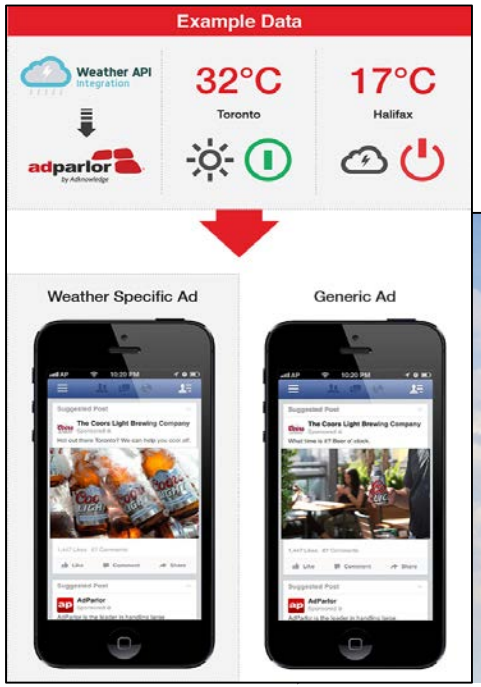


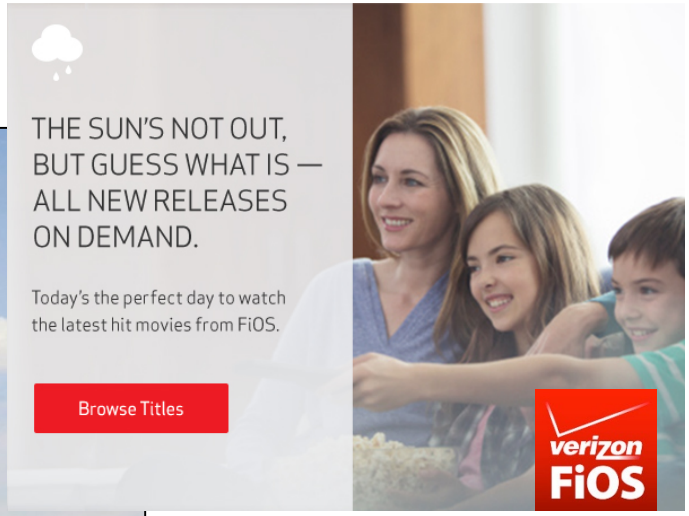
Weather, Ad Copy, and Mobile Promotions:

A 10-million-Users Field Study

FOX | GLOBAL CENTER FOR BIG DATA IN MOBILE ANALYTICS

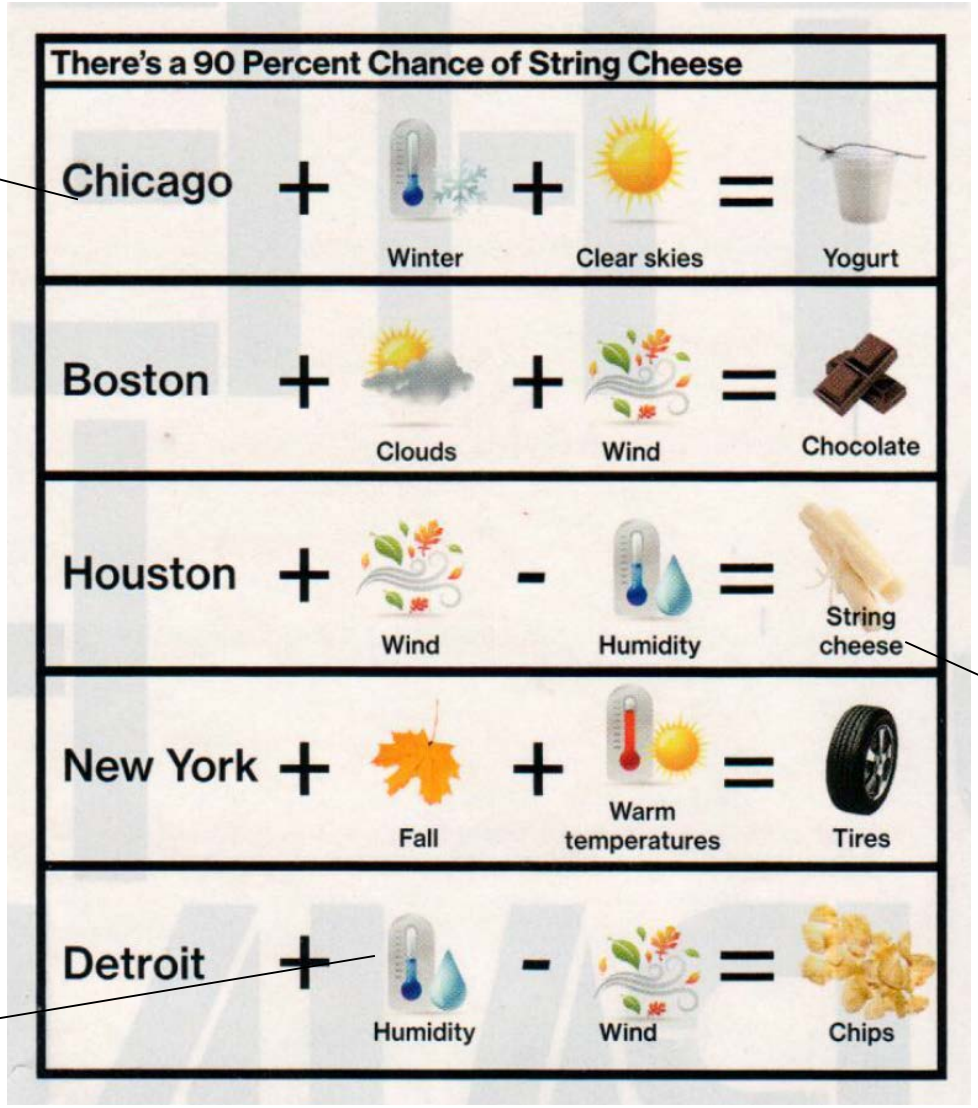
Motivation -- Weather Promotions Examples





App, Weather, and Demand

App 150 mm users



Zip-code store sales (Walmart, P&G)

Weather Condition

BusinessWeek

Literature on Weather

- Weather affects 1/3 of GDP, across B2B B2C sectors
  - Restaurants, apparel, automotive, insurance, agriculture (Shah 2013)
  - 2 billion checks of weather per day on TWC
  - Facebook, Google, Twitter, IBM investment in ads targeting viewers' local weather (WSJ 2014; Adweek 2015)
- Shapes people's psychology
  - Sunlight produces serotonin, good mood (Lambert et al. 2002)
  - Rain leads to depression and crime (Hsiang, Burke and Miguel 2013)

Prior Studies

- **Weather and Purchase**
  - Retailing (Steele 1951)
  - Stock market (Saunders 1993; Hirshleifer and Shumway 2003)
  - Catalog sales (Conlin et al. 2007)
  - Temperature premium (Zwebner, Lee and Goldenberg 2013)
  - Car sales (Busse et al. 2014)

Our Research

- **Ad copy and mood congruency in sunny rainy days**
- **Incremental sales impact of mobile ads**
  - Baseline, causal impact
  - Unexpected weather variations

Weather Effects

- Weather-induced mood hypothesis: affect-as-Information theory for product evaluation (Schwartz and Clore 1983; Batra and Stayman 1990; Kahn and Isen 1993)
  - Sunlight → serotonin, good mood (Lambert et al. 2002)

  - Rain → depressive symptoms and crime, bad mood (Hsiang, Burke and Miguel 2013)

H1: Compared to cloudy, sunny (rainy) weather leads to more and faster (less and slower) incremental sales response to mobile ads and promotions. Also, unexpected weather changes and deviations have stronger effects.

Weather x Ad Copy Frame

- Mood congruence hypothesis: people in positive/Negative moods find positive/negative information more salient (Pham 2008; Isen et al. 1978; Pham and Avnet 2009)
  - Two ad copy frames (prevention vs. neutral frame)
    - Prevention frame = 'do not miss out the opportunity…'
    - Neutral frame= 'dear respected customers…'
  - Sunny weather-induced positive mood mismatches negative tone of prevention ad copy
  - Rainy weather-induced negative mood matches it

H2: Ad copy with a prevention (vs. neutral) frame has a negative interaction with sunny weather, but a positive interaction with rainy weather for the incremental response to mobile promotions.

Challenges and Spurious Correlations

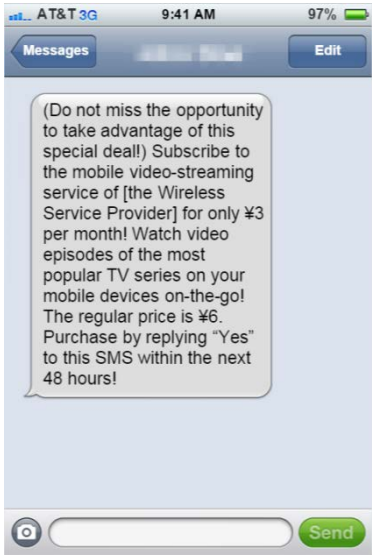
- Cannot manipulate weather
- Weather confounded with geographic locations
  - New York vs. Florida
- Self selection: 'exogenous' variations in weather
  - Changes and deviations from normal weather
- Activity bias vis-à-vis mood explanation
- Big/small data generalizability

Big Field Data: 10 Million Mobile Users

- Cannot manipulate weather
  - Quasi-experiment to randomize SMS ad exposures

- SMS ads promoting a video-streaming service deal
  - Treatment ad copy (prevention frame “Don’t miss the opportunity…”)
  - Control ad copy (Neutral frame “Dear respected customer…”)
  - Holdout (no ad, baseline)

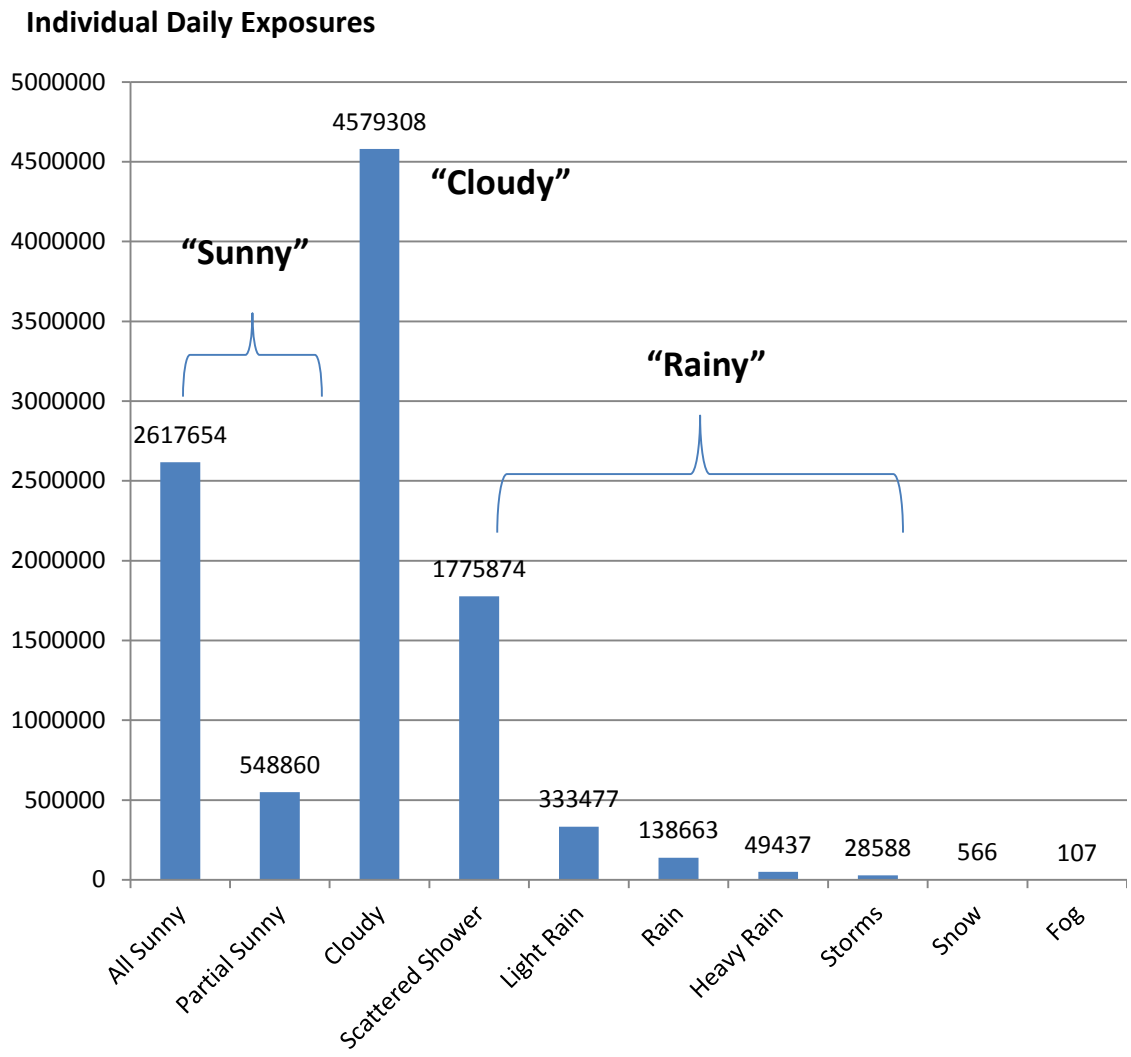
- Dependent Variable: Purchase Ad



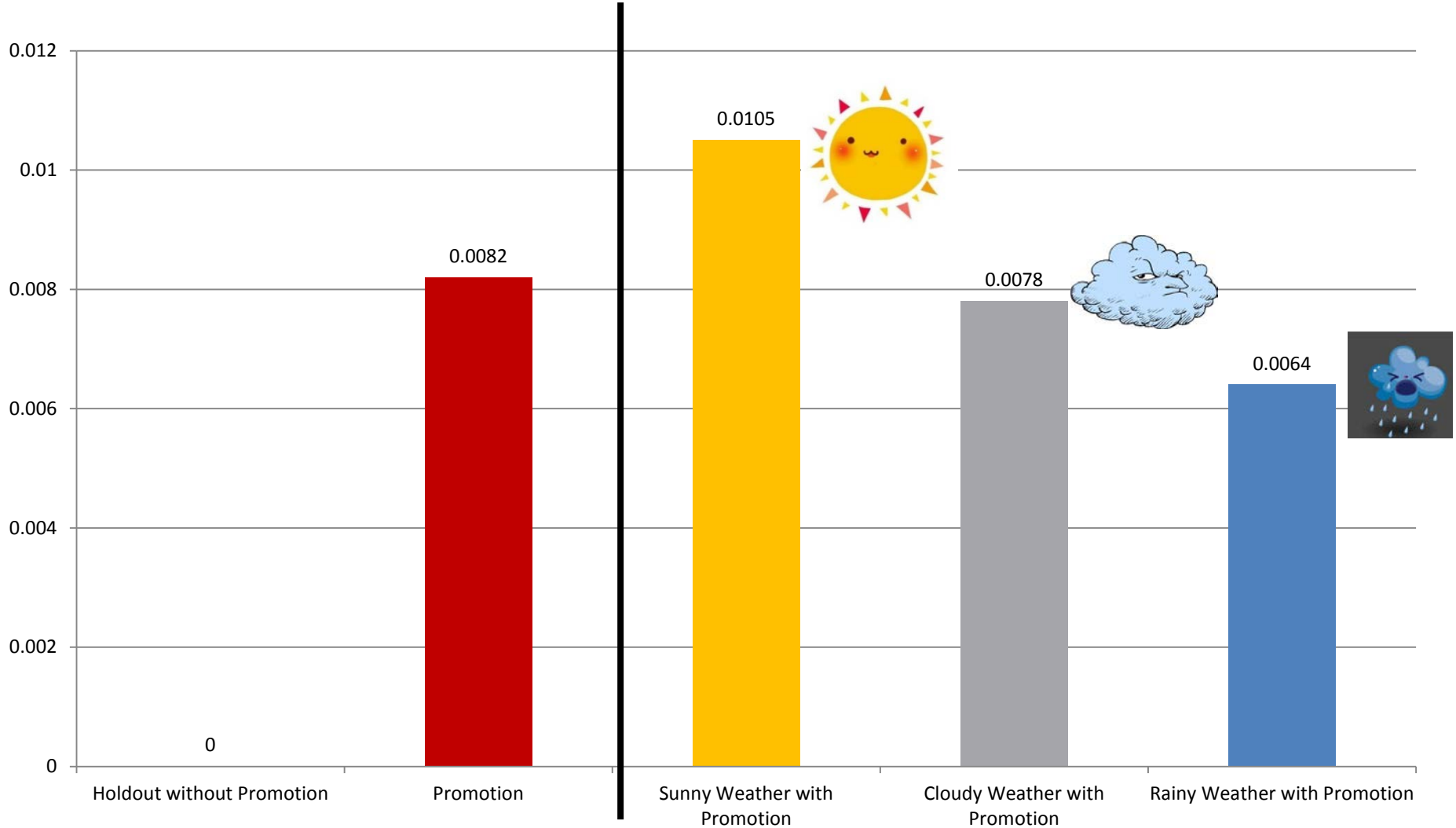
Weather with Mobile Identification

- Traditionally, hard to track location, weather, and promotion response simultaneously at individual level
- Mobile technologies can identify individuals'
  - location
  - weather and forecasts
  - real time responses to ads and coupons

Frequency of Weather Conditions



Consumer Responses to Mobile Promotions



Ad Response Likelihood Model

$$Ad\ Response\ Likelihood_i^{weather} = \frac{\exp(U_i)}{1+\exp(U_i)}$$

$$U_i^{weather} = \alpha_0 + \alpha_1 Sunny_i + \alpha_2 Rainy_i + \beta Framing_i + \Delta ControlVars + \mu\Omega_{\mathbf{R(i)}} + \rho\mathbf{X_i} + \varepsilon_i$$

- *i* is the mobile user
- *Ad Response*$_i$: 1 if the user purchased and 0 otherwise
- *Sunny*$_i$: 1 if the weather of day *t* is sunny and 0 if otherwise.
- *Rainy*$_i$: 1 if the weather of day *t* is rainy, snowy, foggy or stormy, and 0 otherwise.
- *Framing*$_i$: 1 if with prevention frame and 0 neutral ad copy frame.
- ControlVars: temperature, humidity, dew point, air pressure, wind, rural.
- $\Omega_{\mathrm{R(i)}}$: a vector of fixed effect for 31 provinces
- Xi: a vector of fixed effect for days
- Account for behavior usage: only weekday; control mobile usage

Table 1 Sunny (rainy) weather increases (decreases) consumer responses to ads

	(1)	(2)	(3)	(4)
Sunny	**0.3684*** **	**0.4327*** **	**0.1880*** **	**0.1880*** **
	(0.014)	**(0.026)**	**(0.038)**	**(0.037)**
Rainy	**-0.1243*** **	**-0.4621*** **	**-0.1068* **	**-0.1068* **
	(0.017)	**(0.036)**	**(0.045)**	**(0.047)**
Ad Copy Frame	0.5238***	0.8217***	0.7814***	0.7814***
	(0.017)	(0.034)	(0.084)	(0.087)
Wind Speed		0.1542***	0.2812***	0.2812***
		(0.034)	(0.040)	(0.039)
High Temperature		-0.0524***	-0.0191**	-0.0191**
		(0.005)	(0.006)	(0.006)
Temperature Range		0.0072	-0.0226***	-0.0226***
		(0.006)	(0.007)	(0.007)
Visibility		-0.0039	-0.0114**	-0.0114**
		(0.004)	(0.004)	(0.004)
Dew Point		0.0238***	0.0006	0.0006
		(0.002)	(0.002)	(0.002)
Humidity		0.0005	0.0044***	0.0044***
		(0.001)	(0.001)	(0.001)
Air Pressure		1.1496***	-0.0214	-0.0214
		(0.131)	(0.140)	(0.139)
Rural		0.2344***	0.0889**	0.0889**
		(0.028)	(0.028)	(0.027)
Intercept	-5.4551***	-39.9486***	-4.9052	-4.9052
	(0.062)	(3.962)	(4.263)	(4.216)
Wind Direction	No	Yes	Yes	Yes
Location Fixed Effect	Yes	Yes	Yes	Yes
Day Fixed Effect	No	No	Yes	Yes
N	6,744,884	4,058,481	3,321,575	3,321,575
Log Likelihood	-290404.56	-166772.56	-162413.8	-162413.8
AIC	580875.1	333641.1	324939.6	324939.6
BIC	581328	334275.5	325668.5	325668.5
LR chi2	37565.79	20694.18	17339.23	17343.91
Prob > chi2	0.0000	0.0000	0.0000	0.0000

Ad Copy Frame Moderates the Effects

$$U_i^{weather}$$

$$= \alpha_0 + \theta_1 Ad\ copy\ frame_i * Sunny_i + \theta_2 Ad\ copy\ frame_i * Rainy_i$$

$$+ \alpha_1 Sunny_i + \alpha_2 Rainy_i + \gamma Frame_i + \Delta ControlVars + \mu\Omega_{\mathbf{R(i)}} + \rho\mathbf{X_i}$$

$$+ \varepsilon_i$$

Ad copy frame:

Prevention frame ad copy: “Do not miss the opportunity…”

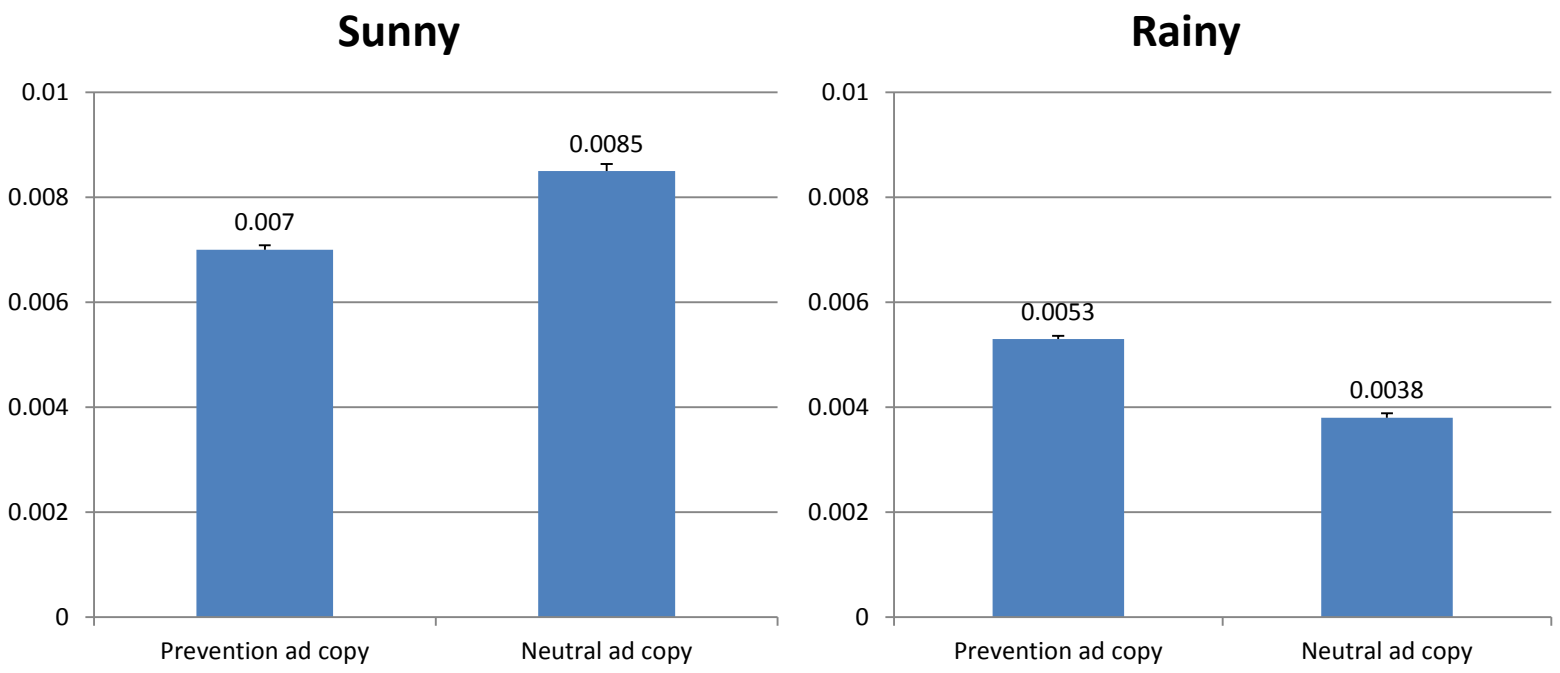
Neutral frame ad copy: “Dear respected customer…”

Table 2 Mobile ads with prevention-framing are less effective in sunny weather, but more effective in rainy weather

	(1)	(2)	(3)
Sunny*Ad Copy Frame	**-0.5225*** **	**-0.7098*** **	**-0.2350** **
	(0.030)	**(0.048)**	**(0.080)**
Rainy*Ad Copy Frame	**0.1835*** **	**0.2393*** **	**0.2239* **
	(0.038)	**(0.067)**	**(0.090)**
Sunny	0.6632***	0.8314***	0.3131***
	(0.023)	(0.038)	(0.051)
Rainy	-0.2452***	-0.5841***	-0.2829***
	(0.034)	(0.059)	(0.072)
Ad Copy Framing	0.7001***	1.0151***	0.8113***
	(0.023)	(0.044)	(0.086)
Weather Covariates	No	Yes	Yes
Location Fixed Effect	Yes	Yes	Yes
Day Fixed Effect	No	No	Yes
N	6,744,884	4,058,481	3,321,575
Log Likelihood	-290193.29	-166627.46	-162404.18
AIC	580456.6	333354.9	324924.4
BIC	580936.9	334015.7	325679.3
LR chi2	37988.33	20984.38	17358.47
Prob > chi2	0.0000	0.0000	0.0000

Ad Copy Moderates Weather Effects

Figure 3 Mean Marginal Effects of Weather and Ad Copy Interaction effects



Ad copy frame:

Prevention frame ad copy: “Do not miss the opportunity…”

Neutral frame ad copy: “Dear respected customer…”

Unexpected Changes and Deviations in Weather

- Following a rain shower, the sun bursts out…, moments are exhilarating...weather changes.” (Easton, 2012)

- Backward-looking (Better-than-Yesterday weather)
- Forward-looking (Better-than-Forecasts)

Table 5 Changes in Weather Matter (Backward Looking, yesterday weather)

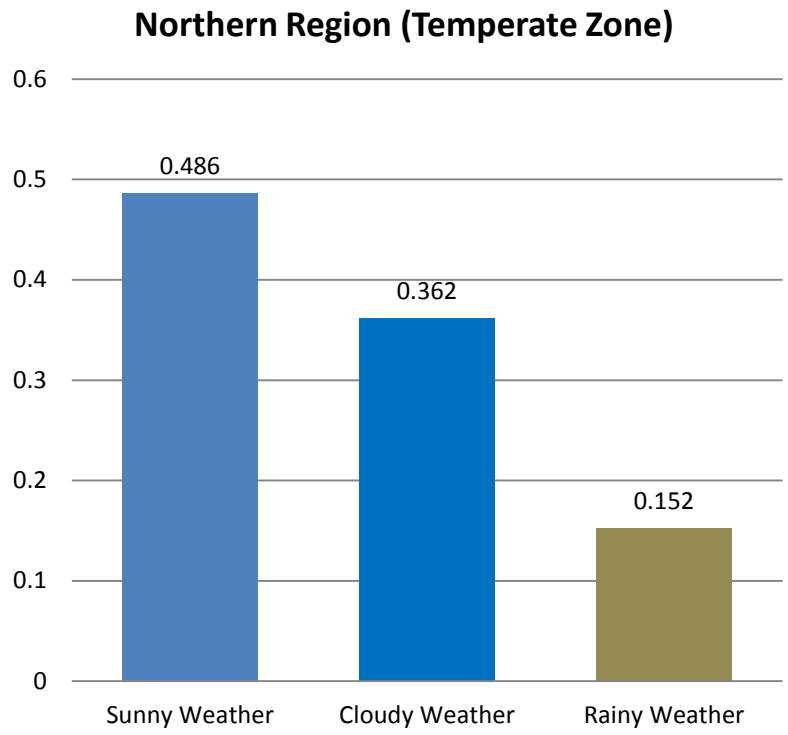
	(1)	(2)
Better_than_yesterday	**0.1135*** **	**0.0960*** **
	(0.012)	**(0.012)**
Worse_than_yesterday	**-0.2086*** **	**-0.2644*** **
	(0.012)	(0.014)
Sunny		
Rainy		
Weather Covariates	Yes	Yes
Location Fixed Effect	Yes	Yes
Day Fixed Effect	No	Yes
N	5,820,418	5,600,909
Log Likelihood	-360207.3	-343946.09
AIC	720482.6	687984.2
BIC	720944.2	688607
LR chi2	32236.01	31606.06
Prob > chi2	0.0000	0.0000

Table 6 Changes in Weather Matter (Forward Looking, tomorrow forecast)

	(1)	(2)
Better_than_forecast	**0.0767*** **	**0.0679** **
	(0.021)	**(0.021)**
Worse_than_forecast	**-0.1459*** **	**-0.1753*** **
	(0.022)	**(0.022)**
Sunny		
Rainy		
Weather Covariates	Yes	Yes
Location Fixed Effect	Yes	Yes
Day Fixed Effect	No	Yes
N	2,088,283	1,414,148
Log Likelihood	-117074.77	-110874.42
AIC	234245.5	221850.8
BIC	234848	222471.1
LR chi2	12293.17	7226.75
Prob > chi2	0.0000	0.0000

Evidence with Deviations from Normal Weather

- Across climatic zones, weather varies systematically.
  North China=temperate zone, South China=subtropical zone.



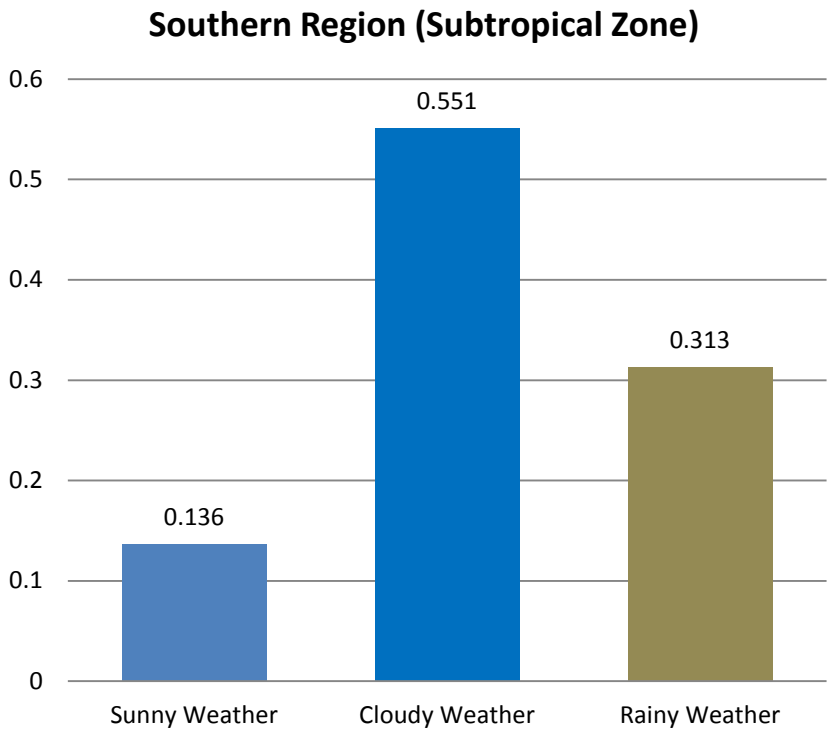


Table 7 Weather Deviations Matter

	North		South
Sunny	**0.0406****	<	**0.2904*****
	(0.015)		**(0.016)**
Rainy	**-0.0921*****		**-0.0665*****
	(0.021)		**(0.019)**
Sunny*South			
Rainy*South			
Intercept	-5.9477***		-6.5763***
	(0.098)		(0.095)
Weather Covariates	Yes		Yes
Location Fixed Effect	Yes		Yes
Day Fixed Effect	Yes		Yes
N	5,009,603		4,788,301
Log Likelihood	-263560		-235383
AIC	527182		470825.1
BIC	527598.2		471213.2
LR chi2	28421.56		22838.43
Prob > chi2	0.0000		0.0000

Ad Response Speed Model

- Weather may change each hour of a day
- Proportional hazard model

$$\mathrm{h(t)} = \mathrm{h_0}(t)\exp(U_{it}^{weather})$$

$$U_{it}^{weather} = \alpha_0 + \alpha_1 HourlySunny_{it} + \alpha_2 HourlyRainy_{it} + \beta Framing_i + \Delta ControlVars + \mu\Omega_{\mathbf{R(i)}} + \rho\mathbf{X_i} + \varepsilon_{it}$$

  - Purchasing within the deadline of 48 hours.
  - h(0) is the baseline hazard, indicating the hazard when all variables in the function of $\mathrm{U}_i^{Weather}$ are equal to zero for cloudy weather.

Table 3 Purchase Rate of Hourly Weather Conditions

	Purchase Rate	Number of Observation
Hourly Sunny	0.00022	2643566
Hourly Cloudy	0.00016	2847163
Hourly Rainy	0.00013	2834813
Total	0.00017	8325542

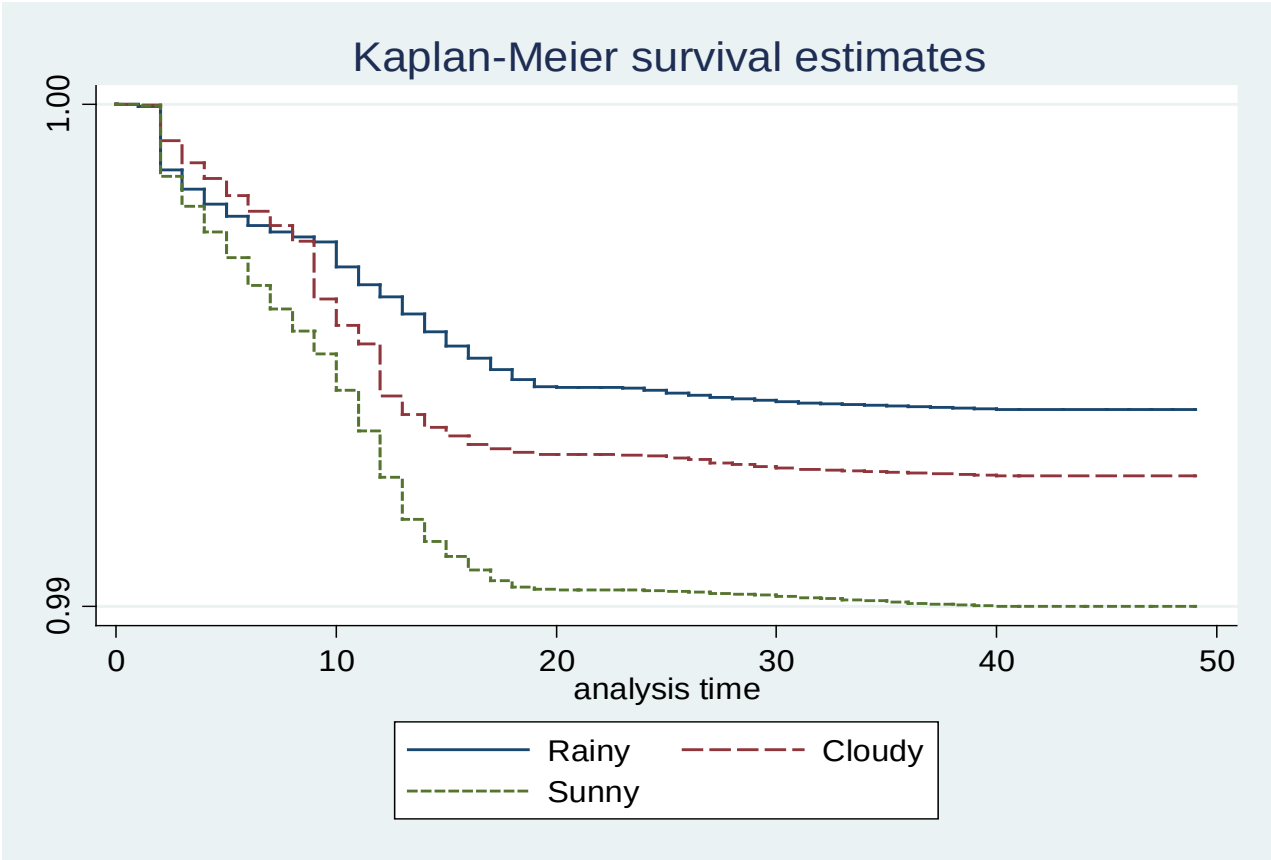


Table 4 Hour-by-hour analyses, sunny (rainy) weather increases (decreases) purchase hazard (9am-5pm)

	(1)	(2)
Hourly Sunny Weather	**0.6304*** **	**0.5481*** **
	(0.019)	**(0.022)**
Hourly Rainy Weather	**-0.4465*** **	**-0.5247*** **
	(0.051)	**(0.053)**
Hourly Sunny*Ad Copy Framing		
Hourly Rainy* Ad Copy Framing		
Ad Copy Framing		
Weather Covariates	No	Yes
Location Fixed Effect	Yes	Yes
Day Fixed Effect	Yes	Yes
N	59,814,313	55,164,292
Log Likelihood	-398471.57	-367346.64
AIC	797025.1	734817.3
BIC	797677.3	735798.5
LR chi2	31416.30	38775.47
Prob > chi2	0.0000	0.0000

Passed More Robustness Checks

- Falsification Check
- Alternative Measure of Weather
  - Amount of sunlight
  - Partial vs. all sunny weather
  - Interaction with temperature
- Accounting for Activity Bias
  - Weekdays daytime vs. night time
  - Mobile usage behavior (Study 2)

Smaller Data with Another Study

- Product with e-book reading (vs. video streaming)
- Setting with mobile APP (vs. SMS)
- Notification ads (vs. promotions)
- Manipulated mood books/neutral books/holdout
- DV: purchase of e-books, likelihood and amount

Table 8 Weather has no impact on holdout group

	Purchase or not	Purchase amount
Sunny	-0.0099	0.0019
	(0.352)	(0.024)
Rainy	-0.4006	-0.0005
	(0.466)	(0.032)
App Launches	3.6461***	0.0032***
	(0.121)	(0.000)
App Session	2.4089***	0.0041***
	(0.140)	(0.000)
Intercept	-10.7182***	-0.0434
	(2.138)	(0.139)
Weather Covariates	Yes	Yes
Location Fixed Effect	Yes	Yes
Day Fixed Effect	Yes	Yes
N	13,231	13,231
Log Likelihood	-455.9497	
AIC	993.8994	
BIC	1301.002	
LR chi2	12087.21	
Prob > chi2	0.0000	
R^2	0.9298	0.358

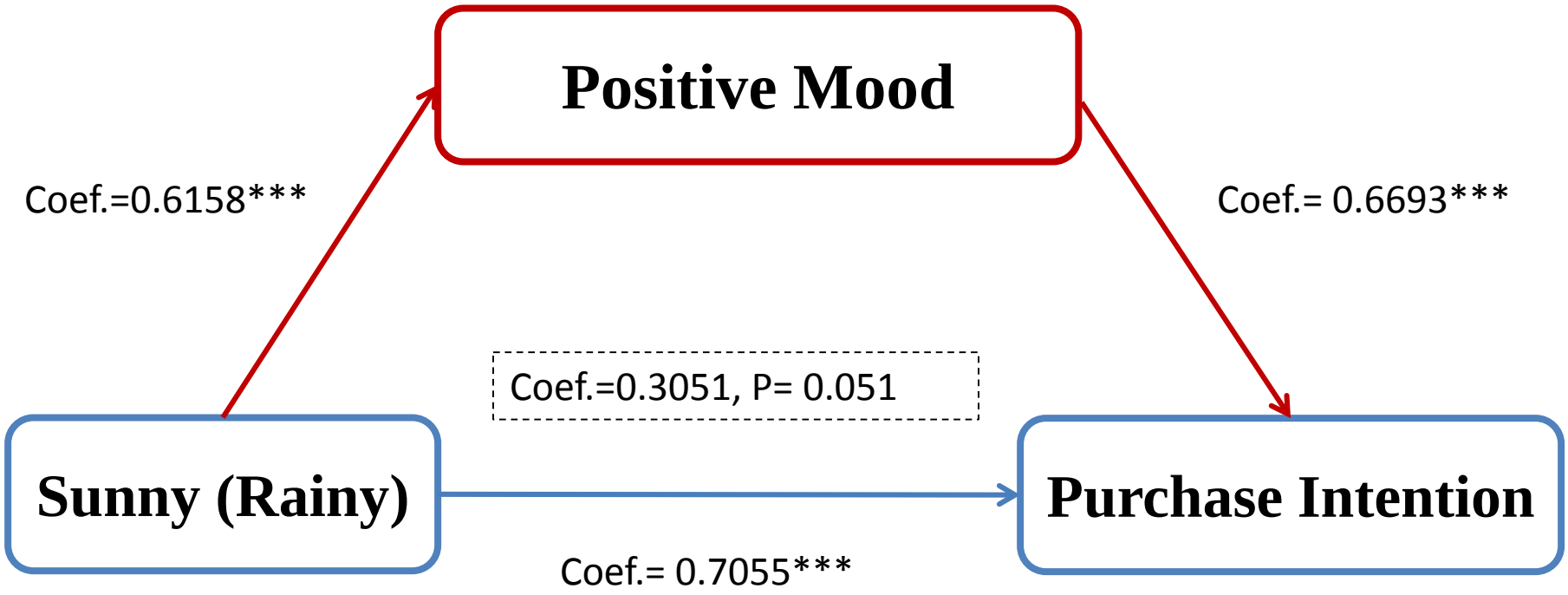
Table 9 Sunny (rainy) weather increases (decreases) consumer responses to mobile ads (e-book)

	Purchase or not	Purchase or not	Purchase amount	Purchase amount
Sunny	**0.3744*** **	**0.2165*** **	**0.1285*** **	**0.0687*** **
	(0.038)	**(0.053)**	**(0.020)**	**(0.019)**
Rainy	**-0.2377*** **	**-0.5874*** **	**-0.0763*** **	**-0.1306*** **
	(0.035)	**(0.055)**	**(0.016)**	**(0.020)**
Moodbook	-0.1822***	-0.0860**	-0.0699***	-0.0245*
	(0.026)	(0.033)	(0.013)	(0.012)
App Launches		0.5492***		0.0001***
		(0.014)		(0.000)
App Session		0.0429***		0.0003***
		(0.012)		(0.000)
Intercept	-0.8779***	-44.1073***	0.4890***	-7.6376***
	(0.016)	(5.315)	(0.008)	(1.915)
Weather Covariates	No	Yes	No	Yes
Location Fixed Effect	Yes	Yes	Yes	Yes
Day Fixed Effect	No	Yes	No	Yes
N	42,069	40,266	40,266	40,266
Log Likelihood	-24867.525	-16819.974		
AIC	49773.05	33695.95		
BIC	49937.34	33936.84		
LR chi2	436.81	14474.56		
Prob > chi2	0.0000	0.0000		
R^2			0.016	0.251

Table 10 Stronger effect of weather for mood books

	Purchase or not	Purchase or not	Purchase amount	Purchase amount
Sunny	**0.3364*** **	**0.2192*** **	**0.1090*** **	**0.0460***
	(0.041)	**(0.056)**	**(0.021)**	**(0.020)**
Rainy	**-0.2609*** **	**-0.7390*** **	**-0.0821*** **	**-0.1334*** **
	(0.039)	**(0.058)**	**(0.019)**	**(0.021)**
Sunny*Moodbook	**0.1670*** **	**0.1369***	**0.0789*** **	**0.0874*** **
	(0.063)	**(0.079)**	**(0.032)**	**(0.029)**
Rainy*Moodbook	**0.0994**	**0.0079**	**0.0229**	**0.0111**
	(0.079)	**(0.095)**	**(0.036)**	**(0.032)**
Moodbook	-0.2348*** **	-0.1199*** **	-0.0895*** **	-0.0431*** **
	(0.033)	(0.041)	(0.016)	(0.014)
Intercept	-0.8661*** **	-8.2824	0.4937*** **	-7.6593*** **
	(0.016)	(4.800)	(0.008)	(1.915)
Weather Covariates	No	Yes	No	Yes
Mobile Usage	No	Yes	No	Yes
Location Fixed Effect	Yes	Yes	Yes	Yes
Day Fixed Effect	No	Yes	No	Yes
N	42,069	40,266	42,069	40,266
Log Likelihood	-24863.735	-16963.146		
AIC	49769.47	33984.29		
BIC	49951.06	34233.79		
LR chi2	444.39	14188.21		
Prob > chi2	0.0000	0.0000		
R^2			0.006	0.252

Survey Evidence: Mechanism



Conclusion and Future Directions

- Weather
  - Big data evidence for small, subtle effects of sunshine and rain
  - Weather-neutral digital product, mood explanation

- Mobile Ads
  - Higher ROI
  - Designing ad copy (quant and behavioral)

- Future research
  - Weather forecasts, mood regulation, and promotions
  - Online and offline O2O omnichannel sales



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