Cause and *burn* in development

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Abstract

A fundamental way to reason about causation is in terms of direct contact, like billiard balls colliding. Although collision-like causes have played an important role in philosophical and psychological theories of causation, humans conceptualize many events that lack direct contact as causes. If Andy hits Suzy with his bike, Suzy falls into a fence and it breaks, Andy is a cause of the fence breaking. We also treat absences as causes. If Suzy forgets sunscreen and gets sunburned, the absence of sunscreen is a cause. Moreover, there are linguistic distinctions between verbs that refer to these: Andy "caused" the fence to break but Suzy "broke" it. The absence of sunscreen "caused" Suzy's sunburn, but the sun "burned" it. We explored how children develop these mappings, focusing on "cause" and verbs like "burn". Because "make" is more frequent than "cause", we included it too. We tested 690 children and 150 adults. Experiment 1 examined causal chains. Children as young as 4 thought Andy "caused" the fence to break, but Suzy "broke" it and "made" it break. Experiment 2 examined causation by absence. Only older children thought the absence of sunscreen "caused" the sunburn. Yet in Experiment 3, even 4-year-olds cited absences in explaining Suzy's sunburn. Despite rarely hearing "cause", young children understand it and verbs like "break" to mark subtle distinctions between causes: "break" refers to direct causes; "cause" to indirect causes in chains. Absences are more challenging, but children refer to them in causal explanations before mapping "cause" to them.

Keywords: causation; language understanding; semantics; pragmatics; cognitive development

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Introduction

Some say it's the cement of the universe (Hume, 1789). Others that it's the glue between observed events (Schlottmann, 2001). Whatever your views on adhesion, determining what causes particular outcomes is involved in many of the most profound scientific and cultural achievements, from the discovery of fire to the development of atom splitting. The capacity to determine what causes what is a crowning achievement of human cognition with some aspects of causal understanding being unique to humans (e.g., Goddu & Gopnik, 2024), including that we use different causal expressions to refer to different types of causes (e.g., Rose, Sievers, & Nichols, 2021). Here, we explore how children's understanding of causal language develops.

Linguists distinguish between lexical and periphrastic causatives. Lexical causatives are single clause expressions that encode the notions of cause and effect in a single verb, such as "break", "burn", and "crack". Periphrastic causatives are two-clause expressions, such as "caused to break" (e.g., Song & Wolff, 2003). These causatives differ in meaning: Lexical causatives can refer only to direct causes while periphrastic causatives can refer to both direct or indirect causes (Aryawibawa, Qomariana, Artawa, & Ambridge, 2021; Fodor, 1970; McCawley, 1978; Pinker, 1989; Shibatani, 1976; Song & Wolff, 2003; Wierzbicka, 1988; Wolff, 2003), where linguists usually characterize direct causes as those that contact their effects, while indirect causes don't (e.g., Dixon, 2000; Fillmore, 1972; Levin & Hovav, 1999; Pinker, 1989; Shibatani, 1976; Wierzbicka, 1975, see also Wolff, 2003, for discussion). For instance, if Sara opens a window, a breeze blows through, and the door opens, it seems appropriate to say that Sara caused the door to open, but not that she opened it. The breeze opened it (Wolff, 2003).

The linguistic distinction between lexical and periphrastic causatives relates to the philosophical distinction between two kinds of causal relations: production and dependence (Godfrey-Smith, 2010; Hall, 2004). On the production view, causes bring about effects via spatiotemporally continuous processes (Dowe, 2000; Salmon, 1984; Wolff, 2003). These can involve direct contact between a single cause and effect—such as Suzy kicking a fence and breaking it—but can also involve chains of events—such as Andy hitting Suzy with his bike, Suzy falling into the fence, and the fence breaking—where the distal cause initiates the chain and the proximal cause makes contact with the effect. On the dependence view, effects counterfactually depend on their causes and are characterized in terms of counterfactuals such as, "if the cause hadn't occurred, then the effect wouldn't have occurred" (Lewis, 1973a). These two views yield different verdicts about causation by absence, such as whether forgetting to water the plants caused them to die. Here, there is no production but there is dependence: if the plants had been watered, they wouldn't have died (Bernstein, 2016; Gerstenberg & Stephan, 2021; Henne, Ángel Pinillos, & Brigard, 2017; Lewis, 1973b; McGrath, 2005; Schaffer, 2000).

Rose, Sievers & Nichols Rose et al. (2021) show that the philosophical distinction between causal relations and the linguistic distinction between causal expressions is reflected in people's language use. For example, if Suzy goes to the beach, forgets her sunscreen and gets a sunburn, adults judge that the absence of sunscreen *caused her skin to burn* but not that it *burned* her skin. The sun burned her skin. Rose et al Rose et al. (2021) suggest that lexical causatives, such as "break", "burn", and "crack" are largely used for productive causes, and that "cause" tends to be used for non-productive causes, such as absences.

Here, we hypothesize that this division of labor between lexical and periphrastic causatives arises from an interplay between the meaning of these causal expressions, and pragmatic inferences that resolve potential ambiguities in context. For example, if someone asks what caused Suzy's skin to burn (rather than asking what burned her skin), one could answer truthfully by mentioning the sun (the direct cause) or that Suzy forgot to put on sunscreen (the absent cause). Pragmatic reasoning helps to resolve this ambiguity. Assuming shared knowledge of the situation, if a speaker used "caused to burn" in their question, it's likely that a listener will infer that the speaker is referring to the lack of sunscreen. If the speaker wanted to refer to the sun, they could have asked the question using "burn" instead. This kind of reasoning exemplifies a common pattern in language use and interpretation (Levinson, 1987; McCawley, 1978). When a lexical causative (e.g., burn) and a periphrastic causative (e.g., caused to burn) can be used to refer to the same event (e.g., a person's sunburn), the lexical causative tends to be understood to refer to a direct cause and the periphrastic causative to a non-direct cause (e.g., an indirect or absent cause).

In this paper, we investigate how children's understanding of the mapping between different causal expressions and different causal relations develops. Before turning to our experiments, we briefly discuss prior work on how children's causal cognition and language develops.

Development of causal cognition

Young children appreciate that causation often happens through direct contact. Older children realize that remote events and absences can be causes, too.

Direct causes

Direct contact induces the perception of causation early in development. Infants view one object as causing a second one to move if the first object moves, makes contact with the second, and stops moving at the same time as the second starts to move. If there is no contact, or a temporal delay, but the second object moves anyhow, infants don't view this interaction as causal (Leslie & Keeble, 1987; Michotte, 1963; Muentener & Carey, 2010).

Just as direct contact between a cause and effect is important for perceiving causation, it also matters for how children reason about it. When two-year-old children are shown that a toy airplane affixed to a base lights up when a block comes into contact with the base, they will make the block contact the base when asked if they can make it go (Bonawitz et al., 2010). In contrast, when the cause and effect are not in direct contact, such as when the airplane is connected to the base by a long wire, toddlers who are shown that the airplane lights up when a block comes into contact with the base will not make the block contact the base when asked if they can make it go. This implies that although children appreciate early in development the productive notion of causation when there is direct contact between cause and effect, they fail to understand that causes can be indirectly connected to their effects.

Indirect causes and absences

Around the age of 3 to 4, children begin to appreciate that causation doesn't always require contact. For instance, they will hold an object over a detector (without touching it) upon seeing that doing so makes the detector light up (Bonawitz et al., 2010; Bullock & Gelman, 1979; German & Nichols, 2003; McCormack, O'Connor, Beck, & Feeney, 2016; Shultz, 1982). Around 5 years of age, children recognize some absences as causes. When children are told that a storeowner doesn't salt an icy sidewalk in front of their store and someone slips on the ice and is injured, they are more inclined to say that the storeowner is "the cause" of the injury than when someone slips on their shoelace just before crossing the ice (Schleifer, Shultz, & Lefebvre-Pinard, 1983). Insofar as children view some absences as causes, this suggests that they have developed an understanding of dependence-based causation.

Development of causal language

Children acquire many lexical causatives (e.g., "burn") earlier than periphrastic causatives (e.g., "caused to burn"). To understand causal expressions, and what kinds of events lexical and periphrastic causatives refer to, both semantic and pragmatic processes are at play.

Lexical and periphrastic causatives

"Break", "drop", "dry", and "open", as well as a range of other lexical causatives, are included in the lexicon of most English-speaking children between the ages of 2 and 2½ (Frank, Braginsky, Yurovsky, & Marchman, 2016). Around this time, children use lexical causatives in their intransitive (e.g., "The fence broke.") and transitive forms (e.g., "Andy broke the fence.") in adult-like ways (Bowerman, 1974; Gergely & Bever, 1986).

At this same age, children also understand novel verbs used in transitive, but not intransitive sentences, as having causal meaning. Naigles Naigles (1990) showed 2-year-old children scenes where two actions were performed at the same time. In one, the causal scene, a bunny pushed down on a duck's shoulders, making the duck squat. In the other, the non-causal scene, the duck and bunny twirled their arms in sync. While watching these, children heard novel verbs in either transitive form ("The duck is gorping the bunny.") or intransitive form ("The duck and the bunny are gorping."). Then both scenes appeared on separate screens and children were asked to find "gorping". Children looked longer at the causal scene when hearing the transitive sentence and longer at the non-causal scene when hearing the intransitive sentence (see also Arunachalam, Escovar, Hansen, & Waxman, 2013; Arunachalam & Waxman, 2010; Bunger & Lidz, 2004, 2006; Naigles, 1990; Yuan & Fisher, 2009; Yuan, Fisher, & Snedeker, 2012). When hearing a novel verb in a transitive sentence, children, much like adults (Kako, 2006), expect that verb to encode a causal relationship, one that involves spatiotemporal continuity (e.g., Arunachalam & Dennis, 2019; Kline, Snedeker, & Schulz, 2017; Naigles, 1996; Scott & Fisher, 2009). Together, these findings suggest that children map verbs presented in transitive sentences to a notion of causation that involves spatiotemporal continuity, a production-based notion.

What does this suggest about children's understanding of periphrastic causatives? These, like lexical causatives, also feature in transitive sentences. Might they also be un-

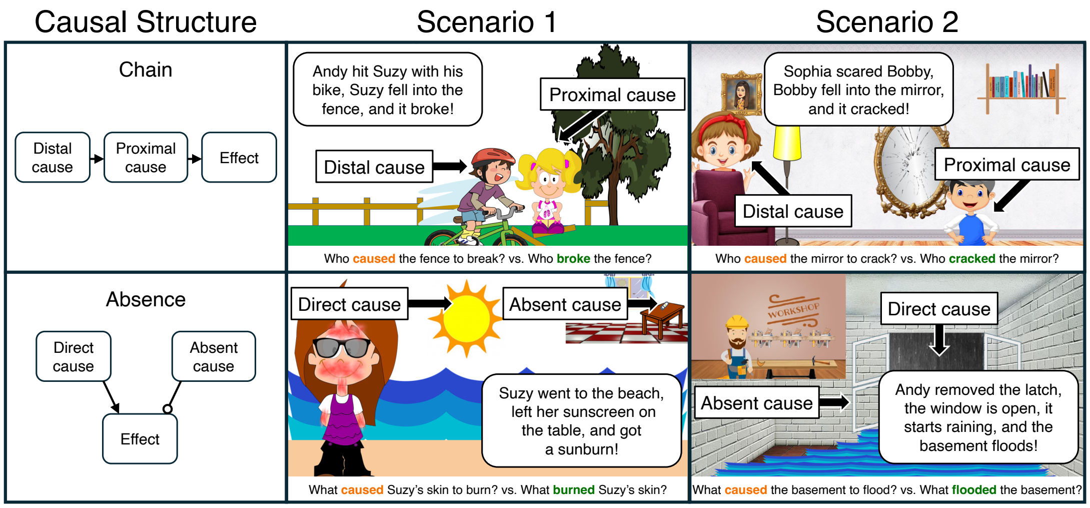

Figure 1

***Experiment Overview**: Abstract causal structures and concrete illustrations of the final stage in the different scenarios. The top row shows the chain scenarios from Experiment 1, and the bottom row shows the absence scenarios used in Experiment 2 and 3. As shown at the bottom of each scenario image, participants were asked questions that either used a periphrastic causative (e.g., "caused to break") or a lexical causative (e.g., "broke") . In one condition, the periphrastic causative was "caused" (shown here), and in the other it was "made".*

derstood to refer to direct, productive causes? One reason to think they might, comes from work by Bowerman (1974). Between the ages of 2 and 2½, children acquire one of their first periphrastic causatives, "made". Children then do two things. They *overlexicalize*, using a lexical causative when an adult would use a periphrastic construction (e.g., "Water bloomed these flowers" (= made these flowers bloom)) and *overanalyze*, using a periphrastic construction where a lexical causative is called for (e.g., "Then I'm going to sit on him and made him broken." (= break him); Bowerman, 1982). This suggests that young children may have trouble distinguishing between what events lexical and periphrastic causatives refer to.

However, six-year-old children no longer overlexicalize or overanalyze (Gergely & Bever, 1986). One possibility then is that, around this time, children begin to distinguish lexical from periphrastic causatives, understanding them to refer to different events much like adults do. Children might understand that "cause" can refer to indirect causes, and even absences, whereas lexical causatives can only refer to direct causes. To draw these distinctions, children have to rely on their understanding of the semantics and pragmatics of different causal expressions. We briefly discuss these next.

Semantics and pragmatics

Periphrastic causatives, such as "caused" or "made", and lexical causatives, such as "broke" or "cracked", might form a scale of specificity (see also Beller & Gerstenberg, 2024).

For example, “caused to break” is more general in that it’s true of many possible ways in which breaking happened, including directly breaking, indirectly breaking or breaking by absence. In contrast, “break” is more specific—it accurately describes only a subset of the many ways in which one could cause something to break, namely, those where there is some direct spatiotemporal continuity. If that’s right, then children’s understanding of causal verbs might bear some similarities to scalar terms. For instance, “some” is more specific than “all”. Though it’s not literally false to say “some” even when “all” is true, using “some” pragmatically implies that “all” is not true (because the speaker could have said “all”). Consequently, adult participants don’t find it acceptable for a speaker to say, for example, that “Some of the horses jumped over the fence.” when in fact all of the horses jumped over the fence (see e.g., Noveck, 2001, for discussion).

In contrast, children who are around 5- to 6-years-old say that a puppet “answered well” when all horses jumped over a fence and the puppet said “some of the horses jumped over the fence” (Huang & Snedeker, 2009; Noveck, 2001; Papafragou & Musolino, 2003). It seems that young children understand “some” and “all” in ways that accord with their literal semantics and then, over development, understand them like adults, to be used in ways that avoid unwanted pragmatic inferences. That said, there are a range of circumstances where even young children engage in various forms of pragmatic inference (Bohn & Frank, 2019; Bohn, Tessler, Merrick, & Frank, 2021, 2022; Stiller, Goodman, & Frank, 2015). In determining what different causal verbs refer to, children need to rely on their understanding of the semantics and pragmatics of different causal expressions.

Our question

Across development, children first recognize production-based causes that typically involve contact, then realize that causes need not always contact their effects, and finally appreciate that absences can be causes, too (see also e.g., Goddu & Gopnik, 2024). What is unclear is how, and when, they map different causal expressions onto these different types of causes.

Part of the reason that we know so little about the development of the word “caused” is that it is almost never used in developmental work, even though it is commonplace in work on adult causal judgment (e.g., Alicke, 1992; Alicke, Rose, & Bloom, 2012; Hitchcock & Knobe, 2009; Icard, Kominsky, & Knobe, 2017; Kominsky & Phillips, 2019; Lagnado & Channon, 2008; Livengood, Sytsma, & Rose, 2017; Lombrozo, 2010; Samland & Waldmann, 2016; Sytsma, Livengood, & Rose, 2011; Walsh & Sloman, 2011). Children are instead asked what “made” an outcome occur, whether they can “make” it happen (e.g., Ammon & Slobin, 1979; Bonawitz et al., 2010; Gopnik, Sobel, Schulz, & Glymour, 2001; Kushnir & Gopnik, 2007; Samland, Josephs, Waldmann, & Rakoczy, 2016; Schulz & Sommerville, 2006; Shultz, 1982; Sobel, Tenenbaum, & Gopnik, 2004), or whether something happened “because” of something else (e.g., Bebout, Segalowitz, & White, 1980; Hickling & Wellman, 2001; Hood & Bloom, 1979; McCabe & Peterson, 1985; Peterson & McCabe, 1985).

In many ways, it’s understandable that “caused” doesn’t usually feature in developmental work. “Caused” is much less frequent than “made” in adult speech. According to the Corpus of Contemporary American English (Davies, 2008), “caused” is ranked 563 while “made” is ranked 50. Young children may not hear or produce the word “caused” very often. But since “caused” almost never features in developmental work, we don’t know how children understand it. Do children appreciate that “caused”, “made”, and lexical causatives can refer to different kinds of events?

Our approach

We investigate children’s understanding of causal expressions in situations that feature causal chains and situations involving causation by absence (see Figure 1).

We examine children’s inferences about what event a speaker asked about, depending on whether they used a periphrastic causal construction, such as “caused” or “made”, or a lexical causative, like “broke’, “burned”, “cracked”, and “flooded”—each a change of state verb that can be combined with “caused” or “made” in periphrastic constructions (e.g., “Suzy caused the fence to break”; Levin, 1993). The lexical causatives come from prior work (Rose et al., 2021) and are of particular interest because they are familiar to children, belong to a class of verbs that can be used in both transitive and intransitive form (e.g., transitive: “Suzy broke the fence”; intransitive: “The fence broke”), have a “cause” predicate in their argument structure (e.g., [x doing something] CAUSED [y to become z]), and are thus closely linked to causal meanings (Levin, 2005). Our main interest is in the contrast between lexical causatives (e.g., “broke”) and periphrastic causatives (e.g., “caused” or “made”) across development.

Experiment overview

Experiment 1 looks at causal chain scenarios, and Experiment 2 at absences. Younger children didn’t select absences in Experiment 2, so we investigated whether they would do so when asked a “why” question in Experiment 3. For all results reported in this paper, we analyzed the data using Bayesian logistic mixed effects models. We will refer to a statistical result of interest as “credible” when the 95% credible interval excludes 0 (or excludes 1 for odds ratios). We pre-registered separate analyses for each selected referent (e.g., “Andy”—distal cause; “Suzy”—proximal cause) and report these results in the Appendix. Here, we focus on directly comparing which referent was selected for a given causal verb, explicitly marking where our pre-registered hypotheses apply. All experiments, data, analyses, and links to pre-registrations are available here: https://github.com/davdrose/cause_burn_development

Experiment 1: Causal chains

The goal of this experiment was to determine whether adults and children understand “caused”, “made” and lexical causatives to refer to different events in causal chain scenarios.

Methods

Participants

We recruited 120 adult participants (Age: M = 35, SD = 13; Gender: 55 female, 56 male, 8 non-binary, 2 no response/other; Race: 12 Asian, 7 Black, 93 White, 9 no response/other) and 300 children (Gender: 128 female, 135 male, 37 no response/other).[1] Adults were recruited through Prolific and paid at a rate of $12 an hour. Children were recruited through Lookit (Scott & Schulz, 2017) and families were paid $5 for their participation.

Procedure

Children were tested asynchronously and began with warm-up trials, which were included to help them become comfortable with saying their answers out loud. After being introduced to Maggie, and being told that they would help her learn English, children were presented with two pairs of sentences: "I live in Maple Street/I live on Maple street" and "I put socks on my feet/I put socks on my feets". For each one, they were asked whether it is right or wrong for Maggie to say that.

Children then proceeded to the test scenarios (see Figure 1 top row). In one, Andy hits Suzy with his bike, she falls into a fence and it breaks; in the other, Sophia hides behind a chair, jumps out, scares Bobby, he falls into a mirror and it cracks. In the "caused versus lexical causatives" condition, children were asked in the fence scenario "Who caused the fence to break?" and "Who broke the fence?". In the "made versus lexical causatives" condition, they were asked "Who made the fence break?" and "Who broke the fence?". In the mirror scenario, they were asked either "Who caused the mirror to crack?" (in the "caused versus lexical causatives" condition) or "Who made the mirror crack?" (in the "made versus lexical causatives" condition) as well as "Who cracked the mirror?". Children said their responses out loud.

The procedure for adults was the same except that they didn't complete warm-up trials, and instead of saying responses out loud, they wrote them in a text box. The adult version of the experiment was programmed in jsPsych (de Leeuw, 2015).

Design

Participants were randomly assigned to the "caused versus lexical causatives" or "made versus lexical causatives" condition. In both conditions, the scenario and question order was randomized. We also counterbalanced which character was in which causal role (e.g., either Suzy or Andy was the one on the bike).

Response coding

We pre-registered coding responses into two categories: "distal" if the character on the bike (or behind the chair) was mentioned and "proximal" if the character who fell into the fence (or the mirror) was mentioned. Our coding scheme was not mutually exclusive. It was possible for a participant to refer to both a distal and proximal cause in the same response, or to neither of the two.

Results

Figure 2 shows the results. The top row (A and B) show the results from our analyses, which focus on the relative proportion with which children selected the distal

[1] We pre-registered that we would collect data from 30 4 year olds, 30 5 year olds, 30 6 year olds, and 60 7–9 year olds.

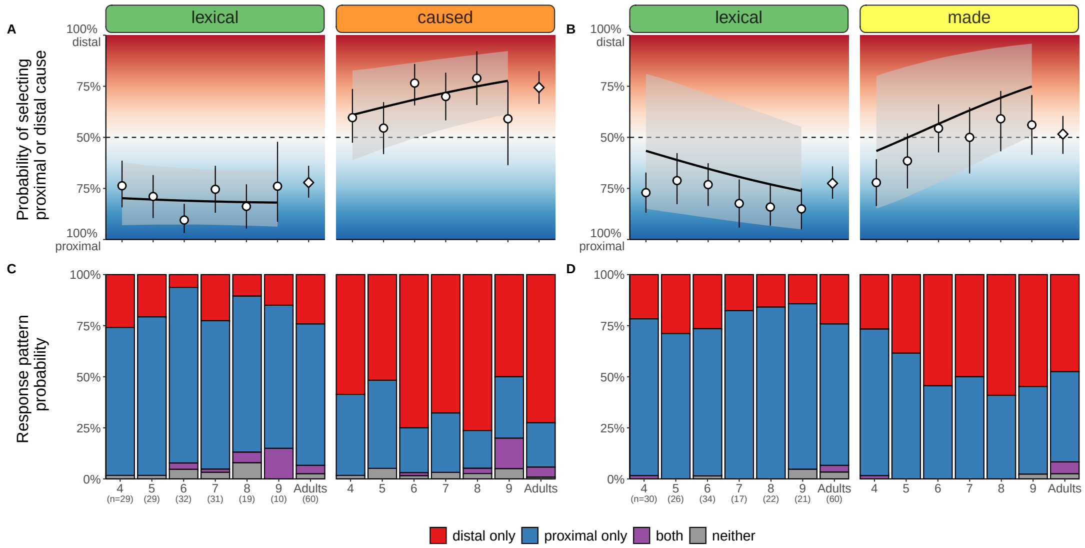

Figure 2

Experiment 1*: Probability of selecting a proximal or distal cause in the "caused versus lexical causatives" condition (A) and "made versus lexical causatives" condition (B). Large points show the percentage with which each age group selected either referent. Error bars show 95% bootstrapped confidence intervals. Regression lines show the fits of Bayesian logistic mixed effects models with 80% credible intervals. These estimates exclude "neither" responses. Response patterns in the "caused versus lexical causatives" (C) and "made versus lexical causatives" (D) condition for each age group. "both" means that they mentioned both the distal and proximal cause, "neither" means they mentioned neither.*

cause versus the proximal cause depending on whether the speaker used a lexical causative or a periphrastic causative. For these, we included all responses except for those where participants selected "neither" a distal nor a proximal cause. The full response patterns are shown in the bottom row (C and D). Very few participants provided "neither" or "both" responses and most participants selected only a distal or proximal cause.

We report the results from the "caused versus lexical causatives" and the "made versus lexical causatives" conditions in turn. We then compare "caused" and "made".

"Caused" versus lexical causatives

As predicted, we found that children were more likely to select the distal cause for "caused" compared to "lexical" (caused: 67%, 95% confidence interval (CI) [61%, 72%]; lexical: 20%, CI [16%, 25%], odds ratio: 13.8, 95% credible interval (CrI) [7.8, 22.4]). The same was true for adults (caused: 74%, CI [67%, 82%], lexical: 28%, CI [20%, 36%], odds ratio: 18.2, CrI [6.27, 40.7]).

There was no credible effect of age on children's selections of the distal cause (.07, CrI [−.11, .26]), and there was no interaction between causal verb and age (.21, CrI [−.07, .48]).

"Made" versus lexical causatives

As predicted, children were more likely to select the distal cause for "made" compared to "lexical" (made: 47%, CI [41%, 52%], lexical: 22%, CI [17%, 27%], odds ratio: 4.8, CrI [2.8, 7.4]), and the same was true for adults (made: 52%, CI [43%, 61%], lexical: 28%, CI [19%, 36%], odds ratio: 4.6, CrI [2.0, 8.7]).

There was no credible effect of age on selecting the distal cause (.05, CrI [−.14, .25]), but there was an interaction between causal verb and age (.58, CrI [.31, .86]) where selection of the distal cause decreased with age for "lexical" (−.24, CrI [−.49, 0]) but increased for "made" (.34, CrI [.12, .56]).

"Caused" versus "made"

We found that children were overall more likely to select the distal cause for "caused" compared to "made" (odds ratio: 2.61, CrI [1.76, 3.68]). The same was true for adults (odds ratio: 4.17, CrI [1.86, 7.63]).

Discussion

Children understand some causal verbs to distinguish different kinds of causes. When Andy hits Suzy with his bike, she falls into the fence and it breaks, they think "Andy", the distal cause, "caused" the fence to break and that "Suzy", the proximal cause, "broke" it. Indeed, 4-year-olds already choose different referents in causal chain scenarios when a speaker uses "caused" versus a lexical causative. They thought that the proximal cause, Suzy, "broke" the fence, and were inclined to think that the distal cause, Andy, "caused it to break". In contrast, "made" is treated more like a lexical causative early on. Children become less likely to think that "made" refers to proximal causes over development. But they, like adults, don't come to think that "made" clearly refers to distal causes. "Caused", however, is clearly understood to refer to distal causes by both adults and children.

Children have a strong preference to map lexical causatives to proximal causes: Suzy, the person who fell into the fence, "broke" it (see also e.g., Arunachalam & Dennis, 2019; Kline et al., 2017; Naigles, 1990). They also map "caused" to distal causes: Andy, the person on the bike who hit Suzy, "caused" the fence to break. But it could be that their selection of distal causes when asked a question using "caused" is explained by demand characteristics or a simple strategy where alternative answers are given for each question. However, if this were the case, then at the same time that 4-year-olds treat "caused" as referring to distal causes, they should also understand "made" to refer to them, especially since lexical causatives are already available to select the proximal cause. But they don't.

That children already understand "caused" to refer to causes that are more remote from their effects raises the possibility that they might even use "caused" to refer to events that are disconnected from their effects, like absences. We examine this next in Experiment 2.

Experiment 2: Absences

The goal of this experiment was to determine whether children understand "caused", "made" and lexical causatives as referring to different events when presented with situations

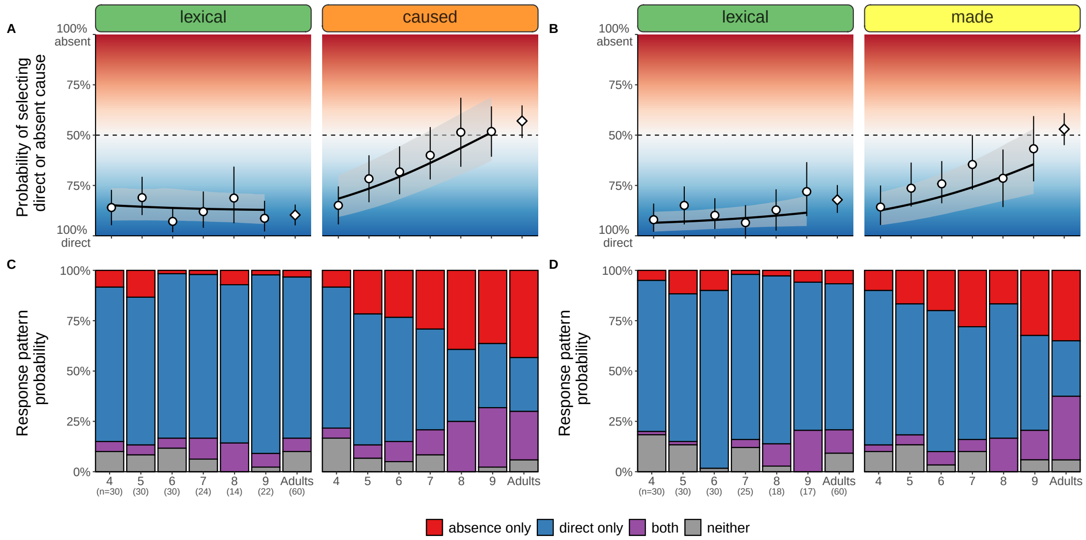

Figure 3

Experiment 2: *Probability of selecting a direct or absent cause in the "caused versus lexical causatives" condition (A) and "made versus lexical causatives" condition (B). Large points show the percentage with which each age group who selected either referent. Error bars show 95% bootstrapped confidence intervals. Regression lines show the fits of Bayesian logistic mixed effects models with 80% credible intervals. These estimates exclude "neither" responses. Response patterns in the "caused versus lexical causatives" (C) and "made versus lexical causatives" (D) condition for each age group. "both" means that they mentioned both the absent and direct cause, "neither" means they mentioned neither.*

involving causation by absence.

Methods

Participants

We recruited 120 adult participants (Age: M = 30, SD = 10; Gender: 68 female, 49 male, 2 non-binary, 1 no response/other; Race: 12 Asian, 12 Black, 83 White, 13 no response/other) and 300 children (Gender: 147 female, 153 male).[2] Adults were recruited through Prolific and paid at a rate of $12 an hour. Children were recruited through Lookit (Scott & Schulz, 2017) and families were paid $5 for their participation.

Procedure

The procedure was the same as in Experiment 1. However, this time participants saw different scenarios (see Figure 1 bottom row). In one of the scenarios, Suzy goes to the beach, forgets her sunscreen and gets a sunburn. In the other, Andy removes the latch

[2] We pre-registered that we would collect data from 30 4 year olds, 30 5 year olds, 30 6 year olds, and 60 7–9 year olds.

from his basement window, the window is open when it starts to rain, and the basement floods. In the "caused versus lexical causatives" condition, children were asked in the sunburn scenario "What caused Suzy's skin to burn?" and "What burned Suzy's skin?". In the "made versus lexical causatives" condition, they were asked "What made Suzy's skin burn?" and "What burned Suzy's skin?". In the flood scenario, they were asked "What caused Andy's basement to flood?" (in the "caused versus lexical causatives" condition) and "What flooded Andy's basement?" or "What made Andy's basement flood?" (in the "made versus lexical causatives" condition) and "What flooded Andy's basement?" Children said their responses out loud.

Design

Participants were randomly assigned to the "caused versus lexical causatives" or "made versus lexical causatives" condition. In both conditions, the order of the scenarios and questions were randomized.

Response coding

We pre-registered coding responses into two categories: "absence" (e.g., if the sunscreen was mentioned) and "direct" (e.g., if the sun was mentioned). As in Experiment 1, our coding scheme was not mutually exclusive.

Results

Figure 3 shows the results. The top row (A and B) show the results from our analyses, which focus on the relative proportion with which participants selected the absent cause versus the direct cause. Very few participants provided "neither" responses (see bottom row (C and D) of Figure 3) and we again excluded these from our analyses. Most participants selected only an absent or direct cause but adults and older children were also somewhat inclined to select "both" when a periphrastic causative was used. We again report the results from the "caused versus lexical causatives" and the "made versus lexical causatives" condition in turn. We then compare "caused" and "made".

"Caused" versus lexical causatives

As predicted, we found that children were more likely to select the absent cause for "caused" compared to "lexical" (caused: 35%, CI [30%, 41%], lexical: 13%, CI [9%, 17%], odds ratio: 3.8, CrI [2.2, 5.6]). The same is true for adults (caused: 57%, CI [49%, 65%], lexical: 10%, CI [5%, 16%], odds ratio: 12.4, CrI [5.0, 23.2]).

There was a credible effect of age on children's selections of the absent cause (.14, CrI [0, .31]), and there was an interaction between causal verb and age (.39, CrI [.08, .65]). Older children were more inclined to select the absent cause for "caused" (.33, CrI [.17, .49]) but not for "lexical" (−.05, CrI [−.29, .22]).

"Made" versus lexical causatives

We predicted that there would be no difference in what cause children would select. In contrast, we found that children were more likely to select the absent cause for "made" compared to "lexical" (made: 27%, CI [22%, 32%], lexical: 12%, CI [8%, 16%], odds ratio:

3.4, CrI [1.9, 5.5]). The same is true for adults (made: 53%, CI [45%, 61%], lexical: 18%, CI [11%, 25%], odds ratio: 5.5, CrI [2.9, 9.4]).

There was a credible effect of age on children's selections of the absent cause (.21, CrI [.02, .43]) but no interaction between causal verb and age [.15, CrI [−.15, .44]).

"Caused" versus "made"

We found that children were not more likely to select the absent cause for "caused" compared to "made" (odds ratio: 1.4, CrI [.93, 1.94]). The same was true for adults (odds ratio: 1.17, CrI [.67, 1.81]).

Discussion

When Suzy went to the beach, forgot her sunscreen and got a sunburn, young children almost never referred to the absence—the sunscreen—when asked what "caused" her skin to burn, "made" it burn, or "burned" it. Instead, they referred to the sun. With increasing age, children were more inclined to refer to an absence of sunscreen when they heard a periphrastic causative and were somewhat more likely to do so when the periphrastic causative was "caused" compared to "made".

While young children already have available a mapping of "caused" to distal causes in chains, the mapping of "caused" to absences shows protracted development. This could be because it is more difficult for children to map "caused" to absences. They might, for instance, find it more challenging to draw a connection between the use of this word and this kind of referent. Or they might not even have the capacity to conceive of absences. In Experiment 3, we ask whether children can conceive of absences by considering whether they refer to them in causal explanations.

Experiment 3: Absences and explanation

Our goal in this experiment was to determine whether participants would refer to absences when simply asked "why" an outcome occurred. Why-questions are often answered with "because", and adults are more likely to refer to absences with "because" compared to "caused" (Livengood & Machery, 2007). Here, we test whether children do so, too.

Methods

Participants

We recruited 30 adult participants (Age: M = 34, SD = 12; Gender: 10 female, 16 male, 3 non-binary, 1 no response/other; Race: 6 Asian, 3 Black, 200 White, 1 no response/other) and 91 children (Gender: 53 female, 38 male).[3] Adults were recruited through Prolific and paid at a rate of $12 an hour. Children were recruited through Lookit (Scott & Schulz, 2017) and families were paid $5 for their participation.

[3] We pre-registered that we would collect data from 30 4 year olds, 30 5 year olds, and 30 6 year olds.

Procedure and design

The procedure was the same as in Experiment 2. However, this time participants were asked different questions. In the sunburn scenario, participants were asked, "Why did Suzy's skin burn?" and in the flood scenario, they were asked, "Why did the basement flood?". The order of the scenarios was randomized.

Response coding

We pre-registered the same coding scheme as in Experiment 2. As in our previous experiments, our coding scheme was not mutually exclusive.

Results

Figure 4 shows the results. Our analyses focus on the proportion of responses that mention an absent or direct factor. In contrast to children, adults were somewhat inclined to select "both" the absent and direct factor, and children were somewhat more inclined than adults to select "neither" the absent nor direct factor.

As predicted, when asked "Why did Suzy get a sunburn?", we found that children were more inclined to select absences, such as the sunscreen, than direct factors, such as the sun (absence: 73%, CI [66%, 79%], direct: 19%, CI [13%, 25%], odds ratio: 11.8, CrI [6.7, 18.7]. So were adults (absence: 93%, CI [87%, 100%], direct: 27%, CI [15%, 38%], odds ratio: 53.5, CrI [9.1, 183]. Indeed, as the results show, even the youngest children in our sample were more likely to select absent than direct factors when asked a "why" question.

Discussion

When young children are told that Suzy goes to the beach, forgets her sunscreen and gets a sunburn and asked, "What caused Suzy's skin to burn", they tend to say "the sun". But when they are asked, "Why did Suzy's skin burn?", they say "because she forgot her sunscreen". This suggests that even though children can conceive of absences, they don't refer to absences when hearing the word "caused" until later.

General discussion

Linguists distinguish two kinds of causal expressions, lexical causatives and periphrastic causatives. Similarly, philosophers distinguish two kinds of causal relations, production and dependence. Recent work has found that adults use lexical causatives, like "burn", for productive causes that are spatiotemporally continuous with their effects and periphrastic causatives, like "cause", for dependence-based causes such as absences (Rose et al., 2021). This suggests that there is a deep connection between the different causal expressions that linguistics recognize and the different causal relations that philosophers have characterized. Here, we examined the developmental mapping of different causal verbs to different causes.

Our findings reveal that, in fact, early in development, aspects of the connection between causal language and causal relations are already available to children. When considering a situation where Andy hits Suzy with his bike, Suzy falls into the fence and it breaks, 4-year-old children already refer to the proximal cause, Suzy (Experiment 1), when

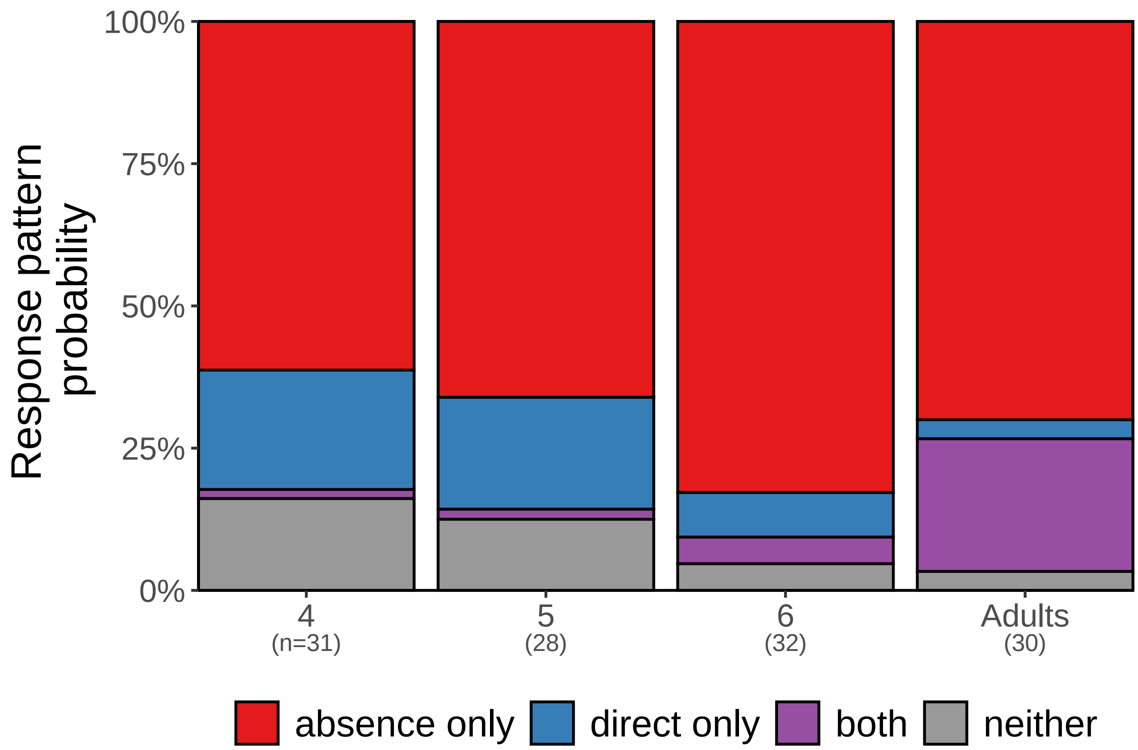

Figure 4

Experiment 3*: Probability with which children refer to the different causes, separated for each age group along with the number of participants. "both" means that they mentioned both the absent and direct factor, "neither" means they mentioned neither.*

asked "Who broke the fence?". Likewise, when considering a situation where Suzy goes to the beach, forgets her sunscreen and gets a sunburn, they refer to the direct cause, the sun (Experiment 2), when asked "What burned Suzy's skin?". This suggests that young children treat lexical causatives, like "broke" and "burned", as picking out causal relations involving direct spatiotemporal contiguity.

Lexical causatives map to direct productive causes, like proximal causes, early in development. But young children also show a sophisticated understanding of "caused", mapping it to indirect productive causes, even though "caused" is rarer and less familiar than lexical causatives, like "broke", and other periphrastic causatives like "made". In fact, 4-year-old children already map "caused" to distal causes in a chain. When asked "Who caused the fence to break?", they refer to Andy, the person on the bike who hit Suzy (Experiment 1). So while children understand more frequent and familiar lexical causatives like "broke" to refer to proximal causes in chains, they also understand that "caused" can refer to distal causes in chains. At the same time they appreciate this, they don't distinguish "made" from lexical causatives, despite "made" being more frequent and familiar than "caused". Not even adults understand "made" to clearly refer to distal causes. Only "caused" does.

While young children show an early command in mapping different causal verbs to different productive relations, such as distal and proximal causes in chains, mapping periphrastic causatives to dependence-based causes like absences shows protracted development. When Suzy goes to the beach, forgets her sunscreen and gets a sunburn (Experiment 2), young children almost never refer to forgetting the sunscreen when asked "What caused her skin to burn?" or "What made her skin burn?". With increasing age, children become more inclined to refer to absences when hearing periphrastic causatives and are somewhat more likely to do so when the periphrastic causative is "caused".

In contrast to young children's ability to map different causal verbs to different productive causes in chains—"caused" to distal causes and lexical causatives like "broke" to proximal causes—mapping periphrastic causatives to absences is more challenging. Yet children can think of absences before mapping "caused" to them. While 4-year-old children don't refer to an absence when asked, "What caused Suzy's skin to burn?", they do when asked "Why did Suzy's skin burn?" (Experiment 3).

Together, our findings suggest that lexical causatives, like "broke" and "burned", and periphrastic causatives, like "made" and "caused" map to different causes over the course of development. We now discuss how semantic and pragmatic factors might contribute to the development of these mappings.

Semantic development

Lexical causatives refer to ways of directly causing particular outcomes. They specify many different direct, productive relations, like "burning" and "breaking", that even young children understand.

Across development, lexical causatives don't undergo semantic expansion in that they don't broaden their domain of application. Lexical causatives have a narrow range—they only refer to direct productive causes—and not to indirect causes or absences. As such, they provide an early emerging, stable set of meanings that allow reference to many different and specific ways of producing outcomes.

Young children understand "made" much like they do "broke" or "burned": "made" refers to direct productive causes. Yet unlike lexical causatives, "made" undergoes some semantic expansion across development. Despite the fact that neither adults nor children tend to reliably refer to distal or absent causes when asked what "made" something happen, they are nonetheless more inclined to refer to these than when considering lexical causatives. Still, "made" tends to refer to productive causes. But in contrast to the many different productive relations specified by lexical causatives, "made" provides a more general way to refer to productive causes, one that doesn't specify the particular manner in which the effect was produced. In this way, "made" might express a generic kind of production.

"Caused" has a more general meaning than "made"—one that goes beyond referring to productive causes. One possibility is that the meaning of "caused" is closely tied to that of counterfactual necessity, such that one event "caused" another to happen when it wouldn't have happened without it (see also e.g., Nadathur & Lauer, 2020). This may be something children already recognize at 4-years-old when selecting distal causes. So when 4-year-old children refer to Andy as the one who "caused" the fence to break, they might appreciate that if Andy hadn't hit Suzy with his bike, the fence wouldn't have broken. Even if children have this meaning available for "caused" it may initially have a relatively narrow domain of application: it can refer to distal causes but not absences. So while 4-year-olds can think of absences—they cite Suzy forgetting her sunscreen when asked "why" she got a sunburn—they don't refer to them when asked what "caused" her skin to burn. They do so later, once the semantics of "caused" expands to include absences.

Questions about the semantic development of "caused", "made" and lexical causatives, like "burned", raise questions about how many causal concepts are developing. There are a number of different possibilities, including that there is a single concept (e.g., Gerstenberg, Goodman, Lagnado, & Tenenbaum, 2021), two concepts that correspond to production and dependence (see e.g., Hall, 2004; Lombrozo, 2010) or many more causal concepts (e.g., Rose et al., 2021). For instance, it may be that each lexical causative expresses a unique productive relation, "made" expresses a generic kind of production, and "caused" expresses dependence. However many causal concepts there are, semantic expansion of "caused" and "made" might explain some of the developmental patterns we have uncovered. But pragmatics factors are also plausibly involved.

Pragmatic development

As verbs like "caused" and "made" undergo semantic expansion, children develop a better understanding of what causal expressions mean. Several pragmatic factors could contribute to children's developing causal language understanding. We suggest some of them here, drawing on the Rational Speech Acts (RSA) framework (Degen, 2023; Frank & Goodman, 2012; Goodman & Frank, 2016).

Suppose that lexical causatives can only refer to direct causes and that periphrastic causatives can refer to any kind of cause. If Andy hits Suzy with his bike, she falls into the fence and it breaks, pragmatic inference will lead a listener to infer that a speaker wanted to refer to Andy, when they asked "Who caused the fence to break?": If they had wanted to refer to Suzy, they would have asked "Who broke the fence?" instead. How could developments in pragmatic reasoning help explain the overall pattern of results we observe? The RSA framework suggests three factors that could matter: speaker optimality, utterance cost, and reference prior. Here, we outline the general idea, and provide a concrete implementation in the appendix.

Speaker optimality captures how likely a speaker uses more informative utterances. If older children assume that speakers are more likely to be informative, then this helps explain the general pattern that older children are more likely to differentiate between the referents depending on whether they hear a lexical or periphrastic causative.

Utterance cost captures how costly it is for a speaker to say something. An utterance is more costly when it's more difficult to say and when it comes to mind less easily (Degen, 2023; Degen, Hawkins, Graf, Kreiss, & Goodman, 2020). Periphrastic causatives are longer expressions than lexical causatives (e.g., "caused to break" versus "broke"), so their utterance cost is higher. "Caused" is rarer than"made", so "caused" is more costly than "made". This difference in utterance cost between the expressions accounts for the fact that listeners are more likely to infer that the distal or absent cause was referred to when a speaker used "caused" compared to "made". If a speaker was willing to incur a greater cost, they must have wanted to be particularly informative.

Finally, the *reference prior* captures how likely a speaker is to refer to specific events. By assuming that speakers are more likely to refer to direct causes than distal causes, and even less likely to refer to absences, we can account for some of the differences between the scenarios. Hypothetically, even if the semantics of "caused" and "made" were identical, differences in their interpretation could arise from pragmatic effects like the ones we've outlined here. In reality, it is likely that both semantic and pragmatic mechanisms jointly produce the changes in children's causal language understanding that we observed in our experiments. In the appendix, we also look at how children's answers are affected by which causal expression they hear first. Order effects can provide further evidence for the role of pragmatic inference in language understanding (e.g., Clark, 1990; Diesendruck & Markson, 2001; Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar, 1996; Halberda, 2003).

Conclusion

We examined how children develop a mapping from different causal verbs to different kinds of causes. They understand that lexical causatives, like "burn", refer to direct causes that produce their effects, that periphrastic causatives, like "cause", can to refer to causes that are more remote from their effects, and eventually come to understand that "cause" can refer to absences, too. We have argued that both semantic and pragmatic mechanisms contribute to this development, and that more work is needed to tease these contributions apart.

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Author contributions

Conceptualization: DR, SY, SN, EM & TG; Methodology: DR, SY, SN, EM & TG; Software: DR, SY, TG; Validation: DR, TG; Formal Analysis: DR, TG; Investigation: DR, SY; Data Curation: DR, SY; Writing—Original Draft: DR; Writing—Review & Editing: DR, SN, EM, TG; Visualization: DR, TG; Supervision: DR, EM, TG; Project Administration; DR, EM, TG; Funding Acquisition: EM, TG.

The authors declare that there are no competing interests.

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