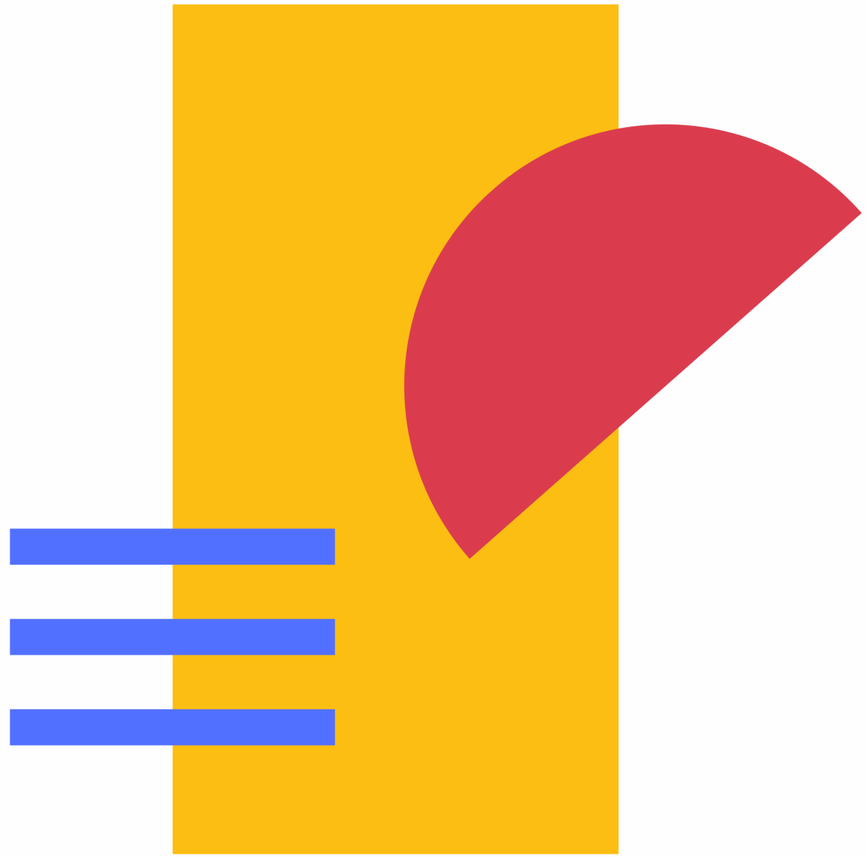
# Time and Singular Causation—A Computational Model

by Ignacio, Afnan

# The Problem

Are two events co-occuring mere a coincidence? or is there a causal relationship between them?



# Related Work

## Mostly Focuses on Causal Selection

e.g., Cheng & Novick, 1991; Hitchcock & Knobe, 2009; Icard, Kominsky, & Knobe, 2017; Kominsky, Phillips, Gerstenberg, Lagnado, & Knobe, 2015; Lagnado, Gerstenberg, & Zultan, 2013; Novick & Cheng, 2004; Phillips, Luguri, & Knobe, 2015

## Two Major References of the Paper

The computational model of singular causation judgments is based on the power PC framework of causal attribution developed by Cheng and Novick (2005) and extension mentioned in Stephan and Waldmann (2018)

# Time and Singular Causation Model

## Relevant Terms

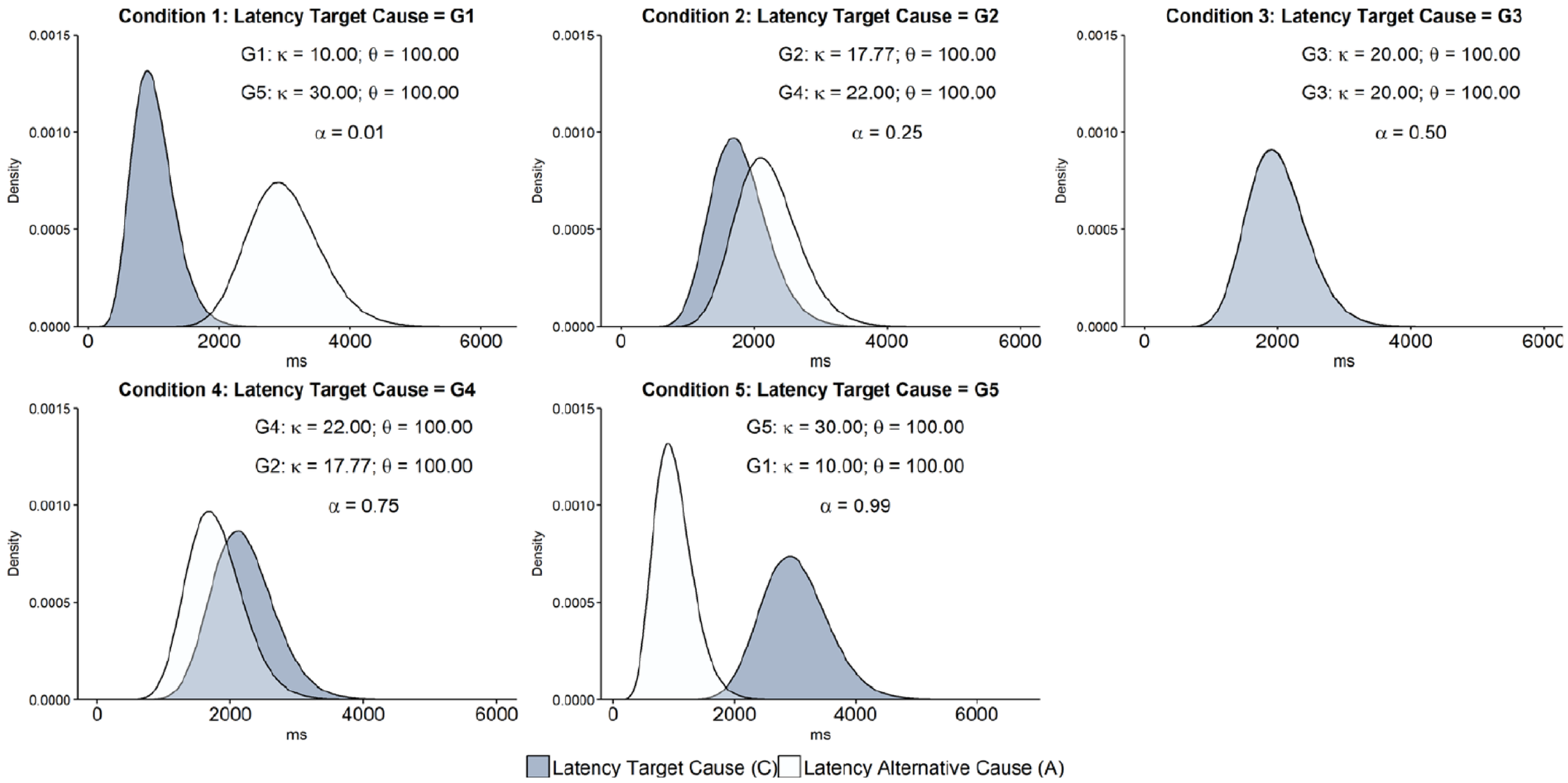
- Causal Strength
- Causal Onset and Causal Latency
- Alpha as variable to model time
- Determine alpha by Montecarlo sampling of gamma distributions

## Relevant Equations

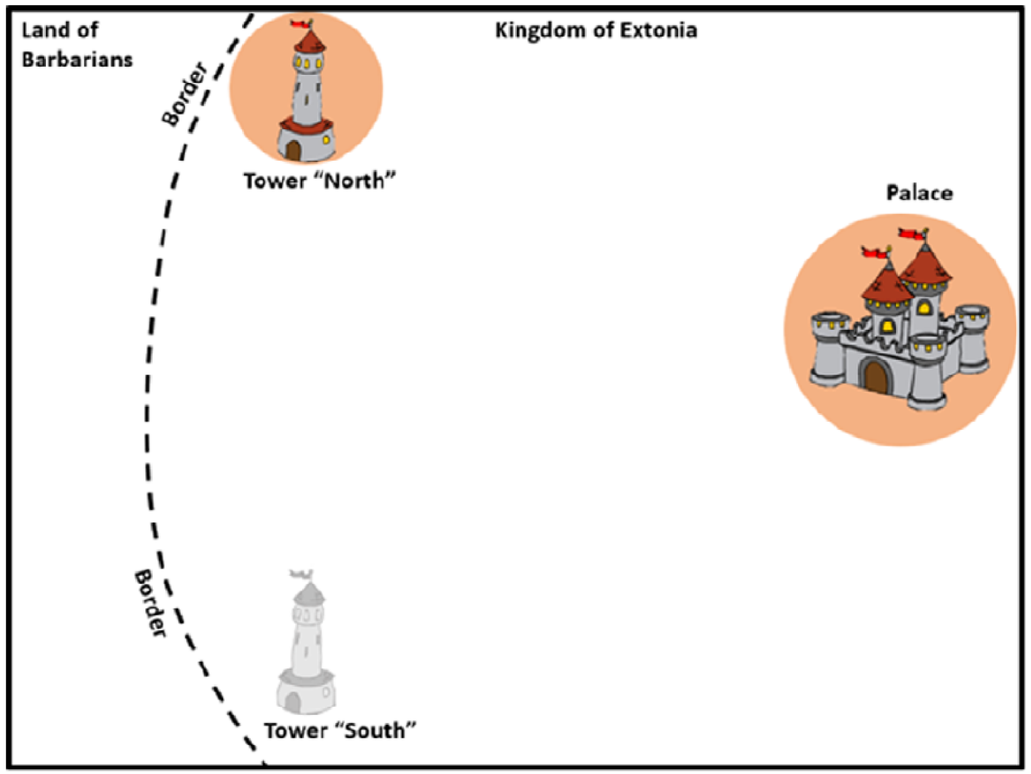
$$P(c \to e \mid c, a, e) = \frac{w_c(1 - w_a \cdot \alpha)}{w_c + w_a - (w_c \cdot w_a)}$$

$$\alpha = P(t_{a \to e} + \Delta_t < t_{c \to e} \mid e, c, a)$$

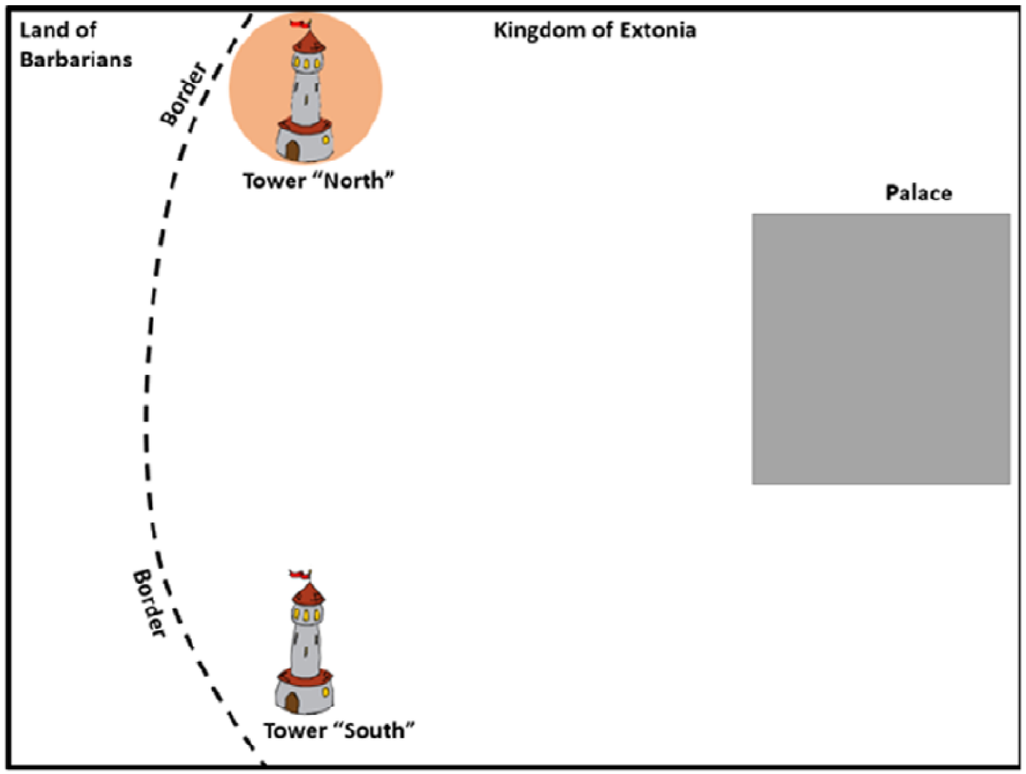
# Gamma Distributions



# The cover story




(A) Screen during the causal-latency learning phase




(B) Screen during the onset-difference learning phase

# Methods

## Replicated Experiments

### Experiment 1

- Assumes non-probabilistic causal latencies.
- Assumes deterministic causal strengths (=1).
- Vary causal onset and causal latency values.
- Determine the role of temporal values in human judgement of singular causation.

### Experiment 2

- Assumes probabilistic causal latencies.
- Assumes deterministic causal strengths (=1).
- Assumes  equal onset.
- Vary distributions of causal latencies (alpha value).
- Determine if humans are sensitive to probabilistic causal latencies,

### Experiment 3

- Assumes probabilistic causal latencies.
- Assumes probabilistic causal strength,
- Assumes  equal onset,
- Determine the interaction effect between causal strength and probabilistic causal latency.

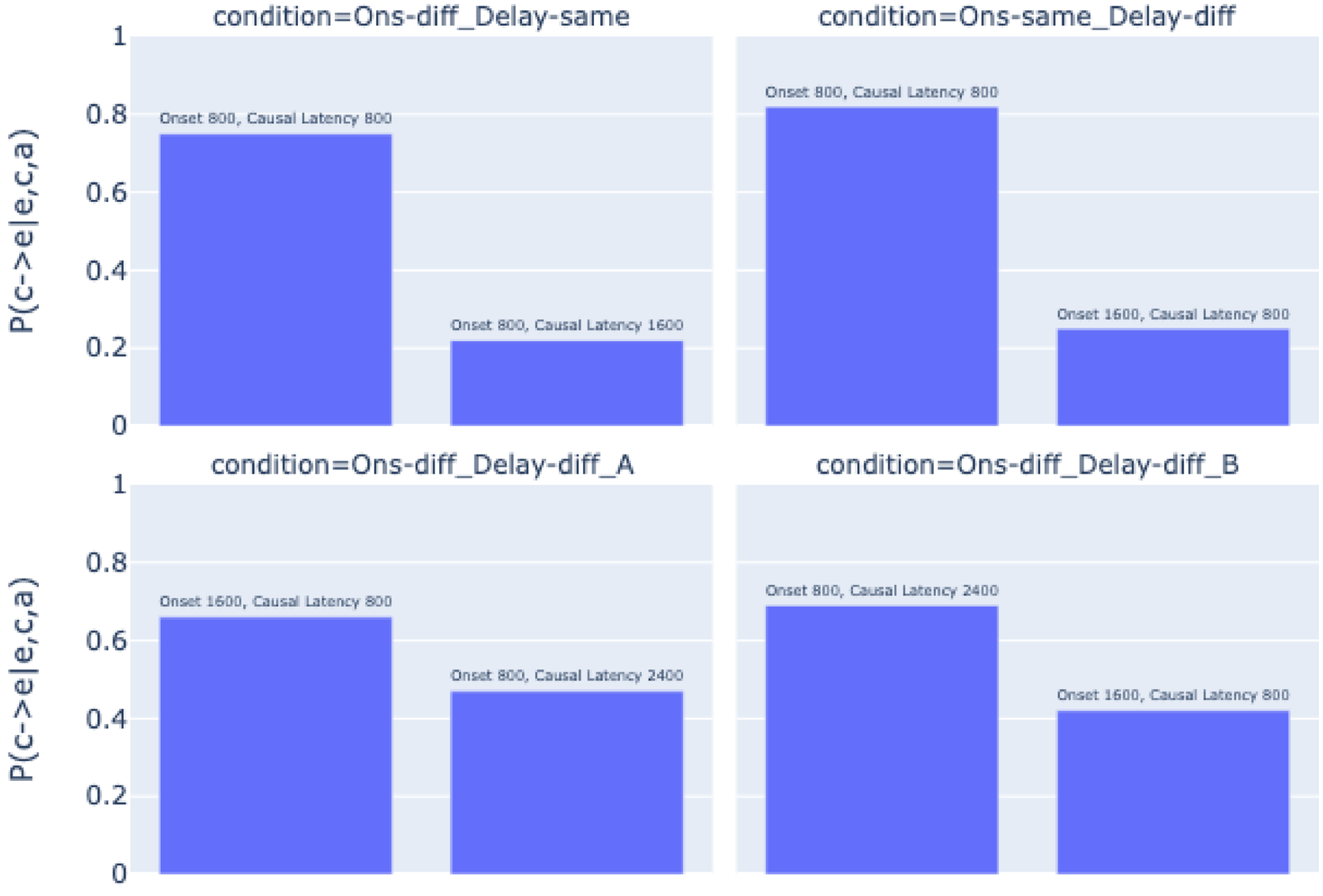
# Experiment 1

## Dataset

| | subjID | condition | taskOrder | firstTower | earlyTower | targetCause | scaleOrientation | rating | respTime | targetCauseRec |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 142 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-North | HC-L | 0.5 | 75293 | Early Tower |
| 1 | 265 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-North | HC-L | 0.4 | 44481 | Early Tower |
| 2 | 440 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-North | HC-L | 0.8 | 64142 | Early Tower |
| 3 | 75 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-North | HC-R | 0.2 | 66309 | Early Tower |
| 4 | 207 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-North | HC-R | 0.8 | 7932 | Early Tower |
| 5 | 321 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-North | HC-R | 0.5 | 61014 | Early Tower |
| 6 | 135 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-South | HC-L | 0.5 | 5019 | Late Tower |
| 7 | 180 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-South | HC-L | 0.7 | 53423 | Late Tower |
| 8 | 291 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-South | HC-L | 0.3 | 48054 | Late Tower |
| 9 | 76 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-South | HC-R | 1.0 | 31556 | Late Tower |
| 10 | 277 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-South | HC-R | 1.0 | 25568 | Late Tower |
| 11 | 294 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-North | Q-South | HC-R | 0.7 | 57849 | Late Tower |
| 12 | 46 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-South | Q-North | HC-L | 0.2 | 29136 | Late Tower |
| 13 | 272 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-South | Q-North | HC-L | 0.8 | 15015 | Late Tower |
| 14 | 317 | Ons-diff_Delay-diff_A | DurFirst | FT-North | ET-South | Q-North | HC-L | 0.6 | 20108 | Late Tower |

# Experiment 1: Results

## Predictions found from the experimental data vs Predictions done by our model





```
{
    "Ons-diff_Delay-same": [
        "Cause0: 1.0",
        "Cause1: 0.0"
    ],
    "Ons-same_Delay-diff": [
        "Cause0: 1.0",
        "Cause1: 0.0"
    ],
    "Ons-diff_Delay-diff_A": [
        "Cause0: 1.0",
        "Cause1: 0.0"
    ],
    "Ons-diff_Delay-diff_B": [
        "Cause0: 1.0",
        "Cause1: 0.0"
    ]
}
```

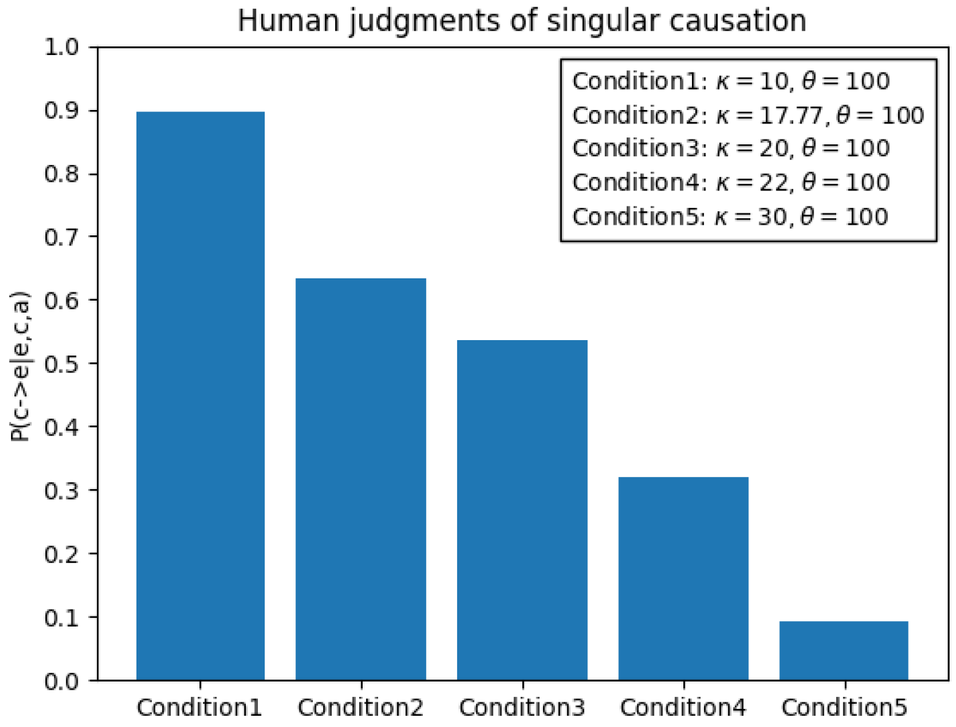
# Experiment 2

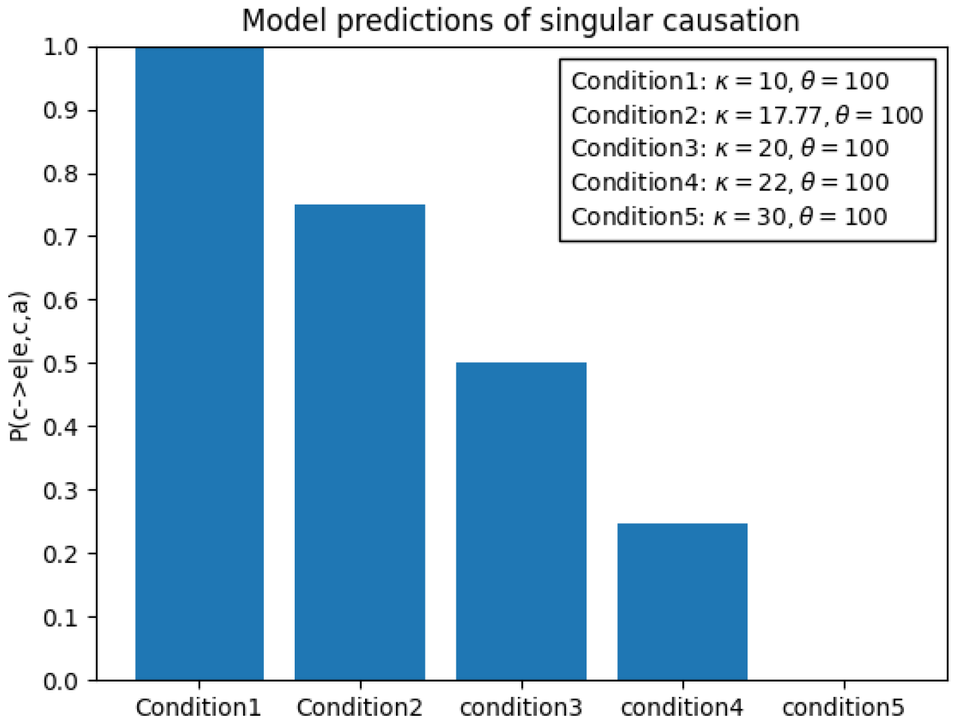
## Dataset

| | subjID | FirstTower | GammaDiff | Target | ScaleOrientation | Alpha | Rating | RespTime | AlphaRec |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | FT-North | S-F_1 | Q-North | HC-L | 0.99 | 0 | 33780 | Hundred |
| 1 | 2 | FT-North | S-F_2 | Q-North | HC-R | 0.75 | 1 | 60476 | SeventyFive |
| 2 | 3 | FT-North | F-S_2 | Q-South | HC-R | 0.75 | 5 | 46900 | SeventyFive |
| 3 | 5 | FT-South | F-S_1 | Q-South | HC-L | 0.01 | 10 | 47995 | Zero |
| 4 | 6 | FT-North | F-S_2 | Q-North | HC-R | 0.25 | 8 | 34674 | TwentyFive |
| 5 | 7 | FT-South | Control | Q-South | HC-R | 0.50 | 10 | 18589 | Fifty |
| 6 | 8 | FT-South | F-S_1 | Q-North | HC-R | 0.99 | 1 | 29637 | Hundred |
| 7 | 9 | FT-South | F-S_1 | Q-South | HC-R | 0.01 | 9 | 22698 | Zero |
| 8 | 10 | FT-North | Control | Q-North | HC-L | 0.50 | 5 | 28398 | Fifty |
| 9 | 11 | FT-North | S-F_1 | Q-North | HC-R | 0.99 | 1 | 33282 | Hundred |
| 10 | 12 | FT-North | Control | Q-South | HC-R | 0.50 | 8 | 37340 | Fifty |
| 11 | 13 | FT-North | F-S_2 | Q-North | HC-L | 0.25 | 7 | 34255 | TwentyFive |
| 12 | 14 | FT-North | F-S_1 | Q-South | HC-R | 0.99 | 1 | 28532 | Hundred |
| 13 | 15 | FT-South | F-S_2 | Q-North | HC-R | 0.75 | 3 | 18830 | SeventyFive |
| 14 | 19 | FT-South | Control | Q-North | HC-R | 0.50 | 7 | 29546 | Fifty |

# Experiment 2: Results

## Predictions found from the experimental data vs Predictions done by our model



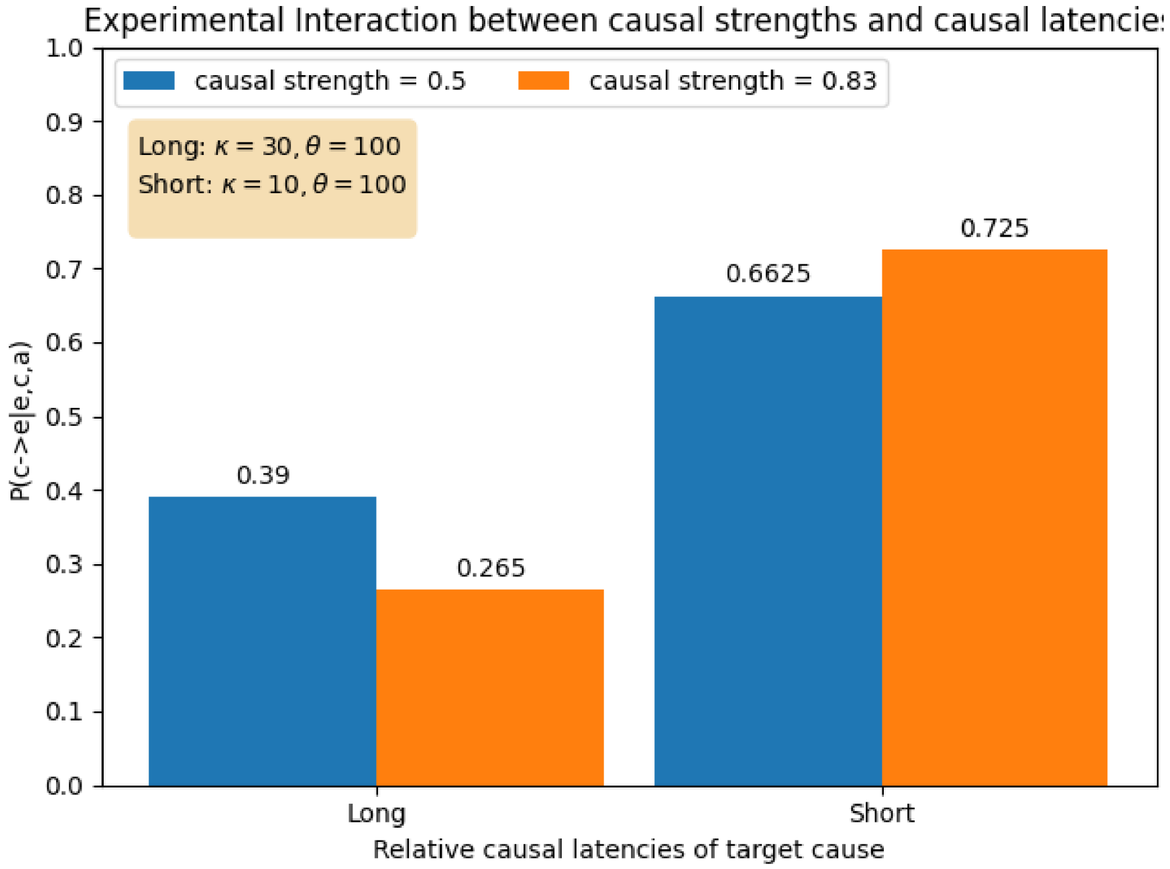
# Experiment 3

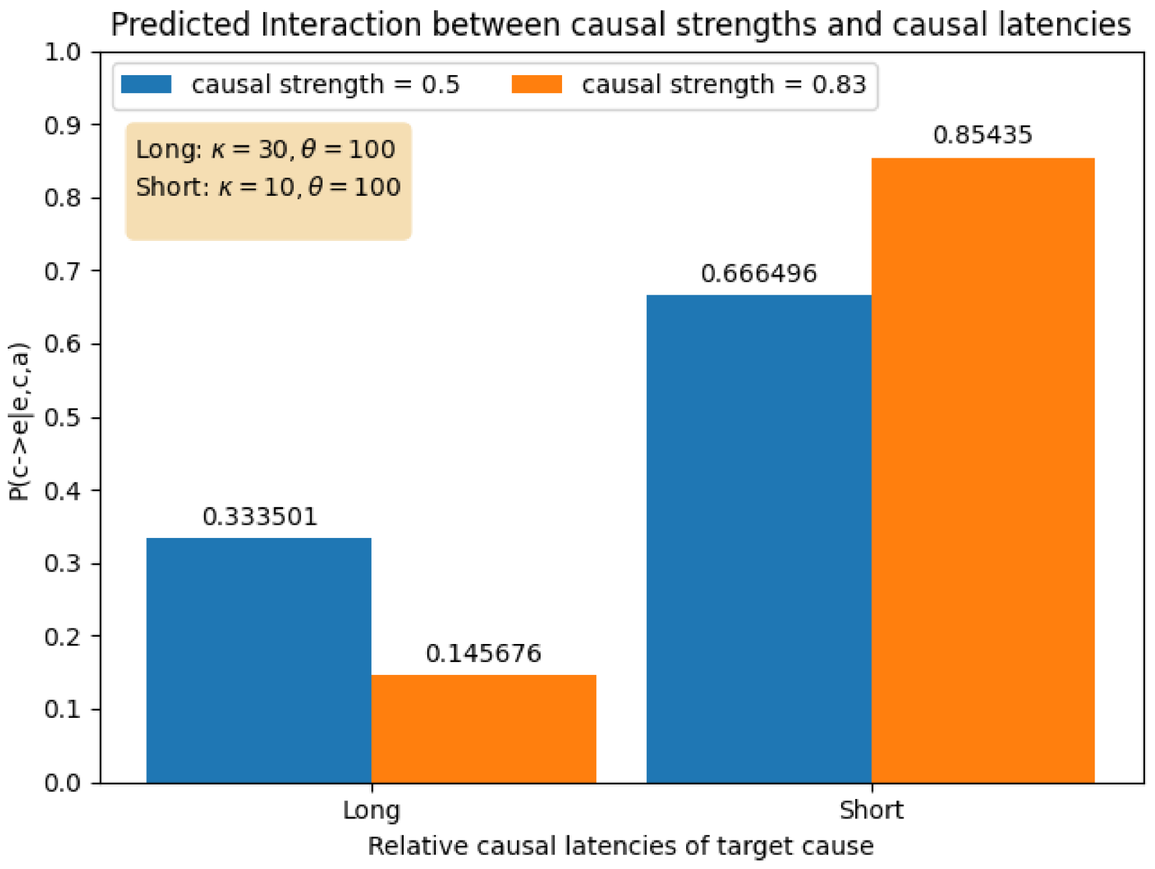
## Experimental Data

| | subjID | instrtest | FirstTower | GammaDiff | Target | ScaleOrientation | Alpha | Power | Rating | RespTime | AlphaRec | PowerRec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | valid | FT-South | S-F_1 | Q-South | HC-L | 0.99 | 0.50 | 0.2 | 55750 | Hundred | Fifty |
| 1 | 2 | valid | FT-South | F-S_1 | Q-North | HC-L | 0.99 | 0.50 | 0.5 | 73035 | Hundred | Fifty |
| 2 | 3 | valid | FT-North | F-S_1 | Q-South | HC-R | 0.99 | 0.50 | 0.3 | 35582 | Hundred | Fifty |
| 3 | 4 | valid | FT-North | F-S_2 | Q-South | HC-L | 0.99 | 0.83 | 0.2 | 26715 | Hundred | EightyThree |
| 4 | 5 | valid | FT-North | S-F_2 | Q-South | HC-L | 0.01 | 0.83 | 0.8 | 43451 | Zero | EightyThree |
| 5 | 7 | valid | FT-South | F-S_2 | Q-South | HC-R | 0.01 | 0.83 | 0.8 | 52828 | Zero | EightyThree |
| 6 | 8 | valid | FT-South | F-S_2 | Q-North | HC-L | 0.99 | 0.83 | 0.4 | 37145 | Hundred | EightyThree |
| 7 | 9 | valid | FT-North | F-S_2 | Q-North | HC-R | 0.01 | 0.83 | 0.5 | 92960 | Zero | EightyThree |
| 8 | 10 | valid | FT-South | F-S_2 | Q-South | HC-L | 0.01 | 0.83 | 0.8 | 39264 | Zero | EightyThree |
| 9 | 11 | valid | FT-North | S-F_2 | Q-North | HC-L | 0.99 | 0.83 | 0.2 | 17639 | Hundred | EightyThree |
| 10 | 15 | valid | FT-North | F-S_1 | Q-North | HC-L | 0.01 | 0.50 | 0.4 | 20354 | Zero | Fifty |
| 11 | 14 | valid | FT-North | S-F_2 | Q-South | HC-R | 0.01 | 0.83 | 0.9 | 34510 | Zero | EightyThree |
| 12 | 12 | valid | FT-North | S-F_1 | Q-North | HC-R | 0.99 | 0.50 | 0.5 | 22266 | Hundred | Fifty |
| 13 | 16 | valid | FT-North | F-S_1 | Q-South | HC-L | 0.99 | 0.50 | 0.0 | 29125 | Hundred | Fifty |
| 14 | 18 | valid | FT-North | S-F_1 | Q-North | HC-L | 0.99 | 0.50 | 0.5 | 14197 | Hundred | Fifty |

# Experiment 3: Results

## Predictions found from the experimental data vs Predictions done by our model



# Conclusion

- Participants in experiments tended to make causal inferences based on the temporal order of events and the presence of a singular cause.
- People use mental simulations and counterfactual reasoning to make causal inferences, and these processes can be influenced by individual differences, task demands, and other contextual factors.

# Extension

- Incorporate the role of multiple causes in causal inference and investigating the impact of context on causal inference