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Aboody, Rotem

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Contents

<i>How Does Imagining Outcomes Affect Children's Causal Reasoning</i> — Rotem Aboody	4
<i>Residue or Residon't? The Value of Archaeological Micro-debris in Unraveling Dhiban's Imperial Past</i> — Nicholas P. Ames	12
<i>The Khmer Tour Guide: An Economical, Political and Cultural Nexus in Siem Reap, Cambodia</i> — Rose Gephart	21
<i>Understanding Mechanism Behind Cultural Differences in Seeking Propensity</i> — Josephine Juanamarga	27
<i>The Food System and a Role for Ecological Ethics</i> — Isaac Kreisman	43
<i>Community and Exclusion in the Gay Mecca</i> — Andrew Levine-Murray	49
<i>Understanding and Self-Advocacy: Students with Learning Disabilities, Unrecognized Talent</i> — Tabitha A. Mancini	54
<i>The Constructed Landscapes of Horace's Poetic Autobiography in the Odes</i> — Erin Lam	61

<i>Contemplative Neuroscience: An Integrative Approach for Investigating Consciousness</i> — Dayna Stimson	67
<i>Caya Coven: Eclectic Paganism in the East Bay Area</i> — Jennifer Stover	74
<i>The Poetics of Punk: The Ramones</i> — Alex Taitague	81
<i>Dutch New York: Multiculturalism in New Amsterdam</i> — Marissa Teitalman	86
<i>Beyond the Binary: New Roles and Implications of NGOs in Haiti</i> — Julia Uyttewaal	91
<i>Teuf Love: Verlan in French Rap and Youth Identity</i> — Kelsey Westphal	97
<i>Street Theater at Astor Place: The Silk Stocking Regiment and the Politics of Public Performance</i> — Eli Wirtschafter	102
<i>Taking Steps: Exploring College Predispositions in College Track, Oakland Youth</i> — Katherine Zepeda-Arreola	110
<i>The Body as a Vehicle for Memory: Perec, Mishima, and the World That We Traveled in One Summer</i> — Lisa Levin	116
<i>Taking up Space: Locating Thoreau, Whitman, and Kerouac in Place</i> — Robyn Taylor	122

HOW DOES IMAGINING OUTCOMES AFFECT CHILDREN'S CAUSAL REASONING?

By Rotem Aboody

I. Introduction

Why do children spend so much time engaged in pretend play, imagining possibilities that may never come to pass? Why expend so much energy considering unreal worlds when there is still so much to learn about the real one? What could children possibly be gaining from this process, which at first glance may seem to produce enjoyment and little else?

Previous research into the possible effects of pretend play on development has been inconclusive, finding correlations in some domains and none in others. For example, it has been found that when framed in a pretend context, children's reasoning about certain logical syllogisms actually improves.^{1,2} Additionally, pretend play seems to positively influence understanding and production of narratives containing a complex series of associated causal events.³ It has also been proposed that pretend play is linked to later development of theory of mind.^{4,5} However, results in this domain (in addition to the domains of language and self-regulation) have been largely correlational and somewhat inconsistent, casting into doubt the direction of the effects.⁶ In addition, research into the possible effects of pretend play on development has found no correlation in the domain of creativity, and only inconsistent results in the domains of problem solving and social skills.⁷ While children who are more likely to engage in pretend play in naturalistic scenarios are also more likely to be intelligent, experimental manipulations have revealed no conclusive causal relationship between these two factors.⁸

1 Gentil M. Dias and Paul Harris. "The Effect of Make-Believe Play on Deductive Reasoning." *British Journal of Developmental Psychology* 6, no. 3 (1988): 219.

2 Gentil M. Dias, and Paul Harris. "The Influence of the Imagination on Reasoning by Young Children." *British Journal of Developmental Psychology* 8, no. 4 (1990): 314-16.

3 Jeffrey L. Danksy, "Cognitive Consequences of Sociodramatic Play and Exploration Training for Economically Disadvantaged Preschoolers." *Journal of Child Psychology and Psychiatry* 21, no. 1 (1980): 56.

4 Alan M. Leslie, "Pretense and Representation: The Origins of "Theory of Mind."" *Psychological Review* 94, no.4 (1987): 416.

5 Alan M. Leslie, "Pretending and Believing: Issues in the Theory of ToMM." *Cognition* 50 (1994): 214-16.

6 Angeline S. Lillard, Matthew D. Lerner, Emily J. Hopkins, Rebecca A. Dore, Eric D. Smith, and Carolyn M. Palmquist. "The Impact of Pretend Play on Children's Development: A Review of the Evidence." *Psychological Bulletin*. Advance online publication. (2012) no pagination specified, accessed Nov. 10, 2012, doi:10.1037/a0029321.

7 Ibid.

8 Ibid.

What is lacking in this literature is a coherent theory that details the mechanisms by which engaging in pretense leads to learning. Pretense clearly enhances certain skills; why might skills such as syllogistic reasoning be affected, while creativity is not? In an attempt to explain the disparities in this field, Walker and Gopnik have put forth the following proposal: They postulate that pretending engages a special type of reasoning called counterfactual reasoning.⁹ They believe that this type of reasoning is central to children's exploration and understanding of the world's causal underpinnings.¹⁰ Therefore, according to this theory, children's engagement in pretend play not only helps them learn about the world's causal relations through counterfactual reasoning, but also strengthens the cognitive processes required for this reasoning to occur.¹¹

II. Background

What is causal reasoning? Intuitively, causal reasoning is defined as the ability to recognize one or more events as *causing* another event.¹² Effective causal reasoning requires knowledge of the underlying structures of the world; without a good understanding of these structures, it is difficult to make accurate predictions about the consequences of events. Once acquired, this knowledge can be organized into a web of interrelated variables called a *causal map* (see Figure 1).^{13,14} For example, if I were to slip and accidentally push my laptop off of a table, it would fall to the ground. I know this, even though this has never happened to me before, because I understand the underlying causal relations of the world: I understand that a gravity-like force exists, and that this force pulls things towards the ground.

Because I understand this causal relation, I can form a causal map like the one that appears in Figure 1. This map not only allows me to reason about the causal structure of the world, but it also allows me to compute the probability of each event causing the subsequent event to occur. For example, my laptop may not be next to me every time that I slip; therefore I might only actually push my laptop after slipping, say, 15% of the time. However, the rest of the relationships in this causal map are fairly reliable; gravity almost always pulls things towards the earth, and if I push my laptop, chances are that it will fall most of the time; therefore, these events have a high probability of causing each other.

At first, causal learning and imagination may seem to belong to completely different domains; as anyone may point out, human imagination is not necessarily constrained by causal relationships observed in the real world. However, further examination will reveal that imagination and causal learning are indeed closely related. In fact, the ability to imagine possibilities is an essential component of recent computational accounts of causal learning.^{15,16} We often reason about causal relationships in order to imagine alternative outcomes, and we imagine alternative outcomes to reason about causal relationships. In the laptop example, I can imagine that pushing my laptop hadn't made it fall (which would result in a different causal relationship), thus imagining

9 Walker, Caren M. and Alison Gopnik. "Pretense and Possibility – A Theoretical Proposal About the Effects of Pretend Play on Development: Comment on Lillard, Lerner, Hopkins, Dore, Smith, & Palmquist (2012)." *Psychological Bulletin*. In press.

10 Ibid.

11 Ibid.

12 Alison Gopnik, Clark Glymour, David M. Sobel, Laura E. Schulz, Tamar Kushnir, and David Danks. "A Theory of Causal Learning in Children: Causal Maps and Bayes Nets." *Psychological Review* 111 (2004): 6.

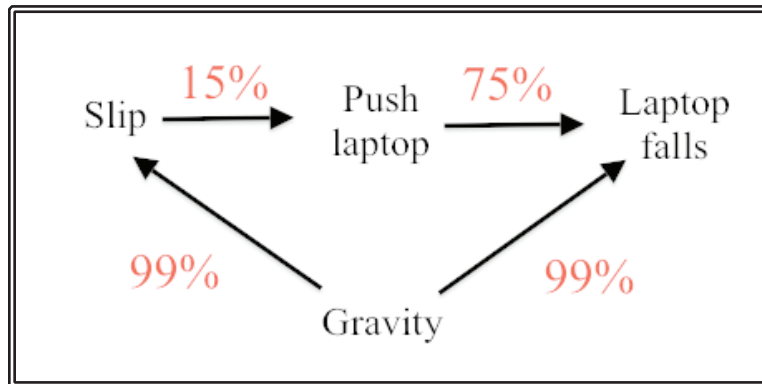
13 Ibid., 5.

14 Clark Glymour. "Learning, Prediction, and Causal Bayes Nets." *Trends in Cognitive Science* 7, no. 1 (2003): 43.

15 Caren M. Walker and Alison Gopnik. "Causality and Imagination" in *The Development of Imagination*. Edited by Marjorie Taylor. New York: Oxford University Press, in press.

16 Sloman, Steven A., and David A. Lagnado. "Do we "do"?" *Cognitive Science* 29 (2005): 5.

FIGURE I
AN EXAMPLE OF A CAUSAL MAP



an alternative in which my laptop remains in its place. Or, I can start by generating an alternative outcome: imagining that my laptop hadn't fallen. If my laptop hadn't fallen, then either gravity does not exist, I must not have slipped, or I must not have pushed it. I can thus reason about the existing causal relationships by imagining a different outcome.

When we imagined that pushing the laptop had not made it fall, thus changing a variable in the causal map, we performed an *intervention*: one variable of the causal map was changed, while the others remained constant. And when this premise was followed through to the conclusion that the laptop would not have fallen, a *counterfactual*, an imagined alternative, was produced. In this manner, causal maps can allow learners to reason about and operate on the causal structure of the world. A causal understanding of the world is crucial for counterfactual reasoning abilities, because if one does not understand the causal relations of the world, it is impossible to predict what would happen if the causal relations were different.

The ability to imagine alternatives is a crucial component of recent Bayesian accounts of learning.¹⁷ Scientists who ascribe to a Bayesian view of learning believe that children and adults learn through a process of theory revision, much as scientists themselves form and alter theories.^{18,19} In this view, learners begin with a prior hypothesis, a way they believe the world works (for example, I believe that gravity exists). Learners can then generate alternative causal models in an attempt to find a better theory (I can imagine a world in which gravity does not exist).²⁰ Once an alternative model is generated, a learner must then generate an alternative pattern of evidence that this model would produce (if gravity does not exist, what should I observe? Objects should not fall when I drop them, etc.).²¹

The learner can then compare this alternative pattern of evidence to real-world evidence, and assess the fit between the two. Depending upon the fit, the learner can then either accept or reject the alternative causal model (if gravity did not exist, objects would not fall if I were to drop

17 Caren M. Walker and Alison Gopnik. "Causality and Imagination" in *The Development of Imagination*. Edited by Marjorie Taylor. New York: Oxford University Press, in press.

18 Ibid.

19 Daphna Buchsbaum, Sophie Bridger, Deena S. Weisberg, and Alison Gopnik. "The Power of Possibility: Causal Learning, Counterfactual Reasoning, and Pretend Play." *Philosophical Transactions of the Royal Society* 367 (2012): 2204.

20 Ibid.

21 Ibid.

them. But objects do indeed fall, so I reject the alternative causal model).²² Clearly, counterfactual reasoning abilities are a crucial prerequisite to Bayesian learning; for Bayesian learning to occur, learners must be able to reason from a premise they currently do not believe is true, and chart out its causal consequences.²³ They must be able to imagine alternatives to the current situation. In this sense, counterfactuals are enormously powerful learning tools.

Studies have shown that when adult participants are given information about a causal structure, as in the laptop example, these participants would be able to predict the results of hypothetical interventions (alterations of variables).²⁴ However, less is understood about children's abilities. We would assume that children are also good at this, given that we know children that can reason causally about the world, and engage in counterfactuals spontaneously during pretend play. Indeed, it has been shown that children are able to use information about causal structure to predict the outcome of actual novel interventions.²⁵ However, it has also been proposed that *imagined* interventions may produce results similar to actual interventions.²⁶ In essence, if children understand the causal structure on which they operate an imagined intervention should allow children to explore and pretend about alternative possibilities (produce counterfactuals) without acting in the real world.²⁷ These imagined alternatives should actually feed back into children's causal knowledge, possibly even clarifying or making more explicit the relations and potential outcomes of the entire causal system.²⁸ Therefore, we wish to investigate whether imagined interventions function similarly to actual interventions in the real world, allowing 4- and 5-year-old children to infer a high probability outcome in the absence of observation.

A recent study from our lab has provided evidence for the correlation of pretend play and counterfactual production. This study demonstrated that when introduced to a novel causal system, children's counterfactual reasoning ability is linked to their ability to engage in causally constrained pretend play (pretend play that maintains the causal rules and relations established at the beginning of play).²⁹ As this study was correlational in nature, it could be that the observed result is epiphenomenal, reflecting children's knowledge about the causal relationships of the world, and their ability to form counterfactual inferences about these relationships.³⁰ However, it may be that "pretend play itself plays a role in the development of causal thinking and learning".³¹

In 2011, Joh, Jaswal and Keen investigated the effects of visualization on gravity bias in three-year-old children. Gravity bias is the tendency of young children to believe that if a ball is dropped, it will fall to some location directly below, even if it is dropped into a tube leading to another location.³² Children in this study were assigned to one of three conditions: an *imagine condition*,

22 Ibid.

23 Caren M. Walker and Alison Gopnik. "Causality and Imagination" in *The Development of Imagination*. Edited by Marjorie Taylor. New York: Oxford University Press, in press.

24 Sloman, Steven A., and David A. Lagnado. "Do we "do"?" *Cognitive Science* 29 (2005): 27.

25 Laura Schulz, Alison Gopnik, and Clark Glymour. "Preschool Children Learn About Causal Structure from Conditional Interventions." *Developmental Science (special section on Bayesian and Bayes-Net approaches to development)* 10, no. 3 (2007): 331.

26 Caren M. Walker and Alison Gopnik. "Causality and Imagination" in *The Development of Imagination*. Edited by Marjorie Taylor. New York: Oxford University Press, in press.

27 Ibid.

28 Ibid.

29 Daphna Buchsbaum, Sophie Bridger, Deena S. Weisberg, and Alison Gopnik. "The Power of Possibility: Causal Learning, Counterfactual Reasoning, and Pretend Play." *Philosophical Transactions of the Royal Society* 367 (2012): 2205.

30 Ibid., 2209.

31 Ibid.

32 Amy S. Joh, Vikram K. Jaswal, and Rachel Keen. "Imagining a Way Out of the Gravity Bias: Preschoolers

where children were asked to imagine the trajectory of the ball before making a prediction, a *wait condition*, in which researchers described the movement of the ball through the tube before children were asked to make a prediction and a *control condition*, in which children were asked to make a choice without receiving further instructions.

First, children were familiarized with the concept of tubes (i.e. that one can roll a ball through a tube). Children were then introduced to the study apparatus, which consisted of a large wooden frame. At the top and bottom of the frame were three evenly spaced openings. The tubes could be attached so as to connect any top opening to any bottom opening. Children were first familiarized with the apparatus with no tubes attached, and after being given their condition-specific instructions, one tube was attached at a time. Children were asked to predict the trajectory of the ball before it was dropped in, so that they could then witness the path of the ball through each tube. This introduction was immediately followed by twelve test trials. All three of the tubes were attached in such a way that no tube connected a top opening to a bottom opening directly beneath it.

In each test trial, children were given their control-specific instructions to predict the final location of the ball. The ball was dropped after their predictions. Children in the *imagine condition* were more accurate than children in the other conditions at predicting the final location of the ball, and also had the lowest rate of gravity-bias errors.³³ Children in the *imagine condition* were also significantly more likely than those in other conditions to switch predictions before indicating they were ready for the ball to be dropped, and were also significantly more likely than children in other conditions to improve their performance across trial.³⁴

As we have seen, instructing young children to visualize and imagine may benefit them in certain situations. However, past work has yet to demonstrate a link between pretend play and counterfactual reasoning that is easily generalizable to the real world. For example, the device used in Joh, Jaswal, and Keen's experiment is deterministic: any one action can result in only one outcome.³⁵ However, real-world situations are rarely deterministic; instead they are probabilistic. One action can result in many outcomes, each with a varying degree of probability. Would engaging in pretense boost accuracy in choosing an intervention to perform on a novel *probabilistic* apparatus? And while the Buchsbaum, et al. study is a solid first step towards understanding the relationship between pretend play and counterfactual reasoning, the study is correlational in nature, and thus cannot provide evidence for a causal link between pretense and counterfactual reasoning.³⁶ To investigate whether such a causal link exists between engaging in pretense and improved counterfactual reasoning in a probabilistic setting, we designed the following experiment.

Children were introduced to a new "toy" (the apparatus pictured in Figure 2a), and were told that it could be used to play games. A ball was then produced, and children were shown that when the ball was dropped into *one* of the cups, it made the cup play music—in this case, the red cup would play music. The ball had no effect on the other cup. This factor was easily counterbalanced between subjects, as the music was actually produced by the experimenter activating a wireless doorbell that was hidden from participants' view. Children were then introduced to the first training tunnel (Figure 2b). Children were shown that a ball could pass through the tunnel, and were instructed that the ball could only be dropped into the orange side of the tunnel. Children were

Can Visualize the Solution to a Spatial Problem." *Child Development* 82, no. 3 (2011): 744-45.

33 Ibid, 747-48

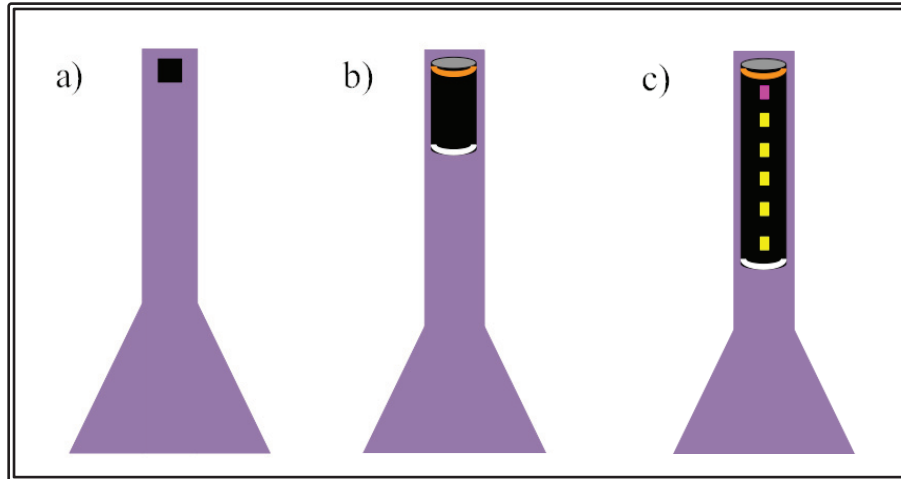
34 Ibid.

35 Ibid., 746.

36 Daphna Buchsbaum, Sophie Bridger, Deena S. Weisberg, and Alison Gopnik. "The Power of Possibility: Causal Learning, Counterfactual Reasoning, and Pretend Play." *Philosophical Transactions of the Royal Society* 367 (2012): 2205.

FIGURE II

A) APPARATUS, B) TRAINING TUNNEL NUMBER ONE,
AND, C) TRAINING TUNNEL NUMBER TWO

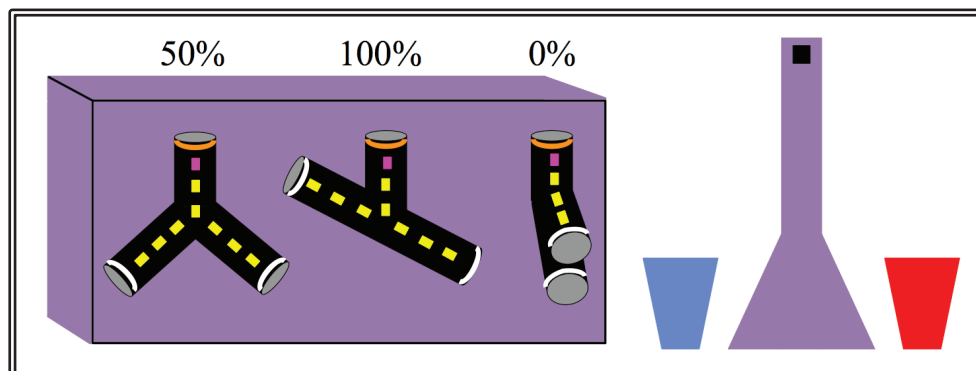


then also introduced to the condition-specific tracing task they would have to perform, detailed below. Children practiced this task with the second training tunnel (Figure 2c).

The test tunnels were then presented (Figure 3). Children were told that the goal was to make the cup play music, and that they would get to pick which tunnel would be the most likely to make the cup play music. But before the children were allowed to pick, they were asked to play a game. In the *experimental condition*, children were told that they were going to play an imagination game. The left-most tunnel (called the 50% tunnel for its two equally-possible outcomes) was selected from the purple box, and attached to the apparatus. The children were told, “Put your finger on the pink square, and show me down the yellow line where you think the ball will go, and pretend to catch it at the end.” When the children were finished, the tunnel was replaced onto the purple box, and this process was repeated for the two remaining tunnels: the 100% tunnel, which could only lead to one outcome, and the 0% tunnel, which could never lead to the desired outcome as it projected out towards the viewer, and not above either cup.

FIGURE II

FULL TEST APPARATUS



In the *control condition*, the children were told that they were going to play an exploration game. Children in this condition were told, “Put your finger on the pink square, and pick one of the yellow lines to follow with your finger. Then grab the end of the tunnel.” When the child was done, the process was repeated for the two remaining tunnels.

Children were then reminded that the goal was to make the red cup play music, and that they would have only one chance to make it play music, so they should pick the best tunnel. The tunnels were briefly presented one more time, and children were told to think about which tunnel they wished to choose during this time. Then, children were asked to choose which tunnel they thought would be the best at making the cup play music. Lastly, an explanation of their choice was elicited.

Preliminary findings were null. Pearson’s chi-square revealed that condition did not significantly influence children’s final intervention choice: $\chi^2(2, 56) = 0.3059, p = 0.8582$ (in this study, chance was 33%, because there were three possible choices). A one-tailed exact binomial test confirmed that four-year-olds were at chance in the control condition ($p = 0.7388$) as well as in the experimental condition ($p = 0.5245$). Five-year-olds in both conditions performed almost significantly above chance, answering correctly about 60% of the time ($p = 0.0576$), but their performance was not at ceiling. Pearson’s chi-square confirmed that five-year-olds performed significantly more accurately than four-year-olds on this task: $\chi^2(2, 56) = 7.7294, p = 0.02097$.

Further analysis revealed an interesting trend. Children who chose the correct intervention (regardless of condition) were those who chose to trace the “correct” side of the 50% tunnel—the side that would produce the music. This means that the children who were making the inference that they should be tracking the side that produced the effect were the ones answering correctly. After all, if children were not taking effect into account, they should be split 50/50 whether they chose the left or right side of the 50% tunnel. This implies that children in the control condition may have been spontaneously imagining outcomes. To address this issue, we have made several changes to our methods.

In the original experiment, children were told the goal (to make the cup play music) in the beginning. This may have caused the children in the control condition to spontaneously form the inference that they should track the side that produced the effect, and may have also caused these children to spontaneously imagine outcomes. In a new version of the experiment, children will be introduced to the goal at the *end* of the game, giving children space to explore. In addition, to strengthen children’s motivation to produce the desired effect, children will also be told that they will receive a sticker if they can make the red cup play music. We hypothesize that the imagination activity will prompt children’s consideration of possibilities (counterfactual reasoning), and therefore help them form the correct inference—namely, that intervening on the causal system by choosing the 100% tunnel will produce the highest probability of the desired result occurring.

III. Conclusion

In conclusion, a multitude of studies have shown that children form causal maps of the world. Children should then be able to intervene upon these causal maps. Children may be able to use counterfactuals to generate appropriate interventions on a causal system. We hope to learn whether prompting children to engage in pretense will allow them to arrive at the most effective intervention on a novel probabilistic causal system.

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