The Development of the Counterfactual Imagination

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Key words: *counterfactual reasoning, imagination, mental representation, cognitive development*

Abstract

When reasoning counterfactually, we think of alternative possibilities to what we know to be true about the world by imagining what would have happened had a situation been different. Research has yielded mixed findings and substantial debate over when this ability develops, how it is best conceptualized, and what functions it serves. In this article, we propose a framework of counterfactual reasoning in development. We argue that counterfactual reasoning is best understood by looking both at the representations of reality children manipulate counterfactually, and the cognitive processes that make up and contribute to counterfactual reasoning. In so doing, we highlight the fact that many of the component skills are present in early childhood. This framework yields testable predictions about children's counterfactual reasoning across a range of situations. We also discuss recent work that examines the contribution of counterfactual reasoning to learning in childhood.

Much of our time is spent thinking about what we know to be untrue. We often generate counterfactual thoughts especially when faced with unexpected or negative events, imagining what could have been done differently to undo the negative outcome (e.g*., If I hadn't left food in my office, there wouldn't be mice living here now.*). Counterfactuals are not only generated when thinking about personal events, but are also involved in scientific, legal, and historical reasoning. For instance, generating counterfactual alternatives to historical events (e.g., *What if Napoleon had won the Battle of Waterloo?*) can help explain causal forces in both the past and the present. Considering counterfactual possibilities (e.g., *What would the world be like with no bees?*) can stimulate scientific hypotheses, inspire documentaries, and drive policy.

The boundary conditions for counterfactual thinking and the extent to which it relies on the same underlying cognitive mechanisms as related abilities, such as future thinking and pretend play, are the subjects of substantial debate (e.g., Beck, 2016; Weisberg & Gopnik, 2013). Many researchers construe counterfactual reasoning broadly as the ability to generate alternative representations to reality. On this broad interpretation, counterfactuals may take the form of imagined alternatives to past events, future hypotheticals, pretend play, and even fiction (e.g., Weisberg & Gopnik, 2013; Woodward, 2011). Other researchers argue that counterfactual reasoning is a specific ability to reason about alternatives to *past events* (e.g., Beck, 2016; Epstude & Roese, 2008). In large part, this is likely due to the fact that thinking counterfactually about the past serves unique social and psychological functions (e.g., attributing causation and blame, adapting one's behavior; Epstude & Roese, 2008). Given this debate, it is perhaps unsurprising that conclusions about when children begin to reason counterfactually are mixed. Indeed, for nearly every finding showing that children of a certain age *can* think counterfactually, there is another finding that, given a slightly different set of criteria, children fail to do so. Evidence suggests that the earliest children can reason counterfactually is at around age 4 (e.g., Guarjardo & Turley-Ames, 2004; Harris, German, & Mills, 1996; Nyhout & Ganea, 2019a), but studies show that children do not do so until middle to late childhood (e.g., Beck, Robinson, Carroll, & Apperly, 2006; Rafetseder, Schwitalla, & Perner, 2013).

Apart from a lack of consensus on what researchers mean when they use the word counterfactual, we need a unified theoretical framework that specifies the processes involved in generating counterfactuals so we can draw specific and testable predictions. By characterizing the cognitive processes involved in counterfactual reasoning, we can understand more deeply what this type of reasoning shares with other abilities and how it is distinct. In this article, we present a process view of counterfactual reasoning, which explains discrepant findings and leads to new predictions. We conceptualize counterfactual reasoning as a form of reasoning in which one contemplates a *change to a mental representation* and reasons about the *causal* implications of this change. Therefore, we take a narrower view than those who suggest that counterfactuals are any form of alternative to reality, but a broader view than those who confine counterfactuals to past events. The process of contemplating a change to a representation could be enacted either on a past event from episodic memory or a causal system (e.g., an ecosystem) from semantic memory. Given that most research with children has focused on *past event* counterfactuals, most of our discussion is in this context. Limited work has focused on children's counterfactual reasoning about causal systems from semantic memory, but we expect a similar developmental timeline and developmental and situational constraints to affect this ability.

First, we outline the core cognitive processes underlying counterfactual reasoning, highlighting that many of them are present as developmental precursors in toddlerhood, and relate them to other abilities to imagine alternatives. Then, we outline constraints on children's ability to think counterfactually. These include the model of reality that children represent, domain-specific causal knowledge, and domain-general cognitive abilities. This framework integrates aspects of previous accounts highlighting the role of domain-specific (Sobel, 2011) and domain-general abilities (Beck & Riggs, 2014) in counterfactual reasoning. We interpret the findings through the lens of this framework, and conclude by highlighting emerging areas of research on the utility of counterfactual reasoning in learning.

A Framework for the Development of Counterfactual Reasoning

Core Processes

When thinking counterfactually, one represents a change to reality and the causal implications of this change. We argue that these can be divided into three core processes. In describing these processes, we refer to a common task in studies of the development of counterfactual reasoning. In Harris and colleagues' (1996) seminal study, children hear about a girl, Carol, who enters her kitchen wearing muddy boots and makes the floor dirty. They are then asked what the state of the floor would have been had she removed her shoes.

First, the child must retrieve from memory a representation of a system of two or more related variables (e.g., the event involving Carol and her muddy shoes). Children possess the ability to *represent* entities that are absent late in their first year of life (Harris, 1973) and can retrieve *event representations* around 16 months (Bauer & Mandler, 1989), although early on these representations are mostly script-based (Hudson, 1990). Second, the child manipulates a feature of the representation by positing a false premise (e.g., imagining that Carol had removed her shoes). By age 2, children can *manipulate* existing representations based on new verbal information (e.g., represent a previously dry teddy bear as wet; Ganea & Saylor, 2013) and in their third year, they can also do so with representations of past events by combining events from episodic memory with present information (Király, Oláh, Csibra, & Kovács, 2018). Finally, the child infers causal implications of the false premise (e.g., the floor would be clean), while keeping everything else in the representation of the event unchanged. Making causal inferences on the basis of a *false or negative premise* first appears in the context of pretend play around the age of 2 (Kavanaugh & Harris, 1994) and children can reason deductively about false premises (e.g., all sheep are purple) around the age of 3 (Dias & Harris, 1988). Nevertheless, the ability to consider multiple alternatives based on negative premises is cognitively demanding and develops over the preschool years (Grigoroglou, Chan, & Ganea 2019; Mody & Carey, 2016).

In some instances, these processes may be shared with other abilities to consider alternatives to reality, but we argue that they are not *essential* for these other abilities. Consider pretend play, an ability some researchers have argued relies on the same cognitive processes as counterfactual reasoning (e.g., Amsel & Smalley, 2000; Weisberg & Gopnik, 2013). For instance, Weisberg and Gopnik (2013) argue that both abilities involve disengaging from reality to entertain a premise that counters fact, making causal inferences about this premise while keeping the alternative and real worlds separate. While we agree with Weisberg and Gopnik that specifying the process underlying counterfactual reasoning is necessary, we disagree with aspects of their characterization of this process. Whereas counterfactual reasoning *necessarily* involves retrieving and manipulating a *mental representation* of reality, pretend play does not. Moreover, counterfactual premises *conflict* with reality, but this need not be the case in pretense. According to Harris (2000):

> In the case of pretend play, children do not set up a contrast between an imaginary event and an actual event. They simply invent, watch, or describe an imaginary event; the imaginary event has no close cousin in reality with which it contrasts. (p. 124)

Counterfactual reasoning is based off and constrained by reality. Like counterfactual reasoning, pretend play typically involves making causal inferences based on false premises (Weisberg & Gopnik, 2013). In this sense, both are informed by causal knowledge of the real world, but only counterfactual reasoning involves a comparison to a specific representation of reality. Moreover, the counterfactual representation and the initial representation are mutually exclusive in the sense that they cannot both be true.

As we have reviewed, children possess fundamentals of counterfactual reasoning from a young age. Yet research indicates that they do not reason counterfactually in many instances through middle childhood. Why might this be? We propose that once the general ability to reason counterfactually is in place, children's ability to entertain a counterfactual alternative in a given situation depends both on the particular features of their representation of reality and the development of a suite of cognitive abilities.

Models of Reality

To understand children's counterfactual thinking, we argue that it is essential to characterize their model of reality since this is the input from which counterfactual inferences are drawn. This may be a representation of an event from episodic memory (e.g., two people walked into the kitchen with muddy shoes) or a causal system from semantic memory (e.g., an ecosystem). The extent to which the representation in question is an accurate depiction of reality depends in part on the ease and accuracy with which children store and retrieve such representations from memory. Developmentally, we expect children's ability to encode and retrieve memory representations to constrain their counterfactual reasoning. We also expect children's counterfactual reasoning to be scaffolded when their memory is supported (through repeated exposure to the same events or use of visual cues).

Beyond ease and accuracy of memory, *how* a child has interpreted an event or system determines the parameters of his or her model, in terms of the number of and presence or absence of causal relations between events or entities, and the probabilistic nature of these relations. These features influence the causal inferences the child draws. This means that children's counterfactual inferences should vary according to the model of reality they represent. Consider a case in which children are asked to reason about a scenario with *two* individuals who walked on a floor with muddy shoes. A child who represents the two antecedent events as independent (e.g., the two went into the kitchen separately) will generate different counterfactual inferences than one who represents them as connected (e.g., one character imitated the other). Evidence from a recent study supports this prediction: When presented with narratives in which antecedent events were disconnected as in a common effect model (events A and B both independently cause C) versus connected as in a causal chain model (event A causes event B, both cause C), 8-year-olds made counterfactual inferences that were consistent with these models (Nyhout, Henke, & Ganea, 2019). Six-year-olds could reason more successfully about scenarios in which antecedent events were causally *connected* to one another than when they were disconnected. When causal relations between events were ambiguous, the performance of both younger and older children was chance-like.

The *complexity* of the causal model, in terms of the number of intervening events, can influence counterfactual reasoning. For instance, children find it easier to reason about direct rather than indirect effects of counterfactual changes, both in short narratives involving agents (German & Nichols, 2003; but see Beck, Riggs, & Gorniak, 2010) and in biological systems (e.g., food chains; Nyhout, Sweatman, & Ganea, 2019). Children also appear to reason earlier about simple events with a single cause than events in which two or more events lead to the same outcome (*overdetermined* events). For instance, 4-year-olds who heard a single-cause story in which a character made a floor dirty with her muddy shoes inferred that the floor would be clean if she had removed her shoes (Harris et al., 1996; Rafetseder et al., 2013). However, in overdetermined cases, when a second cause of an outcome was present (e.g., another character with muddy shoes) and children were asked to consider that *one* of the characters had removed his or her shoes, children as old as 6 (Nyhout, Henke, et al., 2019) or even 13 (Rafetseder et al., 2013) answered incorrectly that the floor would be clean, disregarding the second cause of the outcome. Based on these findings, Rafetseder and colleagues (2010, 2013, 2014) have argued that young children who correctly answer in the single-cause cases rely on a simpler form of reasoning, *basic conditional reasoning*, in which children use general causal knowledge to arrive at a correct answer.

However, evidence suggests that children can reason counterfactually about overdetermined *physical* events—compared to events involving human agents in narratives—by the age of 4 (Nyhout & Ganea, 2019a) or 6 years (McCormack, Ho, Gribben, O'Connor, & Hoerl, 2018). For example, preschoolers in one study were familiarized with a box that lit up when certain types of blocks were placed on it (Nyhout & Ganea, 2019a). On overdetermined trials, when two causal blocks were placed on the box, 4- and 5-year-olds reasoned correctly that the lights would still be on if one of the two blocks had not been placed on the box. When the stimuli were removed and children had to access and manipulate a mental representation of the event (Study 2), they still reasoned successfully about the overdetermined counterfactual alternative.

In addition to the pattern of causal relations children represent (e.g., causal chain versus common effect) and the complexity of the causal model (e.g., single cause versus overdetermined), we also expect that the *probabilistic nature* of the causal relations within the model will influence counterfactual inferences. Whether children represent a causal relation as deterministic (i.e., A and B always co-occur) or probabilistic (i.e., A and B sometimes co-occur) could lead to different counterfactual inferences. Consider a button that *always* turns on a light versus one that *sometimes* turns on a light (perhaps because its battery is low). If one observes an event in which the light is off and a character stumbles in the dark, and is asked "if she had pressed the button, would the light have come on?" one is likely to have more certainty in the deterministic (*always*) versus the probabilistic (*sometimes*) case. Research with adults indicates that their counterfactual inferences diverge depending on whether a causal relation is deterministic or probabilistic (Rips & Edwards, 2013). In summary, the exact causal relations the child represents and the reliability of those relations—shaped by their domain-specific causal knowledge—influence their counterfactual inferences.

A related factor that is likely to influence children's counterfactual inferences is their domain-specific causal knowledge (Sobel, 2011). Children's domain knowledge influences both how they represent causal relations in their model of reality and the causal inferences they draw based on counterfactual premises. Presumably, the more an individual knows about a domain, the more accurate his or her inferences about changes to real events. Individuals may also perceive events in some domains as more deterministic than others. For instance, adults judge physical events as more deterministic than psychological ones (Strickland, Silver, & Keil, 2017).

Comparing across studies, the findings suggest that children are more successful at reasoning counterfactually about *physical* systems (McCormack et al., 2018; Nyhout & Ganea, 2019a) than about structurally similar problems involving human agents (Nyhout, Henke, et al., 2019; Rafetseder et al., 2013) and biological causal systems (Nyhout, Sweatman, et al., 2019). This could be because children perceive physical events as more deterministic. However, one study that compared children's counterfactual inferences about physical and emotional causal events did not find the predicted differences (Beck et al., 2010). Researchers need to compare children's counterfactual reasoning across different domains, controlling tightly for other potential factors, both within participants and across ages in relation to key developments in children's causal reasoning.

Executive Function

Given the requirements to maintain, manipulate, and compare representations during counterfactual reasoning, executive functions (inhibitory control, cognitive flexibility, and working memory) are implicated (Beck & Riggs, 2014). In studies, individual differences in *inhibitory control* (Beck, Riggs, & Gorniak, 2009), *cognitive flexibility* (Guajardo, McNally, & Wright, 2016), and *working memory* (Guajardo, Parker, & Turley-Ames, 2009) correlated with children's counterfactual reasoning, though findings have been mixed (e.g., Beck et al., 2009). Although executive function is related to counterfactual reasoning, researchers should investigate whether it is a matter of competence or performance. In other words, is it necessary for counterfactual reasoning or does it merely constrain it in contexts where demands are high (e.g., for complex causal structures)?

Language

Children's verbal IQ—which is a proxy for general intelligence—predicts their counterfactual reasoning (Beck et al., 2009). Here, we focus on a more specific linguistic feature of counterfactuals: their grammatical complexity. In many languages, and in most studies, counterfactuals are often framed in the past subjunctive (e.g., *"If I had taken my shoes off…").* Children may not show earlier evidence of counterfactual reasoning because they have not yet mastered this linguistic form (Kuczaj & Daly, 1979). Given that many of the core processes of counterfactual reasoning are in place early in development, we predict that children should have earlier access to counterfactuals that are expressed in less complex linguistic constructions. Children express hypothetical alternatives using simpler language (e.g., *almost*) before they have a command of the past subjunctive (Harris, 1997, Study 2). Developing versions of tasks that place fewer verbal demands on children may allow them to demonstrate success at an earlier age. In specifying the role that language plays in the development of counterfactual thinking, studies should also consider groups whose linguistic input is limited (e.g., deaf children of hearing parents) or nonhuman primates.

New Directions: Counterfactuals in Learning

Most developmental research has asked when children can reason counterfactually. Some work has focused on potential qualitative differences in the processes involved in hypothetical thinking across development (e.g., Rafetseder et al., 2010). A critical next step is for researchers to move beyond the question of when (developmentally) to *when (contextually)* children reason counterfactually, *what* they reason about, and *how* it may support learning. In this section, we highlight emerging research on counterfactual reasoning in light of its purported functions for decision-making and learning.

Much research with adults has examined the functional utility of counterfactuals, suggesting that the availability of counterfactual alternatives affects people's causal judgments (e.g., Mandel, 2003; Wells & Gavanski, 1989) and their future behavior (e.g., Epstude & Roese, 2008). Counterfactual thinking may play a similar role in middle childhood. In one study, 6- and 7-year-olds who experienced regret—a counterfactual emotion—on a delay-of-gratification task were more likely to delay gratification on a subsequent task than children who did not experience regret (McCormack, O'Connor, Cherry, Beck, & Feeney, 2019). Claims about the adaptive nature of counterfactual thinking rest on evidence for their spontaneous use in everyday contexts. Little research has investigated whether children engage in counterfactual reasoning spontaneously (Kuczaj & Daly, 1979; Guajardo et al., 2016). Given that some studies suggest that children are competent at counterfactual reasoning between the ages of 4 and 6, researchers need to investigate the spontaneous occurrence of counterfactuals in more naturalistic contexts.

In addition to influencing behavior, does counterfactual reasoning influence learning? New developmental work is examining the relevance of counterfactual reasoning to *science learning* and *scientific reasoning*. Thinking counterfactually may influence both the *output* and the *process* of scientific reasoning. Given that counterfactuals are imagined interventions, we may predict that counterfactuals support learning about causal systems that are subject to these interventions. Both counterfactual and scientific reasoning involve setting forth a premise and reasoning about its outcomes, and typically involve isolating a single possible cause and holding all else constant (e.g., Gopnik & Walker, 2013; Mackie, 1974; Rafetseder & Perner, 2014). Given the structural similarity between counterfactuals and physical experiments, one may also expect engaging in counterfactual reasoning to provide a mental blueprint for a physical experiment. Recent results support both claims. In one study, 7- and 8-year-olds who were prompted to think counterfactually about the location of the Earth (i.e., whether it was closer to or farther from the sun) had a deeper understanding of the complex concept of planetary habitability than children prompted to think factually about different planets (e.g., Venus and Neptune; Nyhout & Ganea, 2019b). In another study, 7- to 10-year-olds who were prompted to think counterfactually performed more optimally in designing a controlled test of a hypothesis than children given control prompts (Nyhout, Iannuzziello, Walker, & Ganea, 2019).

Researchers need to compare the abilities to reason counterfactually, causally, and scientifically because this work has relevance for both theoretical debates and science education. This work suggests an exciting possibility: Engaging in counterfactual worlds may help children learn about and navigate the world around them.

Authors' Note

We thank Paul Harris, Myrto Grigoroglou, and members of the Language and Learning Lab at the University of Toronto for their feedback on an earlier draft of this article.

This work was supported by Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery award RSD1270194 to P. Ganea, and by Social Sciences and Humanities Research Council of Canada (SSHRC) Insight Development award to A. Nyhout and P. Ganea.

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