*Research Article*

# A Warm Heart and a Clear Head

## The Contingent Effects of Weather on Mood and Cognition

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ABSTRACT—***Prior studies on the association between weather and psychological changes have produced mixed results. In part, this inconsistency may be because weather's psychological effects are moderated by two important factors: the season and time spent outside. In two correlational studies and an experiment manipulating participants' time outdoors (total* N *= 605), pleasant weather (higher temperature or barometric pressure) was related to higher mood, better memory, and "broadened" cognitive style during the spring as time spent outside increased. The same relationships between mood and weather were not observed during other times of year, and indeed hotter weather was associated with lower mood in the summer. These results are consistent with findings on seasonal affective disorder, and suggest that pleasant weather improves mood and broadens cognition in the spring because people have been deprived of such weather during the winter.***

Weather has long held a central place in human experience, and if lay psychology is to be believed, weather continues to be an important determinant of everyday mood and behavior in modern life (Persinger, 1980; Watson, 2000). Given the pervasiveness of this belief, the paucity of scientific knowledge on how weather affects human psychology is surprising. Although the effects of seasons on mood and depression are well documented (e.g., Harmatz et al., 2000; Rosenthal et al., 1984), comparatively few studies have assessed the relationship between daily variation in weather and human mood and cognition.

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We found only two studies related to cognition and weather. In a study manipulating temperature, Allen and Fischer (1978) found that performance on a paired-association memory task peaked at 72 °F (22 °C) and declined with warmer or cooler temperature; Sinclair, Mark, and Clore (1994) found that days that were both sunny and warm were associated with more heuristic and less systematic processing than cloudy and cool days. The number of studies on the relation between weather and mood is somewhat larger. In some studies, low levels of humidity (Sanders & Brizzolara, 1982), high levels of sunlight (Cunningham, 1979; Parrott & Sabini, 1990; Schwarz & Clore, 1983), high barometric pressure (Goldstein, 1972), and high temperature (Cunningham, 1979; Howarth & Hoffman, 1984) have been associated with high mood. However, high temperature has also been associated with low mood (Goldstein, 1972) and low potency (low potency is similar to low mood; Howarth & Hoffman, 1984), and two other studies found no relationships between mood and any weather variable (Clark & Watson, 1988; Watson, 2000).

The largest test of the weather-mood hypothesis (Watson, 2000) collected daily mood reports from 478 undergraduate students in Dallas, Texas, during the fall or the spring (a total of 20,818 observations). No significant correlations were found between mood (measured by self-report using the Positive and Negative Affect Scale, or PANAS) and any of the assessed weather variables (sunshine, barometric pressure, temperature, or precipitation[1]). These null findings were noteworthy because they called into question the commonly held belief that weather affects mood.

However, other lines of research focusing on population-wide behaviors suggest that weather does have some effect on psychological processes. High temperature is reliably associated

[1]Watson (2000) conducted his primary analysis on sunshine and rain, but also reported that neither temperature nor pressure was related to mood.

  

with violent behavior (Anderson, 2001; Baron & Ransberger, 1978), though it is unclear whether this association is best explained by physiological effects of temperature on aggression (Anderson, 2001) or by indirect effects due to the higher likelihood of interpersonal interactions in pleasant weather (Rotton & Cohn, 2000). A second line of research documents that sunnier weather is related to slightly higher stock market returns (Saunders, 1993). A possible interpretation for both findings is that higher temperature and sunlight increase risk tolerance, which in turn increases likelihood for aggression and buying behavior, respectively.

## EFFECTS OF SEASON ON PSYCHOLOGICAL PROCESSES

In contrast to the relatively sparse literature on the psychological changes associated with the weather, hundreds of articles in the past 20 years have considered seasonal effects on psychological functioning, and in particular on seasonal affective disorder (SAD). SAD is seasonally recurrent depression with typical onset during the fall or winter and remission in the spring. It is characterized by typical depressive symptoms as well as atypical symptoms, such as longer sleep duration and carbohydrate craving (Rosenthal et al., 1984). Cognitive impairments in memory, learning, and visual-spatial ability have also been documented (Michalon, Eskes, & Mate-Kole, 1997; O'Brien, Sahakian, & Checkley, 1993). Given that mood tends to reach a low point in the general population during the winter (Harmatz et al., 2000), and that about half of nondepressed people manifest some degree of SAD symptoms during northern winters (Dam, Jakobsen, & Mellerup, 1998; Kasper, Wehr, Bartko, Gaist, & Rosenthal, 1989), SAD can be seen as one extreme along a continuum of normal wintertime behavioral changes.

Several findings about seasonal effects suggest that exposure to sunlight immediately affects mood and cognition. Placebo-controlled studies document that artificial sunlight (produced by a very bright lamp) improves mood and diminishes SAD symptoms for a majority of SAD and non-SAD depressed patients (Kripke, 1998; Stain-Malmgren, Kjellman, & Åberg-Wistedt, 1998), and, most tellingly, improves mood and vitality among nondepressed subjects (Leppamaki, Partonen, & Lonnquist, 2002; Leppamaki, Partonen, Piiroinen, Haukka, & Lonnquist, 2003). Effects are often observed after the first bright-light treatment (Kripke, 1998). Moreover, Lambert, Reid, Kaye, Jennings, and Esler (2002) found that brain serotonin production in 101 healthy, non-SAD males rose or dipped as naturally occurring daily sunlight increased or decreased, respectively.

These findings appear inconsistent with the weak and variable weather findings we reviewed earlier. Exposure to at least one weather phenomenon, sunlight, appears to immediately affect mood and serotonin levels among both depressed and nondepressed people. This suggests that weather does indeed affect mood, and possibly cognition.

## OVERVIEW OF THE CURRENT RESEARCH

For the same reasons that the hedonic value of any emotion-inducing stimulus decreases with continued exposure (Cabanac, 1971), it would be maladaptive for pleasant weather to have the same hedonic effect irrespective of prior exposure. Thus, we predicted that warm and sunny days in the spring (when people have been deprived of such weather) boost mood and alter cognition more than warm and sunny days later in the year, when pleasant weather is less of a novelty.

In addition, it is reasonable to assume that one must be exposed to the weather for it to affect one's psychological processes. However, people in industrialized countries spend an average of 93% of their time inside (Woodcock & Custovic, 1998) and thus are largely disconnected from the weather outside. This suggests that surveys correlating mood with weather might fail to uncover any connection simply because many people have little exposure to the weather.

We conducted three studies to test the hypothesis that the effects of weather on mood and cognition are moderated by season and by degree of direct exposure to the weather. Although sunlight has received the lion's share of attention in the SAD literature, the link between temperature and violence suggests that temperature is also a likely candidate for affecting psychological processes. Other researchers have reported memory impairment associated with SAD (Allen & Fischer, 1978; Michalon et al., 1997; O'Brien et al., 1993) and manipulated temperature (Allen & Fischer, 1978). Thus, the focus of the current studies was on how atmospheric pressure (an assay of sunlight) and temperature are related to cognition and memory.

## STUDY 1: RELATIONSHIPS AMONG WEATHER, MOOD, AND COGNITION IN THE SPRING

### Method

We collected data from 97 participants (54 female and 43 male students ages 18–29) in Ann Arbor, Michigan (42° north latitude) between April 5 and June 15, 2001. Participants responded to a newspaper advertisement and were paid for their time. They completed all measures once, during a single session, and were run individually. Upon arrival, participants filled out questionnaires to report their current mood, how much time they spent outside the day that they came to the lab, their activity level that day (on a verbally anchored scale from 6, *very active*, to 1, *very inactive*), and demographic information. They then completed two cognitive tasks.

Weather was not mentioned until debriefing. We obtained data on temperature and barometric pressure from the National Climatic Data Center (NCDC). Measurements of sunlight were unavailable, but barometric pressure served as a good substitute for sunlight. High pressure is typically associated with clear, sunny weather, whereas low pressure is associated with clouds, precipitation, and storm fronts (Ahrens, 2000). We did not combine temperature and pressure to form an underlying "good weather" variable because the two variables were unrelated ($r = -.06$, n.s.).

We collected information on the following three dependent variables:

- *Mood valence*: Participants reported their mood using the PANAS mood scale (Watson, Clark, & Tellegen, 1988). We subtracted Negative Activation from Positive Activation to create a measure of mood valence, with higher scores denoting better mood (see Barrett & Russell, 1998, for justification of this rotation). In this article, we focus on mood valence rather than Positive Activation (from the PANAS) because (a) our findings in Study 1 indicated that mood valence was more strongly related to weather than positive activation, and (b) mood valence can be assessed quickly with a single-item measure, which was important for Studies 2 and 3.
- *Digit span:* Digit span is an excellent index of working memory capacity (Wechsler, 1997). It was defined as the maximum number of digits participants were able to repeat immediately after hearing a digit string.
- *Openness to new information:* We were also interested in how weather affects cognitive broadening. Cognitive broadening describes a style of thinking in which people become more creative and is hypothesized to be an adaptive shift in cognition that leads to behavioral flexibility and exploration (Fredrickson, 2001; Isen, 2000). Individuals who are in a broad mind-set should modify previously formed attitudes when new information contradicts those attitudes. To measure cognitive broadening, we randomly assigned participants either to read favorable and then unfavorable information about a fictitious employee or to read the unfavorable information first (see Kruglanski & Freund, 1983). Participants then rated the employee's intelligence and performance. Openness to new information was defined as the participant's overall rating of the employee if the unfavorable information was presented first and the reversed rating if the favorable information was presented first. Higher scores indicate a willingness to update initial impressions, reflecting a broad mind-set.

### Results and Discussion

We used multiple regression, controlling for activity level and the time participants came to the lab, to test our prediction that the effects of weather would be moderated by the amount of time spent outside.[2] As in some of the previous research (Clark & Watson, 1988; Watson, 2000), neither temperature nor barometric pressure was directly related to mood valence. However, the interactions of time spent outside with temperature and with barometric pressure were both significantly related to mood valence in the expected direction: As time spent outside increased, the temperature-mood and pressure-mood relationships became more positive (Table 1). These relationships are illustrated in Figures 1a and 1b using median-splits on time spent outside: Among participants who spent more than 30 min outside, higher temperature and pressure were associated with higher moods, but among those who spent 30 min or less outside, this relationship was reversed.

A similar pattern occurred for the cognitive measures (Table 1). Pressure (but not temperature) became more positively related to digit span (Fig. 1c) and to openness to new information (Fig. 1d) as time spent outside increased; that is, among people who spent more than 30 min outdoors, clearer days were associated with higher digit spans and more flexible thinking styles. The relation between digit span and barometric pressure is noteworthy because digit span is a common component of IQ scales (e.g., Wechsler, 1997) and is often considered a stable, trait variable. A supplementary analysis revealed that mood did not mediate these cognitive effects.

**TABLE 1**

***Simultaneous Regression Model Relating Weather and Time Spent Outside to Dependent Measures in Study 1***

| Dependent variable and predictor | $B$ | $SE(B)$ | $r^2$ |
|---|---|---|---|
| Mood valence | | | |
| Temperature | .002 | .101 | .000 |
| Pressure | −.109 | .127 | .010 |
| Time outside | .009 | .118 | .000 |
| Time Outside × Temperature | .216* | .097 | .046 |
| Time Outside × Pressure | .249† | .132 | .063 |
| Digit span | | | |
| Temperature | −.046 | .105 | .002 |
| Pressure | −.009 | .104 | .000 |
| Time outside | −.202† | .118 | .032 |
| Time Outside × Temperature | −.042 | .100 | .002 |
| Time Outside × Pressure | .214* | .101 | .048 |
| Openness to new information | | | |
| Temperature | −.054 | .104 | .003 |
| Pressure | .181† | .104 | .028 |
| Time outside | −.097 | .102 | .009 |
| Time Outside × Temperature | −.022 | .099 | .000 |
| Time Outside × Pressure | .378** | .110 | .113 |

**Note.** Sample sizes vary because of equipment failure and other random errors in data collection. All variables are standardized. Interaction terms are the product of the two standardized predictors in question and are interpreted as the change in the regression slope between the standardized weather and dependent variables when time spent outside increases by one standard deviation (Jaccard, Turrisi, & Wan, 1990). The analysis controlled for activity level and time of day participants came in. The omnibus tests for mood valence ($n$ = 82) and openness to new information ($n$ = 96) were significant, $F(7, 74) = 3.38$, $p = .004$, and $F(7, 88) = 4.30$, $p = .007$, respectively. The omnibus test for digit span ($n$ = 97) was not significant, $F(7, 89) = 1.60$, $p = .112$.
†$p < .10$. *$p < .05$. **$p < .01$.

[2]Assumptions regarding normality of the sampling distributions and equality of variances were satisfied unless otherwise noted.

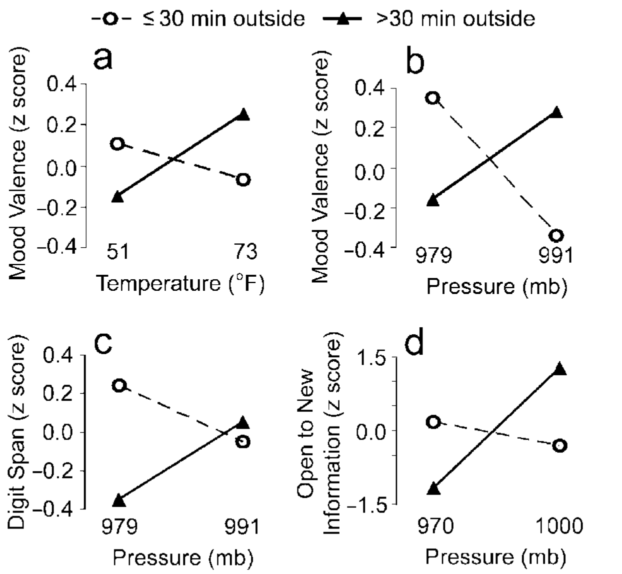


**Fig. 1.** Study 1 results: mood valence (a, b), digit span (c), and openness to new information (d) as a function of temperature or barometric pressure and amount of time spent outdoors in the spring.

## STUDY 2: MANIPULATION OF TIME SPENT OUTSIDE

Although the results of Study 1 were consistent with the hypothesis that the effect of weather on mood and cognition depends on spending time outdoors, the results could also be accounted for if better moods or broader mind-sets are associated with greater willingness or ability to go outside in pleasant weather. To address this self-selection issue, in Study 2 we manipulated the time that participants spent outside before and after we assessed their mood and memory.

### Method

We collected data from 121 participants (85 females and 36 males ages 18–32) in Ann Arbor, Michigan, between April 16 and July 27, 2003. Participants responded to an advertisement in the local newspaper that sought people who relieved stress by "walking outside, dancing, or meditating" and were paid for their time.

Study 2 was part of an unrelated experiment (to be reported elsewhere) on how specific stress-relieving activities affect coping with stressful life events. We matched weather conditions to the extent possible by yoking each participant's session with the session of another participant. Yoked sessions were scheduled in immediate succession on the same day, with one participant randomly assigned to be in the inside condition and the other to be in the outside condition (see the next paragraph).

The first part of each session took place in a windowless room. The participant filled out a baseline questionnaire packet that asked for demographic information and included a measure of mood, as well as several stress measures unrelated to the present study. A research assistant then assessed the participant's digit span. If the participant danced to relieve stress ($n$ = 42), he or she was then randomly assigned to either dance indoors (inside condition) or walk around an outdoor track (outside condition). If the participant walked outdoors to relieve stress ($n$ = 51), he or she was randomly assigned to either walk in a nearby arboretum (outside condition) or walk indoors on a treadmill (inside condition). Finally, if the participant meditated to relieve stress ($n$ = 28), he or she was randomly assigned to either meditate (inside or outside) or proofread a passage (inside or outside).[3] The participant engaged in the assigned activity for 30 min and then returned to complete postactivity measures either outdoors (outside condition) or indoors (inside condition). These measures included the same mood and digit span measures that were completed earlier. Data on temperature and barometric pressure were again obtained from the NCDC. Weather was not mentioned until debriefing.

Openness to new information could not be collected because of time constraints. The following two variables were relevant to the current study:

- *Mood valence change:* Mood valence was measured using an affect grid (J.A. Russell, Weiss, & Mendelsohn, 1989). We subtracted the baseline score from the postactivity score to create an index of mood change over the course of the study.
- *Digit span change:* Digit span was measured using the same procedure employed in Study 1. Digit span change was the postactivity score minus the baseline score.

### Results and Discussion

The interactions of outside/inside condition and weather were in the same direction and of similar magnitude for all three groups of participants (i.e., dancers, walkers, and meditators), so analyses are collapsed across these three groups. Table 2 shows the values of the parameters for the regression equations.[4] As in Study 1, neither temperature nor pressure was directly related to mood, but moods improved for participants who were randomly assigned to be outside on warm, high-pressure (clear) days, whereas moods declined for those randomly assigned to be inside on such days (Figs. 2a and 2b). This interaction was significant for temperature and marginally significant for pressure.

Temperature (but not pressure) was positively related to digit span change among participants assigned to the outside condition (Fig. 2c). It should be noted that pressure, not tempera-

[3]It should be noted that neither the inside condition nor the outside condition was equivalent for the dancers and nature walkers (in the outside condition, dancers walked on a track, but nature walkers walked in a park; in the inside condition, dancers danced to music, but nature walkers walked on a treadmill). The empty cells of this design made it impossible to assess the interaction between stress-relief activity and outside/inside condition, which was of little theoretical interest, but were not problematic to testing our hypothesis.

[4]We analyzed difference scores for each dependent variable, which is equivalent to conducting repeated measures analyses (Maxwell & Delaney, 1990).

**TABLE 2**

*Simultaneous Regression Model Relating Weather and Time Spent Outside to Dependent Measures in Study 2*

| Dependent variable and predictor | *B* | *SE(B)* | $r^2$ |
|---|---|---|---|
| Mood valence change (affect grid) | | | |
| Temperature | −.021 | .090 | .000 |
| Pressure | .027 | .090 | .001 |
| Outside (1)/inside (−1) | −.017 | .090 | .000 |
| Time Outside × Temperature | .299** | .090 | .082 |
| Time Outside × Pressure | .220† | .090 | .040 |
| Digit span change | | | |
| Temperature | −.115 | .093 | .018 |
| Pressure | .133 | .091 | .022 |
| Outside (1)/inside (−1) | −.062 | .092 | .004 |
| Time Outside × Temperature | .194* | .093 | .038 |
| Time Outside × Pressure | .083 | .091 | .008 |

**Note.** Sample sizes vary because of equipment failure and other random errors in data collection. All variables are standardized. Interaction terms are the product of the two standardized predictors in question and are interpreted as the change in the regression slope between the standardized weather and dependent variables when time spent outside increases by one standard deviation (Jaccard, Turrisi, & Wan, 1990). The type of activity the participant used to relieve stress (dancing, meditation, or nature walking) was controlled by entering two variables (created using effect codes) into each regression equation. Activity level and time of day were not controlled because of random assignment. The omnibus test for mood valence change ($n = 120$) was significant, $F(7, 112) = 2.22$, $p = .045$. The omnibus test for digit span change ($n = 119$) was not significant, $F(7, 111) = 1.65$, $p = .141$.
†$p < .10$. *$p < .05$. **$p < .01$.

ture, was related to digit span in Study 1. We discuss this discrepancy in the General Discussion.

## STUDY 3: RELATIONSHIPS AMONG WEATHER AND MOOD ACROSS LOCATIONS AND SEASONS

Study 2 substantively replicated the results of Study 1 and suggested that being inside or outside causally changes the weather-mood and weather-memory associations. Both studies, however, were performed in the spring and early summer in a northern climate, when warm and sunny weather is still somewhat novel. In Study 3, we collected mood data from people in varied geographical locations across 1 year to assess whether the weather-mood association differed across seasons and locations.

### Method

From January to December 2002, we collected information from 387 participants who volunteered to participate on a Web site dedicated to on-line psychological studies: 281 were females and 106 were males; 201 lived in the northern United States and Canada ($\geq$ 38° N), 174 lived in the southern United States (< 38° N), 12 lived in Europe (> 38° N); and ages ranged from 18 through 56 ($M = 25.9$, $SD = 8.7$).

Potential participants clicked on a link titled "Short Disposition Survey," which led to our consent form. Those who agreed to participate completed a demographic page, an implicit mood task, and a single-question mood survey. They then reported how much time they had spent outside that day (average of 64 min) and how active they had been that day (using the same 6-point verbally anchored scale used in Study 1). Weather was not mentioned until debriefing.

As in Studies 1 and 2, we obtained data on temperature and barometric pressure from the NCDC. We analyzed sea-level pressure rather than station-level pressure to account for pressure differences due to elevation. To account for geographical differences in mean temperature, we subtracted the state's, province's, or (if outside North America) country's average temperature across the year from the observed temperature on the day the participant completed the survey (referred to as "temperature" unless otherwise noted).

We collected the following two dependent measures:

- *Implicit mood valence:* First, we administered an implicit measure of mood to expand our previous findings regarding weather-mood associations. Participants were asked to fill in the blank letters of eight words that had one or two letters removed from them (e.g., two of these words were "G L O _ _Y" and "J O _"). In each case, a neutral word ("G L O S S Y" or "J O B") or mood-descriptor words ("G L O O M Y" or "J O Y") could be created. Four of these mood descriptors had a pos-

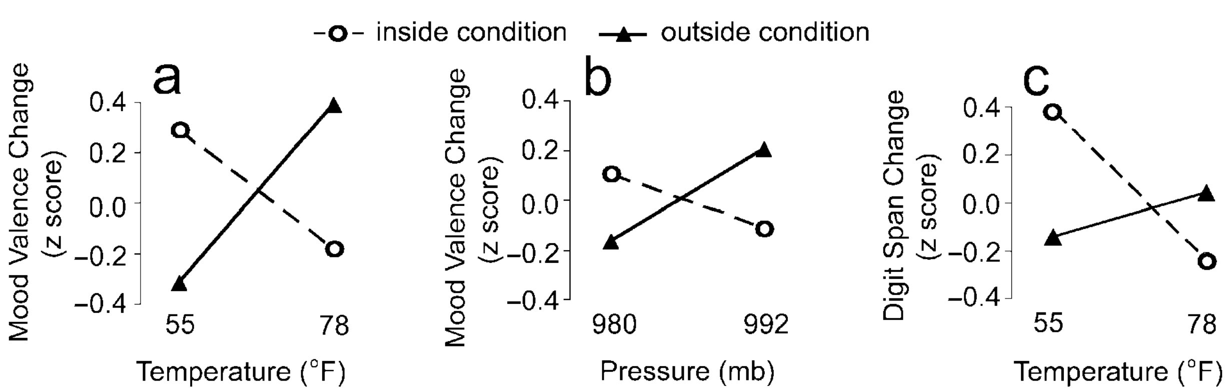


**Fig. 2.** Study 2 results: change in mood valence (a, b) and digit span (c) as a function of temperature or barometric pressure and random assignment to the inside or outside condition in the spring.

itive valence, and four had a negative valence. Implicit mood valence was defined as the number of completed words that were mood descriptors with a positive valence minus the number of completed words that were mood descriptors with a negative valence. Such scales have been found to correlate with momentary mood (Rusting & Larsen, 1998), ostensibly because people tend to perceive stimuli as mood congruent in ambiguous situations.

- *Explicit mood valence:* Because prior experience indicated that an affect grid is potentially confusing without in-person instruction, we did not use an affect grid in this study. Instead, participants indicated their current mood valence on a 9-point Likert scale that was anchored by intensity descriptors of mood valence (1 = *very low*, 9 = *very high*).

**TABLE 3**

*Simultaneous Regression Model Relating Weather and Time Spent Outside to Dependent Measures in Study 3 (Spring Only)*

| Dependent variable and predictor | *B* | *SE(B)* | $r^2$ |
|---|---|---|---|
| Explicit mood valence | | | |
| Temperature | .199 | .118 | .033 |
| Pressure | .262* | .114 | .060 |
| Time outside | .024 | .124 | .001 |
| Time Outside × Temperature | .228* | .111 | .048 |
| Time Outside × Pressure | .051 | .118 | .002 |
| Implicit mood valence | | | |
| Temperature | .202† | .120 | .033 |
| Pressure | .074 | .118 | .006 |
| Time outside | .060 | .125 | .004 |
| Time Outside × Temperature | .235* | .111 | .050 |
| Time Outside × Pressure | .228† | .119 | .042 |

Note. All variables are standardized. Interaction terms are the product of the two standardized predictors in question and are interpreted as the change in the regression slope between the standardized weather and dependent variables when time spent outside increases by one standard deviation (Jaccard, Turrisi, & Wan, 1990). The model controlled for age, activity level, and time of day the questionnaire was completed. The omnibus tests for explicit and implicit mood valence ($n$ = 93) were not significant, $F(8, 84) = 1.34$, $p = .235$, and $F(8, 84) = 1.43$, $p = .198$, respectively.
†$p < .10$. *$p < .05$.

**Results and Discussion**

The primary analyses were conducted separately for each season. We controlled for activity level, the time of day the questionnaire was completed, and (given the greater range of ages in this study than in the others) age. No main effects or interaction terms were statistically significant in the winter (January–March) or fall (October–December) subsamples. The most robust results were in the spring (April–June; see Table 3). Results were consistent with the results of the previous two studies in that the main effects for temperature were nonsignificant for each of the two dependent variables, whereas the interactions of temperature and time spent outside were significant. As participants spent more time outside in the spring, temperature became significantly more related to explicit mood valence and implicit mood valence (see Figs. 3a and 3b). The effects of pressure during the spring were weaker than the effects of temperature. The interaction of time spent outside and pressure was marginally significant for implicit mood valence ($p < .10$; see Fig. 3c), but was unrelated to explicit mood valence.

Of note, warmer temperature in the summer was associated with decreased explicit mood as time spent outside increased (Time Outside × Temperature $B = -.27, p = .02, r^2 = .08$). This effect was driven by participants living in southern climates (Time Outside × Temperature $B = -.36, p = .03, r^2 = .11$; for participants in northern climates, Time Outside × Temperature $B = -.05, p = .88, r^2 = .00$). This result is similar to the findings on the relation between temperature and violence (Rotton & Cohn, 2000) and suggests a curvilinear relationship between mood and temperature. We tested this possibility by regressing raw (geographically uncorrected) temperature and squared raw temperature across the whole year against explicit mood. As expected, there was an inverted-U temperature-mood relationship among participants who had spent more than 45 min outside (temperature squared $B = -.11, p = .03, r^2 = .01$), with the predicted maximum mood occurring at 67.4 °F (19.7 °C). This effect was again much more prominent in southern climates (tem-

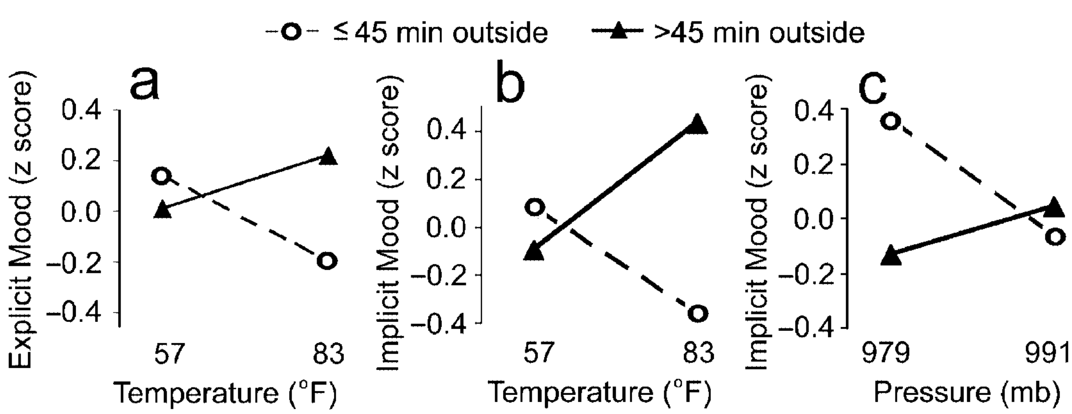


**Fig. 3.** Study 3 results: explicit mood valence (a) and implicit mood valence (b, c) as a function of temperature or barometric pressure and amount of time spent outdoors in the spring.

perature squared $B = -.22, p = .02, r^2 = .04$) than in northern climates (temperature squared $B = -.06, p = .29, r^2 = .00$). Squared temperature was unrelated to mood among participants who spent less than 45 min outside (temperature squared $B = -.01, p = .87, r^2 = .00$), again demonstrating the moderating effect of being outdoors.

It should be noted that the curvilinear effect of temperature does not explain the pattern of findings across the seasons. If it did, a stronger positive association between mood and temperature would be expected in the fall than in the spring; if mood is optimal at 67 °F (19 °C), temperature has more room to increase mood during the fall, which has an average temperature of 62 °F (17 °C), than during the spring, which has an average temperature of 70 °F (21 °C). It should also be noted that the effect of temperature change is asymmetrical: Temperature changes toward cooler weather in the fall did not predict higher mood. Rather, there appears to be something uniquely uplifting about warm days in the spring.

## GENERAL DISCUSSION

Three studies examined how temperature and pressure relate to mood and cognition. Study 1, conducted during a northern spring, indicated that spending time outdoors increases the relationships of temperature and barometric pressure with mood, digit span, and openness to new information. Study 2, in which participants were randomly assigned to be indoors or outdoors, suggests that being outdoors is a causal factor that changes weather-mood and weather-memory relationships. Study 3 indicated that, in addition to time spent outside, season is a critical moderator of weather's effects on mood. Exposure to higher temperatures predicted increased mood during the spring but had the opposite effect on mood during the summer, especially among participants living in southern climates, where high temperatures are increasingly unpleasant.

Contrary to our initial expectations, the effects of the weather on people who spent almost all of their time indoors (i.e., less than 30–45 min outside) was nearly as strong (in the opposite direction) as the effects on those who spent their time outdoors. This result was obtained in all three studies. One possible explanation for this result is that people consciously resent being cooped up indoors when the weather is pleasant in the spring. Another possibility is that brief exposure to pleasant weather places people in mood and mind states that make normal day-to-day indoor activities feel boring or irritating. The current findings do not address the question of whether the effects of weather observed in these studies are due to conscious mediation, to direct physiological effects of the weather, or to some other process.

The overall 95% confidence interval for the springtime Time Outside × Weather *B*s across all 14 tests was $.18 \pm .07$, meaning that spending about 30 to 45 min more outside increased the slope of the relation between standardized temperature or pressure and standardized mood or cognition by .18 units. This probably underestimates the true effect given the error certain to exist in the psychological and behavioral measures (D.W. Russell, Kahn, Spoth, & Altmaier, 1998). Nevertheless, even if error-free measures were available, it is doubtful these effects would be very large simply because weather is likely to be but one among many factors that influence interpersonal differences in mood and cognitive style.

Although the pattern of results forms a coherent picture across the three studies, two apparent discrepancies deserve fuller consideration. First, the interaction between time spent outside and barometric pressure did not approach significance ($p < .10$) for explicit mood in Study 3 during the spring, although this interaction was significant or marginally significant for all other tests involving mood. Second, in Study 1, as time outside increased, pressure significantly predicted increases in digit span, whereas in Study 2, it was temperature that had this effect. What should be made of these seeming inconsistencies? Not very much, we argue. Across varied locations and different methodologies, 12 of 14 springtime Time Outside × Weather *B* terms were in the predicted direction ($B > 0$), a highly improbable pattern of results given the null hypothesis of no effect (exact binomial test $p < .001$). Moreover, 10 of these 14 *B* terms were significant or marginally significant, whereas fewer than 2 should have been if there really were no effects (exact binomial test $p < 10^{-8}$). It is vanishingly unlikely that this pattern of results was due to random error. The "inconsistencies" between studies (as judged by the $p = .05$ threshold) are exactly what should be expected given the sample sizes employed and the likely size of the effect.

Our findings support the hypothesis that both the amount of time people spend outdoors and the season moderate weather's effects on mood and cognition. We hypothesize that pleasant springtime weather is a zeitgeber for changing mood and cognition from their wintertime settings back to their baseline settings. If future work continues to support the hypotheses of this article, the behavioral prescription is straightforward: If you wish to reap the psychological benefits of good springtime weather, go outside.

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