"Outlier Blindness": Efficient Coding Generates an Inability to Represent Extreme Values

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Outline

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Strong prior from neuroscience that people perceive outliers imperfectly and that this imperfection:

– applies similarly over both short and long timescales

– was optimal for our ancestors inasmuch as in their natural environments payoffs would often have a unimodal distribution

How Evolution Optimised Perception under Constraint: Efficient Coding

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- If a neuron's limited outputs were allocated evenly to represent the potentially infinite number of possible values of a stimulus, then that neuron's activity would allow for little if any discrimination between values

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- The optimal solution to the problem: ensuring that neurons learn which values are more likely to occur, and allocate most of their spike outputs to representing the most probable values at the expense of the improbable values.

  E.g., Laughlin 1981, Tobler et al 2005, Wei and Stocker 2015, Ganguli and Simoncelli 2016, and Robson 2001, Netzer 2009, Woodford 2012, Polania, Woodford and Ruff 2019

Our Conjecture in this Study

Outlier Blindness Hypothesis

Efficient coding generates an epiphenomenon (*"outlier blindness"*) in which economic agents are unable to properly perceive extreme outcomes inasmuch as extreme outcomes are highly improbable relative to the range of values the agents are expecting.

The range of values the agents are expecting = the range to which they have been repeatedly exposed ("adapted") in recent past ▸ more

Aim of this Study

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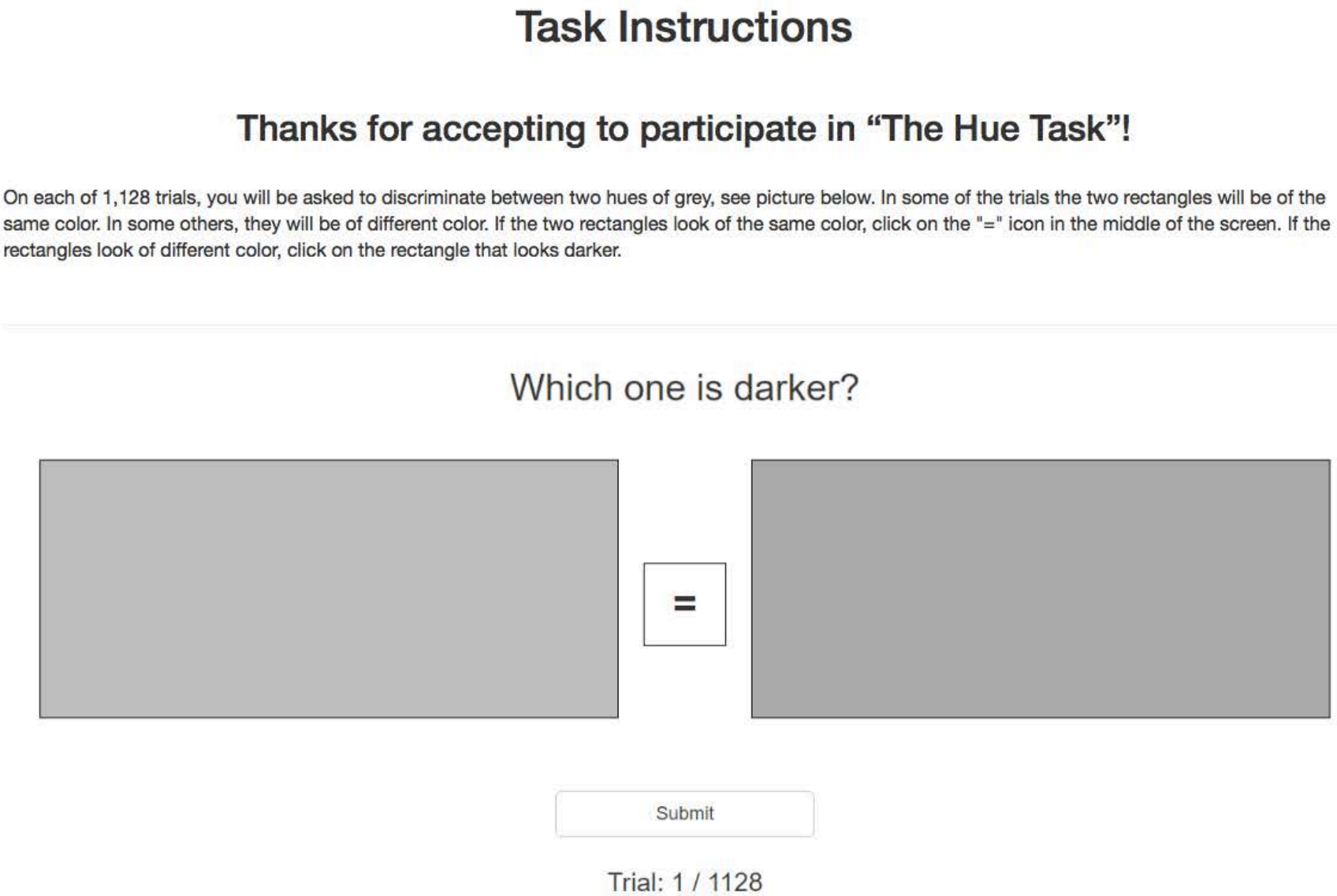
- $\Rightarrow$ We design a purely perceptual (non economic) task involving a simple sensory stimulus

Outline

Testing Outlier Blindness Hypothesis in the Lab



Testing Outlier Blindness Hypothesis in the Lab (cont.)

[Demo of the Task]

Gist of the Design

- On a typical trial, subject asked to discriminate between adjacent shades of grey x and $x+1$, where x randomly drawn from a 12-point scale

- Subject goes through 40-trial "adaptive sequence" in which on each trial, x is drawn from $N(m, s)$, with m and s randomly drawn from $\{3, \ldots, 10\}$ and $\{1, 2\}$ resp. followed by **adaptive test trial** in which x' is in the tail (at least 3 stds from m) ▸ more

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- Each outlier value x' defines a 40-trial control sequence in which on each trial the shade is drawn from $N(x', s)$, followed by **control test trial** with x' ▸ more

Main Stat of Interest

- So by design each adaptive sequence is paired with a control sequence and both sequences are immediately followed by *the same* test trial with x'
- When viewed at the adaptive test trial x' is *improbable* from the perspective of the subject whereas when presented in the control test trial it is *probable* (within the range of values the subject is expecting)

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Outlier blindness hypothesis predicts a decreased accuracy in the adaptive test trials w.r.t the control test trials.

Why the Current Task Settings: To Increase Statistical Power

- 2 sec to reply: to maximize number of trials per subject

  Note: not pivotal for our results (got same results with 4 sec)

- In 13% of the trials the shade x is the same on both sides: to avert some **"ceiling effect"** if task is too easy

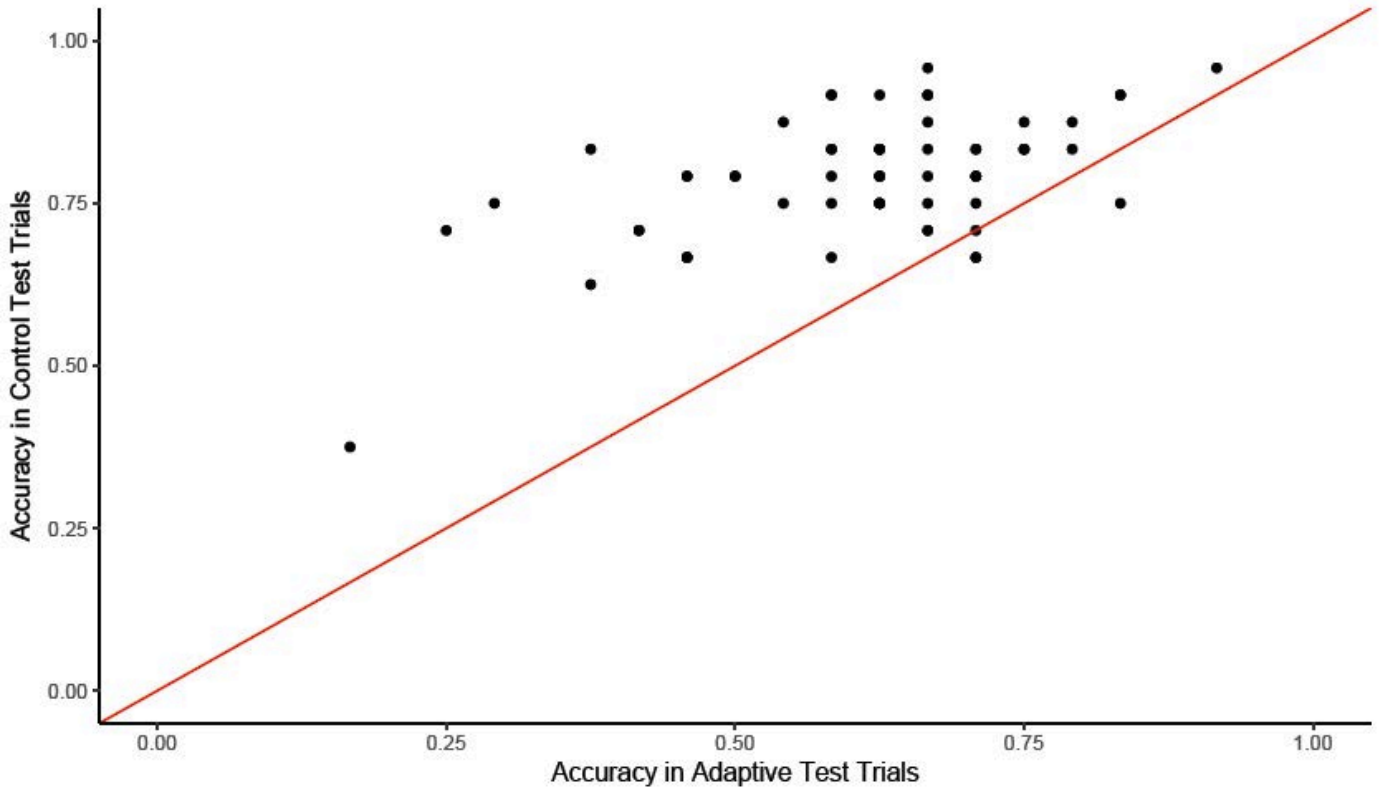
- 12-point scale: to solve tradeoff between minimising choice randomness and making task non trivial

- Use of special procedure with our subjects:

  – **high incentives** (high stakes and "pay all" rule)
  – **screening device** to screen out unmotivated subjects

▸ instructions

Evidence for Outlier Blindness Hypothesis



Each point corresponds to one subject. N=63, 24 observations per subject. x axis: accuracy (fraction of correct replies) in the adaptive test trials. y axis: accuracy in the control test trials

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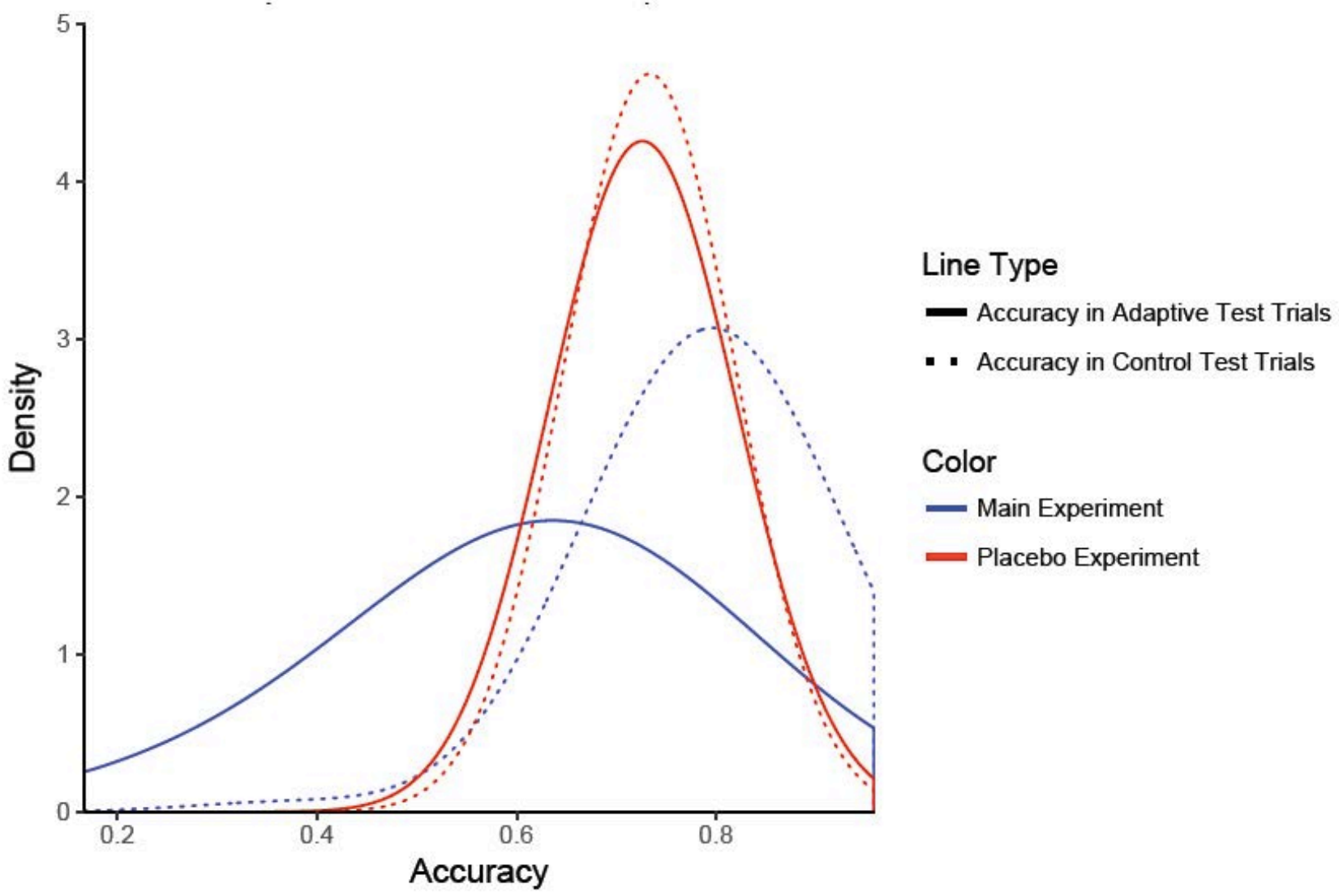
- $\Rightarrow$ By design subjects in the placebo test (N=35) **do not have time to form expectations** about shade values .... so the outlier blindness effect should vanish

Strengthening the evidence: Placebo Test (cont)



Summary

We provide strong evidence for outlier blindness hypothesis: perceptual accuracy is hampered for tail events.

Outline

To Conclude

Discussion

— Follow-Up Investigation

— Related Literature

Follow-Up Interrogation

"How pervasive should we expect the outlier blindness phenomenon to be in the field?"

- Prerequisite for the occurrence of outlier blindness is that the agent has had time to form expectations
- Given that financial markets are notoriously unstable (owing to the frequent occurrence of regime shifts or jumps in values), shouldn't we expect outlier blindness to be a marginal phenomenon in the field?

$\rightarrow$ *"How long does it take for the human brain to form expectations?"*

How long does it take for the human brain to form expectations?

- Our conjecture: It does not take long and a few trials of adaptation may be enough for recalibration of stimulus encoding

  E.g., Ohzawa et al 1985, Bayer&Glimcher 2005, Fairhall 2014, Frydman and Jin 2018

- Consistent with this conjecture, we find outlier blindness effect reappears in 5-trial adaptation experiment (N=31)

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- Consistent with this conjecture, we find outlier blindness effect reappears in 5-trial adaptation experiment (N=31)
- Note recovery is only partial: Effect is significantly bigger in original experiment, also consistent with outlier blindness hypothesis (magnitude of the effect should ↑ with adaptation length)

Takeaway Messages

1. In regard to human psychology: Humans are quick to form expectations
2. In regard to practical implications for financial agents: No one should expect to be immune to the outlier blindness effect including those operating in very unstable environments

Related Literature

Related Literature

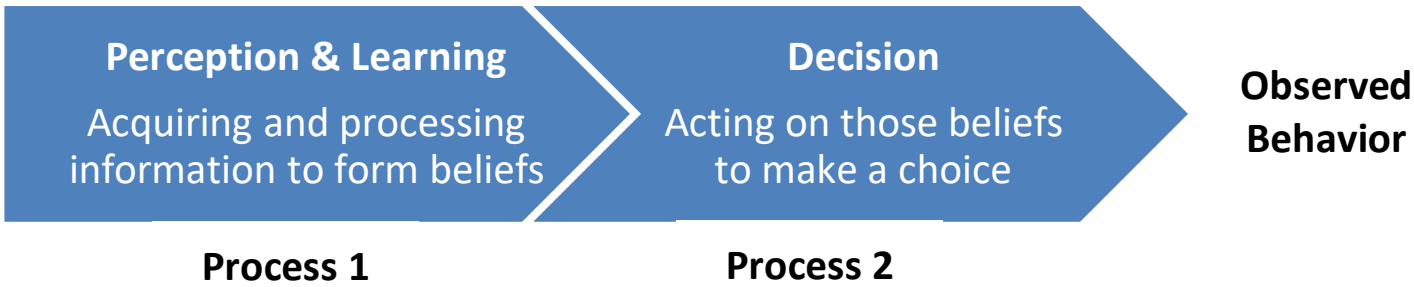
- Literature on the implication of **imprecise perception** on economic decision-making (e.g., Steiner&Stewart 2016, Khaw, Li and Woodford 2017, Gabaix&Laibson 2018, PLN et al 2013, 2018, Frydman&Jin 2018)
- **Evolutionary theories of economic behavior**: human brain optimized for the environmental context in which emerged; maladaptive when taken out of its proper environment (e.g. Robson 2001 and Chapter 6 of Lo 2017)
- **"Inattentional blindness"** (e.g., Chabris&Simons 1999) resulting from **sparse attention** (e.g., Sims 2003, Mackowiak&Wiederholt 2009, Gabaix 2014); cf. also the literature on "focusing illusions" (e.g, Schkade&Kahneman 1998 and Koszegi&Szeidl 2012)
- **Neglected risks** (e.g., Gennaioli et al 2012, Jin 2015, Gennaioli&Schleifer 2018) ▸ more

Acknowledgments

Daniela Grinblatt, for providing great research assistance

Funding from the University of new South Wales is also gratefully acknowledged.

Decision Making Is a Dual Process



Decision making is the result of a dual process:

– Process 1: information acquisition and processing

– Process 2: acting on one's beliefs to make a choice

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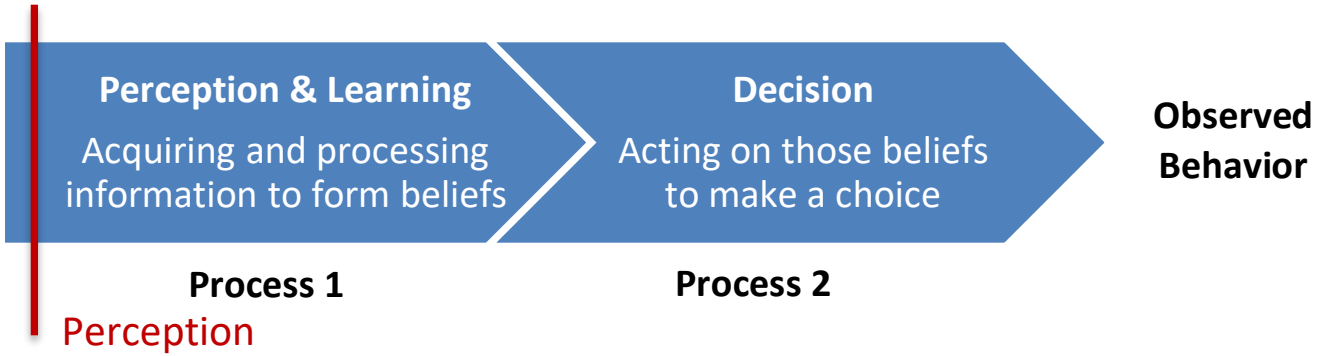

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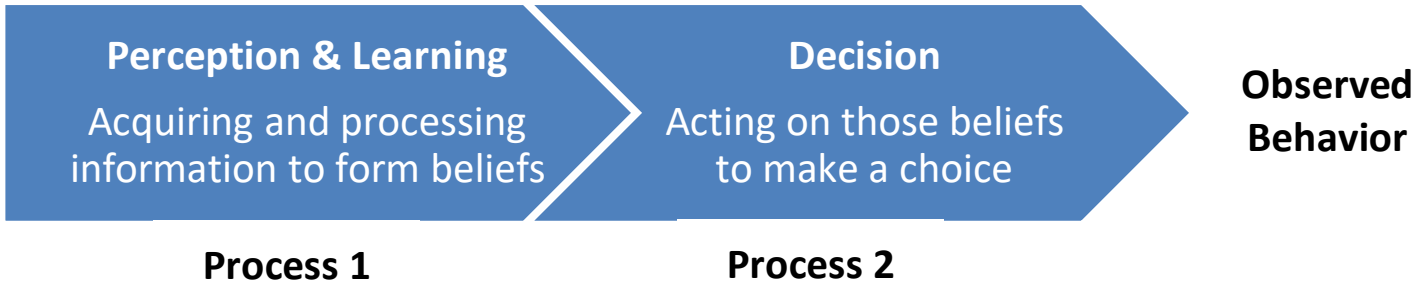
– Process 1: information acquisition and processing

– Process 2: acting on one's beliefs to make a choice

In this study we focus on the very bottom-up step of Process 1: what the agents "see" in the first instance

What the agents see or cannot see is gonna determine all the rest (what they can learn in particular)

Decision Making Is a Dual Process



- Decision making is the result of a dual process:
  - Process 1: information acquisition and processing
  - Process 2: acting on one's beliefs to make a choice
- In an economic decision-making task, separating purely perceptual factors (Process 1 related) from behavioral factors related to risk attitude (Process 2 related) is impossible

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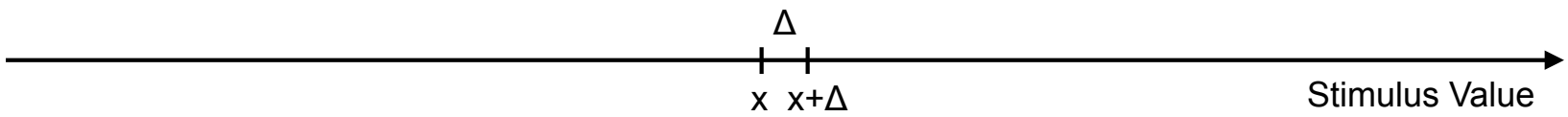
Outlier Blindness Hypothesis



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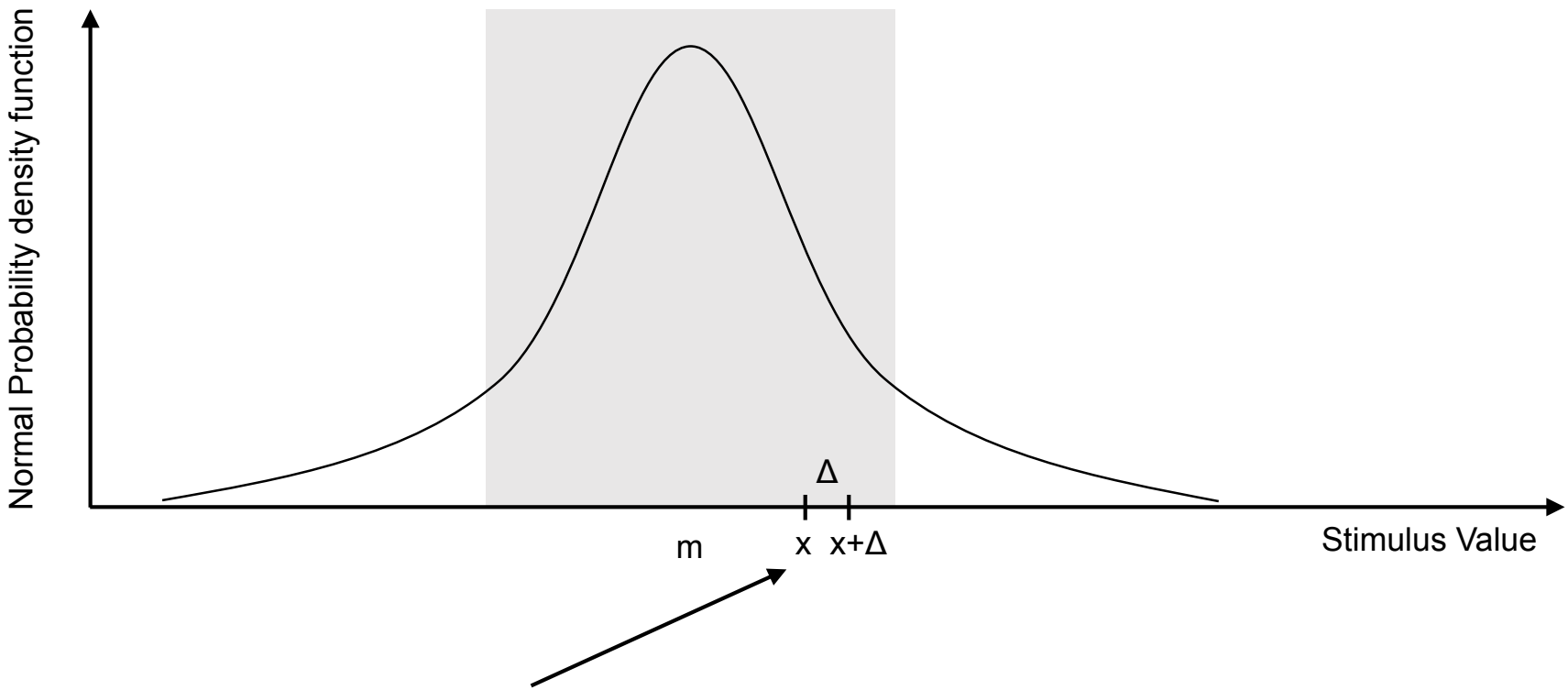


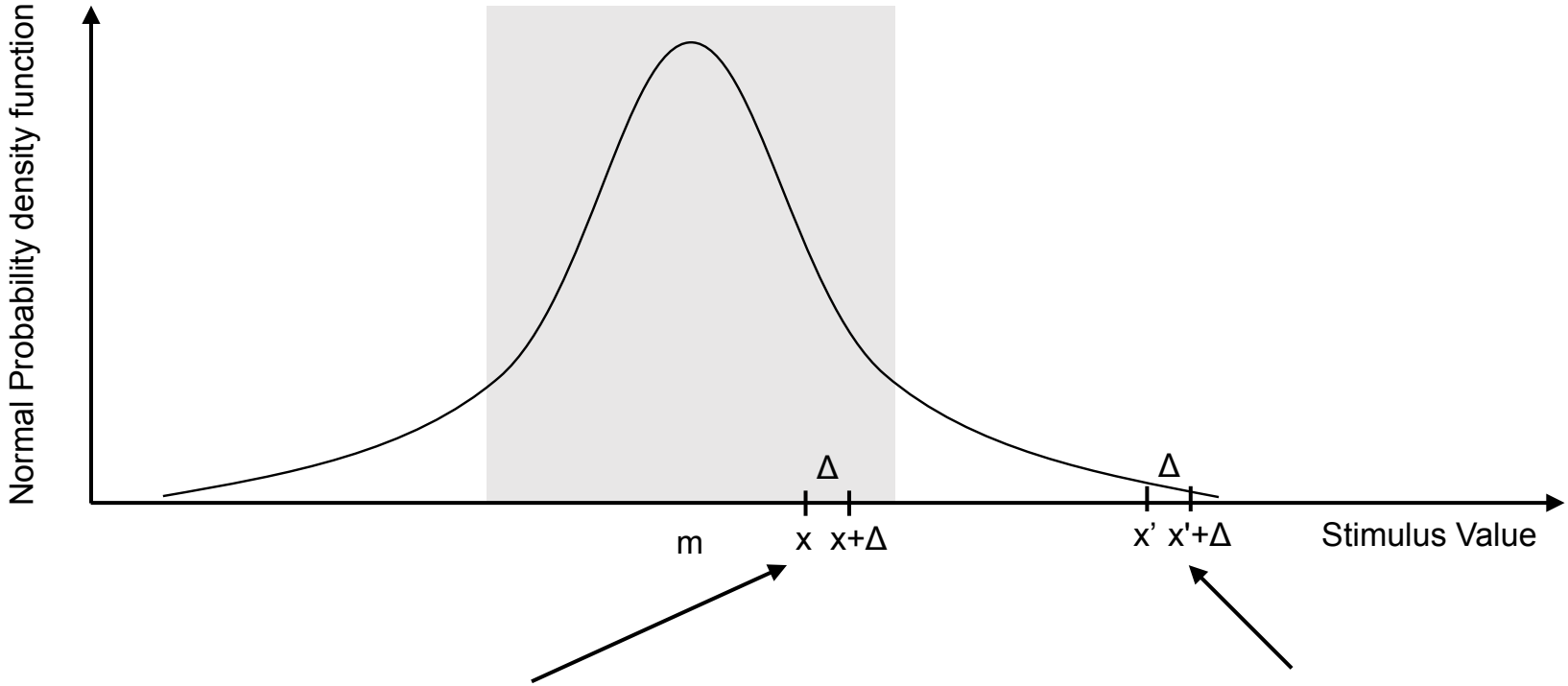
Adaptation

The agent is to discriminate many times between stimulus values x and x+Δ with x drawn from N(m,σ)

--> After some time, the agent's perceptual system is adapted to N(m,σ)

Outlier Blindness Hypothesis

back



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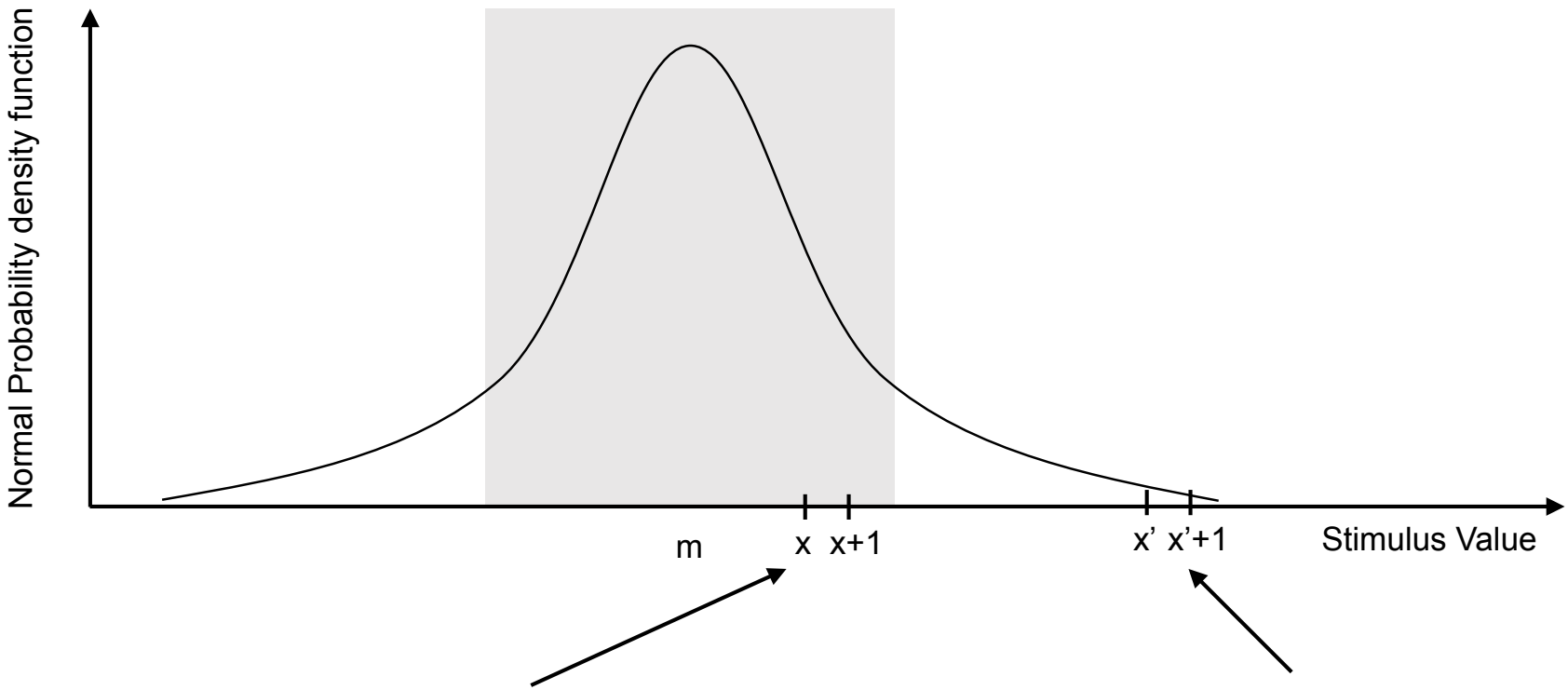
"Outlier blindness"

For the agent this value is improbable --> hard to discriminate between x'and x'+Δ

Experimental Design



"Adaptive sequence"

On each of 40 trials, subject is asked to discriminate between shade value x and x+1 with x drawn from N(m,σ)

"Adaptive test trial"

Immediately following the adaptive sequence, subject is asked to discriminate between x' and x'+1

Controlling for the "Extreme-Value Effect" (Weber-Fechner Law)

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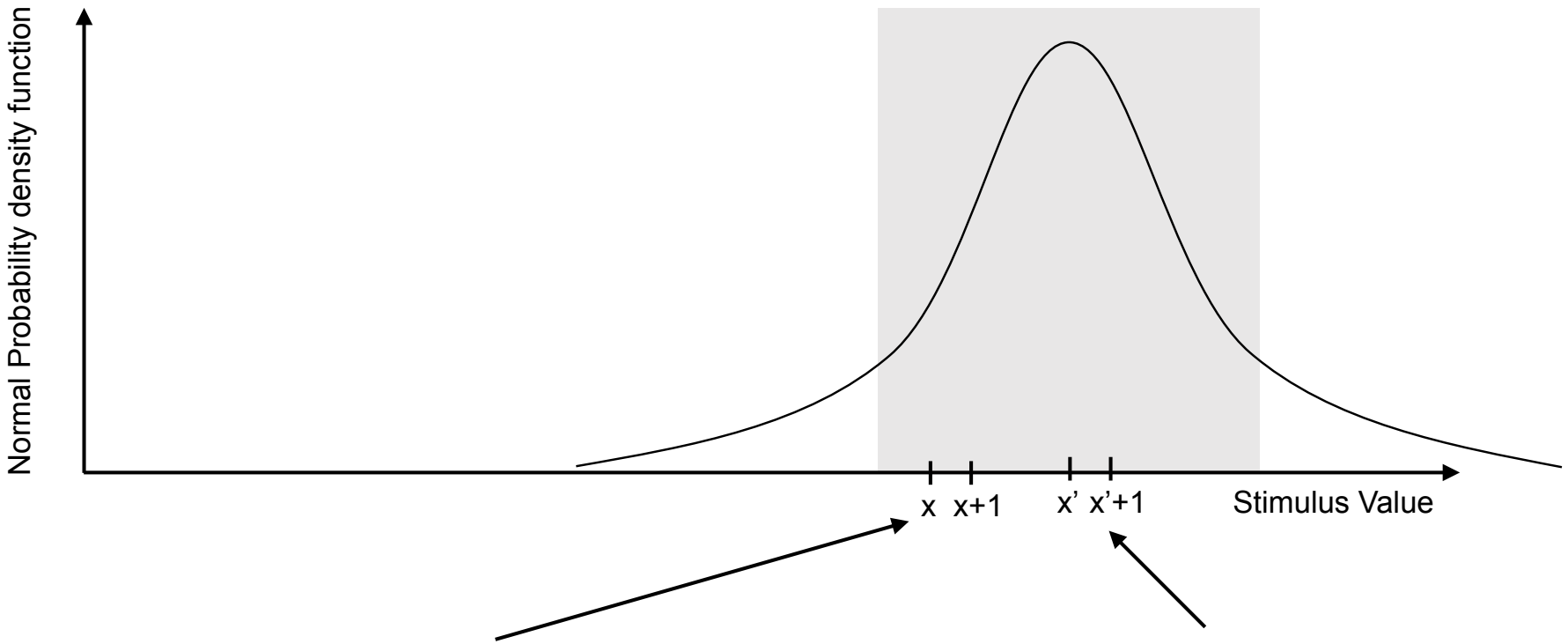
back



"Control sequence"

On each of 40 trials, subject is asked to discriminate between shade values around x'

"Control test trial"

Immediately following the control sequence, subject is asked to discriminate between x' and x'+1

Task instructions

◂ back

We (the experimenters) want to reward very significantly high performance in this task. You will earn $0.10 per correct reply and will lose $0.25 per incorrect reply. Since you will be playing 1,128 trials overall, this means you can earn a lot of money potentially—more than $100—if you perform well in the task.

Please Note:

- You will lose $1 if you fail to reply within the imparted time on a given trial (2 sec — note the pace of the game is high).
- The task is quite long (about 30 minutes overall). There will be a short break after the first 15 minutes.

The task therefore requires you to keep the pace and pay attention for a prolonged period of time. To familiarize you with the task settings before performing the task, we offer you the opportunity to do a 3-minute training session in which you will be playing a few trials of the task; note these trials will NOT be counting for your final payment (your replies won't be recorded).

Please indicate your choice:

I wish to do the training session before performing the task

I wish to skip the training session and go directly to the task

Outlier Blindness and Neglected Risks

- Our study may help in building a narrative of the "quiet period" within Gennaioli and Shleifer 2018's *diagnostic expectations* framework

- "Quiet period": complete lack of reaction of investors to the regime shift news of the housing bubble burst in 2006 and ensuing domino effect during the pre-Lehman period

  During that period evidence for a major regime shift was compelling, yet investors ignored it and continued to neglect tail risk

- One explanation is that they missed it as a result of outlier blindness because their perceptual system was not yet adapted to the new regime

back