## Title
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# Preschoolers and adults make inferences from novel metaphors

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**Abstract**

Historically, metaphors have facilitated creative change across multiple disparate domains. Similarly, human adults use metaphors to guide their everyday thinking and reasoning. While previous research in cognitive development has demonstrated that preschoolers *understand* metaphors, less is known about how preschoolers might *learn* from metaphors. The current experiments investigate whether preschoolers can use novel metaphors to make additional inferences about artifacts. Experiment 1 demonstrates that both four-year-olds and adults who hear novel positive and negative metaphors (e.g., "Daxes are clouds. Daxes are not suns.") can form additional inferences based on these metaphor (e.g., that daxes let out water rather than light up). Experiment 2 conceptually replicates this result using a modified paradigm with only positive metaphors (e.g., "Daxes are clouds"). Taken together, these findings suggest that children can not only understand, but also learn from, metaphors. Consequently, metaphors may be a powerful learning mechanism in both adulthood and early childhood.

**Keywords:** cognitive development; metaphor comprehension; inferential reasoning

## Introduction

Metaphors are figurative utterances that directly compare concepts from one domain to concepts in other unrelated domains. Metaphors occur frequently in both everyday language (e.g., "I got lost in a sea of people") and famous creative works (e.g., Emily Dickinson's "Hope is the thing with feathers"). In human adults, metaphors can facilitate communication and provide effective frameworks for reasoning about abstract concepts, thus influencing attention, memory, and information processing (Camp, 2009; Thibodeau et al., 2017). Moreover, metaphors are a force for creative change across many disparate domains: for example, metaphors facilitate the development of new insights about old concepts in art and poetry (Camp, 2009; Kulvicki 2020), new word meanings in language (Bowdle & Gentner, 2005; Camp, 2006; Holyoak & Stamenkovíc, 2018), and new discoveries and theories in science (Kuhn, 1993).

While researchers have investigated the influence of metaphors on human adult cognition, less is known about whether and how metaphors might impact thinking and reasoning in young children. Some previous research has suggested that young children have difficulties understanding metaphors (Winner et al., 1980), possibly due to an inability to reason about abstract relations (Silberstein et al., 1982) or a pragmatic inability to understand non-literal language (Winner, 1997). Under this view, children may only understand metaphors in an adult-like fashion quite late in development, possibly not until adolescence (Demorest et al., 1983; Silberstein et al., 1982; Winner, 1997). However, other researchers have argued that metaphor comprehension might actually emerge much earlier in ontogenesis (Pouscoulous & Tomasello, 2020; Zhu et al., 2020). Indeed, recent work showed that children develop sophisticated relational reasoning abilities in their preschool years (Christie & Gentner, 2014; Goddu, Lombrozo, & Gopnik, 2020; Hochmann et al., 2017) or even earlier (Anderson et al., 2018; Walker et al., 2016; Walker & Gopnik, 2017). Moreover, additional research demonstrated that preschoolers can understand other kinds of non-literal language, such as metonyms (Falkum et al., 2017; Köder & Falkum, 2020; Zhu, 2021). Consistent with these findings that preschoolers can reason about abstract relations and understand non-literal language, more recent work suggested that preschoolers are also able to understand metaphors. For example, Pouscoulous and Tomasello (2020) showed that children as young as three years of age understand metaphors based on perceptual similarities (e.g. "The bottle with the big belly" to refer to a round bottle over a slender bottle). Similarly, Zhu and colleagues (2020) demonstrated that four- and five-year-olds understand abstract metaphors based on functional similarities between concepts (e.g., "clouds are sponges"; "roofs are hats"). Specifically, young children differentiated between functional metaphors (e.g., "roofs are hats") and nonsense statements (e.g., "dogs are scissors"), and a subset of children were even able to explicitly state the functional similarities between concepts in the metaphors (e.g., "roofs and hats both cover you").

While this research suggests that children can understand metaphors, less is known about whether metaphors might facilitate further thinking and reasoning in children, as they do in adults (Thibodeau et al., 2017). Given that metaphors can facilitate the discovery of new information (Kuhn, 1993), one possibility is that children may be able to use metaphors to make novel inferences. While previous research demonstrates that preschoolers can represent similarities between two familiar concepts – for example, by noticing that sponges and clouds both hold water (Gentner, 1988; Zhu et al., 2020) – it is unknown whether preschoolers can also use metaphors to make entirely new inferences – for example, by using their knowledge of clouds to learn about the features of novel artifacts. If preschoolers can make new inferences from metaphors, this may suggest that metaphors are a powerful learning mechanism, not only in adulthood, but also in early childhood. Though developmental psychologists have



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extensively studied children's learning mechanisms, there is little research on children's capacity to learn from metaphors.

Thus, the current paper is the first to investigate whether young children can learn from metaphors, specifically by using metaphors to make novel inferences and thus guide their acquisition of new knowledge. In two experiments, we investigated whether preschoolers can *learn* from metaphors. In Experiment 1, we presented four-year-olds with vignettes about novel artifacts and compared these novel artifacts to natural or social kinds, using both *positive metaphors*, which assert that two disparate concepts are similar (e.g., "Daxes are clouds"), and *negative metaphors*, which use negation to assert that two disparate concepts are dissimilar (e.g., "Daxes are not suns"). Moreover, Experiment 1 also validated this novel paradigm with adult participants. In Experiment 2, we conceptually replicated the preschooler results from Experiment 1, using only positive metaphors.

## Experiment 1

In Experiment 1, we investigated whether preschoolers and adults are capable of learning from metaphors. Specifically, we asked whether preschoolers and adults can make additional inferences about the functions of novel artifacts, after hearing about the novel artifacts in metaphoric utterances (e.g. "Daxes are clouds"). In order to ensure that participants interpreted the utterances as non-literal metaphors comparing two conceptually distinct items (e.g., "Juliet is the sun") rather than literal category statements (e.g., "Juliet is a girl"), we explicitly specified that all the novel items were artifact kinds (i.e., toys) and compared these novel items to natural or social kinds (e.g., animals, occupations). Additionally, in Experiment 1, we presented participants with both positive and negative metaphors about each novel item (e.g., "Daxes are clouds. Daxes are not suns."). This ensured that participants' correct responses were driven by a sensitivity to the contents of the metaphor and the overall sentence structure, and not by simpler, lower-level associative mechanisms (e.g., hearing "cloud" might encourage participants to select the cloud-related response, without attending to the actual metaphor).

## Methods

**Participants.** We adhered to a stopping rule of 32 participants in each age group, leading to a total of 32 4-year-old participants (M = 4.59 years, SD = .26 years, range = 4.04 – 4.99 years, 14 females and 18 males) and 32 adult participants (M = 21.19 years, SD = 1.68 years, range = 18.20 – 25.64 years, 26 females and 6 males). Researchers tested three additional children whose data were excluded due to experimenter error. Children were recruited from a local database and adults were recruited from a university campus. All participants were tested online, over Zoom. All experiments reported in this paper were approved by the university's Committee for the Protection of Human Subjects. All adult participants and parents of child participants provided informed consent. The preschooler component of the experiment is preregistered at https://osf.io/9kjb4/.

**Stimuli and Procedure**. The experimenter presented participants with stories, which participants viewed using either a computer or tablet. The experimenter introduced the paradigm to the participant by showing them a clipart picture of a girl and saying, "This is my friend Sophie. Sophie makes a lot of toys in her toy factory. She's going to tell you about her toy, and then your job is to guess what Sophie's toy can do! Ready to play?"

On each trial, the experimenter introduced a novel toy, using both a positive and a negative metaphor (e.g., "Sophie says, 'This toy is a dax. Daxes are clouds. Daxes are not suns.'"). As the experimenter presented this information verbally, clipart pictures (e.g., a novel toy, a cloud, and a sun) appeared on the screen. To help participants remember which metaphor was the positive comparison and which metaphor was the negative comparison, the pictures of the two

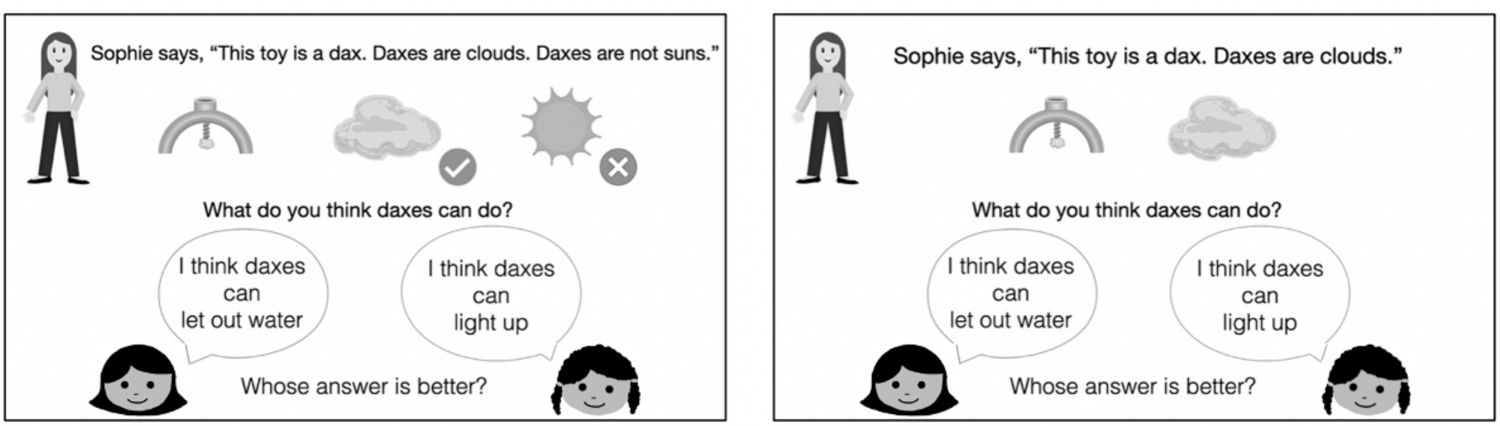


Figure 1. Example of a test trial, presented in either Experiment 1 with positive and negative metaphors (left) or Experiment 2 with only positive metaphors (right).

Table 1: Experiment 1 Metaphors and Inferences

| Novel Toy | Metaphor A | Metaphor B | Inference A (Corresponding to Metaphor A) | Inference B (Corresponding to Metaphor B) |
|---|---|---|---|---|
| Daxes | Daxes are clouds | Daxes are suns | Daxes can let out water | Daxes can light up |
| Lubbos | Lubbos are snails | Lubbos are bees | Lubbos can move slowly | Lubbos can buzz loudly |
| Wugs | Wugs are songbirds | Wugs are cheetahs | Wugs can make music | Wugs can move quickly |
| Feps | Feps are ballerinas | Feps are soldiers | Feps can twirl around | Feps can shoot pebbles |
| Biboos | Biboos are seagulls | Biboos are kangaroos | Biboos can fly | Biboos can bounce |
| Blickets | Blickets are eyes | Blickets are teeth | Blickets can help you see things | Blickets can help you chop things |
| Meelees | Meelees are stars | Meelees are ponds | Meelees can sparkle | Meelees can hold water |
| Pims | Pims are ducks | Pims are fireflies | Pims can float in the water | Pims can glow in the dark |

comparison items were accompanied with either a small green checkmark to indicate a positive metaphor (e.g., a checkmark placed beside the cloud served as a reminder that daxes *are* clouds) or a small red "x" symbol to indicate a negative metaphor (e.g., an "x" symbol placed beside the sun served as a reminder that daxes are *not* suns). Then, the experimenter asked about the toy's function (e.g., "What do you think daxes can do?"). A person appeared on the left side of the screen and provided an answer consistent with one of the metaphors (e.g., "This person says, 'I think daxes can let out water'", an inference consistent with the cloud metaphor) Then, another person appeared on the right side of the screen and provided an answer consistent with the other metaphor (e.g., "This person says, 'I think daxes can light up'", an inference consistent with the sun metaphor). The experimenter then asked the participant to choose between the two choices (i.e., "Whose answer do you think is better?"). Once the participant answered by providing a response (e.g. "let out water"), the experimenter began the next trial. No feedback was provided. For an example of a trial, see Figure 1. On the final trial, the experimenter also asked participants for an open-ended explanation to justify their response on that trial (e.g., if the participant selected "let out water" on the final trial, the experimenter followed up by asking, "Why do you think daxes let out water?").

Each participant received eight trials. For a complete list of metaphors and corresponding inferences, see Table 1. Each trial's structure followed the design described above, in which a participant must infer the function of the novel toy based on the metaphor they heard. The order of the eight trials was randomized. Within participants, we counterbalanced the left-right placement of the correct answer. Across participants, we also counterbalanced which metaphors were positive and negative, such that half of the participants heard that daxes were clouds and not suns, and the other half of the participants heard that daxes were suns and not clouds. Moreover, across participants, we counterbalanced whether the positive or negative metaphors were mentioned first, such that half of the participants heard the positive metaphor before the negative metaphor (e.g., "Daxes are sun. Daxes are not clouds."), and the other half of the participants heard the negative metaphor before the positive metaphor (e.g., "Daxes are not suns. Daxes are clouds.").

## Results

In the following analyses, the dependent variable was the proportion of correct (i.e., metaphor-consistent) responses. We found that adults overwhelmingly selected the correct response, $M = 99.61\%$, $SE = .40\%$, $t(31) = 127$, $p < .001$. In a preregistered analysis, we found that four-year-olds also selected the correct response significantly above chance levels, $M = 85.94\%$, $SE = 3.40\%$, $t(31) = 10.56$, $p < .001$ (see Figure 2).

In additional exploratory analyses, we examined participants' average performance on each of the eight test trials. Adults selected the correct response significantly above chance levels across all eight trials ($p < .001$ on all trials). On individual trials, adults' responses ranged from 97% correct (on the ballerina/soldier trial) to 100% correct (on all other trials). Likewise, preschoolers also selected the correct response significantly above chance levels across all eight trials ($p < .002$ on all trials). Preschoolers' responses ranged from 75% correct (on the snail/bee and eye/teeth trials) to 97% correct (on the duck/firefly trial). Adults' and preschoolers' responses on individual trials were still significantly above chance levels after correcting for multiple comparisons (Benjamini & Hochberg, 1995).

In addition to examining individual trials, we also examined the performance of individual participants. Specifically, we demonstrate that a significant proportion of adults and children in the sample perform above chance levels by responding correctly on 100% (8/8) trials (binomial test, $p < .01$). 97% of adults (31 out of 32 participants) responded correctly on all eight trials (a number significantly higher than one would expect by chance, binomial test, $p < .001$). Similarly, 69% of preschoolers (22 out of 32 participants) also responded correctly on all eight trials (again, a number significantly higher than one would expect by chance, binomial test, $p < .001$).

In further exploratory analyses, we examined the explanations that participants provided to justify their responses on the final trial of the experiment. Each participant provided a single explanation on the final trial, leading to a total of 64 explanations (i.e., 32 adult explanations and 32 child explanations). Explanations were coded blind to participants' performance on the test trials. Explanations were sorted into four categories: Explicit Metaphor, Implicit Metaphor, Toy, and Irrelevant. Explicit Metaphor explanations appealed explicitly to the natural/social kind in the positive metaphor (e.g., "Because blickets are eyes and eyes are used to see things"; Because it's a seagull"). Implicit Metaphor explanations appealed to the features of the natural/social kind involved in the positive metaphor, but did not explicitly name the natural/social kind itself (e.g., "Because they have wings"; "To catch their prey"). Toy explanations appealed to features of the novel toys, rather than mentioning the comparison items (e.g., "They have a little bucket at the end"; "Because they have batteries"). Irrelevant explanations were nonsensical or non-responses (e.g., "Because it sounds like the right answer"; "I don't know"). Two coders coded all explanations. Intercoder reliability was 95%, converging on the same category for 61 out of 64 explanations.

All adults provided explanations that appealed to the metaphor. Specifically, 94% of adults (30 out of 32 adults) provided Explicit Metaphor explanations and 6% of adults (2 out of 32 adults) provided Implicit Metaphor explanations. Similarly, 66% of preschoolers (21 out of 32 preschoolers) also provided explanations that appealed to the metaphor. Specifically, 47% of preschoolers (15 out of 32 preschoolers) provided Explicit Metaphor explanations, 19% of preschoolers (6 out of 32 preschoolers) provided Implicit Metaphor explanations, 6% of preschoolers (2 out of 32 preschoolers) provided Toy explanations, and 28% of preschoolers (9 out of 32 preschoolers) provided Irrelevant explanations. Thus, all adults and the majority of preschoolers appealed to the metaphors in their explanations, either explicitly or implicitly.

In the following analyses, we also examined preschoolers' task performance based on whether they appealed to the metaphor in their explanation (i.e., Explicit Metaphor and Implicit Metaphor explanations) or not (i.e., Toy and Irrelevant explanations). We found that preschoolers who appealed to the relevant metaphors in their explanations (i.e., by providing Explicit Metaphor or Implicit Metaphor explanations) performed significantly above chance levels, $M$ = 91.67%, $SE$ = 3.27%, $t(20) = 12.76$, $p < .001$. Preschoolers who did not appeal to metaphors in their explanations (i.e., by providing Toy or Irrelevant explanations) still performed significantly above chance levels, $M$ = 75%, $SE$ = 6.74%, $t(10) = 3.71$, $p = .004$. Both groups' task performance remained significantly above chance levels after correcting for multiple comparisons (Benjamini & Hochberg, 1995). Crucially, although both groups performed above chance levels, the preschoolers who appealed to metaphors performed significantly better than the preschoolers who did not appeal to metaphors, $t(30) = 2.52$, $p = .02$.

## Discussion

Experiment 1 showed that both adults and preschoolers can make inferences from novel metaphors. Specifically, after hearing a metaphor about a novel artifact, adults and preschoolers successfully inferred the function of a novel artifact. Moreover, 100% of adults justified their responses by appealing to the novel metaphor, either explicitly implicitly. Similarly, the majority of preschoolers also justified their responses by appealing to the novel metaphor explicitly or implicitly. Though both preschoolers who appealed to metaphors and preschoolers who did not appeal to the metaphors performed quite well on the task, the former group provided significantly more correct responses than the latter group. Adults' and preschoolers' verbal explanations further demonstrated that participants were using metaphors, rather than lower-level associative strategies, to guide their responses. Overall, the results of Experiment 1 thus provide initial evidence that both adults and young children can not only understand, but also *use* metaphors, specifically for higher-order thinking and reasoning. Consequently, metaphors may be a useful learning mechanism in early childhood.

## Experiment 2

Experiment 1 demonstrated that both preschoolers and adults can make additional inferences from novel metaphors. Moreover, by juxtaposing positive and negative metaphors (e.g., "Daxes are clouds. Daxes are not suns."), Experiment 1 showed that preschoolers and adults made these inferences by carefully attending to the metaphoric utterances, rather than by relying on simple, lower-level associations. However, in more naturalistic contexts, metaphors are not generally contrasted against each other; rather, a single metaphor is often presented alone (e.g., Shakespeare wrote that "Juliet is the sun", not that "Juliet is the sun but not the earth"). Consequently, Experiment 2 seeks to conceptually replicate the developmental findings in Experiment 1, using a more naturalistic paradigm involving only positive metaphors (e.g., "Daxes are clouds").

## Methods

**Participants.** Similar to Experiment 1, we adhered to a preregistered stopping rule of 32 participants ($M$ = 4.43 years; SD = .32 years; range = 4.02 – 4.98 years; 16 females and 16 males). Researchers tested two additional children, whose data were excluded due to experimenter error (one child) and external interference (one child). All children were recruited from a local participant database and tested online over Zoom. Experiment 2's preregistration can be found at https://osf.io/37yd6/.

**Stimuli & Procedure.** Experiment 2's stimuli procedure was identical to Experiment 1's stimuli and procedure, except participants received only a positive metaphor (e.g., "Daxes are clouds.") rather than both positive and negative metaphors (e.g., "Daxes are clouds. Daxes are not sponges."). Across participants, we counterbalanced which metaphor was presented, such that half the participants heard one positive metaphor (e.g., "Daxes are clouds.") and the other half of participants heard another positive metaphor (e.g., "Daxes are sponges.") Only the images corresponding to the positive metaphors (e.g., a picture of a cloud for "Daxes are clouds") appeared onscreen (see Figure 1).

## Results

In a preregistered analysis, we found that four-year-olds selected the correct response significantly above chance levels, $M = 78.13\%$, $SE = 3.22\%$, $t(31) = 8.72$, $p < .001$. In additional exploratory analyses, we examined preschoolers' average performance on each of the eight test trials. Preschoolers consistently selected the correct response significantly above chance levels across all eight trials ($p < .03$ on all trials). Preschoolers' responses ranged from 69% correct (on the cloud/sun and songbird/cheetah trials) to 91% correct (on the eye/teeth trial). Preschoolers' responses on individual trials remained significant after correcting for multiple comparisons (Benjamini & Hochberg, 1995).

In addition to examining individual trials, we also examined the performance of individual participants. A significant proportion of adults and children in the sample perform above chance levels by responding correctly on 100% (8/8) trials (binomial test, $p < .01$). 22% of children (7 out of 32 participants) responded correctly on all eight trials (a number significantly higher than one would expect by chance, binomial test, $p < .001$).

In further exploratory analyses, we examined the explanations that participants provided to justify their responses. Explanations in Experiment 2 were coded using the same four explanation categories from Explanation 1 (i.e., Explicit Metaphor, Implicit Metaphor, Toy, and Irrelevant). Two coders coded all explanations. Intercoder reliability was 97%, converging on the same category for 31 out of 32 explanations.

Similar to the results of Experiment 1, Experiment 2 showed that the majority of preschoolers provided explanations that appealed to the metaphor, either explicitly or implicitly. Specifically, 44% of preschoolers (14 out of 32 preschoolers) provided Explicit Metaphor explanations, 28% of preschoolers (9 out of 32 preschoolers) provided Implicit Metaphor explanations, 9% of preschoolers (3 out of 32 preschoolers) provided Toy explanations, and 19% of preschoolers (6 out of 32 preschoolers) provided Irrelevant explanations. Thus, the majority of preschoolers appealed to the relevant metaphors, when justifying their responses on the task.

Moreover, we also examined preschoolers' task performance based on whether they appealed to the metaphor in their explanation (i.e., Explicit Metaphor and Implicit Metaphor explanations) or not (i.e., Toy and Irrelevant explanations). Preschoolers who appealed to the relevant metaphors in their explanations (i.e., by providing Explicit Metaphor or Implicit Metaphor explanations) performed significantly above chance levels, $M = 82.61\%$, $SE = 3.22\%$, $t(22) = 10.14$, $p < .001$. Similarly, preschoolers who did not appeal to metaphors in their explanations (i.e., by providing Toy or Irrelevant explanations) still performed significantly above chance levels, $M = 66.67\%$, $SE = 6.91\%$, $t(8) = 2.41$, $p = .04$. Both groups' task performance remained significantly above chance levels after correcting for multiple comparisons (Benjamini & Hochberg, 1995). Similar to the results of Experiment 1, although both groups in Experiment 2 performed above chance levels, the preschoolers who appealed to metaphors provided significantly more correct responses than the preschoolers who did not appeal to metaphors, $t(30) = 2.39$, $p = .02$. Overall, Experiment 2 used a slightly modified experimental paradigm to conceptually replicate preschoolers' success from Experiment 1, thus providing further evidence that young children can learn from metaphors.

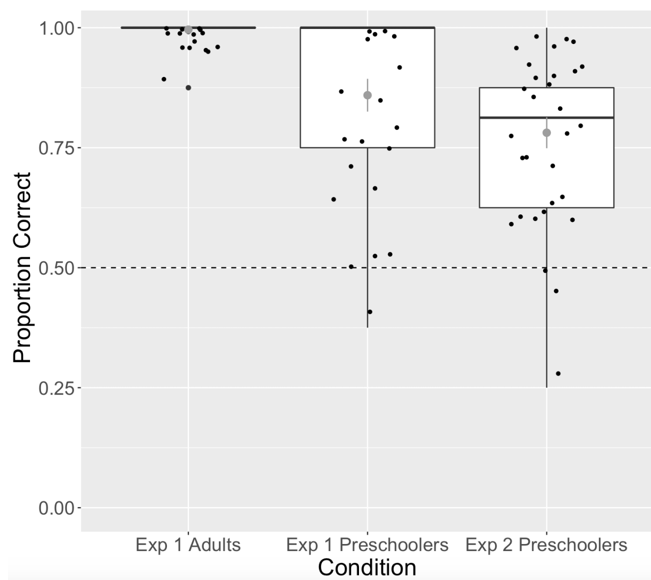


Figure 2: Experiment 1 and 2 results.

## Discussion

Experiment 2 conceptually replicated the results of Experiment 1, by confirming that preschoolers can form inferences from novel metaphors. While Experiment 1 included both positive and negative metaphors (e.g., "Daxes are clouds. Daxes are not suns."), Experiment 2 used a more naturalistic paradigm including only positive metaphors (e.g., "Daxes are clouds."). In Experiment 2's slightly modified paradigm, preschoolers were still able to form the appropriate additional inferences corresponding to the novel metaphors they heard. Moreover, similar to Experiment 1, the majority of preschoolers in Experiment 2 justified their responses by appealing to the novel metaphor explicitly or implicitly.

Preschoolers who appealed to metaphors in their explanations also performed significantly better than preschoolers who did not appeal to metaphors in their explanations, though both groups performed above chance levels. Overall, Experiment 2 provides additional evidence that preschoolers can use metaphors to facilitate their thinking, reasoning, and learning.

## General Discussion

This work shows that young children can not only *understand* metaphors, but also *use* metaphors in the service of further thinking and reasoning. Specifically, preschoolers and adults can use metaphors to make additional inferences, and thus learn, about novel concepts. Experiment 1 showed that preschoolers succeed at making inferences on a metaphor task that uses both positive and negative metaphors (e.g. "Daxes are clouds. Daxes are not suns."). The inclusion of both positive and negative metaphors in Experiment 1 suggests that children were indeed using the metaphors, rather than lower-level associative strategies, to guide their responses. Moreover, adults also performed at ceiling on Experiment 1, thus validating this new metaphor inference paradigm. Experiment 2 then built on these initial results by conceptually replicating preschoolers' success in Experiment 1, but using a more naturalistic metaphor task involving only positive metaphors (e.g., "Daxes are clouds"). Overall, preschoolers successfully used metaphors to guide their inferential reasoning and learning, in both a positive-and-negative-metaphor paradigm (Experiment 1) and a positive-metaphor-only paradigm (Experiment 2). Moreover, in both experiments, the majority of preschoolers appealed to the metaphors when providing an explanation for their responses, and the preschoolers who appealed to metaphors performed better than preschoolers who did not appeal to metaphors. These findings suggest that preschoolers can use metaphors to facilitate thinking and reasoning.

The present experiments contribute to a recent, growing body of literature suggesting that young children may possess a relatively sophisticated ability to understand non-literal language (Falkum et al., 2017; Pouscoulous & Tomasello, 2020; Zhu, 2021; Zhu et al., 2020). Moreover, by demonstrating that preschoolers can make additional inferences from novel metaphors, the present research suggests that metaphors may be a powerful learning mechanism that could allow children to acquire new information. Just as metaphors facilitate novel scientific discoveries in the history of science (Kuhn, 1993) and higher-order cognitive processes in human adults (Thibodeau et al., 2017), metaphors may also contribute to young children's learning. Interestingly, because metaphors frequently provide a new perspective (Camp, 2006; 2009) without necessarily providing new information, metaphors may be a powerful case of "learning by thinking", which allows for the acquisition of new knowledge with little or no additional data (Lombrozo, 2018; Xu, 2019). Overall, the present work contributes to multiple areas of cognitive development research, such as language acquisition and early learning processes, by providing exciting initial evidence of preschoolers' ability to understand and learn from metaphors.

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