Journal of Applied Psychology
2014, Vol. 99, No. 3, 504–513

0021-9010/14/$12.00 DOI: 10.1037/a0035559

RESEARCH REPORT

Rainmakers: Why Bad Weather Means Good Productivity

Jooa Julia Lee and Francesca Gino
Harvard University

Bradley R. Staats
University of North Carolina at Chapel Hill

People believe that weather conditions influence their everyday work life, but to date, little is known about how weather affects individual productivity. Contrary to conventional wisdom, we predict and find that bad weather increases individual productivity and that it does so by eliminating potential cognitive distractions resulting from good weather. When the weather is bad, individuals appear to focus more on their work than on alternate outdoor activities. We investigate the proposed relationship between worse weather and higher productivity through 4 studies: (a) field data on employees' productivity from a bank in Japan, (b) 2 studies from an online labor market in the United States, and (c) a laboratory experiment. Our findings suggest that worker productivity is higher on bad-, rather than good-, weather days and that cognitive distractions associated with good weather may explain the relationship. We discuss the theoretical and practical implications of our research.

Keywords: weather, productivity, opportunity cost, distractions

Supplemental materials: http://dx.doi.org/10.1037/a0035559.supp

In this article, we seek to understand the impact of weather on worker productivity. Although researchers have investigated the effect of weather on everyday phenomena, such as stock market returns (Hirshleifer & Shumway, 2003; Saunders, 1993), tipping (Rind, 1996), consumer spending (Murray, Di Muro, Finn, & Popkowski Leszczyc, 2010), aggression in sports (Larrick, Timmerman, Carton, & Abrevaya, 2011), and willingness to help (Cunningham, 1979), few studies have directly investigated the effect of weather on work productivity. Moreover, to date, no studies have examined psychological mechanisms through which weather affects individual worker productivity, the focus of our current investigation.

We theorize that thoughts related to salient outdoor options come to mind more easily on good weather days than on bad weather days. Consistent with our theorizing, Simonsohn (2010) found that cloud cover during visits to a college known for its academic rigor by prospective students predicted whether they enrolled in the visited school. Prospective students who visited on a cloudier day were more likely to enroll than were those who visited on a sunnier day. Cloudy weather reduced the opportunity costs of outdoor activities such as sports or hiking and thus increased the attractiveness of academic activities.

To gain insight into how people intuitively think about this relationship, we asked 198 adults (M_{age} = 38 years, SD = 14.19; 42% male) to predict the impact of weather on individuals' work productivity. Among our respondents, about 82% stated that good weather conditions would *increase* productivity, and about 83% responded that bad weather conditions would *decrease* productivity. These survey results indicate that people indeed believe that weather will impact their productivity and that bad weather conditions in particular will be detrimental to it.

This conventional wisdom may be based on the view that bad weather induces a negative mood and therefore impairs executive functions (Keller et al., 2005). In contrast to this view, we propose that bad weather actually *increases* productivity through an alternative psychological route. We theorize that the positive effects of bad weather on worker productivity stem from the likelihood that people may be cognitively distracted by the attractive outdoor options available to them on good weather days. Consequently, workers will be less distracted and more focused on bad weather days, when such outdoor options do not exist, and therefore will perform their tasks more effectively.

This article was published Online First January 13, 2014.

Jooa Julia Lee, Harvard Kennedy School, Harvard University; Francesca Gino, Negotiation, Organizations & Markets Unit, Harvard Business School, Harvard University; Bradley R. Staats, Operations, Kenan-Flagler Business School, University of North Carolina at Chapel Hill.

This research was supported by Harvard Business School, the University of North Carolina at Chapel Hill's Center for International Business Education and Research, and the University Research Council at the University of North Carolina at Chapel Hill. We thank Max Bazerman and Karim Kassam for their insightful comments on earlier drafts of this article. We are also grateful to Kanyinsola Aibana, Will Boning, Soohyun Lee, Nicole Ludmir, and Yian Xu for their assistance in collecting and scoring the data. We gratefully acknowledge the support of management at our field site, and the support and facilities of the Harvard Decision Science Laboratory and the Harvard Business School Computer Laboratory for Experimental Research (CLER).

Correspondence concerning this article should be addressed to Jooa Julia Lee, Harvard University, Harvard Kennedy School, 124 Mt. Auburn Street, Suite 122, Cambridge, MA 02138. E-mail: jooajulialee@fas.harvard.edu

Psychological Mechanisms of the "Weather Effect" on Productivity

When working on a given task, people generally tend to think, at least to some extent, about personal priorities unrelated to that task (Giambra, 1995; Killingsworth & Gilbert, 2010). Task-unrelated thoughts are similar to other goal-related processes in that they can be engaged in without explicit awareness, though they are not directed toward the given task (Smallwood & Schooler, 2006). Thus, when the mind wanders, attention shifts away from the given task and may lead to failures in task performance (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Prior work notes that general cognitive interference can have costly effects on worker productivity (for a review, see Jett & George, 2003). Workers who experience cognitive interference are distracted, showing an inability to focus on a task (Fisher, 1998) and a greater likelihood of committing errors while completing the task (Flynn et al., 1999).

Thinking about salient and attractive outdoor options is a form of task-unrelated thinking that serves as a cognitive distraction that shifts workers' attention away from the task at hand. Accordingly, we expect it will be harder for workers to maintain their task-related thoughts on good weather days than on bad weather days. As a result, we also predict that workers will be less productive on good weather days than on bad weather days. More specifically, we argue that on a bad weather day, individuals will have a higher ability to focus on a given work task not because of the negative mood induced by the weather but because fewer distracting thoughts related to outdoor options will be readily available in their minds. Consequently, they will be able to better concentrate on their tasks and work more productively on bad weather days. In our research, we consider tasks where productivity requires high levels of attention and focus, which allow workers to complete their work faster. Thus, we expect fewer cognitive distractions to be associated with higher levels of work productivity. Taken together, these arguments lead to the following hypotheses:

> *Hypothesis 1.* Good weather conditions, such as lack of rain, will decrease worker productivity on tasks that require sustained attention and focus, compared to bad weather conditions.

> *Hypothesis 2.* Good weather conditions will increase the salience and attractiveness of outdoor options, compared to bad weather conditions.

> *Hypothesis 3.* The relationship between good weather conditions and worker productivity will be mediated by greater cognitive distractions (i.e., salience of one's outdoor options).

To test our predictions, we used empirical data on worker productivity, measured by individual performance on tasks conducted in a Japanese bank (Study 1), an online marketplace (i.e., Amazon Mechanical Turk, Studies 2 and 3), and the laboratory (Study 4). We focused on precipitation as the key measure of bad weather given the previous finding that precipitation is the most critical barrier to outdoor physical activities (Chan, Ryan, & Tudor-Locke, 2006; Togo, Watanabe, Shephard, & Aoyagi, 2005).

Study 1: Field Evidence From a Japanese Bank

Method

In Study 1, we examined the proposed link between weather conditions and productivity by matching data on employee productivity from a mid-size bank in Japan with daily weather data.[1] In particular, we assessed worker productivity using archival data from a Japanese bank's home-loan mortgage-processing line. For the sake of brevity, we discuss the overall structure of the operations here; more detailed information can be found in Staats and Gino (2012). Our data includes information on the line from the rollout date, June 1, 2007 until December 30, 2009, a 2.5-year time period. We examined all transactions completed by the permanent workforce, 111 workers who completed 598,393 transactions. Workers at the bank conducted the 17 data-entry tasks required to move from a paper loan application to a loan decision. Included were tasks such as entering a customer's personal data (e.g., name, address, phone number) and entering information from a real estate appraisal. Workers completed one task at a time (i.e., one of 17 steps for one loan); when a task was completed, the system assigned the worker a new task. The building in which the work took place had windows through which workers could observe the weather. Workers were paid a flat fee for their work; there was no piece-rate incentive to encourage faster completion of work.

In addition to the information on worker productivity, we also assembled data on weather conditions in Tokyo, the city where the individuals worked. The National Climactic Data Center of the U.S. Department of Commerce collects meteorological data from stations around the world. Information for a location, such as Tokyo, was calculated as a daily average and includes summaries for temperature, precipitation amount, and visibility.

Measures

Completion time. To calculate *completion time*, we took the natural log of the number of minutes a worker spent to complete the task ($\mu = 0.39$, $\sigma = 1.15$). As we detail below, we conducted our analyses using a log-linear learning curve model.

Weather conditions. Since our main variable of interest is precipitation, we included a variable equal to the amount of precipitation each day in inches, down to the hundredth of an inch ($\mu = 0.18$, $\sigma = 0.53$). To control for effects from other weather-related factors, we also included temperature ($\mu = 62.1$, $\sigma = 14.6$) and visibility ($\mu = 10.3$, $\sigma = 5.1$). With respect to the former, it may be that productivity is higher with either low or high temperatures. Therefore, we entered both a linear and quadratic term for temperature (in degrees Fahrenheit). Finally, because worse visibility could be related to lower productivity, we included the average daily visibility in miles (to the tenth of a mile).

Control variables. We controlled for variables that have been shown to affect worker productivity. These included: same-day, cumulative volume (count of the prior number of transactions handled by a worker on that day); all prior days' cumulative volume (count of transactions from prior days); load (percentage

[1] The data reported in Study 1 have been collected as part of a larger data collection. Findings from the data have been reported in separate articles: Staats and Gino (2012) and Derler, Moore, and Staats (2013).

of individuals completing work during the hour that the focal task occurred; see Kc & Terwiesch, 2009); overwork (a comparison of current load to the average, see Kc & Terwiesch, 2009); defect; day-of-week, month, year, stage (an indicator for each of the 17 different steps); and individual indicators.

Results and Discussion

We used a log-linear learning curve model because individuals' performance improves over time with experience. Using this approach, we conducted our analyses at the transaction level. Therefore, in our models, we controlled for the effects of the worker, task, and time, and then examined the effect of weather on worker productivity. For our primary model, we used a fixed effects linear regression model with standard errors clustered by individual.

Column 1 in Table 1 shows our main model, which we used to test Hypothesis 1. Examining rain, we found that the coefficient is negative and significant (coefficient $= -0.01363$). In terms of the effect size, we found that a one-inch increase in rain is related to a 1.3% decrease in worker completion time for each transaction. Given that there are approximately 100 workers in the operation, a 1.3% productivity loss is approximately equivalent to losing one worker for the organization on a given day. Based on the average yearly salary of the associate-level employees at this bank and the average frequency of precipitation, this loss could cost approximately $18,750 for this particular operation a year. When accumulated over time for the entire bank of nearly 5,000 employees, a 1.3% productivity loss could be interpreted as a significant loss in revenue for the bank: at least $937,500 a year. Further, in a city the size of Tokyo (approximately 9 million people) our identified effect could translate into hundreds of millions of dollars in annual lost productivity.

Next, it is important to properly account for the standard errors in our model as we have many observations nested within a small number of individual workers. Therefore, in Column 2, we clustered the standard errors by day, not by worker. In Column 3, we used Prais-Winsten regression with panel-corrected standard errors adjusted for heteroskedasticity and panel-wide, first-order autocorrelation. Then, in Column 4, we used the fixed effects regression model from Columns 1–3 but used block-bootstrapped standard errors. In each model, the coefficient on rain is negative and statistically significant. Finally, in Columns 5 and 6 we added additional controls with first individual fixed effects interacted with monthly fixed effects and then individual fixed effects interacted with stage fixed effects. In conclusion, using a within-subject design, this study showed that greater rain is related to better worker productivity.

Study 2: Online Study of Weather and Productivity

Although Study 1 offers valuable information on employees' actual work productivity, only the time taken to complete a task was used as an outcome variable, as error rates were low (less than 3%) and showed little variation across employees. In Study 2, we sought a conceptual replication of the effect of weather on completion time while also using a task that would permit us to measure error rates. We could thus investigate productivity not only in terms of quantity (speed at which workers completed their given task) but also in terms of quality (accuracy of detecting errors and correcting them). To account for the potential influence of weather-driven moods, in addition to new productivity measures, we collected data on whether workers felt positive or negative affect while completing the task.

Method

Participants and procedure. We recruited U.S. residents to participate in an online survey in early March, when weather conditions vary significantly depending on where workers are located. Three hundred twenty-nine online workers ($M_{\text{age}} = 36.52$ years, $SD = 12.79$; 48% male) participated in a 30-min study and received a flat fee of $1. We first gave all workers a three-paragraph essay that included 26 spelling errors; we asked them to find as many errors as they could and correct the errors they found.[2]

Once all the workers had completed the task, they completed a questionnaire that included measures of state emotions to control for potential effects of affect. Finally, we asked workers to complete a demographics questionnaire that also included questions about the day's weather and their zip code.

Measures.

Productivity. We computed the time (in seconds) workers spent on the task of correcting spelling errors (i.e., speed). Given that each worker spent a different amount of time on the task, we calculated speed by dividing the number of typos detected by the total time taken in seconds. We then log-transformed the variable to reduce skewness. In addition, we computed how many spelling errors were *correctly* identified and fixed as a measure of accuracy.

State emotions. We used the 20-item form of the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988). Participants indicated how much they felt each emotion "right now" using a 7-point scale. We calculated two summary variables for each participant: positive ($\alpha = .90$) and negative affect ($\alpha = .91$).

Weather questionnaire. Workers were asked to report their zip code, which enabled us to find the daily weather data of the specific area on a specific day (http://www.wunderground.com). To ensure that workers' perceived weather matched actual weather conditions, we also asked them to think about the weather conditions of the day, relative to their city's average weather conditions, using a 5-point scale (1 = *one of the best* to 5 = *one of the worst*).

Results and Discussion

We first tested whether actual weather matched workers' perceptions of the day's weather. Indeed, subjective perceptions of bad weather were associated with lower temperature ($r = -.24$, $p < .001$), higher humidity ($r = .21$, $p < 0.001$), more precipitation ($r = .23$, $p < 0.001$), more wind ($r = .31$, $p < 0.001$), and lower visibility ($r = -.26$, $p < 0.001$).

Table 2 reports summary statistics. Table 3 summarizes a series of regression analyses. Consistent with Hypothesis 1, more rain was associated with higher productivity, measured in terms of both speed and accuracy (Model 1). This relationship holds even after controlling for key demographic variables and state emotions

[2] More detailed instructions and materials are available online as supplemental materials (Appendix A).

Table 1
Summary Regression Results on Completion Time for Study 1

Variable	Model 1 Main model B	SE	2 Cluster by day B	SE	3 Prais-Winsten B	SE	4 Block bootstrap B	SE	5 Individual × Month fixed effects B	SE	6 Individual × Stage fixed effects B	SE
Rain (inches)	−0.01363*	0.006068	−0.01363*	0.006869	−0.01284***	0.002788	−0.01363*	0.005686	−0.01167*	0.004827	−0.01336*	0.006055
Temperature (degrees)	0.006964	0.004340	0.006964*	0.003341	0.006789***	0.001773	0.006964	0.004364	0.004519	0.003473	0.006863	0.004438
Temperature^2	−6.425e−05	3.710e−05	−6.425e−05*	2.680e−05	−6.323e−05***	1.382e−05	−6.425e−05	3.819e−05	−4.588e−05	2.946e−05	−6.449e−05	3.756e−05
Visibility (miles)	9.799e−04	7.311e−04	9.799e−04	6.991e−04	8.483e−04*	3.443e−04	9.799e−04	7.040e−04	8.176e−04	5.755e−04	7.808e−04	7.102e−04
Same-day, cumulative volume	−1.696e−04*	6.511e−05	−1.696e−04***	2.259e−05	−1.040e−04***	9.373e−06	−1.696e−04**	6.031e−05	−1.274e−04***	2.909e−05	−1.661e−04**	5.830e−05
All prior days' cumulative volume	−4.507e−05*	1.801e−05	−4.507e−05***	3.674e−06	−4.581e−05***	1.672e−06	−4.507e−05*	1.823e−05	−1.809e−05	2.380e−05	−3.477e−05*	1.661e−05
All prior days' cumulative volume^2	1.524e−09*	6.132e−10	1.524e−09***	1.461e−10	1.508e−09***	6.198e−11	1.524e−09*	7.360e−10	1.380e−09	1.205e−09	1.323e−09*	5.905e−10
Load	−0.4181***	0.05738	−0.4181***	0.02195	−0.4014***	0.01030	−0.4181***	0.05965	−0.3283***	0.05141	−0.3651***	0.04788
Overwork	0.2603***	0.04925	0.2603***	0.02583	0.2468***	0.009857	0.2603***	0.05339	0.1898***	0.04601	0.2166***	0.04108
Defect	0.2206***	0.03507	0.2206***	0.01661	0.3108***	0.006690	0.2206***	0.03900	0.2398***	0.03609	0.2487***	0.03500
Constant	−0.3350	0.2192	−2.1010***	0.1693	−2.4212***	0.08566	−0.3350	0.2394	0.1733	0.2160	1.0083***	0.2154
Individual × Month fixed effect	—		—		—		—		Yes		—	
Individual × Stage fixed effect	—		—		—		—		—		Yes	
Observations	598,393		598,393		598,393		598,393		598,393		598,393	
R^2	0.3563		0.4591		0.3374		0.3563		0.08806		0.04908	

Note. $n = 598{,}393$. All models include indicators for the individual, stage, month, year, and day of week.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 2
Summary Statistics for Study 2

Variable	*M*	σ	1	2	3	4	5	6	7	8	9
1. Speed	2.84	0.64									
2. Accuracy	17.87	4.82	**.82**								
3. Precipitation	0.28	0.93	**.12**	**.11**							
4. Perceived bad weather	3.01	0.82	.01	.01	**.24**						
5. Positive affect	4.00	1.14	−.04	−.04	.02	−.09					
6. Negative affect	1.53	0.83	−.03	−.05	−.02	.01	−.06				
7. Female	1.52	0.50	.02	.05	−.10	.06	.08	−.09			
8. Age	37.23	12.88	−.08	.05	.00	.06	.10	**−.15**	**.13**		
9. Education	4.19	1.49	**.13**	**.18**	.05	.02	.06	−.05	.05	**.11**	
10. Income	3.84	2.68	**.13**	**.13**	−.01	−.06	.01	.03	.04	−.02	**.25**

Note. Bold denotes significance of less than 5%.

(Model 2). These findings suggest that bad weather is associated with both indicators of productivity, increased speed, and accuracy.

Study 3: Online Study of Weather and Salience of Outdoor Options

We conducted a third study to test Hypothesis 2, which suggests that good weather conditions raise the attractiveness of outdoor options compared to bad weather conditions.

Method

Participants and procedure. We recruited 77 online workers (M_{age} = 33.02 years, *SD* = 11.99; 53% male) on MTurk to participate in a 5-min study for a flat fee of $0.20. We randomly assigned participants to one of two weather conditions (good vs. bad). Participants were primed on the weather; half of them read, “Please imagine that it is a beautiful, sunny day outside for the next 10 seconds,” and the rest read, “Please imagine that it is raining outside for the next 10 seconds.” We then asked all workers to write down as many non-work-related activities as possible that they would like to engage in (up to 10). Workers were also asked to rate the attractiveness of these activities using a 5-point scale (from 1 = *the least attractive* to 5 = *the most attractive*). Among all activities listed, we counted the number of outdoor and indoor activities separately.

Results and Discussion

Workers who were told to imagine good weather conditions listed significantly more outdoor activities they would like to engage in ($M = 4.47$, $SD = 2.91$) than did workers who imagined bad weather conditions ($M = 1.31$, $SD = 2.10$), $t(75) = -5.48$, $p < .001$, although the total number of non-work-related activities (which include both indoor and outdoor activities) did not differ across weather conditions, $t(75) = 1.48$, $p = .14$. Similarly, attractiveness ratings for these outdoor activities were higher for those who imagined good weather ($M = 3.77$, $SD = 0.14$), compared to bad weather ($M = 1.38$, $SD = 0.29$), $t(75) = –7.32$, $p < .001$. This finding suggests that outdoor activities were indeed more salient and attractive when workers perceived weather to be good than bad.

Study 4: Laboratory Study of Outdoor Options and Productivity

In Study 4, we carefully chose the days on which we conducted our study sessions to take advantage of natural variation, then we experimentally manipulated subjects’ exposure to outdoor options. Through moderation, we seek to provide evidence in support of our mediation hypothesis that the salience of attractive outdoor options is directly linked to cognitive distractions. To test for the mediating role of outdoor options and cognitive distractions through a moderation approach (Spencer, Zanna, & Fong, 2008), we chose weather conditions and manipulated the mediating factor (in our case, exposure to outdoor options).[3] Using a 2 × 2 design, we expect to find an interaction between weather conditions and exposure to outdoor options in predicting work productivity (consistent with Hypothesis 3). Further, we predict that productivity will be lower on good weather days compared to bad weather days, regardless of the outdoor-options manipulation, as these options are already salient and attractive without our prompt. Thus, we expect to see our predicted effect (better performance on bad weather days) in the condition in which we do not introduce outdoor options as distractions.

Method

For our first manipulation, we varied whether the task was undertaken on days with poor weather (rainy) or good weather (sunny). For our second manipulation, the participants either were primed by exposure to a variety of outdoor options prior to the task or were not primed by exposure to outdoor options. We used this second manipulation to vary the level of cognitive distraction created by thinking about outdoor activities one may engage in, a manipulation based on prior research (e.g., Simonsohn, 2010). During the entire experiment, the laboratory’s lighting and temperature levels were fixed at the same level, and participants were

[3] We selected this method of manipulating the availability of outdoor options instead of relying on self-reports, which are less reliable and more likely to be biased (i.e., asking participants how distracted they felt or how frequently they thought about outdoor options). This approach is considered a stronger test of the mediation hypothesis than measuring the mediating factor through the use of self-reported measures (Rucker, Preacher, Tormala, & Petty, 2011; Spencer et al., 2005).

Table 3
Summary Regression Results in Study 2

	Speed				Accuracy			
	Model 1		Model 2		Model 1		Model 2	
Variable	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Precipitation	0.07**	0.02	0.07**	0.02	0.54**	0.15	0.52**	0.15
Female			0.04	0.07			0.30	0.54
Age			−0.00	0.00			0.01	0.02
Education			0.05*	0.02			0.47*	0.01
Income			0.02	0.01			0.18	0.09
Positive affect			−0.02	0.04			−0.23	0.28
Negative affect			−0.03	0.04			−0.39	0.36
Constant	2.81***	0.04	2.72***	0.24	17.62***	0.28	15.45***	1.72
Observations	321		321		321		321	
R^2	0.01		0.05		0.01		0.06	
Root *MSE*	0.62		0.62		4.79		4.71	

* $p < .05$. ** $p < .01$. *** $p < .001$.

able to see the outside weather through the lab's window. There was no significant difference in show-up rates between bad versus good weather days.

Participants and procedure. We recruited 136 students (M_{age} = 21.82 years, *SD* = 3.51; 48.89% male) through the study pool at the Harvard Decision Science Laboratory. Students signed up online in advance to participate in an hour-long study and were paid a $10 participation fee. They were also told that, depending on the completion time of their data entry, they could receive an additional $10 bonus.

Participants in the exposure-to-outdoor-options condition viewed photos of outdoor activities taking place in good weather conditions and were asked to evaluate the attractiveness of each activity. Participants were then asked to pick their favorite depicted activity or the activity in which they engaged most frequently and to discuss as vividly as possible what they would do in the depicted scene. By contrast, participants in the control group were asked to describe their typical daily routine.

Next, all participants completed the data-entry task, which involved entering five sets of questionnaire responses written in Italian from printed copies into a spreadsheet.[4] All participants finished entering five surveys and received the additional $10. After all participants completed their data-entry task, they answered a questionnaire that included state emotions, subjective weather perceptions, and demographic questions.

Measures

Productivity. We assessed speed and accuracy as measures of productivity. For speed, we first calculated the number of words entered, then divided this number by the amount of time spent completing the task, given that each survey data consisted of a different number of words. We assessed accuracy by counting the number of *correct* words entered for each person.

State emotions. Similar to Study 2, we controlled for the potential influence of affect by measuring both positive ($\alpha = .93$) and negative affect ($\alpha = .89$) using PANAS.

Subjective weather perceptions. As a manipulation check for our weather manipulation, we asked participants whether they thought the weather on the day of their participation was "good" or "bad."

Results and Discussion

We excluded 10 participants who failed to follow our instructions, as their completion time was not recorded correctly. Table 4 reports the descriptive statistics and correlations among the key variables used in our analyses.

Manipulation check. Almost 90% of the participants who participated on a good weather day (60 out of 67) felt that the weather was good; almost 93% of participants who participated on a rainy day (64 out of 69) felt that the weather was bad, $\chi^2(1, N = 136) = 92.29$, $p < .001$. These weather variables were not significantly correlated with our manipulation of exposure to outdoor options, which we randomized.

Main analyses. Hypothesis 3 predicted that bad weather conditions increase productivity by decreasing thoughts about outdoor options, which should reduce cognitive distractions. Given the design of Study 4, this hypothesis would be supported by a significant interaction between weather conditions and exposure to outdoor options in predicting productivity. To test this hypothesis, we conducted a series of regression analyses (Table 5). As shown in Model 1, exposure to outdoor options decreased data-entry speed and accuracy. We did not find a statistically significant effect of bad weather on productivity (for speed, $\beta = 1.60$, $p = .10$; for accuracy, $\beta = 13.33$, $p = .10$). As predicted, the effect of weather on speed was qualified by a significant interaction between exposure to outdoor options and weather conditions, while the interaction effect on accuracy did not reach significance criteria. We conducted similar analyses while controlling for demographics and state emotions (Model 2). After holding these variables constant, the interaction effect on speed remained robust, and the interaction effect on accuracy became statistically significant.

A simple slope analysis supports Hypothesis 3 (see Figure 1). When no outdoor options were made salient to participants, bad weather significantly increased data-entry speed ($\beta = 3.04$, $p = .04$). When participants were exposed to outdoor options, however,

[4] Further details of the instructions and materials used in this study are available online as supplemental materials (Appendix B).

Table 4
Summary Statistics for Study 4

Variable	*M*	σ	1	2	3	4	5	6	7	8	9
1. Speed	30.03	3.55									
2. Accuracy	190.49	31.81	**.90**								
3. Good weather indicator	0.48	0.50	−.02	−.01							
4. Outside option indicator	0.52	0.50	−.14	**−.20**	−.04						
5. Age	21.94	3.57	**−.20**	−.16	.05	−.06					
6. Female	1.52	0.50	**.18**	.10	.01	−.07	−.07				
7. Income	4.90	3.40	.13	.09	.00	.06	**−.19**	.06			
8. Education	3.42	1.03	−.11	−.04	.09	.00	**.71**	−.07	**−.26**		
9. Positive affect	35.93	12.16	.03	.07	.09	−.07	.11	−.09	.06	−.00	
10. Negative affect	19.59	9.67	.00	−.01	.04	.13	−.15	.10	−.05	.01	−.13

Note. Bold denotes significance of less than 5%.

weather conditions no longer predicted speed significantly ($\beta = 0.19$, $p = .76$). Similarly, when there were no outdoor options, bad weather significantly increased data-entry accuracy ($\beta = 24.90$, $p = .05$), a relationship that no longer held for those distracted by outdoor options ($\beta = 1.87$, $p = .74$).

To summarize, we found that having attractive outdoor options decreased productivity through increased cognitive distractions. In line with previous work (Bailey & Konstan, 2006; Speier, Valacich, & Vessey, 1999), we demonstrate that making outdoor options salient in people's minds alone could impair their ability to concentrate. Good weather conditions were harmful for productivity, an effect that seemed to disappear when outdoor options were made salient. This interaction effect between weather conditions and exposure to outdoor options suggests that people can be relatively more productive at work on rainy days, unless they are actively distracted. On sunny days, participants are likely to already be distracted, as outdoor options are salient in their minds. Together, consistent with Hypothesis 3, these findings show that cognitive distractions created by the salience of outdoor options may serve as a mechanism through which bad weather conditions increase productivity.

General Discussion and Conclusion

Our main goal in this article was to provide an alternative psychological route of *limited attention* through which bad weather conditions influence productivity, even when we hold affective influences constant. Our evidence from both the field and the lab was consistent with the predictions of our theoretical model.

Although numerous previous studies used weather to induce either positive or negative moods (Cunningham, 1979; Goldstein, 1972; Keller et al., 2005; Parrott & Sabini, 1990; Schwarz & Clore, 1983) to study the effect of moods, our result does not support this weather-mood hypothesis. Using a meta-analysis, Shockley, Ispas, Rossi, and Levine (2012) found that positive affect is associated with enhanced overall job performance. In Studies 2 and 4, however, weather conditions did not induce positive nor negative affect, and affect did not predict productivity. Yet it is not our goal to suggest that the weather-mood hypothesis is unwarranted or that affect plays no role in cognition. Although these influences were not realized in our study, they may still be in place, even if to a lesser extent than previous research posited.

Table 5
Summary Regression Results in Study 4

	Speed				Accuracy			
	Model 1		Model 2		Model 1		Model 2	
Variable	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Exposure to outdoor options	−2.20*	0.87	−2.26*	0.87	−22.82**	7.68	−23.90**	7.75
Good weather indicator	−1.49	0.91	−1.58	0.92	−12.02	8.09	−13.61	8.26
Interaction (Outdoor Options × Weather)	2.51*	1.27	2.60*	1.27	20.61	11.16	21.88*	11.34
Age			−0.27	0.13			−2.62*	1.14
Female			1.14	0.63			5.42	5.65
Income			0.14	0.63			1.10	0.87
Education			0.46	0.44			6.50	3.97
Positive affect			0.02	0.03			0.26	0.24
Negative affect			−0.01	0.03			−0.14	0.03
Constant	31.28***	0.64	32.70***	2.69	203.27***	5.67	219.07	24.22
Observations	123		122		125		124	
R^2	0.05		0.14		0.07		0.13	
Adjusted R^2	0.03		0.07		0.04		0.07	
Root *MSE*	3.50		3.43		31.08		30.82	

* $p < .05$. ** $p < .01$. *** $p < .001$.

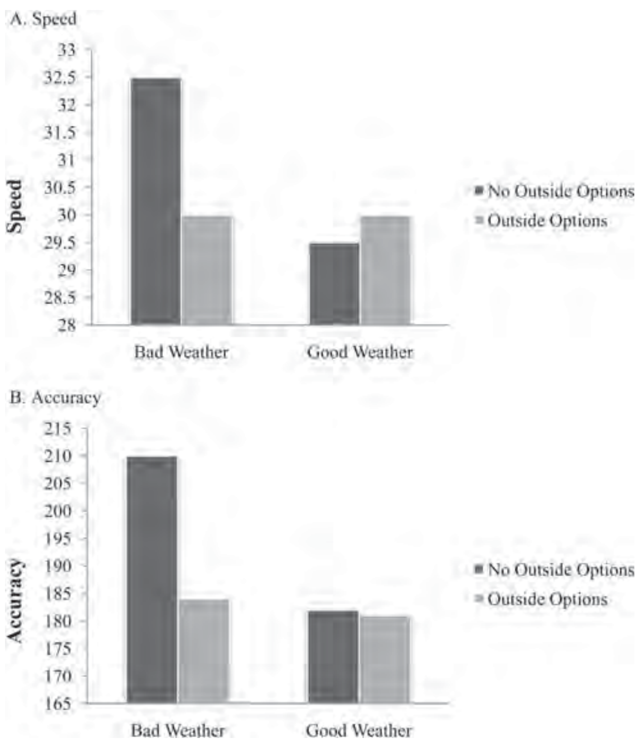

Figure 1. Exposure to outdoor options moderates the relationship between weather conditions and productivity.

One potential moderator that could address these seemingly contradictory results is workers' exposure to outside weather, either by spending time and working outside or by looking outside through windows. In fact, Keller et al. (2005) found that the amount of time spent outdoors moderated the effects of weather on mood and cognition. Both of our studies were conducted in a climate-controlled environment where individuals were asked to complete a series of tasks requiring attention and focus, such as a workplace (Study 1), an online labor market (Studies 2–3), and the laboratory (Study 4). Thus, this may explain why outside weather conditions played a lesser role in influencing workers' affective state but created a more significant variation in the level of cognitive distraction. In such contexts, weather may primarily act on people's cognition rather than on their affective states, as weather influences their level of distraction when they think about attractive outdoor options, as we have shown. Future research examining the role of weather across these different contexts (i.e., workers who typically work outside the office, or workers who work in an office without windows) would further our understanding of the relationship between weather, affect, and cognition.

It should also be noted that our measure of job performance was limited to the data entry task, which requires attention, and thus more likely to be affected by cognitive distractions, rather than affective influences. Positive affect tends to encourage less constrained, less effortful, and more creative problem solving (Schwarz & Clore, 1983). In fact, positive moods induced by good weather conditions may broaden workers' cognition, thus increasing the flexibility of their thoughts (Keller et al., 2005). Consequently, future research should include different types of tasks that could measure other aspects of job performance. For example, weather-induced positive moods may improve workers' productivity on tasks that require creativity, as well as affective interpersonal skills such as empathy and emotional intelligence.

Research also shows that bad weather conditions may lead people to prefer spending time at work because attractive outdoor options are not available to them (e.g., Connolly, 2008; Zivin & Neidell, 2010). Although our studies did not allow for testing this possibility, future studies should investigate the potential role of differing incentives. If workers have incentives to finish their work early on sunny days, rather than having fixed work hours per day, their motivation to leave early might offset productivity loss due to cognitive distractions.

In addition, there might be individual differences in people's responses to weather conditions (see Klimstra et al., 2011, for "weather reactivity") and their preference for outdoor activities. Such dispositions may contribute to the variance in how outside weather conditions are perceived and may also explain the lack of significant correlations between weather and moods. Future studies should further examine the role of such individual differences in modulating the role of outside weather in influencing worker productivity.

Theoretical and Practical Implications

Our research extends previous work on the influence of weather conditions on behavior. Prior work has focused on the effects of weather on behavior through people's affective reactions to weather conditions (e.g., Larrick et al., 2011). Our work demonstrates that weather conditions also influence individuals' cognition. By reducing the potential for cognitive distractions, bad weather was actually better than good weather at sustaining individuals' attention and focus, and, as a result, increasing their productivity.

Our results also deepen understanding of the factors that contribute to work productivity. Prior research has focused primarily on factors that are directly under one's control or the control of the organization (e.g., Staats & Gino, 2012). We document the influence of weather conditions, incidental factors that affect work productivity. Distractions that arise at work have been studied under the assumption that they can be avoided. In fact, engaging in distractions, such as Internet surfing, may have positive effects on productivity (due to increased stimulation, Jett & George, 2003). Similarly, perceived autonomy over lunch breaks reduced fatigue at the end of the day (Trougakos, Hideg, Cheng, & Beal, in press). Thus, a concerted effort to take advantage of good weather for break purposes could offset potential negative effects on productivity. Future studies may explore the consequences of different types of distractions at work, including how to structure break programs to restore the workers' cognitive resources.

Weather is one of the many factors that may lead workers to engage in non-work-related thoughts. Bad weather eliminates only one type of distracting thoughts; other factors may influence worker productivity to a larger degree (i.e., explicit incentives and implicit goal-oriented motives). Despite our small effect size in Study 1, our findings shed light on how seemingly irrelevant, uncontrollable factors may influence workers' productivity and also learning over time. In fact, operational improvement efforts often focus on issues that have effect sizes less than 1%. Companies realize that even small efficiency improvements can translate to cost advantages. This finding calls for further investigation of the factors that can increase task-unrelated thoughts that may adversely affect productivity. Research could also examine how expectations of certain conditions (e.g., rain when sunshine was expected) might moderate the effect of task-unrelated thoughts.

Our research also has practical implications. Although weather conditions are exogenous and uncontrollable, to tap into the effects of bad weather on productivity, organizations could assign more clerical work of the type that does not require sustained attention but does allow for more flexible thinking on rainy days than sunny days. Since we found that cognitive distractions led to higher error rates, individuals may wish to avoid working on a task in which errors would be costly when they have task-unrelated priorities. In addition, organizations may give productivity feedback to each employee and allow flexible working hours that could maximize productivity. We also note that if an organization wishes to maintain a consistent work output, then the weather forecast might be a valuable input to a staffing model. Finally, as Cachon, Gallino, and Olivares (2011) noted, weather is an important variable for facility location. Our results suggest that, holding all other factors constant, locating operations in places with worse weather may be preferable.

References

Bailey, B., & Konstan, J. (2006). On the need for attention-aware systems: Measuring effects of interruption on task performance, error rate, and affective state. *Computers in Human Behavior, 22,* 685–708. doi:10.1016/j.chb.2005.12.009

Cachon, G., Gallino, S., & Olivares, M. (2011). *Severe weather and automobile assembly productivity* [Working paper]. Available at Social Science Research Network database. (SSRN 2099798)

Chan, C. B., Ryan, D. A., & Tudor-Locke, C. (2006). Relationship between objective measures of physical activity and weather: A longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity, 3,* 21. doi:10.1186/1479-5868-3-21

Connolly, M. (2008). Here comes the rain again: Weather and the intertemporal substitution of leisure. *Journal of Labor Economics, 26,* 73–100. doi:10.1086/522067

Cunningham, M. (1979). Weather, mood, and helping behavior: Quasi experiments with the sunshine Samaritan. *Journal of Personality and Social Psychology, 37,* 1947–1956. doi:10.1037/0022-3514.37.11.1947

Derfler, R., Moore, C., & Staats, B. (2013). *Enhancing ethical behavior through task variety: How task design supports deliberative thinking* [Working paper]. London Business School, London, England.

Fisher, C. D. (1998). Effects of external and internal interruptions on boredom at work: Two studies. *Journal of Organizational Behavior, 19,* 503–522. doi:10.1002/(SICI)1099-1379(199809)19:5<503::AID-JOB854>3.0.CO;2-9

Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Berger, B. A., & Smith, L. A. (1999). Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. *American Journal of Health-System Pharmacy, 56,* 1319–1325.

Giambra, L. M. (1995). A laboratory method for investigating influences on switching attention to task-unrelated imagery and thought. *Consciousness and Cognition, 4,* 1–21. doi:10.1006/ccog.1995.1001

Goldstein, K. (1972). Weather, mood, and internal-external control. *Perceptual and Motor Skills, 35,* 786. doi:10.2466/pms.1972.35.3.786

Hirshleifer, D., & Shumway, T. (2003). Good day sunshine: Stock returns and the weather. *Journal of Finance, 58,* 1009–1032. doi:10.1111/1540-6261.00556

Jett, Q., & George, J. (2003). Work interrupted: A closer look at the role of interruptions in organizational life. *The Academy of Management Review, 28,* 494–507. doi:10.5465/AMR.2003.10196791

Kc, D., & Terwiesch, C. (2009). Impact of workload on service time and patient safety: An econometric analysis of hospital operations. *Management Science, 55,* 1486–1498. doi:10.1287/mnsc.1090.1037

Keller, M., Fredrickson, B., Ybarra, O., Côté, S., Johnson, K., Mikels, J., . . . Wager, T. (2005). A warm heart and a clear head the contingent effects of weather on mood and cognition. *Psychological Science, 16,* 724–731. doi:10.1111/j.1467-9280.2005.01602.x

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330,* 932. doi:10.1126/science.1192439

Klimstra, T., Frijns, T., Keijsers, L., Denissen, J., Raaijmakers, Q., van Aken, M., . . . Meeus, W. (2011). Come rain or come shine: Individual differences in how weather affects mood. *Emotion, 11,* 1495–1499. doi:10.1037/a0024649

Larrick, R. P., Timmerman, T. A., Carton, A. M., & Abrevaya, J. (2011). Temper, temperature, and temptation: Heat-related retaliation in baseball. *Psychological Science, 22,* 423–428. doi:10.1177/0956797611399292

Manly, T., Robertson, I. H., Galloway, M., & Hawkins, K. (1999). The absent mind: Further investigations of sustained attention to response. *Neuropsychologia, 37,* 661–670. doi:10.1016/S0028-3932(98)00127-4

Murray, K., Di Muro, F., Finn, A., & Popkowski Leszczyc, P. (2010). The effect of weather on consumer spending. *Journal of Retailing and Consumer Services, 17,* 512–520.

Parrott, W., & Sabini, J. (1990). Mood and memory under natural conditions: Evidence for mood incongruent recall. *Journal of Personality and Social Psychology, 59,* 321–336. doi:10.1037/0022-3514.59.2.321

Rind, B. (1996). Effect of beliefs about weather conditions on tipping. *Journal of Applied Social Psychology, 26,* 137–147. doi:10.1111/j.1559-1816.1996.tb01842.x

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). Oops: Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia, 35,* 747–758. doi:10.1016/S0028-3932(97)00015-8

Rucker, D. D., Preacher, K. J., Tormala, Z. L., & Petty, R. E. (2011). Mediation analysis in social psychology: Current practices and new recommendations. *Social and Personality Psychology Compass, 5,* 359–371. doi:10.1111/j.1751-9004.2011.00355.x

Saunders, E. (1993). Stock prices and wall street weather. *American Economic Review, 83,* 1337–1345.

Schwarz, N., & Clore, G. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology, 45,* 513–523. doi:10.1037/0022-3514.45.3.513

Shockley, K. M., Ispas, D., Rossi, M. E., & Levine, E. L. (2012). A meta-analytic investigation of the relationship between state affect, discrete emotions, and job performance. *Human Performance, 25,* 377–411. doi:10.1080/08959285.2012.721832

Simonsohn, U. (2010). Weather to go to college. *The Economic Journal, 120,* 270–280. doi:10.1111/j.1468-0297.2009.02296.x

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132*:946–958. doi:10.1037/0033-2909.132.6.946

Speier, C., Valacich, J., & Vessey, I. (1999). The influence of task interruption on individual decision making: An information overload perspective. *Decision Sciences, 30,* 337–360. doi:10.1111/j.1540-5915.1999.tb01613.x

Spencer, S. J., Zanna, M. P., & Fong, G. T. (2005). Establishing a causal chain: Why experiments are often more effective than mediational analyses in examining psychological processes. *Journal of Personality and Social Psychology, 89,* 845–851. doi:10.1037/0022-3514.89.6.845

Staats, B., & Gino, F. (2012). Specialization and variety in repetitive tasks: Evidence from a Japanese bank. *Management Science, 58,* 1141–1159. doi:10.1287/mnsc.1110.1482

Togo, F., Watanabe, E., Park, H., Shephard, R. J., & Aoyagi, Y. (2005). Meteorology and the physical activity of the elderly: The Nakanojo study. *International Journal of Biometeorology, 50,* 83–89. doi:10.1007/s00484-005-0277-z

Trougakos, J. P. Hideg, I., Cheng, B. H., and Beal, D. J. (in press). Lunch breaks unpacked: The role of autonomy as a moderator of recovery during lunch. *Academy of Management Journal*.

Watson, D., Clark, L., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54,* 1063–1070. doi:10.1037/0022-3514.54.6.1063

Zivin, J. G., & Neidell, M. J. (2010). *Temperature and the allocation of time: Implications for climate change* (NBER Working Paper No. 15717). Cambridge, MA: National Bureau of Economic Research.

Received May 22, 2013
Revision received November 25, 2013
Accepted December 2, 2013 ■

Correction to Lee et al. (2014)

In the article "Rainmakers: Why Bad Weather Means Good Productivity" by Jooa Julia Lee, Francesca Gino, and Bradley R. Staats (*Journal of Applied Psychology*, Advance online publication. January 13, 2014. doi: 10.1037/a0035559), there is an error in the last paragraph. The sentence "Although weather conditions are exogenous and uncontrollable, to tap into the effects of bad weather on productivity, organizations could assign more clerical work of the type that does not require sustained attention but does allow for more flexible thinking on rainy days than sunny days" should have read . . . "to tap into the effects of bad weather on productivity, organizations could assign more clerical work of the type that requires sustained attention on rainy days, and more creative work that allows for more flexible thinking on sunny days."

DOI: 10.1037/a0036192