Preschoolers Compute Literal and Pragmatic Meanings of Conditionals with Contextual Support

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Abstract

Understanding conditional inferences is fundamental to human reasoning, allowing us to predict the consequences of actions. For instance, the conditional, "If you eat your broccoli, you'll get a candy" can be interpreted literally, meaning eating broccoli is one way to get a reward, or pragmatically, implying it is the only way. Past studies show school-aged children (ages 7-12) struggle to arrive at literal meanings but, interestingly, compute adult-like, pragmatic interpretations at this age. A key limitation of past research is the lack of testing in contexts that favor literal meanings. We conducted two studies to examine whether children can derive literal interpretations when supported by context, focusing on scenarios where adults prefer literal over pragmatic interpretations. We found that preschoolers, as young as 4 years old, are adult-like in computing literal meanings of conditionals when contextually supported, and also can arrive at pragmatic meanings of conditionals. These findings inform theories of logical reasoning and implicature acquisition.

Keywords: conditional reasoning; access to alternatives; logical reasoning; conversational implicatures

Introduction

Conditional reasoning is a fundamental aspect of human cognition. It allows us to engage in hypothetical thinking, enabling the imagination and analysis of possible states of the world. For children, computing conditional inferences is important not only for the development of logical reasoning (Ward & Overton, 1990; Kuhn, 1977), but also for learning about causal relations (Kushnir & Gopnik, 2007, Gopnik et al., 2001), understanding rules and conventions (Harris & Nunez, 1996), thinking about possibilities (Grigoroglu & Ganea, 2022), and understanding future hypotheticals and counterfactuals (Beck et al., 2006; Robinson & Beck, 2000; Rafetseder & Perner, 2012; Riggs et al., 1998). For example, consider a child who hears the statement from their dad, "If you eat your broccoli, you'll get a candy." The child might infer a stronger meaning, concluding that not eating the broccoli means they will not get a candy—interpreting the antecedent as the only path to the reward and the conditional as "If and only if *p*, then *q*." Alternatively, the child might take the statement literally, understanding it to mean that although eating broccoli leads to a candy, it might also be obtained in other ways, such as tidying up the room, finishing homework and so on. While previous research establishes that adults readily access these different interpretations, studies in children, using different methods, conclude that they may not. In the present study, we investigate how preschoolers interpret conditionals and specifically whether they are capable of accessing both of these interpretations.

Multiple previous studies have investigated the development of conditional reasoning in school-aged children (7- to 12-year-olds), and have found that they generally struggle to arrive at literal meanings of conditional statements (Barrouillet & Lecas, 2002; Klaczynski, 2006; Klaczynski et al., 2004: Gauffroy & Barrouillet, 2009; De Neys & Everaerts, 2008; DiBacco, 2008; Barrouillet et al., 2008; Markovits, 2017, but see Rumain et al., 1983).[1] For example, Markovits (2016) presented participants with written conditional statements such as, "If the circle is yellow, then the star is black," and then presented a second written statement like, "The circle is green, and the star is black". Although the literal interpretation of the first statement does not state what happens if the circle is not yellow, children often rejected these cases, compatible with an "if and only if" meaning. Such findings have led multiple previous studies to conclude that children are unable to compute the literal meanings of conditionals, and are generally less proficient logical reasoners, relative to adults.

[1] Note that children's performance in conditional reasoning tasks varies based on several factors, including the type of task (e.g., truth table versus conditional inference and, the nature of the conditional (e.g., abstract, category-based, causal; Gauffroy & Barrouillet, 2009; Janveau-Brennan & Markovits, 1999; Markovits, 2017). For example, children may interpret conditionals literally in category-based scenarios (e.g., "If it is a dog, then it has four legs") and perform better with causal conditionals compared to arbitrary ones (Gauffroy & Barrouillet, 2009; Janveau-Brennan & Markovits, 1999). These variations suggest that the developmental trajectory of conditional reasoning is influenced by the contextual factors and structural characteristics of the tasks.

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There are several reasons to question the conclusion that this difference is due to difficulties in logical reasoning, specifically. First, although adults are capable of deriving literal meanings for such abstract conditionals given reflection, there is considerable evidence that they actually prefer non-literal meanings for such statements, unless strong contextual support for literal meanings is provided. Specifically, children's preferred "if and only if" meaning (e.g., You'll get candy *only* if you eat your broccoli), is compatible with a pragmatic inference that is common in adult reasoners, known as Conditional Perfection (Cornulier, 1983; Geis & Zwicky, 1971; Horn, 2000; Levinson, 2000; van der Auwera, 1997; von Fintel, 2001).

Most prior analyses treat Conditional Perfection as a type of conversational implicature, often grounded in Gricean theories of pragmatic reasoning (e.g., Grice, 1975; Geurts, 2009). Under Gricean accounts of pragmatic reasoning, perfection stems from the assumption that the speaker is being cooperative: hearers assume that the speaker is giving the appropriate amount of information (Maxim of Quantity) and is only making statements that they believe to be true and for which they have evidence (Maxim of Quality). Accordingly, if the speaker believed that there were other ways to get candy, then they would have uttered a more informative alternative statement such as, "If you eat your broccoli or tidy your room, you'll get candy". The fact that the speaker did not utter a more informative alternative leads the listener to conclude that the condition mentioned in the antecedent is the *only* one that will bring about the consequent. Although there are different accounts of how this inference arises, most agree that the pragmatic interpretation of conditionals arises when the condition stated in the antecedent is understood to exhaust the set of conditions sufficient for the consequent. Given this, what has often been described as failure in children's responses to conditionals may, in fact, reflect their reliance on relatively sophisticated pragmatic reasoning.

A second reason to question whether children's reluctance to endorse literal meanings reflects a deficit in logical reasoning is that past studies test children using highly abstract stimuli in contexts that do not support literal interpretations. In an effort to prevent children from drawing on knowledge of real-world causal relations between antecedents and consequents (e.g., if it rains then I will get wet), past studies have primarily asked children to make judgments about arbitrary relations between shapes, colors, letters, etc., without any available context. While it is important to avoid the confound of existing causal relations, it may also be important that the chosen stimuli permit children to easily model their own causal analysis, which may be inhibited by abstract stimuli. Relatedly, abstract stimuli may simply be harder to represent in working memory, given the need to represent multiple properties and the combinations simultaneously in support of reasoning. Given these considerations, age-related differences may reflect differences in domain-general cognitive capacities like working memory, or in higher-order, metacognitive representations of conditionals (Markovits et al., 2015; Evans & Over, 2004).

In the present paper, we conducted two preregistered studies to investigate whether children can compute literal interpretations of conditionals when contextually supported. Specifically, we explored two contexts in which, for adults, literal meanings are preferred. In Experiment 1, we investigated the effect of a contextual factor known to elicit literal responses in adults—the access to alternative antecedents (e.g., Cummins et al., 1991; Cummins, 1995; De Neys et al., 2002; Janveau-Brennan & Markovits, 1999). Pragmatic interpretations of conditionals depend on listeners' knowledge of alternative antecedents that might produce a consequent. For example, under a broadly Gricean account, listeners infer two pragmatic implications for a statement like, "If you eat your broccoli, you'll get a candy": (i) the candy is not freely given (i.e., it is conditional on eating broccoli), and (ii) the candy will be given only if the broccoli is eaten (i.e., an "if and only if p, then q" interpretation), and thus there are no other antecedents that will produce candy. In contrast, literal interpretations emerge when alternative antecedents are available in the common ground. For example, if a child knows that candies are awarded for completing some other task (e.g., tidying toys), eating broccoli is interpreted as merely one sufficient condition among others, increasing the likelihood of a literal interpretation. By manipulating the salience of such alternative antecedents, we tested whether this contextual factor would increase children's tendency to adopt literal interpretations of conditionals. To investigate this, participants in Experiment 1 were presented with a scenario in which either two characters (Explicit-Alternatives Condition) or only one character (No-Explicit-Alternatives Condition) had the opportunity to place items into a box for their animal friend to find later. In Experiment 2, we tested what Austin (1961) called "Biscuit Conditionals" — e.g., statements such as, "If you are hungry, there are biscuits in the cupboard," In such statements, the truth of the consequent does not depend on the truth of the antecedent and remains true even if the antecedent is false — e.g., there are biscuits in the cupboard regardless of whether they are hungry. Such sentences are not typically susceptible to pragmatic interpretation because, under normal circumstances, it would be infelicitous to infer that there are biscuits in the cupboard only if the listener is hungry - i.e., that hunger causes them to appear. In Experiment 2, we asked whether children are able to assign literal meanings to these conditionals, like adults.

Experiment 1: Explicit Alternatives

In Experiment 1, participants heard a conditional statement, such as "If [character] buys items, the animal will find items in the box.", which allowed for two possible interpretations. A literal interpretation would suggest that the mentioned character's action was just one possible way for the animal to find items, implying that other ways might exist—such as the

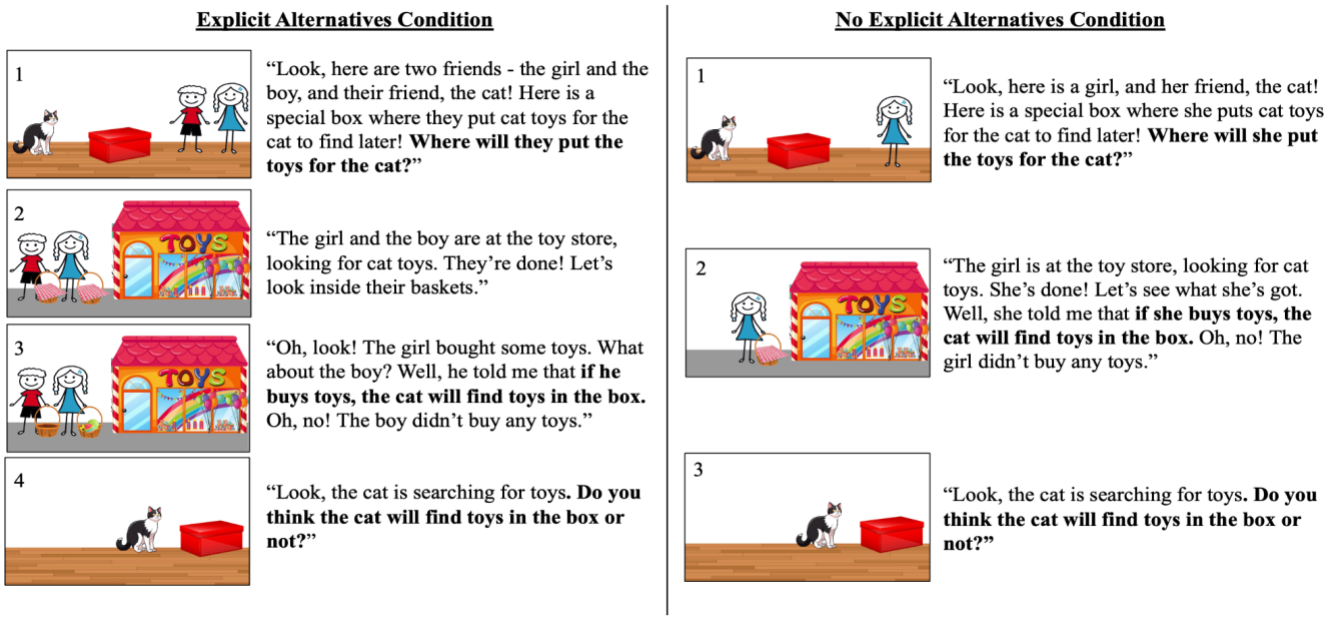

Figure 1: Sample story used in Experiment 1 in Explicit Alternatives Condition (on the right) and No Explicit Alternatives Condition (on the right). Events were presented sequentially from (1) to (3)/(4).

second character's actions in the Explicit-Alternatives Condition. A pragmatic interpretation, on the other hand, would mean that the outcome depended entirely on the mentioned character's action, such that if they did not act, the animal would not find any items.

Methods

Participants: We recruited 66 children from preschools and a children's museum in the US between the ages of 4;0 and 5;11 (M_{age}=4;11), who spoke English as a primary language. Based on our preregistered exclusion criteria, we excluded 6 participants who failed 2 out of 3 attention checks. The final sample included 60 participants, 30 for each condition. We also tested 30 adult participants on the online research platform Prolific.co (n=15 per condition).

Materials & Procedure: Children were tested in person by an experimenter, and adults were tested online using pre-recorded audio stimuli. Participants were randomly assigned to one of two between-subjects conditions: the Explicit Alternatives Condition or the Non-Explicit Alternatives Condition (see Fig. 3).

In the Explicit Alternatives Condition, two characters were introduced to an animal and a box where two additional characters (a girl and a boy) could place items for the animal to find later. After introducing the scene, the experimenter asked, "Where will they put the toys for the cat to find later?" to ensure that participants understood. During each trial, the boy and girl visited a store to shop for items. Next, the contents of one character's basket (e.g., the girl's basket), which contained the target items, were revealed. Before revealing the contents of the other character's basket, the experimenter asked, "What about the boy?" to prompt curiosity. The experimenter then introduced a conditional statement, such as, "If the boy buys toys, the cat will find toys in the box." It was then revealed that the boy did not buy any toys, denying the antecedent of the conditional statement. This was visually reinforced with an image of the boy's empty basket, and participants were asked about the consequent: "Do you think the cat will find toys in the box or not?"

In the Non-Explicit Alternatives Condition, only a single character appeared in the story. After this character returned from their shopping trip, the experimenter used the conditional statements (e.g., "If the boy buys toys, the cat will find toys in the box"), followed by the disclosure that the boy did not buy any toys. Participants were then asked the same questions (e.g., if the cat would find toys in the box). To ensure that participants were engaged and understood the story, Control Trials were included. In Control-Yes Trials, two characters purchased a target item, and the items were visible in their baskets (i.e., the story affirmed the antecedent). In contrast, in Control-No Trials, neither character purchased a target item, and their baskets were empty (i.e., the story denied the consequent).

Each condition consisted of 8 trials. These included 3 critical trials, 1 Control-Yes trial, 1 Control-No trial, and 3 attention-check trials that did not involve conditional language. Participants were presented with one of two pseudo-randomized trial orders. The trials were counterbalanced to ensure that the position and mention of the characters (the girl versus the boy) were evenly distributed across conditions.

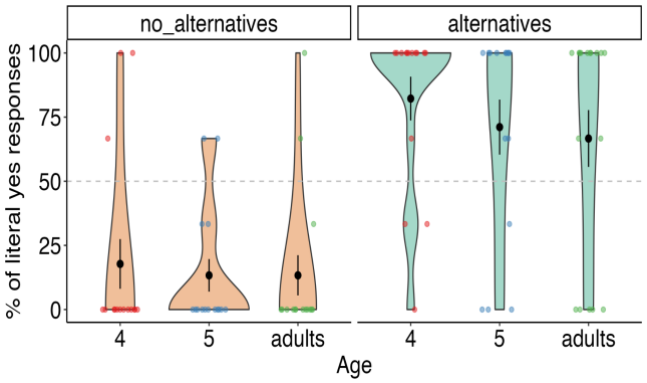

Figure 2: Proportion of literal "yes" responses by Alternatives Type and Age. The width of the shaded area of violin plots represents the proportion of the data located there. Each dot represents a participant. Error bars represent standard error of the mean

Results & Discussion

Our primary question was whether participants' proportion of literal "yes" responses differed between Explicit Alternatives Condition and No Explicit Alternatives Condition for children and adults. We built generalized mixed-effects logistics regression models (GLMMs) predicting the proportion of literal "yes" responses from contrast-coded fixed effects of Alternatives Type (No Explicit Alternatives, Explicit Alternatives) and Group (adults, children). We compared a model with the fixed effect of Alternatives Type against a base model that included only by-subject and by-item random intercepts. There was a significant main effect of Alternatives Type (χ^2 (1) = 71.67, p < .001) Alternatives condition (β = 16.16, SE = 2.4, z = 6.71, p < .001). Adding Group or its interaction with Alternatives Type did not improve the model fit (p > .05, indicating that there were more literal responses in the Explicit Alternatives condition compared to the No Explicit Alternatives Condition.

These results reflect the fact that children gave significantly more literal responses in the Explicit Alternatives condition (M = 0.76, SD = 0.37; t (16) = 3.91, p < .001) and more pragmatic responses in the No Explicit Alternatives condition (M = 0.15, SD = 0.31; t (16) = -6.03, p < .001). For the adult control group, literal responses in the Explicit Alternatives condition (M = 0.66, SD = 0.45; t(16) = 1.50, p > .05) were not significantly different from chance, while responses in the No Explicit Alternatives condition (M = 0.13, SD = 0.30; t(20) = -4.68, p < .001) were significantly more pragmatic (see Figure 2).[2]

In summary, both children and adults gave more literal "yes" responses in the Explicit Alternatives condition compared to the No Explicit Alternatives condition, suggesting that children, like adults, are capable of generating literal meanings for conditional statements, in addition to pragmatically "perfected" meanings.

Experiment 2: Biscuit Conditionals

In Experiment 2, we sought an additional test of children's ability to derive literal meanings of conditional statements under conditions that generally support literal meanings in adults. To do so, we tested children's interpretation of Biscuit Conditionals, in which the antecedent has no clear causal connection to the consequent - e.g., "If you are hungry, there are biscuits in the cupboard." We asked whether children would provide pragmatic responses as predicted by previous studies of older children, or if instead they would resemble adults and access literal meanings when supported by context.

Methods

Participants: We recruited 128 children between the ages of 4;0 and 6;11 from preschools in the US and Canada, and a children's museum in the US. All participants spoke English as a primary language. Based on our preregistered exclusion criteria, we excluded 8 participants who missed more than one attention check trial. Our final sample included 120 children with 40 4-year-olds, 40 5-year-olds and 40 6-year olds.[3] We also tested 40 adult participants on the online research platform Prolific.co.

Materials & Procedure: Materials were presented as an animated slidedeck. Children were tested one-on-one by the experimenter. The experimenter began the session by placing the slidedeck in front of the participant, saying, "I'm going to tell you some stories and ask you some questions after." Participants were randomly assigned one of the two between-subjects conditions: a Standard Conditional condition ("If the girl bakes cookies, the boy will find cookies in the box"), where a pragmatic meaning is supported, or a Biscuit Conditional condition ("If the boy wants to read, he will find books in the box") where a literal interpretation is supported. In each trial participants were told a story involving two characters and a box. In the Standard Conditional group, participants heard a conditional
statement about the characters (e.g., If the girl bakes cookies the boy will find cookies in the box) and the story continued with one of the three context types: two control context types and one critical context type. In the first type of control context (Control-Yes Trials), the story affirmed the antecedent (e.g., The girl baked cookies), and participants were asked about the consequent (e.g., Do you think the boy will find cookies in the box?). In the second type of

[2] As expected, in the Control-Yes trials, children (M = 0.90, SD = 0.30) and adults (M = 1.00, SD = 0.00) showed high accuracy. Similarly, in the Control-No trials, children (M = 0.15, SD = 0.36) and adults (M = 0.07, SD = 0.25) performed as expected.

[3] This experiment was conducted first and included a wider age range; however, it is presented second to facilitate a discussion of the role of alternatives prior to addressing the more specialized case of biscuit conditionals.

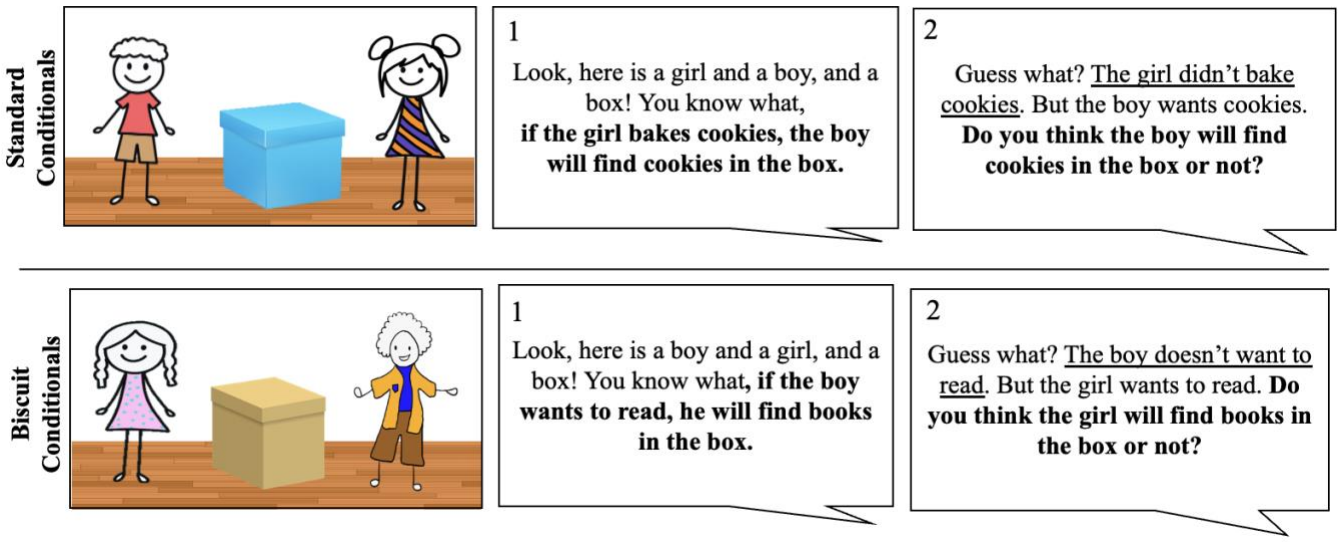

Figure 3:. Sample story used in Experiment 2 in Standard Conditionals (on the top) and Biscuit Conditionals (on the bottom). Events were presented sequentially from (1) to (2).

control context (Control-No Trials), the story denied the consequent (e.g., There are no cookies in the box) with an image of an empty box and asked about the antecedent (Do you think the girl baked cookies?). In the critical contexts (Critical Trials), the antecedent was denied (e.g., The girl didn't bake cookies) and asked about the consequent (e.g., Do you think the boy will find cookies in the box or not?), allowing for either a literal response ("yes") or a pragmatic, perfected, response ("no").

Participants in the Standard Conditional group experienced 11 trials, including 4 critical trials, while those in the Biscuit Conditional group underwent 9 trials, with 4 being critical trials. The discrepancy was because, in the Biscuit Conditional condition, it was not possible to include Control-No cases (e.g., showing an empty box would be in contradiction with the Biscuit statement itself). Each list also included 3 attention check trials without the use of conditional, designed to check attention. Participants received one of two pseudo-randomized trial orders. Trials were counterbalanced for the position and the mention of the characters (the girl vs the boy).

Results & Discussion

Our primary question was whether children and adults were more likely to interpret conditionals literally depending on the Conditional Type. We constructed generalized mixed effects logistic regression models predicting literal "yes" responses and a model with the contrast-coded fixed effects of Conditional Type against a base model that included only by-subject and by-item random intercepts. There was a significant main effect of Conditional Type ($\chi^2(1) = 87.09$, $p < .001$), indicating that there were more literal responses in the Biscuit condition compared to the Standard condition ($\beta = 5.03$, $SE = 0.72$, $z = 6.99$, $p < .001$). When Age was added to the model (4, 5, 6, adults), we found no main effect ($p > .05$). However, there was a significant interaction between Age and Conditional Type ($\chi^2(3) = 14.15$, $p < .01$). *Post hoc* comparisons, Bonferroni corrected for multiple comparisons, revealed no age effects for Biscuit Conditionals, but that for Standard Conditionals, 6-year-olds and adults actually gave more pragmatic "no" responses compared to 4-year-olds ($\beta = 3.81$, $SE = 1.13$, $z = 3.36$, $p = .02$) and 5-year-olds ($\beta = 3.66$, $SE = 1.12$, $z = 3.27$, $= .03$). Thus, if anything, younger children were *more likely* to provide literal responses than older children and adults.

These results reflect the fact that, in the Standard Conditional condition, 4-year-olds ($M = 0.33$, $SD = 0.36$), 5-year-olds ($M = 0.31$, $SD = 0.34$), 6-year-olds ($M = 0.11$, $SD = 0.2$), and adults ($M = 0.03$, $SD = 0.12$) gave fewer literal "yes" responses than expected by chance, compatible with deriving a pragmatic meaning for these items (*t*-tests: 4-year-olds, $t(20) = -2.15$, $p = .04$; 5-year-olds, $t(20) = -2.45$, $p = .02$; 6-year-olds, $t(20) = -9.06$, $p < .001$; adults, $t(20) = -16.91$, $p < .001$). By contrast, in the Biscuit Conditionals condition, 4-year-olds ($M = 0.82$, $SD = 0.29$), 5-year-olds ($M = 0.75$, $SD = 0.27$), 6-year-olds ($M = 0.82$, $SD = 0.25$), and adults ($M = 0.83$, $SD = 0.34$) gave literal "yes" responses significantly more often than expected by chance (*t*-tests: 4-year-olds, $t(20) = 5.14$, $p<.001$; 5-year-olds, $t(20) = 4.16$, $p < .001$; 6-year-olds, $t(20) = 5.85$, $p<.001$; adults, $t(20)=4.33$, $p<.001$)[4].

[4] In the Control-Yes condition, 4-year-olds ($M = 0.79$, $SD = 0.32$), 5-year-olds ($M = 0.81$, $SD = 0.33$), 6-year-olds ($M = 0.86$, $SD = 0.23$), and adults ($M = 0.98$, $SD = 0.11$) performed as predicted. Similarly, in the Control-No condition, 4-year-olds ($M = 0.08$, $SD = 0.18$), 5-year-olds ($M = 0.15$, $SD = 0.33$), 6-year-olds ($M = 0.09$,

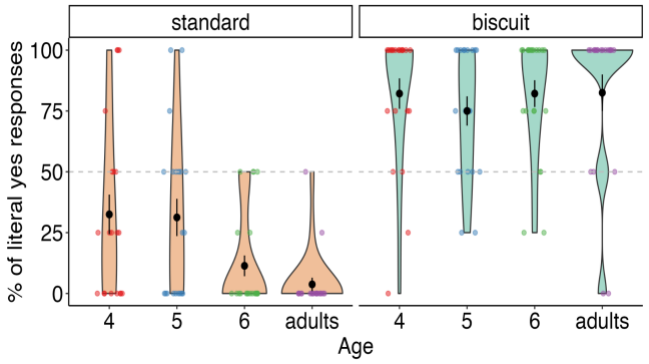

Figure 4: Proportion of literal "yes" responses by Conditional and Age group. The width of the shaded area of violin plots represents the proportion of the data located there. Each dot represents a participant.

In summary, participants were more likely to interpret Biscuit Conditionals literally relative to Standard Conditionals, regardless of age. While no overall age differences were found, younger children (4- and 5-year-olds) were more likely to give literal responses to Standard Conditionals than older children (6-year-olds) and adults, who provided more pragmatic responses. In the Biscuit Conditionals condition, participants across all age groups consistently gave literal responses at rates above chance. These findings suggest that children can flexibly interpret conditionals both literally and pragmatically, depending on the context, with 6-year-olds and adults responding even more pragmatically when there are no contextual cues to suggest the opposite.

General Discussion

We investigated whether preschoolers can access both the literal and pragmatic interpretation of conditionals when supported by context. We found that children can compute literal meanings when (1) potential alternative antecedents for the consequent are salient in the context (Exp. 1), and (2) the literal interpretations are felicitous and expected in the conversation, as in biscuit conditionals (Exp. 2). These results suggest that, when tested with concrete and supportive inferential contexts, children as young as 4 are adult-like in their ability to compute both the literal and the pragmatic meanings of conditionals.

These findings contribute to a broader literature investigating the development of conversational implicature in children. At first glance, our findings are perhaps surprising, given that in previous studies children often struggle to derive conversational implicatures and prefer the literal meanings of quantifiers (e.g., *some/all*) and other logical expressions (e.g., *or;* Noveck, 2001; Papafragou & Musolino, 2003; Chierchia et al., 2001; Huang & Crain, 2020; Skordos et al., 2020; Hochstein et al., 2016; Singh et al., 2016; Tieu et al., 2015). For example, when children hear a sentence like, "Mary ate some of the candies," they often accept scenarios where Mary ate all the candies, whereas adults reject such scenarios because, under a Gricean account, they assume that if the speaker had meant "Mary ate all of the candies," they would have said so explicitly - i.e., they consider the stronger alternative statement containing "all" to pragmatically enrich the original utterance to mean, "Mary ate some, but not all, of the candies." According to the "access to alternatives" account (Barner & Bachrach, 2010; Bale & Barner, 2013; Barner et al., 2011; Foppolo et al., 2012; Gotzner et al., 2020; Skordos & Papafragou, 2016; Stiller et al., 2015) children fail to spontaneously access the stronger alternative statement containing "all," and therefore fail to make the "some, but not all" inference. Similarly, the literal interpretation of conditionals often involves access to alternative antecedents (i.e., that chores as well as broccoli can lead to candy), which may require deliberate cognitive effort that is challenging for children in abstract or otherwise unsupportive contexts. Compatible with this idea, some previous studies have attributed children's difficulties with conditionals to a lack of background knowledge or challenges in retrieving alternative preconditions from semantic memory (e.g., De Neys & Everaerts, 2008; Janveau-Brennan & Markovits, 1999; Quinn & Markovits, 1998). Thus, rather than lacking a logical understanding of conditionals, children may struggle to override pragmatic interpretations because accessing alternative antecedents requires additional cognitive resources and contextual support.

In conclusion, our results suggest that children's challenges with conditional reasoning arise not from deficits in logical reasoning ability but from the difficulty of spontaneously generating alternatives when these are absent from the immediate context. Future research should build on these insights by exploring how children's understanding of conditionals interacts with their abilities in future hypothetical thinking and counterfactual reasoning (e.g., Ganea & Nyhout, 2019; Rafetseder et al., 2010), and reasoning about possibilities (e.g., Leahy & Carey, 2020; Turan-Küçük & Kibbe, 2024). Investigating these connections could provide a more comprehensive understanding of how children develop complex reasoning skills and how different cognitive processes contribute to their ability to engage with conditional statements.

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SD = 0.25), and adults (M = 0.00, SD = 0.00) also demonstrated expected accuracy.

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