts and communications by using an established theoretical and methodological framework to assess the affective dimensions of terms [29,39]. Whereas sentiment analysis tends to be concentrated only on the dimension of valence (happiness/positivity or unhappiness/negativity), the research here has illustrated that additional dimensions are relevant for revealing the affective associations with weather words. Relatedly, this research also supports the contention of Fontaine et al. [32] that the dimension of surprise or predictability is relevant for understanding emotions. On both rational and, now, empirical grounds, surprise and predictability are meaningful for reflecting the emotional experiences people may have for short-fused weather events (e.g., flash floods or tornadoes).

The descriptive statistical data (Table S1 and Supplementary Materials) could be applied in several ways. First, within a natural language processing approach of forecasts, forecast discussions, watches, and warnings, future research could use the affective normative data to quantify the emotional characteristics of different passages of text (e.g., a sentence, a paragraph or an entire product message) [40–42]. Second, no prior research has explored the affective characteristics of different weather watch or warning messages. The data provided in this article about severe weather words as well as phrases that appear in weather service messages (e.g., Tornado Warning) could be used to experiment with employing different weather words or phrases in watch or warning messages. The goal would be to help users both receive the message about the need to be watchful or to shelter while not being emotionally overwhelmed or feeling powerless (or dominated) by the severe weather event. Third, climatologists and biometeorologists may find the data in Table 1 useful for creating more emotionally precise communications about the conditions of a place. For example, it is more positive emotionally to say that the summer of a place is warm, compared to describing it as muggy or steamy, the latter of which are both more negative and less arousing.

This research is limited in several ways, the first of which involves the fact that the data were collected from university students. The higher level of education of the university participants may have contributed to their understanding of the terms in a way that may not exist among the general population. Second, geography was a limitation of this research because the participants at the time were residing in a particular region of the United States. Although this university draws a significant proportion of its students from across the United States, it is possible that different ratings may be obtained for people residing in different climatic regions of the world. For example, snow and snowy connoted somewhat good weather. This evaluation may not be the case for locations that experience heavy winter snows for durations that exceed those in the southeastern United States. The third limitation is that the respondents were primarily white and female, which may also limit the generalizability of the results. Nonetheless, for many of weather conditions examined here, the data may provide a foundation and framework for further research into people's semantic and emotional experiences of the weather.

Regarding future research directions in light of these limitations, it is important to further examine the affective properties of these words by broadening and further diversifying samples of English-speaking participants. The cultural, geographic, and climatic diversity with the United States and other English-speaking regions may necessitate stratifying or bracketing of the affective normative data to reflect more precisely the local experiences of weather and climate [25,26]. Similarly, people in

culturally and linguistically diverse regions of the world may benefit from the translation of the terms provided here so that they could be evaluated by non-English speakers. Alternatively, the methods in this research could be adapted and applied to a lexicon of weather and climate words in other languages for the purposes of assessing the affective properties of those terms.

5. Conclusions

The research in this article examined the affective properties (valence, dominance, arousal, and surprise) of weather words that appear in a variety of English-language weather products, both online and in print. The results of the research revealed the ways that the weather words differed with respect to emotion. These results constitute the Affective Normative Data for English Weather Words (ANEWW). Particular words connote weather conditions that are either good or fair versus inclement. A separate cluster of words and phrases related to weather conditions that are severe or threatening and that are associated with feelings of surprise and being controlled by the effects of the weather. Researchers may find the data from this project useful in retrospective linguistic analyses of weather-related texts. Meteorologists may benefit from this project by finding and using terms from the ANEWW that are apt for the nature of the weather they wish to describe.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4433/11/8/860/s1, Table S1: Weather Words Descriptive Data (excel file format); Table S2: Sample Item and Response Format (manikins used with permission, Elsevier).

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