Uncertainty in Forecasts: A Psychological Perspective

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My Perspective:

- Cognitive Psychologist
  - Individual cognition
  - How the mind works
  - Experimental methods

- Decision-making
  - Conscious steps involved
  - Unconscious influences
  - Information you consider
  - How you understand it



Research Questions

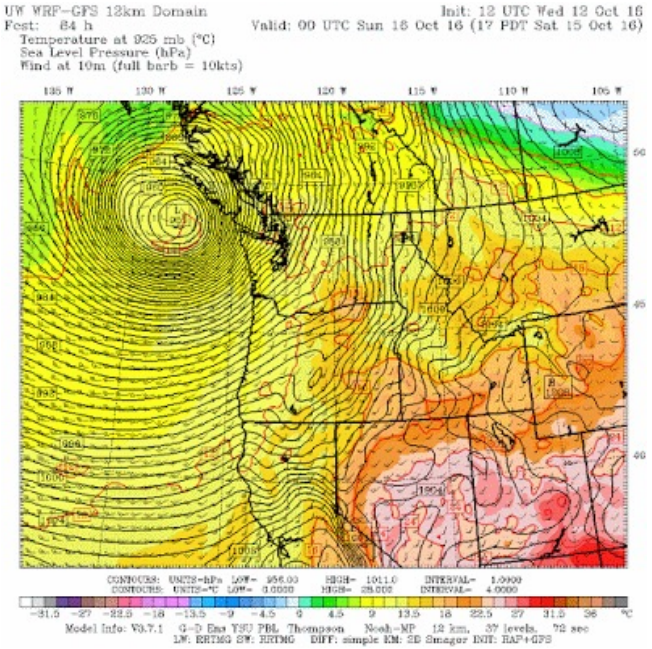
- How people make decisions with forecasts?
  Joslyn & LeClerc, 2013
- What is the impact of false alarms on decisions ?
  LeClerc & Joslyn, 2015
- Does uncertainty information improve decisions?
  Joslyn & LeClerc 2011
  - What is the best way to express uncertainty
    Joslyn, & Nichols, 2009
  - Can people use numeric expressions of uncertainty (30% chance)?
    Joslyn & LeClerc 2011
- Should forecasts include the "Worst Case Scenario"?
  Joslyn, Savelli, & Nadav-Greenberg, 2011
- How important is it for forecasts to be consistent?
  Burgeno & Joslyn 2020

Story: Monster Windstorm
anticipated for Oct 15, 2016

- Global models predicted Typhoon Songda
  - Travel across the Pacific
  - Transition to an extra tropical storm

- Strengthen rapidly as it approached the Pacific Northwest of US

- Produce a storm comparable to famed *Columbus Day Storm*



The Seattle Times

Local News | Photography | Weather

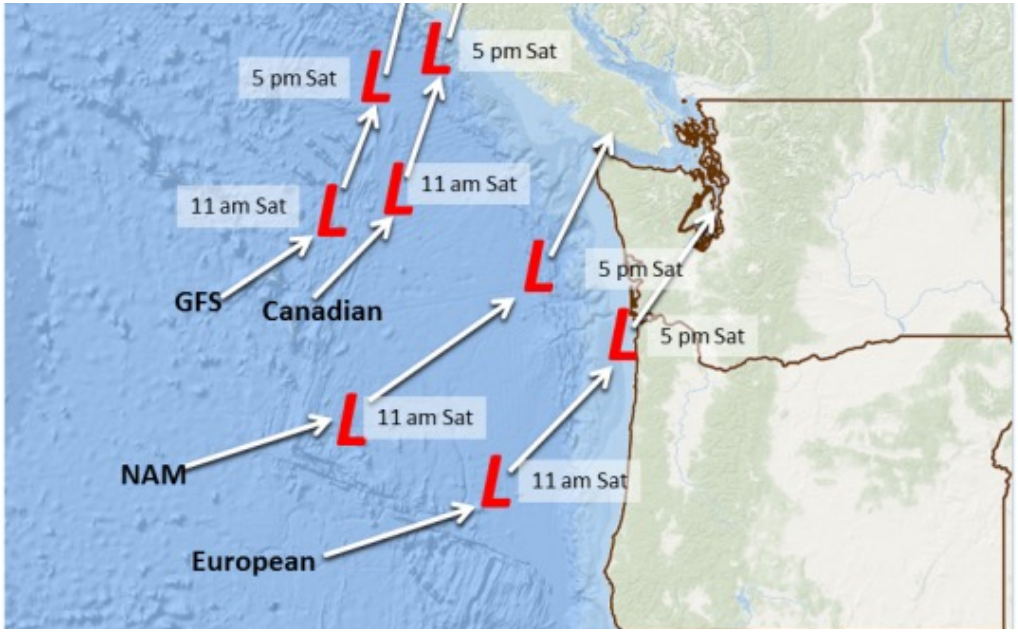
‘Murderous’ Columbus Day Storm of 1962 was spawned by similar typhoon now looming over Pacific

- 1962 storm originated as Typhoon Freda
  - Sustained winds 65 mph (105 km/h)
  - Gusts of at least 80 mph (130 km/h),160 mph off the coast
  - 46 fatalities
  - $230 million (1962 dollars)

- 2016 storm
  - "Historic event"—that language was used repeatedly

Expression of Uncertainty

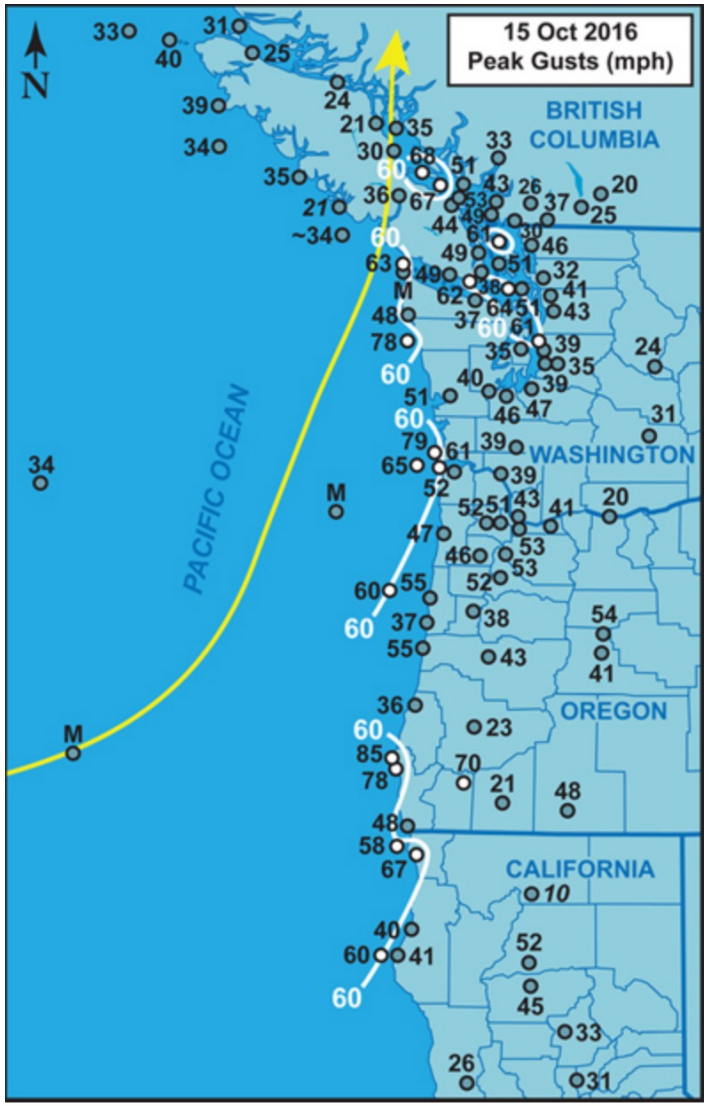
10/12: 1 in 3 chance of easterly track (historic winds over western Washington) on Oct 15 (NWS Discussion/Webinar)



10/14: By some estimates likelihood decreased over time because the size of the low decreased

But forecasters waited to downgrade the forecast

Max Gusts Recorded on Oct 15



Low went further off the coast & reduced in size

Storm	Tacoma McChord	SeaTac Airport	Renton Airport	Boeing Field	West Point	U of W ATG	Everett Paine	Average
15OCT2016	47	39	30	39	61	37	43	42.2
14OCT2016	45	45	35	39	55	37	53	44.1
13MAR2016	55	56	48	54	67	49	60	55.6
10MAR2016	46	45	43	47	53	40	60	47.7
29AUG2015	54	46	39	41	55	~37	61	47.6
11DEC2014	58	49	46	49	55	41	62	51.4
25OCT2014	40	49	45	46	52	45	46	46.1
12MAR2012	41	40	35	35	45	28	47	38.7
02APR2010	43	47	43	44	55	40	62	47.7
12DEC2008	46	45	37	45	59	44	53	47.0
18OCT2007	48	53	46	41	56	39	56	48.4
15DEC2006	69	69	51	56	70	55	66	62.3
04FEB2006	47	47	44	47	66	48	52	50.1
01JAN2006	41	49	40	40	54	40	45	44.1
25DEC2005	40	38	38	35	48	35	48	40.3
27DEC2002	51	52	49	48	59	56	58	53.3
16JAN2000	60	52	53	54	69	55	60	57.6
03MAR1999	55	60	51	52	68	MM	57	57.2

False Alarm

Highly criticized local & national media

What went wrong?

- Little expression of uncertainty
- Over emphasis on the worst-case scenario
- Failure to update



Interviewed EM's over the next 2 weeks

None of them remember hearing anything about uncertainty
Estimated the chance: 50-90% of monster storm, increasing over time

False Alarm

Highly criticized local & national media

What went wrong?

- Little expression of **uncertainty**
- Over emphasis on the **worst-case scenario**
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Forecast Uncertainty

- Many experts think that "the public" cannot understand numeric probabilities (30% chance)

- Categorical/verbal expressions
    - “Small chance” of infection, blood clots, stroke
    - Showers are “likely”
    - Investment risk is

HIGH
MEDIUM
LOW

Problems with Verbal Expressions

- People interpret them very differently

  "Likely" (50%-99%)

  "Possible" bi-modal distribution (5% & 55%)

  Fischer & Jungermann (1996)

  "High Confidence" (50%-90%)

  Joslyn et al (unpublished)

Numerical Expressions of Uncertainty

- More precise

Windschitle & Wells 1996

- Can people
  - Understand them?
  - Make good use (better decisions)?

- Previous research discouraging

Kahneman, 2011

Research Question

Previous decision research:

Do people make *rational* decisions with uncertainty?

Compare human decisions

to standards of rational choice

Humans are not perfectly rational

Our question:

Do people make *better* decisions with uncertainty?

Compare human decisions with uncertainty forecasts

to human decisions with deterministic forecasts

People make better decisions with uncertainty

Experiment: Probabilistic Forecasts

Lab based: Simulated road maintenance task

- Decide whether to apply salt brine to prevent icing
- Must be applied before freezing temperatures
- Decision based on forecast for nighttime low temp



Road Salt Task

Incentive: Monthly budget $36,000

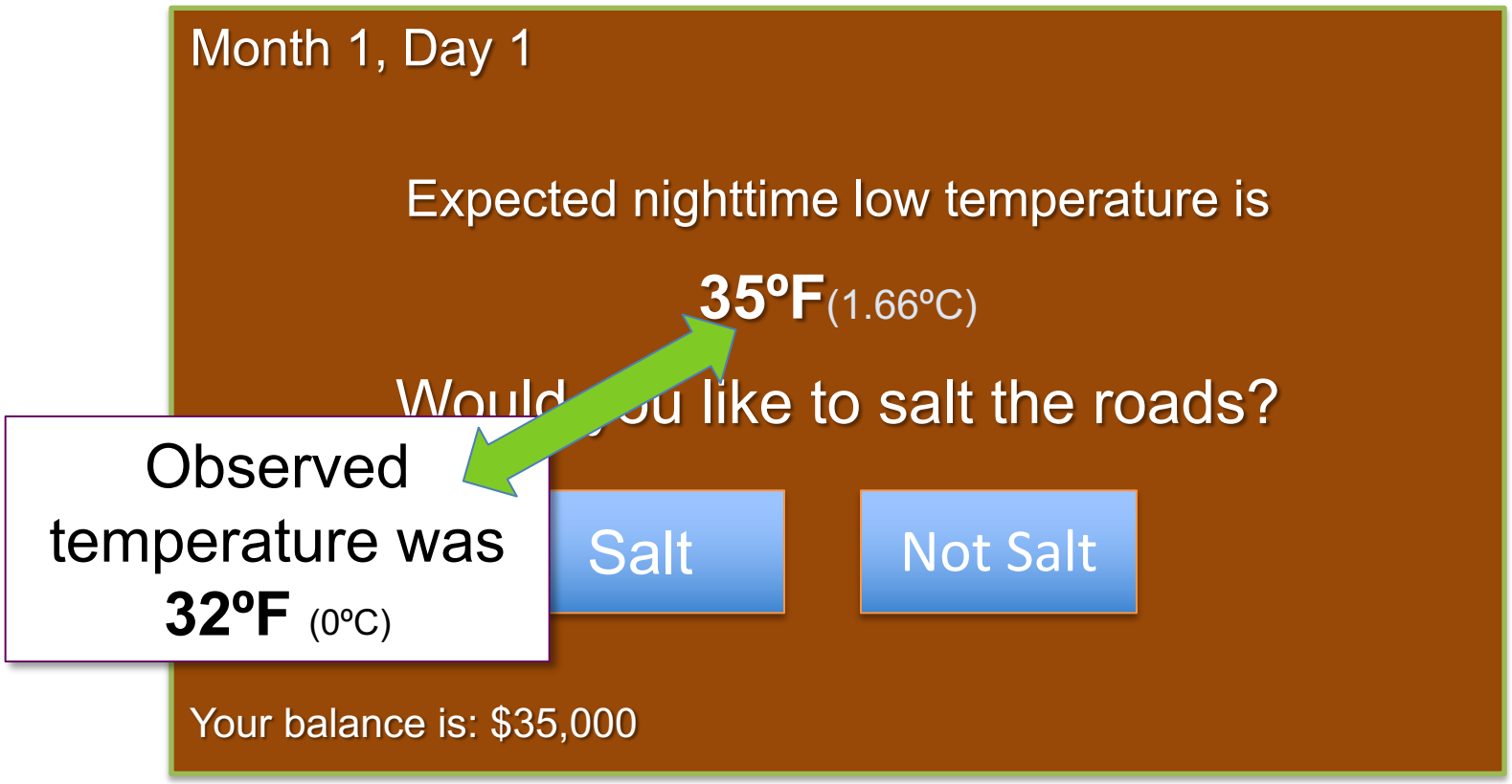
- Cost of treating roads 1 day = **$1,000**
- Penalty (if no treatment & temp ≤ 32°F (0°C)) = **$6,000**
- Each day: temperature forecast for that night
- 2 simulated months (60 decisions, "trials")
  - Real forecasts & outcomes from historical records
- Trust-in-forecast rating after each "month"

Cash reward: commensurate with ending balance (about $1 per thousand)

Individual Trial



Individual Trial



Two Groups (Conditions)

Deterministic forecast

Expected nighttime low temperature 35ºF

Probability of freezing

Expected nighttime low temperature 35ºF

20% chance temp ≤ 32ºF

Results

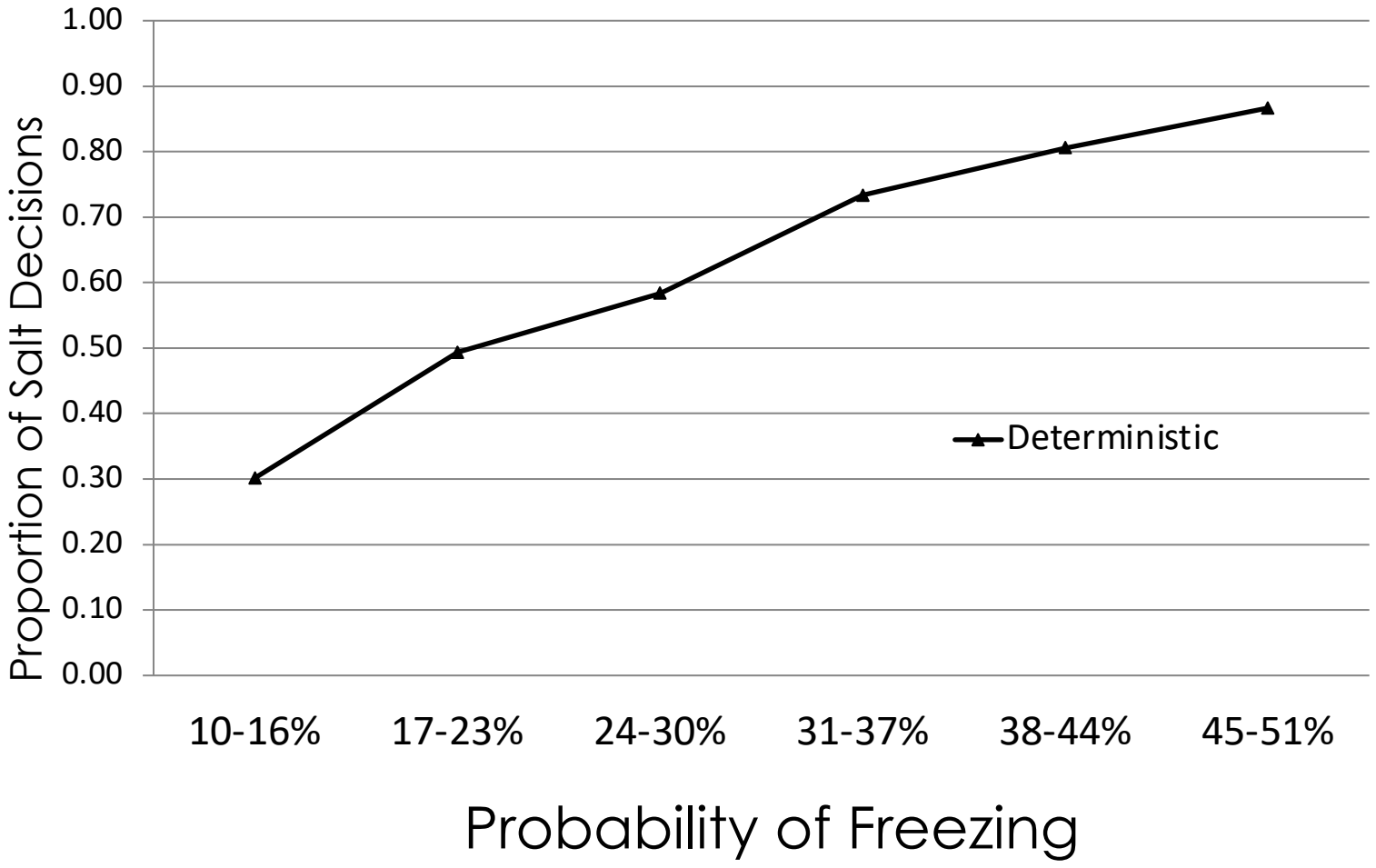
Deterministic forecast

Expected nighttime low temperature 35ºF

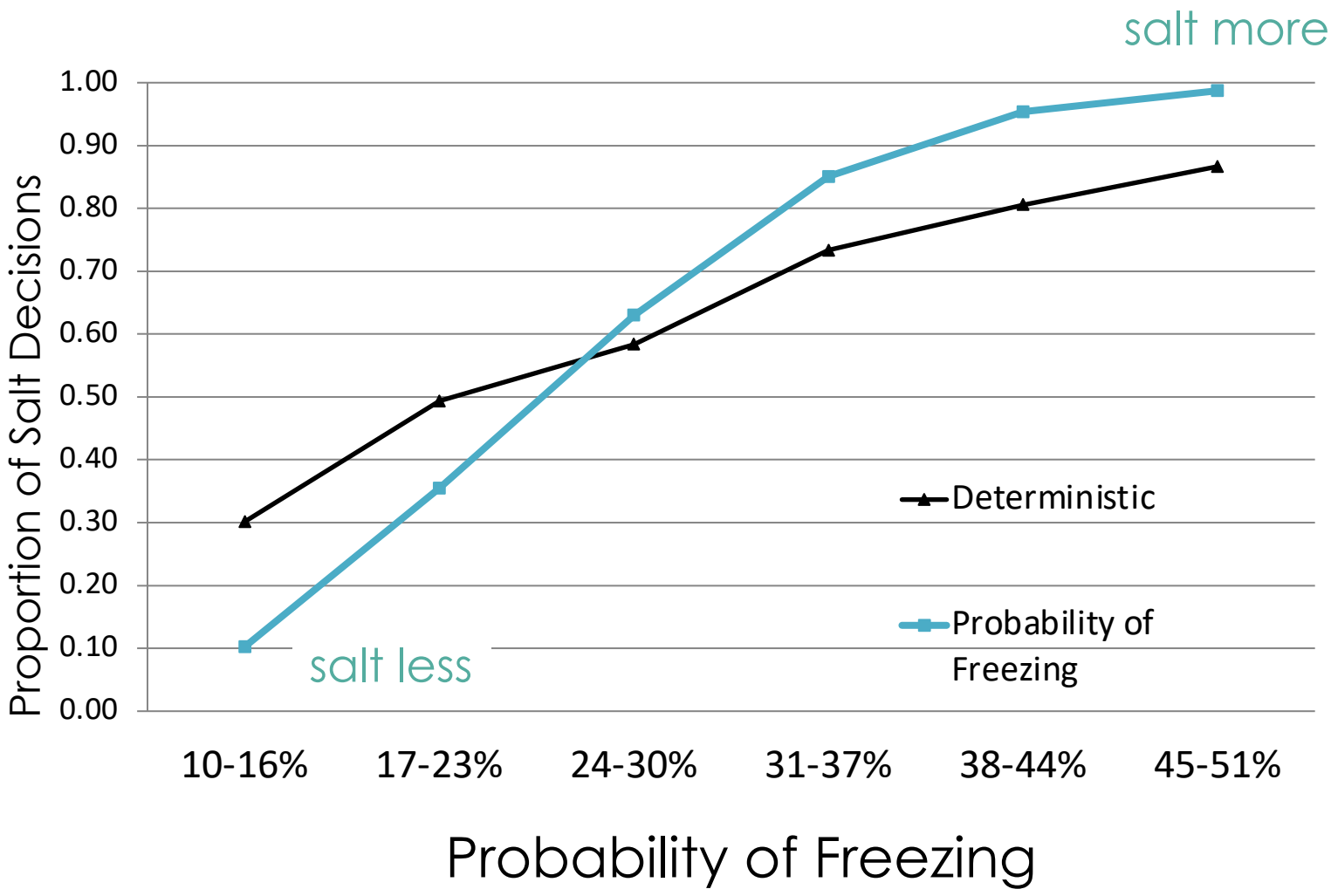
Probability of freezing
- Better decisions
- Larger ending balance
- Greater trust

Expected nighttime low temperature 35ºF

20% chance temp ≤ 32ºF


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion of Salt Decisions
Deterministic
10-16%
17-23%
24-30%
31-37%
38-44%
45-51%
Probability of Freezing

Greater Differentiation



Probabilities

- People make better decisions when they have numeric uncertainty estimate (probabilities)
- People have "working" but not theoretical understanding of probabilities
- Do not need an advanced education to benefit
  - High school education or less = college or more

Grounds et al, 2018

Numeric Uncertainty Expressions Tested

- **Probability:** 30% chance below freezing
  - Better decisions (greater differentiation)
  - Preserves trust

- **Odds Ratio:** Odds today compared to climatological odds
  LeClerc & Joslyn, 2012
  - For very low likelihood (e.g. 10%) rare events

- **Predictive interval:** Values (e.g. temp) between which the observed value will fall with specified probability
  - Error bars
  - Worst & best case scenario

Predictive Interval

Most likely max winds to 45 mph

10% chance less that 30 mph

10% chance greater than 60 mph

What do you think the max wind speed will be?_____

- When only the upper bound (WORST CASE) is given
  - People think wind speed will be significantly higher Joslyn et al 2011
  - More likely to perceive forecast as false alarm
  - Reduces trust in future forecasts
- Give WORST & BEST & most likely outcome
  - People can prepare for the worst
  - Have a better idea what is most likely to happen
  - Less often surprised by the outcome
  - Greater trust in the forecast

CONSISTENCY IN MESSAGING

Consistency in Forecasts

- People often get multiple forecasts for the same event
  - Updates over time from the same source
  - Same time –different sources

- How important is consistency between them?

- Many believe: Consistency is key

  NOAA Social Science Committee, April 2016

What is meant by "Consistency"

- Consistency in terminology
- Consistency in format
- Consistency in fact

Consistency in Terminology

- If you mean the same thing, use the same word
    - **Showers:** precipitation characterized by *suddenness* with which they start and stop, *rapid changes of intensity*, and in the appearance of the sky.
    - Snow **Showers**: shower is a *short duration* of moderate snowfall. Some accumulation is possible
      NOAA's National Weather Service – Glossary
- Inconsistency in terminology could be confusing
    - People expect a word to mean the same each time
    - People expect a word change to indicate change in meaning

Consistency in Format

- When presenting complex information
  - Present it in the same order each time
  - Use same conventions

Consistency in Format

Tuesday Morning Update

National Weather Service - Seattle
Issued: 8:01 AM PT Tuesday, February 12th, 2019
Next Update: Tomorrow by 7 AM
Point of Contact: NWS Operations (24/7) - 206-526-6095

Major Impacts Possible

This includes rare events that could have major impacts on commerce. Precautions necessary to protect lives and property.

OVERVIEW

- Current storm continues with steady precipitation through mid-day, turning showery through Wednesday morning.
- Rain and heavy wet snow may result in water accumulating on roadways. In addition, water may channel through snow from yards nto area roads. Localized street flooding possible.
- Cold temperatures will allow for refreeze during the overnight hours. The highest threat of refreeze is Wednesday night. This will ake for dangerous morning commute conditions.
- Heavy, wet snow and/or rain on snow will continue the threat for tree damage, power outages, and roof collapses.

WEATHER IMPACTS

Western Washington

HIGH Confidence	• Rain and heavy wet snow may result in water or slushy mess accumulating on roadways. In addition, water may channel through snow from yards onto area roads. Localized street flooding possible. • Overnight temperatures around freezing tonight and below freezing Wednesday night may allow for refreeze at night, potentially creating icy/hazardous travel conditions. • Cold temperatures will impact those without power and area's homeless population. • Heavy, wet snow and/or rain on snow will continue the threat for tree damage, power outages, and roof collapses. • Hazardous travel conditions across the Cascade passes will continue into tonight. • High avalanche danger in the Cascades.

FORECAST DETAILS

Western Washington

TODAY
- Steady precipitation continues through about mid-day before becoming more showery.
- Rain/snow line hovering around King-Snohomish County line this morning, shifting north throughout the day in the lowlands.
- Additional snow accumulations will be heavy and wet. Additional accumulations of T-3"
- Rain to the south where temperatures are just above freezing.
- Moderate/heavy snow will continue in the mountain passes, with additional significant accumulation.

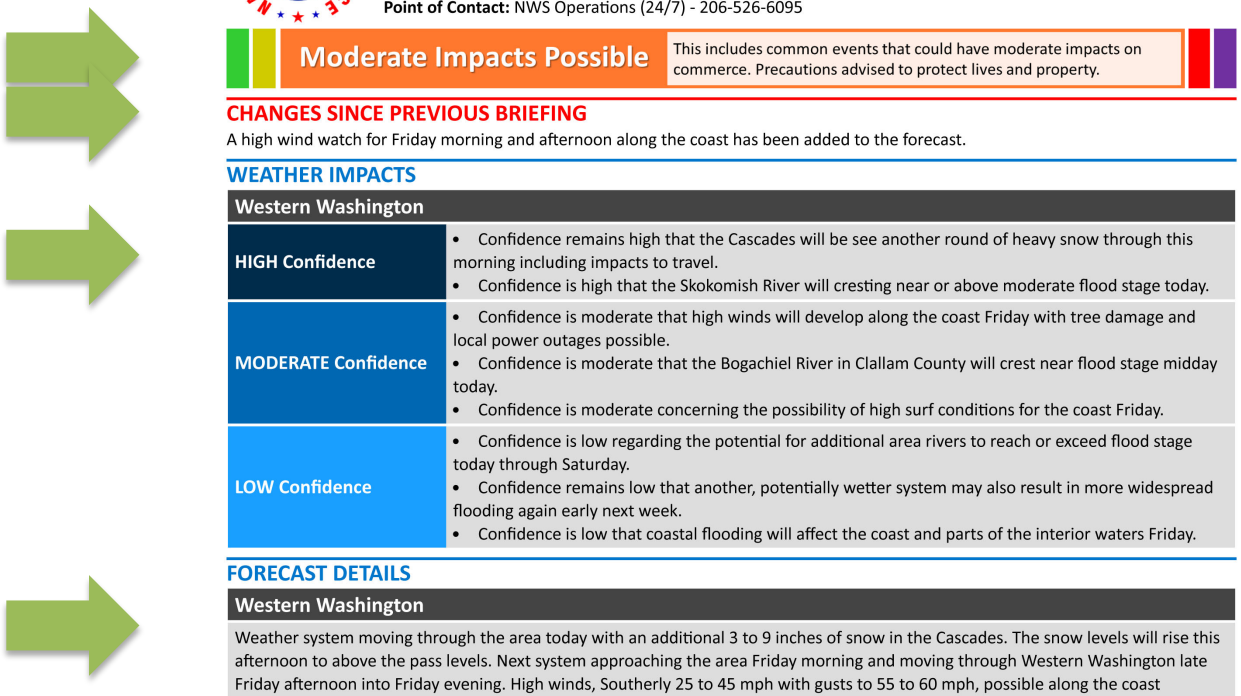
TONIGHT
- Hit/miss showers continue overnight.
- Temperatures drop down around freezing in the central Puget Sound. Below freezing in Whatcom County.

WED
- Hit/miss showers gradually tapering off.
- Afternoon highs in the mid 30's to around 40°F
- Overnight lows: Upper teens - mid 20s

THU - EARLY SAT
- Next storm system arrives during the day Thursday.
- Slightly warmer. Snow levels rising (500-1500 feet).
- Mainly rain everywhere in the lowlands, outside chance of snow in Whatcom Co.
- Additional snow likely in the passes.

See weather.gov/seattle for the latest forecast details for your location.

Consistency in Format



Wet and Windy Weather This Week

National Weather Service - Seattle
Issued: 6:11 AM PT Thursday, December 13th, 2018
Next Update: Thursday by 5 PM
Point of Contact: NWS Operations (24/7) - 206-526-6095

Moderate Impacts Possible — This includes common events that could have moderate impacts on commerce. Precautions advised to protect lives and property.

CHANGES SINCE PREVIOUS BRIEFING

A high wind watch for Friday morning and afternoon along the coast has been added to the forecast.

WEATHER IMPACTS

Western Washington	
HIGH Confidence	• Confidence remains high that the Cascades will be see another round of heavy snow through this morning including impacts to travel. • Confidence is high that the Skokomish River will cresting near or above moderate flood stage today.
MODERATE Confidence	• Confidence is moderate that high winds will develop along the coast Friday with tree damage and local power outages possible. • Confidence is moderate that the Bogachiel River in Clallam County will crest near flood stage midday today. • Confidence is moderate concerning the possibility of high surf conditions for the coast Friday.
LOW Confidence	• Confidence is low regarding the potential for additional area rivers to reach or exceed flood stage today through Saturday. • Confidence remains low that another, potentially wetter system may also result in more widespread flooding again early next week. • Confidence is low that coastal flooding will affect the coast and parts of the interior waters Friday.

FORECAST DETAILS

Western Washington

Weather system moving through the area today with an additional 3 to 9 inches of snow in the Cascades. The snow levels will rise this afternoon to above the pass levels. Next system approaching the area Friday morning and moving through Western Washington late Friday afternoon into Friday evening. High winds, Southerly 25 to 45 mph with gusts to 55 to 60 mph, possible along the coast Beginning Friday morning and continuing into the afternoon hours. After a break on Saturday additional systems will move through the area Sunday through Thursday of next week. There is the potential that the very wet system in the middle of next week could stall over the area which could cause flooding problems for more than just the rivers flowing off the Olympics.

See weather.gov/seattle for the latest forecast details for your location.

Consistency in presentation format facilitates understanding

Consistency in Facts

- If you are giving multiple forecasts for the same event
  - Should forecasts themselves be the same?
  - Will that enhance user trust and understanding?

It is Monday: 10 inches (25cm) of snow on Wednesday
It is Tuesday: 10 inches of snow on Wednesday

] consistent

- What if the most recent information on Tuesday indicates much less accumulation?

Consistency in Facts

- If you are giving multiple forecasts for the same event
  - Should forecasts themselves be the same?
  - Will that enhance user trust and understanding?

It is Monday: 10 inches (25cm) of snow on Wednesday

It is Tuesday: ? inches of snow on Wednesday

- What if the most recent information on Tuesday indicates much less accumulation?

- Stay at 10 inches to remain **consistent**?

  ...or change b/c more recent is likely to be more **accurate**?

Experiment : Decision Task

- Whether to close schools



Closure is required for 6 or more inches of snow

- Must be done night before
- Decision based on forecast

Experiment : Decision Task

On each trial there are 2 forecasts for Wednesday that week

- On Monday : 2 inches of snow on Wed
- On Tuesday : 2 inches of snow on Wed



consistent

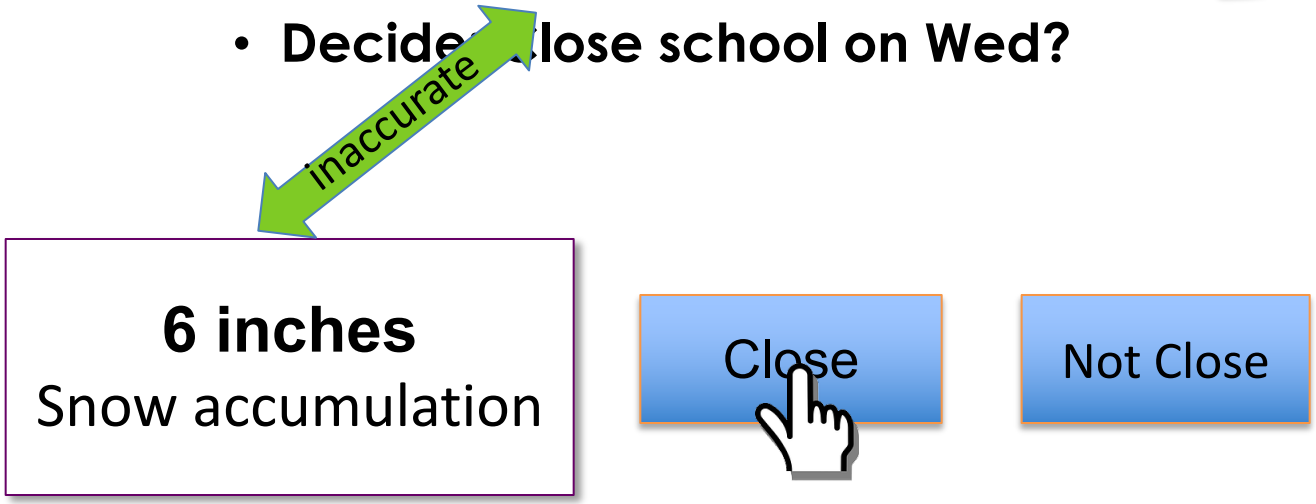
Experiment : Decision Task

On each trial there are 2 forecasts for Wednesday that week

- On Monday : 2 inches of snow on Wed
- On Tuesday : **4** inches of snow on Wed

inconsistent

- **Decide: Close school on Wed?**



- Wednesday outcome: 6 inches of snow

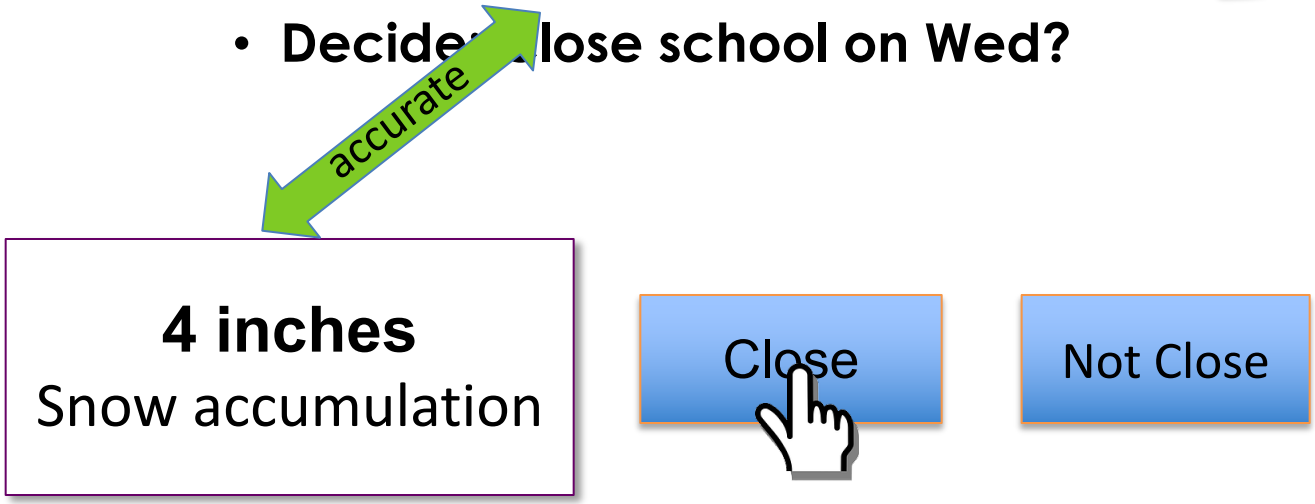
Experiment : Decision Task

On each trial there are 2 forecasts for Wednesday that week

- On Monday : 2 inches of snow on Wed
- On Tuesday : 4 inches of snow on Wed

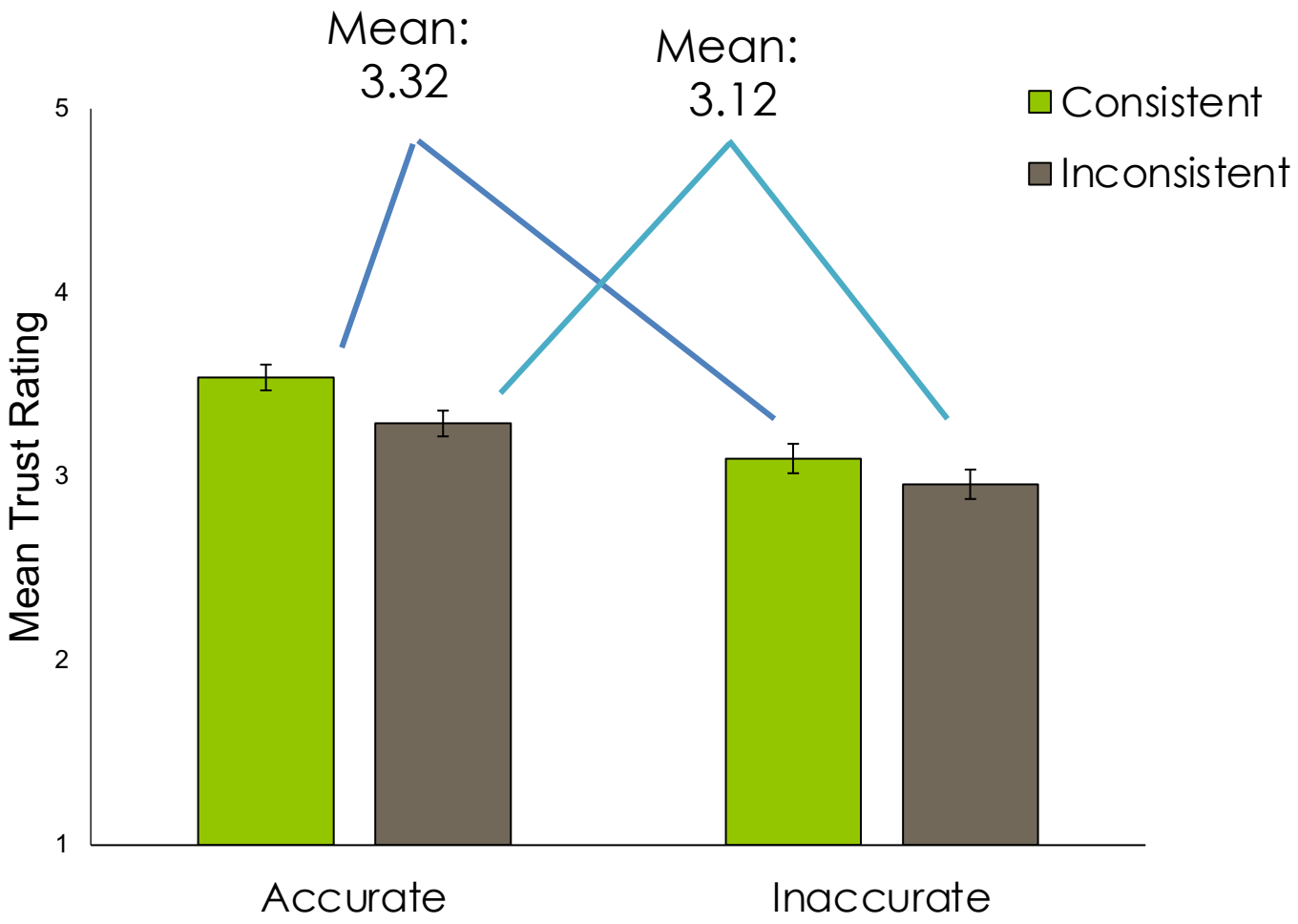
inconsistent

- **Decide close school on Wed?**



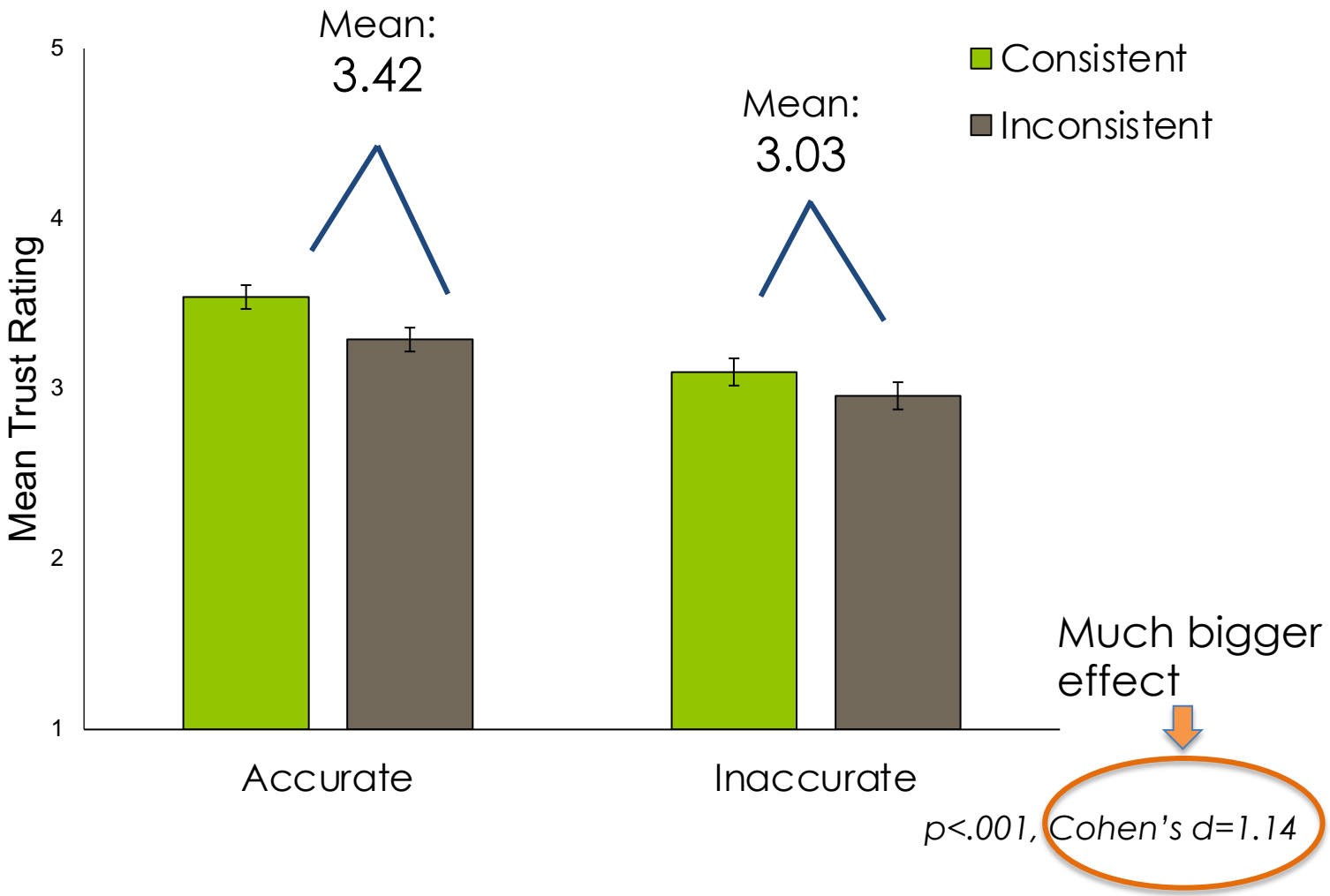
- Wednesday outcome: 4 inches of snow
- Trust rating

Higher Trust for Consistent

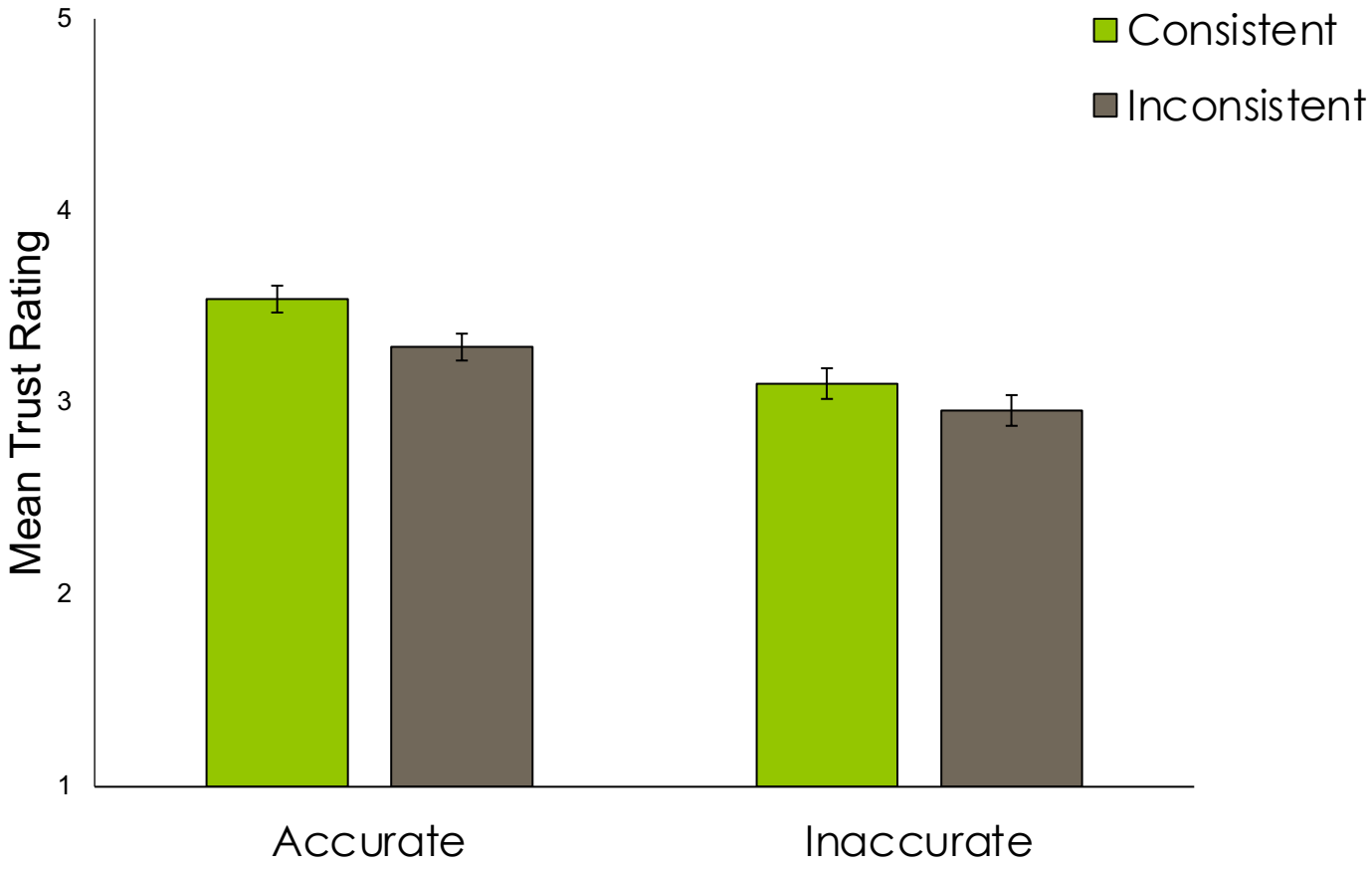


p=.001, Cohen's d=.56

Much higher trust for Accurate



Consistency is important for trust but not as important as accuracy



p<.001, Cohen's d=1.14

How Important is Consistency?

- Very important for terminology
  - Same word-same meaning
- Very Important for format
  - Present information in the same way each time
- Not so much for facts
  - It matters to trust
  - But not as much as accuracy
- If you think more recent information is more accurate: use it
  - Updated forecast provides better information for decision makers

Story: 2016 Wind Event in PNW

- Provide clear uncertainty information (numerical)
  - Helps people to make better decisions
  - Preserves trust
  - Regardless of education Grounds & Joslyn, 2018
- Provide the full range of outcomes
  - Worst case scenario + most likely + best case scenario
  - It will allow people to prepare for the worst
  - Not be surprised when it does not happen
- Provide updates when available
  - Consistency is not as important as good accurate information
  - Inconsistency may provide additional information about uncertainty

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The End

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