

# Attentional mechanisms drive systematic exploration in young children

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## Background

Exploration, or searching for information, is critical for discovering how the world works.

Exploration should be particularly crucial for young children, who have little knowledge about the world.

Converging evidence suggests that systematic exploration is primarily sub-served by prefrontal cortex.

Despite immature PFC early in development, recent research suggests that systematic exploration predominates in young children's choices, indicating that this systematic exploration may be driven by different mechanisms than in adults.

We hypothesize that young children's exploration may instead be more intimately tied to perceptual mechanisms.

In particular, their tendency to distribute attention may promote broad information gathering, facilitating exploratory choice behavior.

This leads to the prediction that interrupting distributed attention allocation through bottom up attentional capture would also disrupt systematic exploration.

## Method

### Design

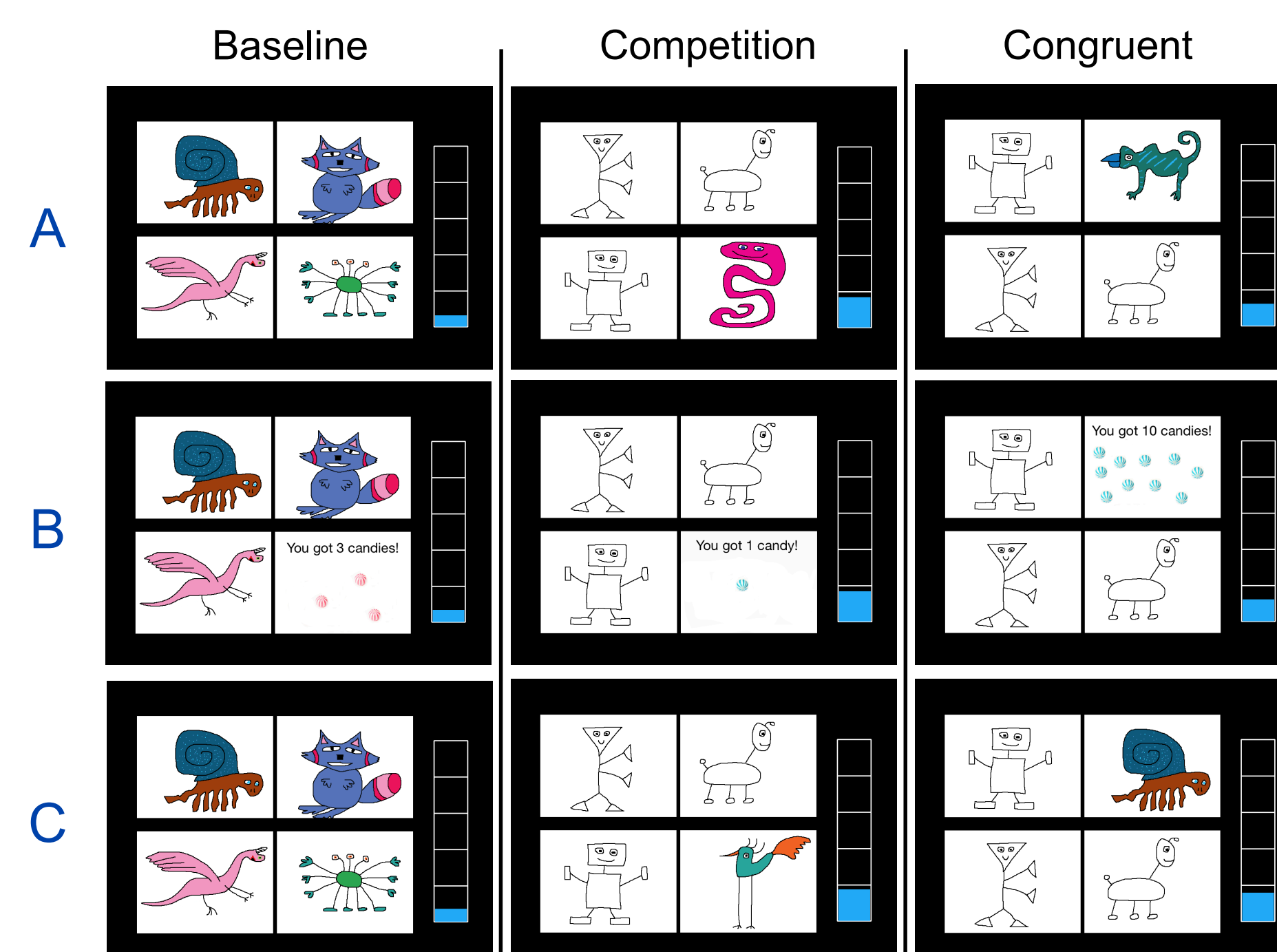
Four-year olds completed a simple decision-making task in one of three conditions that differed in perceptual salience of the choice options. In the Baseline condition all options were of equal salience. In the Congruent condition the highest value option was of greater salience than the other options. In the Competition condition the lowest value was of greater salience than the other options.

### Participants

Baseline	36
Competition	37
Congruent	37

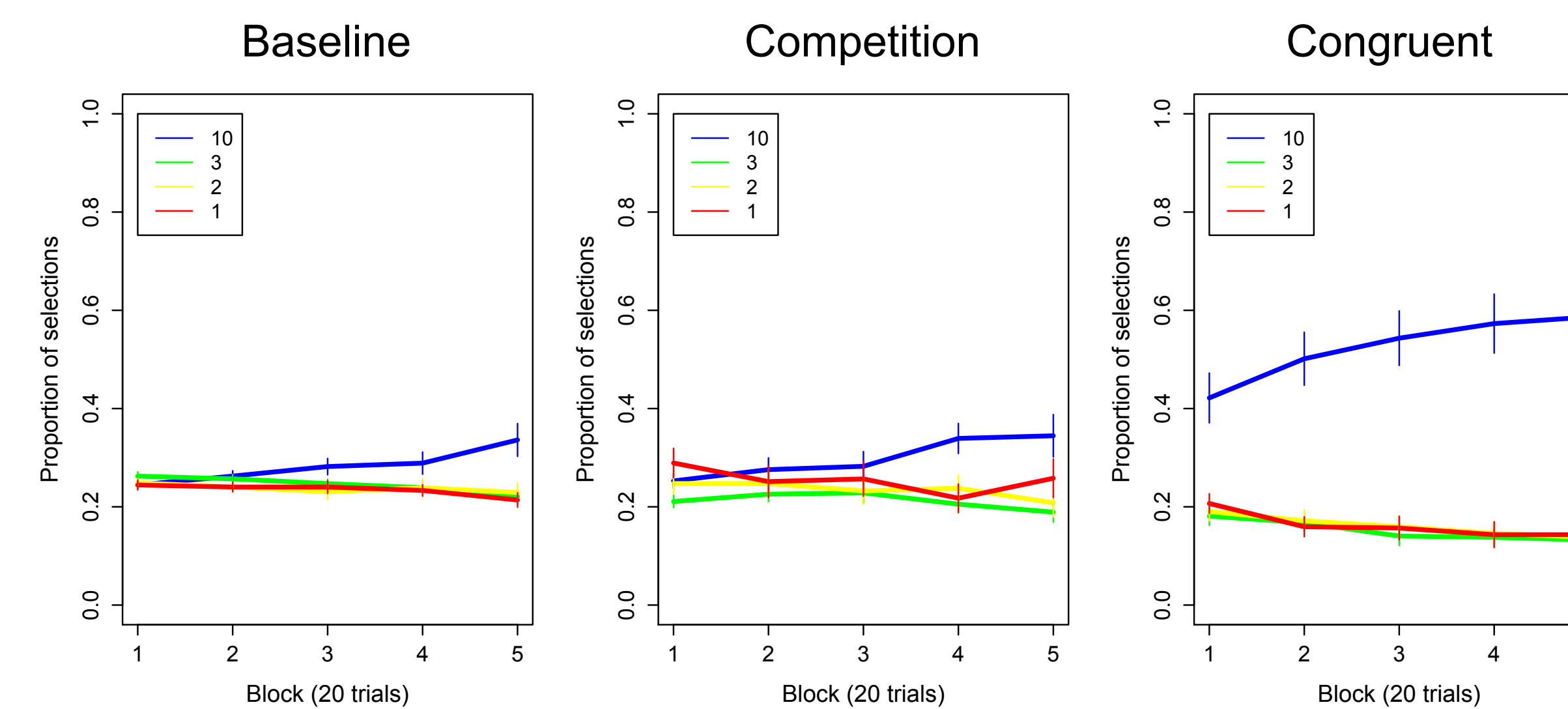
### Task Details

Participants completed 100 trials of the task. (A) On each trial they chose one of four creatures, and (B) received a reward for their choice. (C) A meter kept track of total candy collected. Benchmarks on the meter marked points at which real rewards (stickers) were earned. Rewards were stable across trials and highly separable (10, 3, 2, and 1 virtual candies).



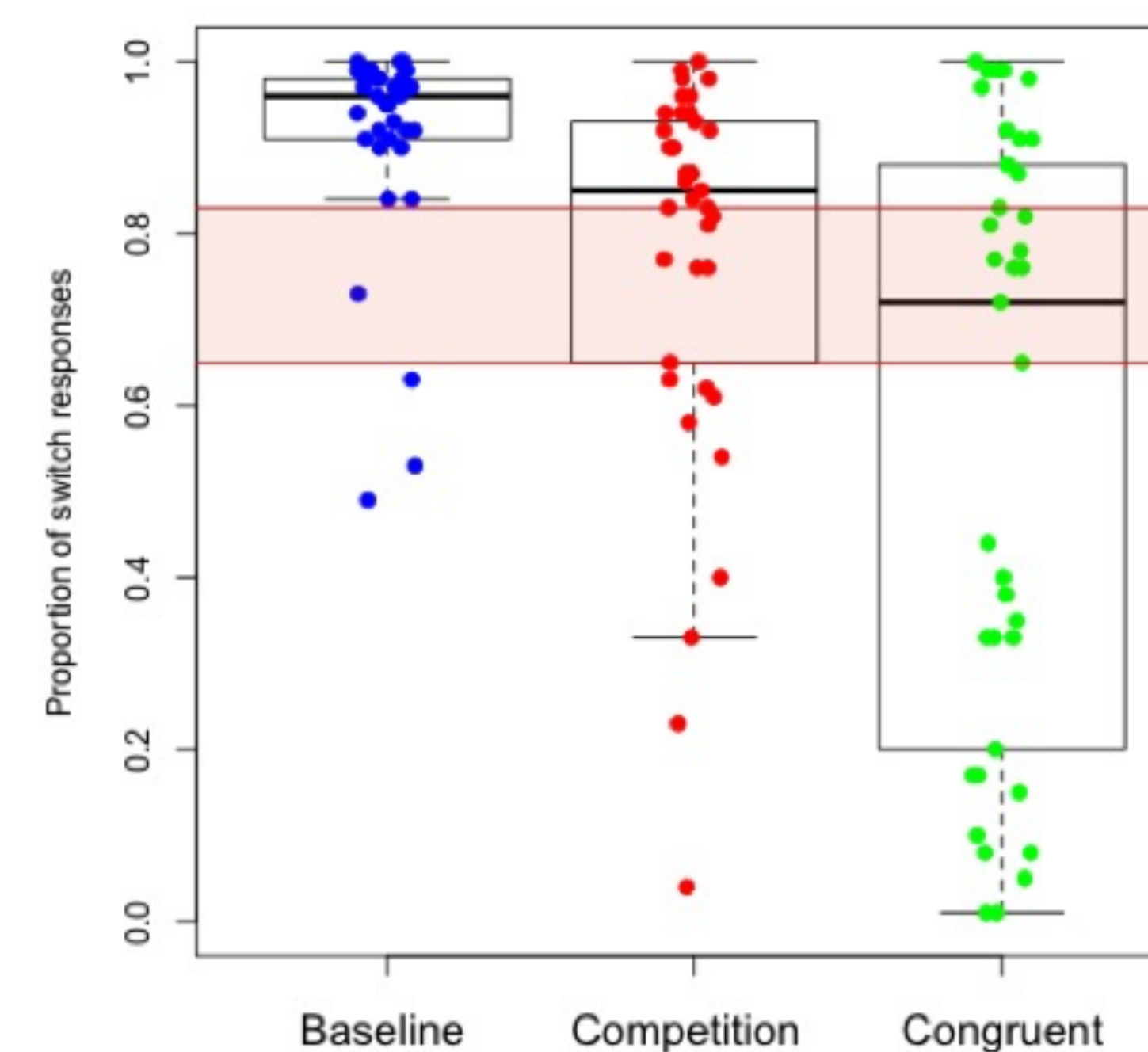
## Results

### Choice proportions



Children in the Congruent condition chose the best option substantially more often than the other conditions, but the salient option was not chosen more often than other options in the Competition condition, suggesting an interaction between salience and reward in determining choices.

### Response switching



Replicating previous findings, the majority of children switched between options well above chance in the Baseline condition. Switching was substantially lower in both the Congruent and Competition conditions, suggesting lower levels of exploration. This may be expected in the Congruent condition, due to increased exploitation, but is surprising in the Competition condition.

## Computational Modeling

$$P(a_{i,t}) = \frac{e^{\beta * [V_{i,t} * (1 - \phi) + L_{i,t} * \phi]}}{\sum_{j=1}^n e^{\beta * [V_{j,t} * (1 - \phi) + L_{j,t} * \phi]}}$$

$V_{i,t}$  : point value

$\beta$  : controls random exploration

$L_{i,t}$  : choice lag

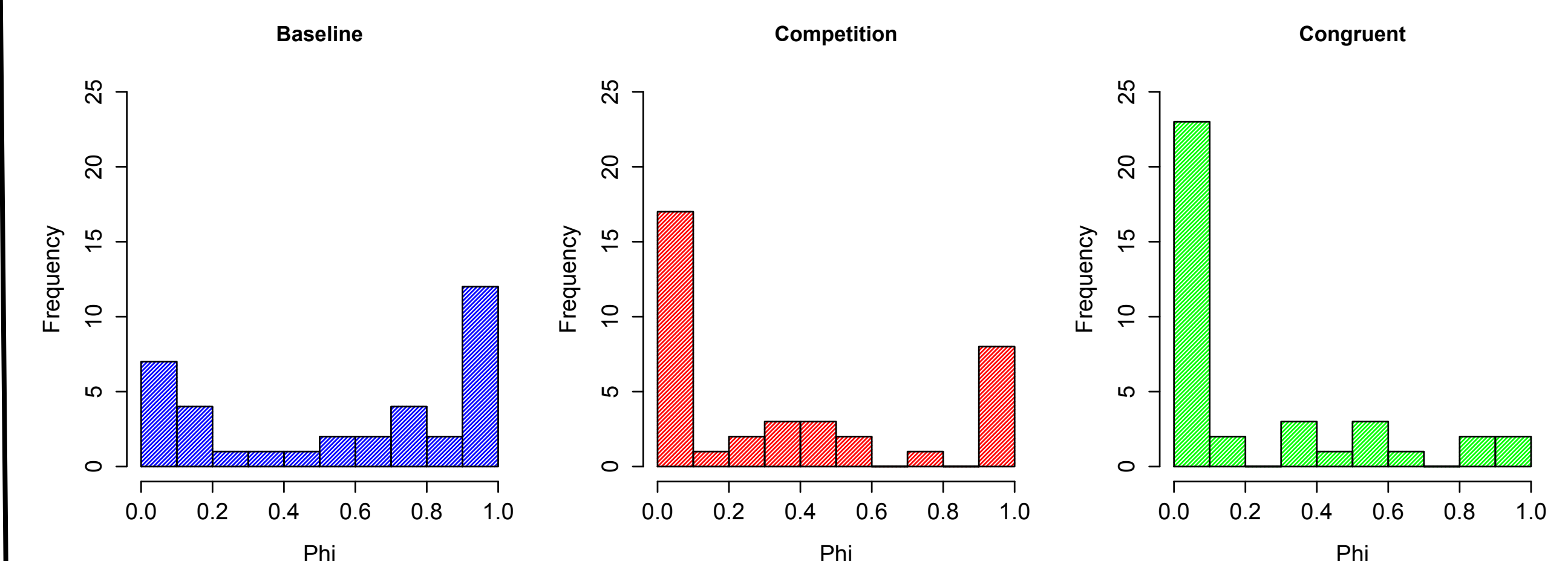
$\phi$  : controls systematic exploration

This model allows us to separate systematic from random exploration, while also providing an estimate of the relative influences of reward value and systematic exploration in determining choices.

The full model was compared a model that did not include systematic exploration (where  $\phi = 0$ ). The full model better fit the large majority of Baseline participants, but better fit only about half of the participants in both the Congruent and Competition conditions.

### Best-fitting Model

	Full model	$\phi = 0$
Baseline	31	5
Competition	20	17
Congruent	18	19



Best-fitting phi value showed different distributions between conditions, with a much greater proportion of low values in the Congruent and Competition conditions compared to Baseline, indicating lower systematic exploration in those conditions.

## Discussion

Manipulating bottom-up attention decreased the level of systematic exploration in young children compared to a Baseline condition.

In addition, children's choices were not simply salience-driven; salience interacted with reward suggesting a complex role of attention in determining young children's choices.

These results point to an integral role of attentional mechanisms in systematic exploratory behavior in young children, in contrast to the top-down PFC mediated processes involved in systematic exploration in adults.

Attentional mechanisms and exploratory decision-making may be part of a larger general pattern in which young children's cognition and behavior are specifically tuned to facilitate broad information gathering—which is particularly critical early in life.