Threshold uncertainty, early-warning signals, and the prevention of dangerous climate change

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Look at the world around you. It may seem like an immovable, implacable place. It is not. With the slightest push—in just the right place —it can be tipped. Malcolm Gladwell, *The Tipping Point* (2000: 259)

A Game Against “Mother Nature”

- United Nations Framework Convention on Climate Change (UNFCCC, 1992):
  - “stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent *dangerous* [emphasis added] anthropogenic interference with the climate system” (Article 1, UNFCCC; 1992)
- Copenhagen (2009) & Cancun (2010) Agreements:
  - “in accordance with the *scientific view* [emphasis added] global temperature should be below 2°C” (Article 1, UNFCCC; 2009)
- Paris Agreement (2015):
  - notes the desirability of “pursuing efforts to limit the temperature increase to 1.5°C” (Article 1(a), UNFCCC; 2015)

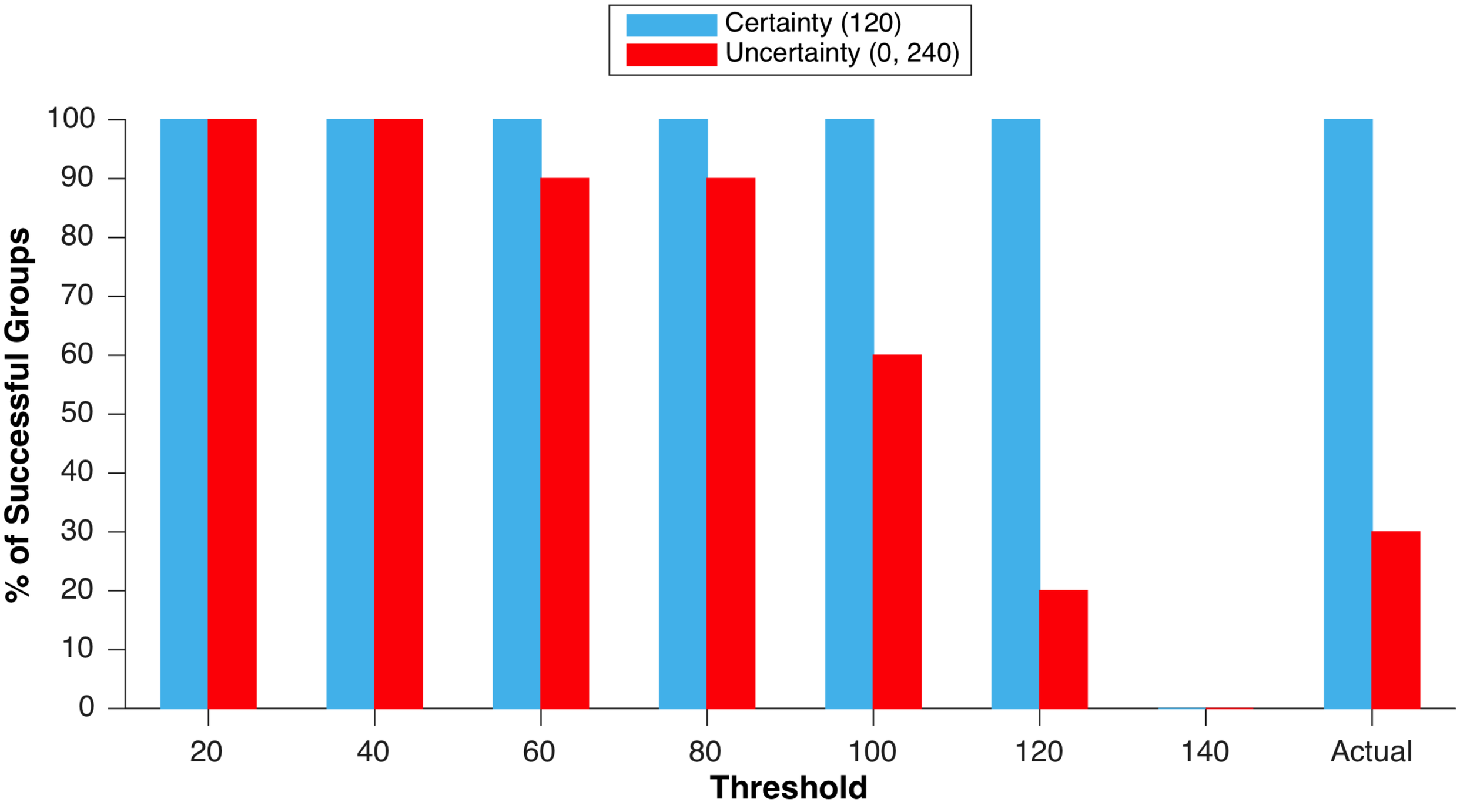
Is 2ºC the Scientific View?

Study	Threshold Element	Estimate of Threshold
Hansen et al. (2007)	Greenland Ice Sheet	1ºC relative to 2000
Rockstrom et al. (2009)	Greenland Ice Sheet	350-550 ppm CO_2
O'Neill & Oppenheimer (2002)	West Atlantic Ice Sheets, Atlantic Thermohaline Circulation	450 ppm CO_2
Oppenheimer & Alley (2005)	West Atlantic Ice Sheets	2-4ºC
Oppenheimer (2005)	West Atlantic Ice Sheets	2ºC relative to 2005
Lenton et al. (2008)	Instabilities in geo-physical sub-systems	Two groupings of thresholds: 0.5-2ºC and 3-6ºC

Dangerous Climate Change Game
(Dannenberg et al. 2015)

- Groups of 6 players, each given a personal endowment of $40
- On each of 10 rounds, players decide whether to contribute $0, $2, or $4 into a damage prevention account
- By the end of the game, total contributions must equal or exceed a threshold amount (*T*):
  - sometimes the threshold is known with **certainty** (*T* = 120)
  - sometimes the threshold is **uncertain** (*T* = [0, 240])
- If the threshold is not reached, each player's endowment is reduced by 90%
- At the start of rounds 1 and 6 players submit non-binding *proposals* and *pledges*

Dannenberg et al. (2015)



Implications

- It is not the number noted on record that matters but what the negotiators know to be true—the threshold is *deeply uncertain*
- The vulnerability in the current negotiations is the credibility of the *science*—the science of locating the critical threshold
- Scientific uncertainty undermines the credibility of "Mother Nature's" threat to tip a critical geophysical system—the free-rider deterrent in the Paris Agreement

Science of "Early-Warning Signals"

nature climate change

REVIEW ARTICLE

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Early warning of climate tipping points

Timothy M. Lenton

A climate 'tipping point' occurs when a small change in forcing triggers a strongly nonlinear response in the internal dynamics of part of the climate system, qualitatively changing its future state. Human-induced climate change could push several large-scale 'tipping elements' past a tipping point. Candidates include irreversible melt of the Greenland ice sheet, dieback of the Amazon rainforest and shift of the West African monsoon. Recent assessments give an increased probability of future tipping events, and the corresponding impacts are estimated to be large, making them significant risks. Recent work shows that early warning of an approaching climate tipping point is possible in principle, and could have considerable value in reducing the risk that they pose.

Elements of the climate system known as tipping elements[1] — which could pass a tipping point this century and undergo a qualitative change in state within this millennium — include the Atlantic thermohaline circulation (THC), West Antarctic ice sheet, Greenland ice sheet, Amazon rainforest, boreal forests, West African monsoon, Indian summer monsoon, and El Niño/Southern Oscillation (ENSO). Passing a tipping point (defined in Box 1) is rise, in turn increasing the impact of hurricane-driven storm surges or tsunamis. Dieback of the Amazon or boreal forests would cause increased wildfires. Disruption of the West African monsoon would affect drought in the Sahel.

If early warning can be achieved for climate tipping points, it could have considerable value for societies, as hinted at by the value of shorter-term, seasonal, climate forecasting to agriculture[22–24].

Aims

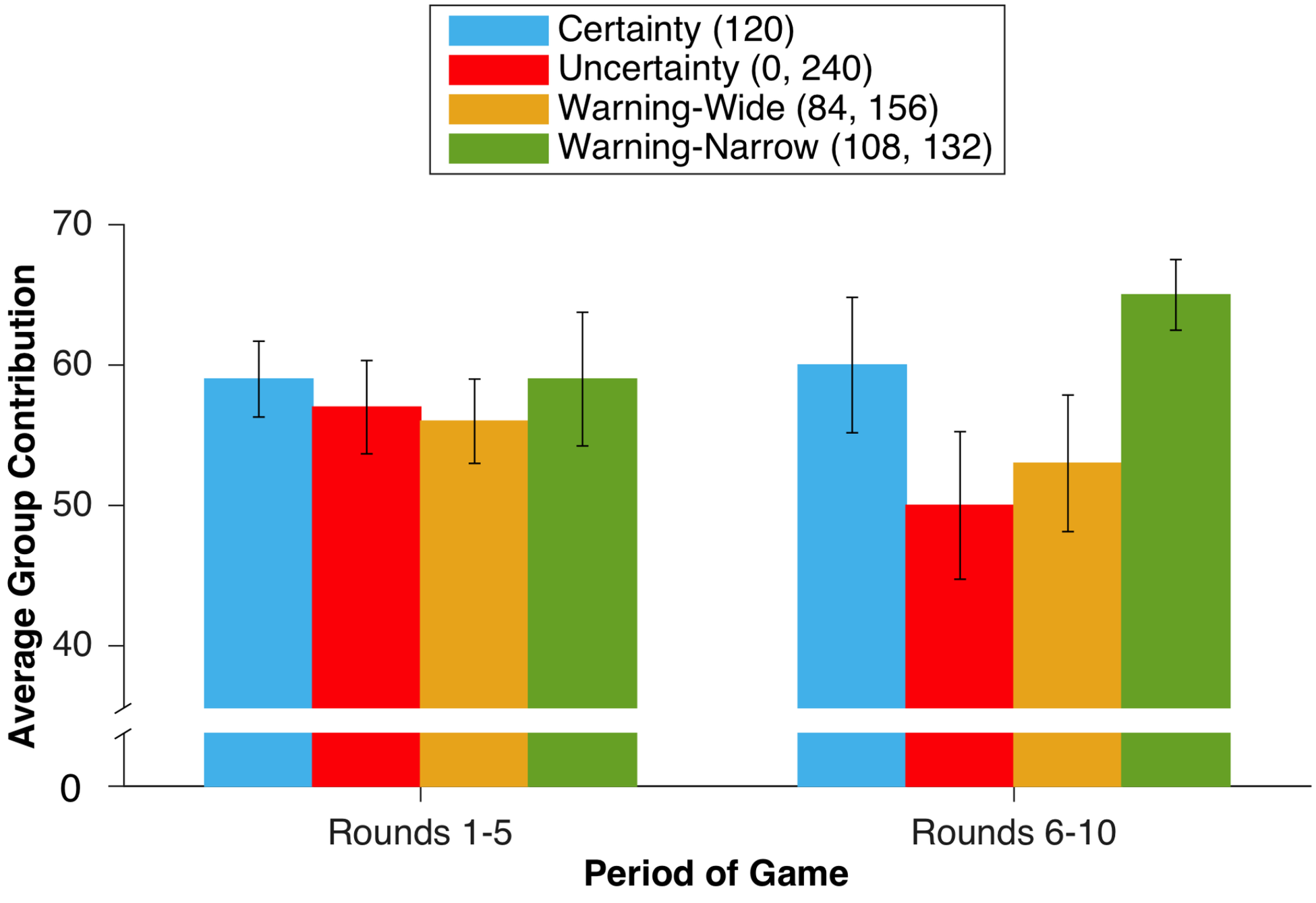
- Using a dangerous climate change game, experimentally examine whether early-warning signals can decrease the probability of crossing a dangerous (uncertain) climate threshold

- Vary the precision of the signal to establish if, and how, the amount by which uncertainty is reduced modulates the probability of avoiding crossing the threshold

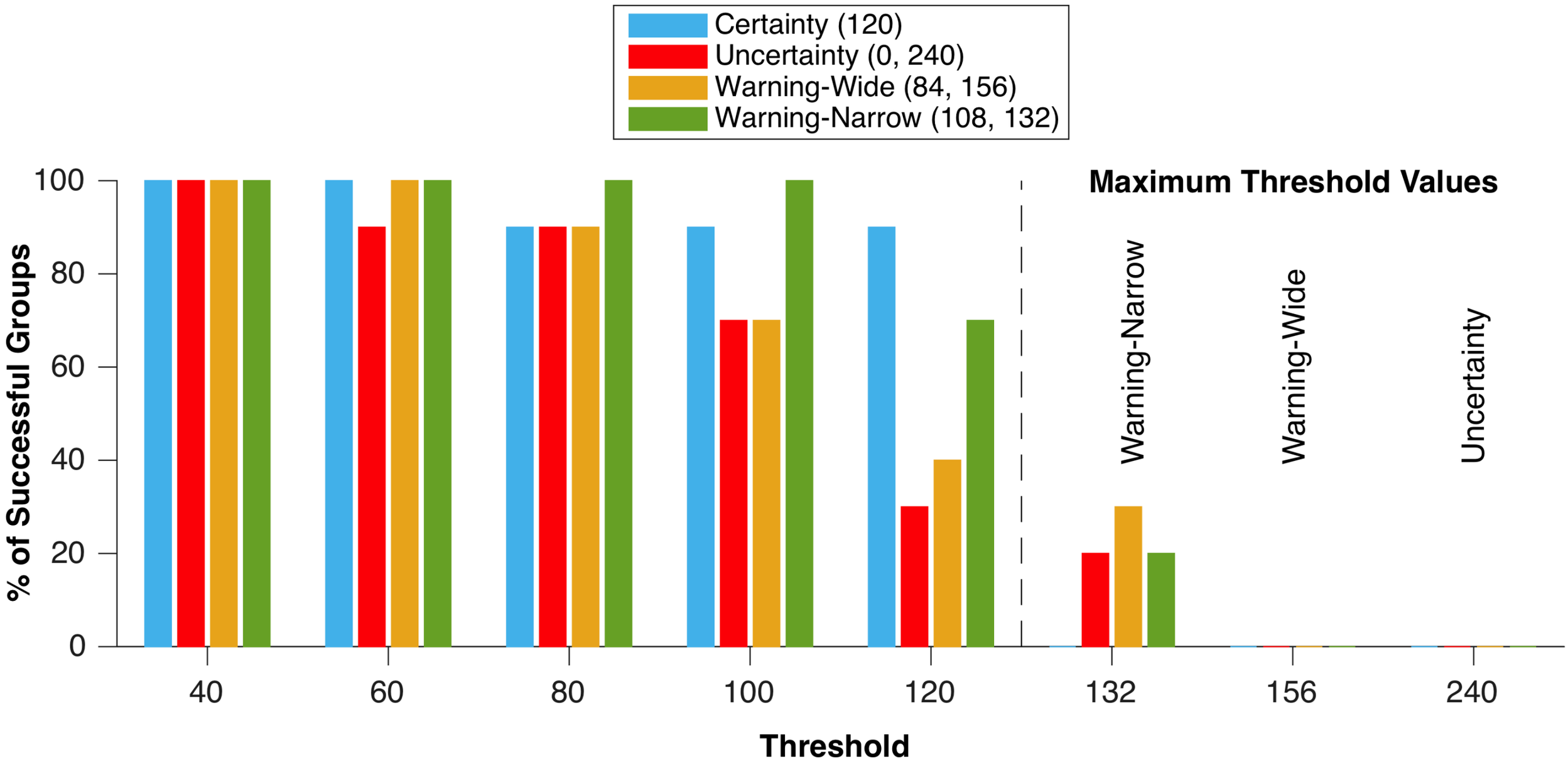
Overview of Experimental Design

Treatment	Threshold Rounds 1-10	Expected Value of *T*	Number of Participants
1. Certainty	120	120	10 groups of 6 = 60
2. Uncertainty	[0, 240]	E(T) = 120	10 groups of 6 = 60
	Threshold Rounds 1-5 / **Threshold Rounds 6-10**		
3. Warning-Wide	[0, 240] / [84, 156]	E(T) = 120	10 groups of 6 = 60
4. Warning-Narrow	[0, 240] / [108, 132]	E(T) = 120	10 groups of 6 = 60

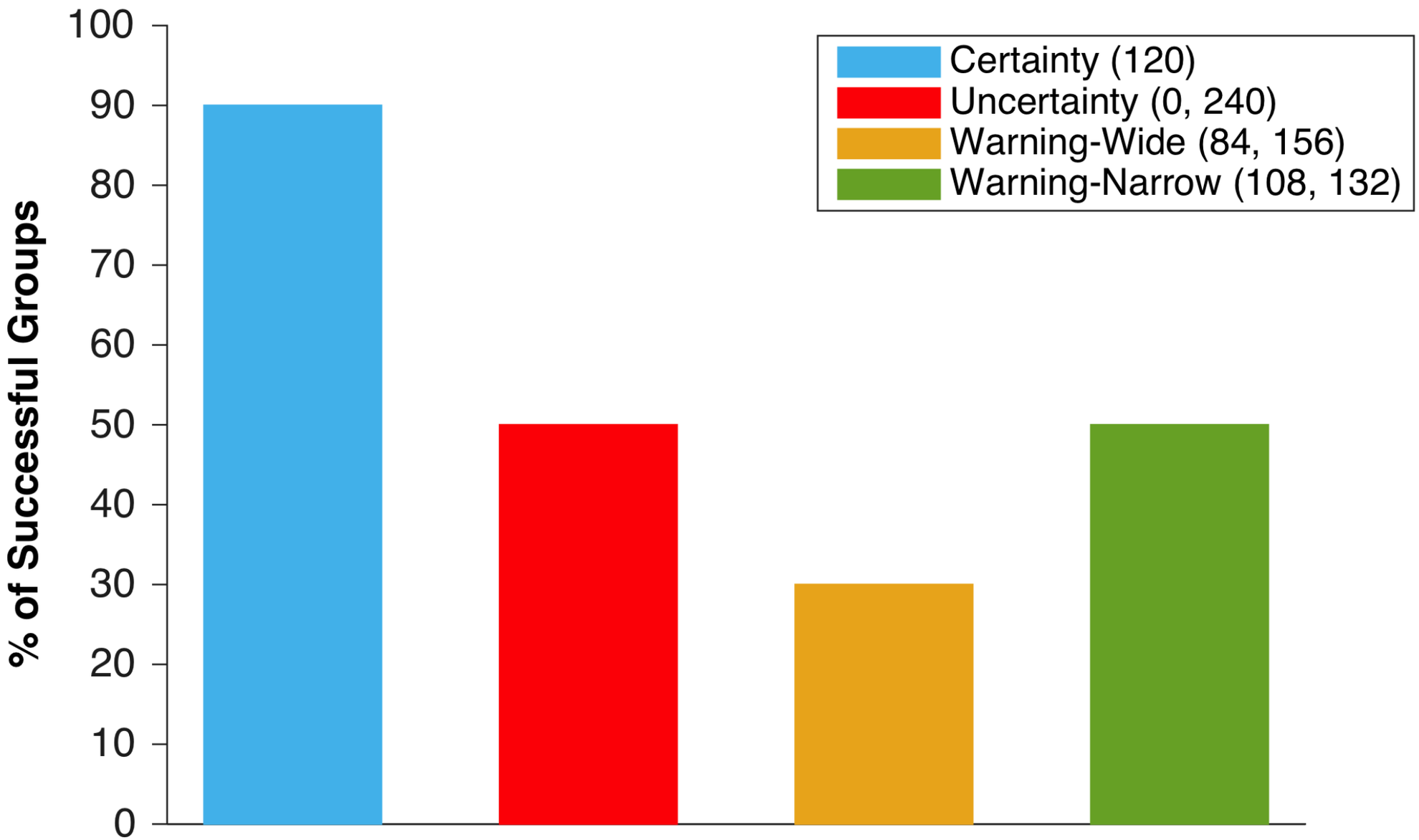
Contributions to The Public Good



Percentage of Successful Groups For Various *Hypothetical* Thresholds



Percentage of Successful Groups For *Actual* Thresholds



Conclusions

- Some evidence that an early-warning can stimulate cooperation:
  - increased contributions to the public good
  - reduced probability of crossing <u>some</u> *hypothetical* thresholds
- The reduction in uncertainty must be substantial:
  - a benefit was obtained with a 90% reduction in threshold uncertainty (warning-narrow)
  - but not with a 70% reduction (warning-wide)
- “A silver lining in an otherwise dark cloud”:
  - an early-warning does not reduce the probability of avoiding crossing the *actual* threshold imposed by “Mother Nature”

Conclusions

- Other limitations of early-warning signals:
  - signals may go undetected
  - signals may be prone to “false alarms” and “missed alarms”
  - signals may reduce uncertainty by too little to transform behaviour
  - worst of all, early-warning signals arrive *late*
- It will be challenging to translate an early-warning into effective risk reduction

Implications for Climate Negotiations

- If a ‘red line’ for dangerous climate change could be identified, then fear of crossing it would discipline behaviour
- However, early-warning signals may reduce uncertainty by too little and too late to prevent countries straying into the climate ‘danger zone’
- Strategic enforcement mechanisms are needed that can recreate the incentives to cooperate that exist when the threshold is certain
- Viable enforcement mechanisms include trade sanctions, exclusion from cherished markets, or the removal of essential licenses and permits