**Adults' use of latent causes for trait inference and direct causes for event prediction**

# Update to Pre-registration

**1. The results of the study - and the unexpected finding**

Upon running the study, the result was partially expected: subjects responded with the similar item above chance in the Event Prediction condition; however, subjects responded with the causal item at chance levels in the Trait Inference condition (Figure U1). This latter result was unexpected, and so we decided to explore the reason for chance performance in the Trait Inference condition.

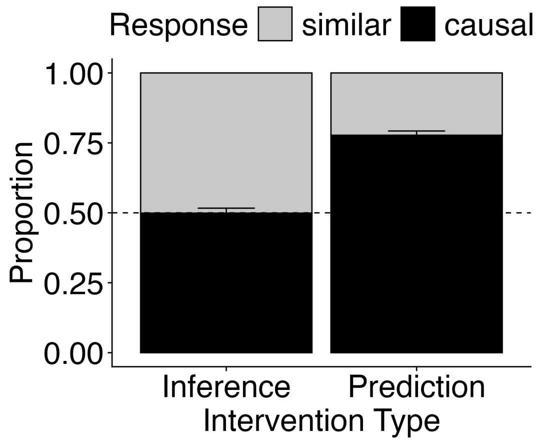



*Figure U1: Preliminary data from the two conditions: subjects select causal choice at higher rates than chance in the prediction condition, and select the similar choice at chance levels in the trait inference condition.*

**2. Exploring reasons for the unexpected finding**

We suspected that the unexpected pattern in the Inference condition was because the pre-registered methods and instructions we followed differed from our pilot study. We identified the two ways in which the pre-registered experiment deviated from the pilot, and re-ran the experiment after accounting for the differences. The differences were as follows:

Firstly, the exact wording of the instructions differed from the wording used in the pilot. In the pilot, the wording on the test question emphasized inferring which capacities co-occur in the creature "Suppose someone told you about a creature that could {jump up and down}. Which of these two other abilities do you think the creature would also have?", whereas in the pre-registered experiment, the wording was more ambiguous about whether it was asking for a capacity which co-occurs or a capacity which causally follows from the target capacity "Suppose that a creature has the capacity to {jump up and down}. Which of these two things can the creature also do? The creature can ..". This omission was made in error.

To test for whether this more ambiguous wording explained our null findings, we ran an additional pilot (pilot 2) using wording that more closely resembled the first pilot, and additionally emphasized that the creature should be able to do only one of the abilities and not the other (see section 3): "Suppose someone told you about a creature that could jump up and down (target ability). The creature has one of the following two abilities, and not the other. Which of these two do you think the creature has?" We found that, in line with our pre-registered prediction and suspicion, subjects selected the causal choice less than chance in this new pilot. Thus we are proposing to re-run this study with the updated wording.

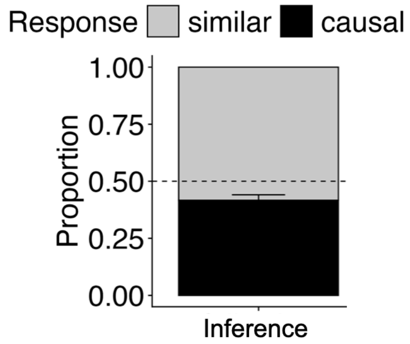



Figure U2: Data from the exploratory Inference study using wording that more closely matched the original pilot. Subjects select the causal item less than chance in this Inference condition.

### 3. Updates to the pre-registration

#### a) Updated stimuli

Armed by this new discovery, we decided to re-preregister the Prediction vs Inference study. The only difference from the original pre-registration is that in the updated Trait Inference condition, we will use the exact wording from our follow-up pilot. This wording more closely resembles the original pilot and also emphasizes that the creature can only do one of the two choice abilities. The wording for the two conditions will now be as follows:

**Trait Inference Condition**

**Instructions**

Welcome! In this game you will be asked to imagine abilities a creature might have. On each trial, the creature will have a target ability (for example, “the capacity to choose what to do”) and two other possible abilities (for example, “the capacity to see something” and “the capacity to get tired”). Your job is to choose which of the two abilities the creature would also have.

**Trials**

Suppose someone told you about a creature that could jump up and down {**target ability**}. The creature has one of the following two abilities, and not the other. Which of these two do you think the creature has?

**Choices**: The ability to get tired {**causal choice**}; The ability to jump up and down {**similar choice**}

**Event Prediction Condition**

**Instructions**

Welcome! In this game you will be asked to predict what will happen in different scenarios. On each trial, there will be a target event that occurs (for example, "a person feels nervous"), and two possible events which could follow (for example "the person experiences joy" or "the person leaps over something"). Your job is to choose the event that you think most likely follows from the target event.

**Trials**
Suppose that a person first jumps up and down {**target ability}.** Next, one of these two things will happen, and not the other. Which of these two events will happen next? The person will…
**Choices**: get tired {**causal choice**}; take a walk {**similar choice**}

**b) Power analysis for Confirmatory Analysis for the updated experiment:**

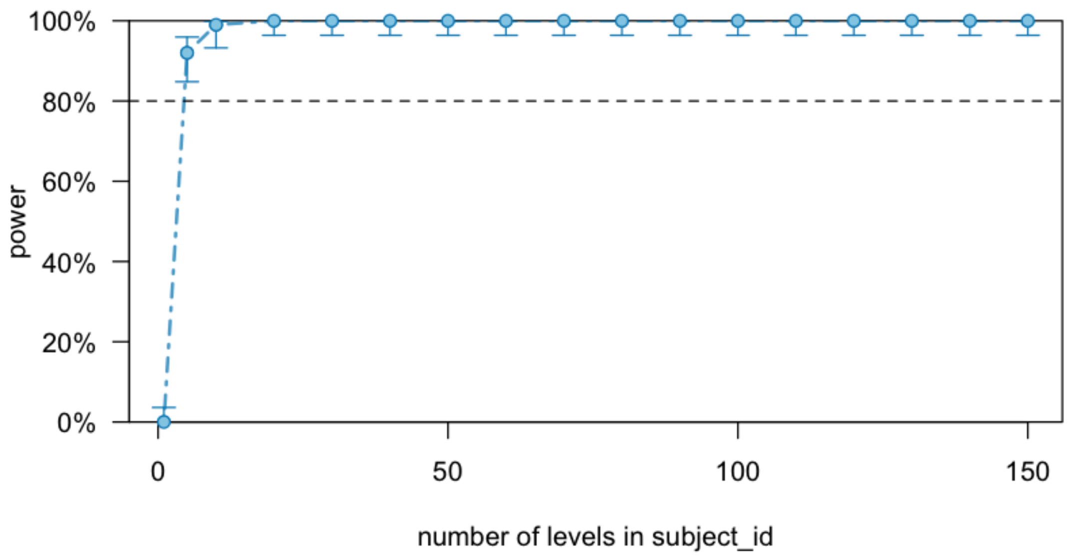
We used the R package *simr* to estimate the power curves for replicating the 2 predicted results. For power analysis purposes, we ran two models targeting each prediction separately: a Prediction-only model for detecting if the mean proportion responding with the causal item in Prediction condition is above chance, and a separate Inference-only model for detecting if the mean proportion responding with the similar item in Inference condition is above chance.

Based on a pilot study (N = 100), the sample size needed to achieve 80% power to replicate the Prediction effect is N<5 and the sample size to replicate the Inference effect is N<40 (Figure U3).

**c) Stopping rule and exclusions for the updated experiment:**

Considering the largest sample required to replicate all effects (N = 40), and that the effect size in the pilot could be inflated due to a small sample size, we conservatively estimate a target sample of 100 participants. To account for a <1% exclusion rate from the pilot study, we will conservatively collect data from 105 participants, prior to exclusions.

(a) Prediction-only



(b) Inference-only

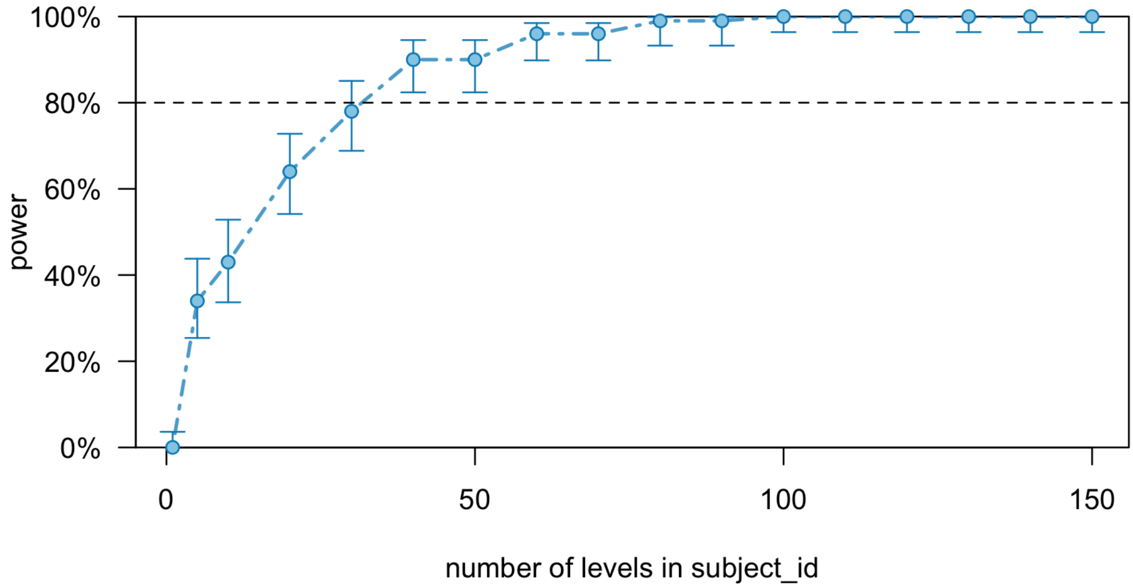



**Figure U3(a-b):** Power curve showing the power that would be achieved (y-axis) using different sample sizes (x-axis) to replicate the fixed effects for the responses ~ condition + (1 | subject_id) models with different datasets. (a) Shows power curve for the Prediction-only model, and (b) shows power curve for the Inference-only model.

**—End of Preregistration Update—**

# Background

This study builds on a prior pre-registered experiment conducted in our lab (Study 1, June 2025: [link redacted for future double-blind review]) which investigated the hypothesis that adults use two representational spaces to organize mental, physical and bodily events. One space groups events based on underlying latent factors, and another space describes how specific events are directly causally connected to each other. Specifically, study 1 found that: (1) adults represent 3 latent factors namely “the mind”, “the mechanical body” and “the biological body” that organize mental events, actions, and physiological events respectively, and (2) adults hold a distinct representation of how events within and across the latent factors causally relate to each other.

An open question regarding the two representational spaces is what kind of content they articulate. One possibility is that these two spaces are intuitive causal-explanatory framework theories about how other people work. Prior work has shown that intuitive theories are common-sense, abstract, causal-explanatory frameworks that help us navigate the world (Gerstenberg & Tenenbaum, 2017; Gopnik & Wellman, 1994). They help people reason about events from different domains: Intuitive psychology, for example, conceives of actions as causally connected to mental states, which allows people to explain, predict and intervene on other agents’ minds and behaviors. Intuitive theories also help people reason about events within the same domain: children’s intuitive understanding of the biological domain helps them explain, predict and plan interventions on bodily states to prevent states of illness and disease, and to infer that members of living species that share internal structure—not superficial perceptual features—will have similar properties (Degn et al., 2025; Gelman & Markman, 1987).

Here, we propose to test the hypothesis that the judgments that we measured in Study 1 constitute two distinct intuitive theories that help us make sense of other agents as mental beings, physical actors, and living systems in terms of (1) Latent Causes and (2) Direct Causes. If the representational spaces measured in Study 1 constitute intuitive theories, then even when not asked to, adults should recruit these beliefs for prediction, explanation, counterfactuals, and intervention. If these two spaces represent two distinct ways of reasoning causally about other agents, then we should be able to predict when people will use beliefs about Latent Causes vs Direct Causes.

In summary, in the current work we propose to test for the functional roles of the Latent Causes and Direct Causes frameworks as distinct intuitive causal theories in common-sense social cognition.

# General Alternative Hypothesis

*The two frameworks (Latent Causes and Direct Causes) support common-sense reasoning:* We hypothesize that the two causal frameworks measured in Study 1 are the basis for our intuitive reasoning within and across the domains of mind, action and body. We predict that adults will spontaneously make use of these representations for inference, explanation, intervention, and counterfactual reasoning.

*The two frameworks do not support common-sense reasoning:* An alternative hypothesis is that while adults can report their beliefs about how mental events, actions, and physiological events are organized when explicitly asked to (like in Study 1), they do not make use of these beliefs during everyday social cognition.

# Current Study

Prior work has demonstrated that infants, children and adults use their intuitive theories to predict future states of the world, such as where a billiard ball will go, or what an agent with false beliefs will do (Gerstenberg & Tenenbaum, 2017; Gopnik & Wellman, 1994). Predictions are made by conditioning on present observations and running forward a causal model to simulate possible future outcomes. Prior work also shows that children and adults can make inferences about the abilities and properties of living kinds, including which abilities tend to co-occur and their hierarchical similarity structure based on a folk taxonomy (Hatano & Inagaki, 1994; Inagaki & Sugiyama, 1988; Kim et al., 2019; Weisman et al., 2021). Following up on prior work from our lab (Study 1), this study tests whether people preferentially use representations of direct causes (i.e. whether A can make B happen) to predict what will happen next, and representations of latent causes (i.e. what is the common cause of A and B) to make an inference about an agent's capacities. By hypothesis, direct causes are relevant for making predictions about immediate future states, and latent causes are relevant for making inferences about co-occurring traits. Thus, we designed a prediction and inference task: In the prediction task (Event Prediction), participants consider which of two possible events will follow from a target event: either an event which is **caused by** the target event or an event which is **similar** owing to sharing a common cause with the target. In the inference task (Trait Inference) participants consider which of two possible things a creature can do, given that they have a target ability: either an ability which is **caused by** the target ability or one which is **similar** to the target owing to having a common cause with the target.

We constructed a stimulus set based on the items and results of Study 1. The set consists of 15 triads of items, each triad consisting of a **target** item (such as "get tired") and a choice set of two items: an event that was most **similar** (i.e. close by in the Sorting Task RDM, but far away in terms of causal successor distance in the Causal Task RDM) to the target, and an event that the target was most likely to cause happen (**causal** item; i.e. a close-by causal successor in the Causal Task RDM but far away in the Sorting Task RDM). Thus, we chose these items based on their joint causal and similarity distance from the target: similar items had lowest similarity distance and largest causal successor distance to the target, whereas causal items had lowest causal successor distance and highest similarity distance to target. We constrained the similar option to be from the same domain as the target (this was already true for 13/15 target items), and the causal option to be from a different domain (this was already true for all target items). The full set of 15 item triads and their respective distances are listed in Figure 1.

| Target and Choice Items | | | |
|---|---|---|---|
| Domain | Target Item | Causal Choice (Causal Distance, Freesort Distance) | Similar Choice (Causal Distance, Freesort Distance) |
| mind | see something | feel scared (0.12, 0.54) | hear something (0.44, 0.18) |
| | hear something | feel scared (0.12, 0.48) | see something (0.42, 0.18) |
| | choose what to do | feel scared (0.28, 0.54) | hear something (0.5, 0.49) |
| | remember something | feel scared (0.15, 0.52) | hear something (0.51, 0.32) |
| | think about something | feel scared (0.14, 0.54) | hear something (0.49, 0.34) |
| action | reach for something | experience pain (0.29, 0.58) | take a walk (0.62, 0.41) |
| | sit down | think about something (0.26, 0.61) | jump up and down (0.83, 0.3) |
| | jump up and down | get tired (0.1, 0.54) | take a walk (0.64, 0.24) |
| | kick something | experience pain (0.13, 0.51) | take a walk (0.59, 0.33) |
| | take a walk | get tired (0.12, 0.53) | jump up and down (0.63, 0.24) |
| body | get tired | sit down (0.09, 0.46) | become hungry (0.44, 0.3) |
| | become hungry | think about something (0.19, 0.58) | feel scared (0.55, 0.44) |
| | feel scared | think about something (0.14, 0.54) | become hungry (0.67, 0.44) |
| | experience pain | sit down (0.13, 0.58) | become hungry (0.61, 0.4) |
| | get sick | sit down (0.14, 0.55) | become hungry (0.49, 0.36) |

**Figure 1**: Stimuli for the current study based on group-averaged responses from two separate samples (total N = 151). The first two columns list the target events and their domains. The remaining two columns list the two options (the “causal choice” vs “similar choice”) associated with that target, and their similarity and causal distance from the target.

# Hypothesis

We hypothesize that when people make predictions about future events, they rely on representations of direct causes (i.e. whether A can make B happen), and when people infer which traits co-occur in an agent, they rely on representations of latent causes (i.e. whether A and B are both caused by a common variable). Specifically, when people are presented with a target event (e.g. target = jump up and down; causal choice = get tired; similar choice = take a walk), they will select the direct cause when predicting what would happen after the target event (e.g. the creature will get tired) and they will select the item with a shared latent cause when inferring which other ability a creature has (e.g. the creature can also take a walk).

We predict that people will be (1) more likely to select the causal item in the Event Prediction than Trait Inference condition, and that they will be (2) more likely than chance to select the causal item in the Event Prediction condition, and (3) less likely than chance to select it item in the Trait Inference condition.

**Dependent variable**

On each trial, the choice between the **causal** and **similar** item.

**Independent variable**

Whether the task involves making an **Event Prediction** or a **Trait Inference.**

# Procedure

Subjects will be randomly assigned to two conditions. Subjects in each condition will be presented with the following instruction page:

> **Event Prediction condition**: Welcome! In this game you will be asked to predict what will happen in different scenarios. On each trial, there will be a target event that occurs (for example “a person feels nervous”) and two possible events which could follow (for example, “the person experiences joy”, or “the person leaps over something”). Your job is to choose the event that you think most likely follows from the target event.
>
> **Trait Inference condition:** Welcome! In this game you will be asked to imagine what a creature can do. On each trial, the creature will have a target ability (for example, “the capacity to feel nervous”) and two other possible abilities (for example, “the capacity to experience joy” and “the capacity to leap over something”). Your job is to choose the ability that you think the creature is most likely to also have.

The next pages will present 15 trials in each condition, randomly interspersed. Across both conditions, trials will consist of a test question and two alternatives in a forced-choice paradigm. The trials will read as follows:

> **Event Prediction condition:** Suppose that a person first **jumps up and down.** Which of these two events will happen next? The person will…
>
> **Trait Inference condition**: Suppose that a creature has the capacity to **get tired.** Which of these two things can the creature also do? The creature can…

Each of the 15 targets will be shown once per condition. Below the test question will be an option between a similar choice and a causal choice. The left-right positions of the choices will be randomised across trials.

There will be two randomly interspersed attention checks, and participants will be excluded if they failed at least one attention check.

After the 30 trials, subjects will be presented with a debrief followed by a demographics questionnaire.

# Analysis Plan

To test for our 3 predictions—namely, that people will be (1) more likely to (1) select the causal item in the Event Prediction than Trait Inference condition (2) more likely than chance to select the causal item in the Event Prediction condition, and (3) less likely than chance to select the causal item in the Trait Inference condition—we will use a mixed effects logistic regression using the lme4 package (Bates et al., 2015) in R. The model specification will be: **response ~ condition + (1 | subject_id), family = binomial(link = ‘logit’)**. We will set the reference group to be the Trait Inference condition, thus the “intercept” will represent the log-odds of selecting the causally relevant item in the Trait Inference condition, the slope coefficient will capture the log-odds difference between the Trait Inference and Event Prediction conditions, and the sum of the intercept and the condition coefficient will give the log-odds of selecting the causally relevant item in the Event Prediction condition. We will confirm our first prediction if the slope coefficient is significant, and we will confirm our second and third predictions by running ‘allEffects()’ from the *effects*’ package, which will generate confidence intervals that show whether each condition mean is different from chance.

Our threshold for statistical significance will be p = .05, two-tailed, and we will use the check_model() function from the performance package (Lüdecke et al., 2021) to conduct quality assurance.

# Sample Size and Stopping Rule

Considering previous pre-registered studies in our lab that investigate adults’ abilities to use the two representational spaces for the related functions of intervention, explanation and counterfactual reasoning ([osf links redacted for peer review]), we conservatively estimate a target sample of 100 participants. To account for a <1% exclusion rate from the pilot study, we will conservatively collect data from 105 participants, prior to exclusions.

# References

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models Usinglme4. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Degn, P., Fiber, Z., & Sullivan, J. (2025). Children’s understanding of the causal mechanisms underlying disease prevention. *Cognitive Development*, *74*(101563), 101563. https://doi.org/10.1016/j.cogdev.2025.101563

Gelman, S. A., & Markman, E. M. (1987). Young children’s inductions from natural kinds:

The role of categories and appearances. *Child Development*, *58*(6), 1532. https://doi.org/10.2307/1130693

Gerstenberg, T., & Tenenbaum, J. B. (2017). *Intuitive Theories* (M. R. Waldmann (ed.)). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199399550.013.28

Gopnik, A., & Wellman, H. M. (1994). The theory theory. In L. A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the Mind* (pp. 257–293). Cambridge University Press. https://doi.org/10.1017/cbo9780511752902.011

Hatano, G., & Inagaki, K. (1994). Young children's naive theory of biology. *Cognition*, *50*, 171–188. https://doi.org/10.1016/0010-0277(94)90027-2

Inagaki, K., & Sugiyama, K. (1988). Attributing human characteristics: Developmental changes in over- and underattribution. *Cognitive Development*, *3*(1), 55–70. https://doi.org/10.1016/0885-2014(88)90030-5

Kim, J. S., Elli, G. V., & Bedny, M. (2019). Knowledge of animal appearance among sighted and blind adults. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(23), 11213–11222. https://doi.org/10.1073/pnas.1900952116

Lüdecke, D., Ben-Shachar, M., Patil, I., Waggoner, P., & Makowski, D. (2021). Performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software*, *6*(60), 3139. https://doi.org/10.21105/joss.03139

Weisman, K., Legare, C. H., Smith, R. E., Dzokoto, V. A., Aulino, F., Ng, E., Dulin, J. C., Ross-Zehnder, N., Brahinsky, J. D., & Luhrmann, T. M. (2021). Similarities and differences in concepts of mental life among adults and children in five cultures. *Nature Human Behaviour*, *5*(10), 1358–1368. https://doi.org/10.1038/s41562-021-01184-8