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Reviews

Priming scalar and *ad hoc* enrichment in children

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ABSTRACT

Sentences can be enriched by considering what the speaker does not say but could have done. Children, however, struggle to derive one type of such enrichments, scalar implicatures. A popular explanation for this, the lexical alternatives account, is that they do not have lexical knowledge of the appropriate alternatives to generate the implicature. Namely, children are unaware of the scalar relationship between *some* and *all*. We conducted a priming study with $N = 72$ children, aged 5;1 years, and an adult sample, $N = 51$, to test this hypothesis. Participants were exposed to prime trials of strong, alternative, or weak sentences involving scalar or *ad hoc* expressions, and then saw a target trial that could be interpreted in either way. Consistent with previous studies, children were reluctant to derive scalar implicatures. However, there were two novel findings. (1) Children responded with twice the rate of *ad hoc* implicature responses than adults, suggesting that the implicature was the developmentally prior interpretation for *ad hoc* expressions. (2) Children showed robust priming effects, suggesting that children are aware of the scalar relationship between *some* and *all*, even if they choose not to derive the implicature. This suggests that the root cause of the scalar implicature deficit is not due to the absence of lexical knowledge of the relationship between *some* and *all*.

Priming enrichment in children

Children's acquisition of language is not as straightforward as learning words and how to combine them. Children also need to learn how to enrich what they hear to infer the speaker's intended meaning (Grice, 1989). Consider the following interactions:

(1) A: John ate some of the cookies.

⇨ John did not eat all of the cookies

(2) A: I hear Helen's husband is rich and intelligent.
B: Well, he's rich.

⇨ Helen's husband is not intelligent.

In (1), a listener might infer that *John did not eat all of the cookies*. Likewise, in (2), they might infer that *Helen's husband is not intelligent*. According to Grice (1989) and many others (Geurts, 2010; Goodman & Frank, 2016; Horn, 1972; Levinson, 2000), such inferences, or *implicatures,* are derived using the *alternative* to what was said. On hearing, "John ate some of the cookies" in (1), the listener recognises that the speaker could have been more informative, for example by saying, "John ate all of the cookies". Since the speaker did not use this more informative alternative, and assuming that they are knowledgeable (*e.g.* they were present when John consumed the cookies), the listener infers that the alternative is not true *i.e. not all.* Similarly, in (2), because Speaker B did not say that Helen's husband was rich and intelligent, which would have been more informative than simply saying he was rich, the listener can infer that Helen's husband is not rich and intelligent.

Implicatures can be classified according to how the alternatives are derived. For our purposes we consider two groups. In the first, *scalar* implicatures (Horn, 1972), implicatures arise due to the scalar ordering of lexical items based on informativity, such as <*warm, hot* > and < *some, all*>. In these scales, stronger terms in the lexicon give rise to sentences that are more informative than sentences with weaker terms. Use of the weaker term in the sentence implicates the negation of the stronger sentence, as in (1). Scalar implicatures are said to be context independent because the same implicatures arise irrespective of the context. For the second group, in contrast, the alternatives can only be derived from context, as in (2) (see Hirschberg, 1985). The resulting implicatures are said to be derived on an *ad hoc* basis since the content of the implicature is not fixed. For example, the inference that *Helen's*

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husband is not intelligent depends on the previous statement about Helen's husband being rich and intelligent. Had Speaker A selected other qualities, such as being rich and kind, a different inference would arise; namely, that Helen's husband *is not kind*.

In this study, we compare children's ability to derive scalar and *ad hoc* implicatures. We used a priming task based on Bott and Chemla (2016) and Rees and Bott (2018) to test whether the difficulty children experience with scalar implicatures (*e.g.* Noveck, 2001) is due to limited lexical knowledge of the scalar relationship between *some* and *all*, an explanation we refer to as the *lexical alternatives* hypothesis.

1. Scalar implicatures in children

There is abundant evidence that children between two- and ten-years-old have difficulty deriving scalar implicatures (*e.g.* Foppolo, Guasti, & Chierchia, 2012; Huang & Snedeker, 2009; Noveck, 2001; Papafragou & Musolino, 2003; Papafragou & Tantalou, 2004; Pouscoulous, Noveck, Politzer, & Bastide, 2007). For example, Papafragou and Musolino (2003) showed four- and five-year-old children pictures where *all* horses had jumped over the fence. When asked if it was true that *some* of the horses jumped over the fence, children agreed, whereas adults did not. Similarly, Noveck (2001) found that when evaluating statements such as "some giraffes have long necks", children did not display adult-like understanding even at age 10.

Explanations for this difficulty are varied but include an absence of cognitive resources necessary for implicature derivation (*e.g.* Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Huang & Snedeker, 2009); an immature pragmatic system (*e.g.* Noveck, 2001; Yoon & Frank, 2019); and greater pragmatic tolerance than adults (Katsos & Bishop, 2011). These explanations are supported by findings that as children age they become more adult-like in their implicature derivation; their performance improves with training; and manipulating task difficulty affects rates of implicature derivation. More recently, however, the consensus is that children have difficulty using or accessing scalar alternatives rather than difficulty computing the implicature (Barner, Brooks, & Bale, 2011; Foppolo, Mazzaggio, Panzeri, & Surian, 2021; Gotzner, Barner, & Crain, 2020; Horowitz, Schneider, & Frank, 2018; Pagliarini, Bill, Romoli, Tieu, & Crain, 2018; Skordos & Papafragou, 2016; Stiller, Goodman, & Frank, 2015; Tieu, Romoli, Zhou, & Crain, 2016). In order to derive a scalar implicature, children need to know what the appropriate alternatives are.

According to this view, which we call the *lexical alternatives account*, children's difficulties with scalar implicatures are rooted in their knowledge of the scale. It is not the case that children are never able to compute scalar implicatures, as seen in their success at computing implicatures with other scales (*e.g. ad hoc*: Horowitz et al., 2018; Stiller et al., 2015; numbers: Barner & Bachrach, 2010; Barner et al., 2011; Papafragou & Musolino, 2003; Sarnecka & Gelman, 2004); rather, there is a specific difficulty associated with the quantifiers *some* and *all*. Namely, children lack knowledge about the scalar relation between *some* and *all* that prevents *all* from being considered an alternative. Children demonstrate knowledge of the core meaning of *some* and *all* early in childhood and are aware that they denote different set meanings (Barner, Chow, & Yang, 2009; Barner, Libenson, Cheung, & Takasaki, 2009). However, it is not until later in development that they link them together as being on the same semantic scale. In other words, early lexical entries contain knowledge of what *some* and *all* mean, but not that *all* is an alternative to *some i.e.* their knowledge of lexical alternatives is lacking.

Evidence supporting the lexical alternatives account comes from Barner et al. (2011), who presented four and five-year-old children with scalar sentences in simple form, *e.g.* "some of the animals are sleeping", and in a form modified with the focus operator, *only*, *e.g.* "Only some of the animals are sleeping." The sentences were made underinformative by pairing them with pictures in which *all* the subjects obeyed the predicate. If children were not aware that *all* and *some* were scale mates, then they would fail to correctly reject underinformative sentences with *only*. Consistent with this hypothesis, children failed to reject underinformative descriptions with or without the modifier *only* (in contrast to adults). Crucially, in a condition with contextually determined alternatives (*ad hoc* items), *e.g.* "Only the dog and cat are sleeping," when the dog, the cat, and the cow were sleeping, children rejected the *only* sentences just as adults did. This confirmed that children understood the focus operator *only* and that their difficulties with alternatives were constrained to lexical scalemates. Thus, while the alternatives used to derive *ad hoc* implicatures were easily accessible, the alternatives used to derive scalar implicatures (stored lexically) were not.

Further support for the lexical alternatives account stems from studies showing that while children are impaired on scalar implicatures, they derive *ad hoc* implicatures based on the same materials with ease (Foppolo et al., 2021; Gotzner et al., 2020; Horowitz et al., 2018). For example, Horowitz et al. showed children three book covers with pictures of animals on each. One picture had animals all of the same type (dogs), another had animals all of a different type (cats), and a third had pictures of two animals of one type (cats) and two of a different type (rabbits). In the quantity condition, children were asked which book corresponded to "some of the animals are cats" and in the *ad hoc* condition, "there are cats". Implicature answers corresponded to the book with the partial set and the book with only cats respectively. In Experiment 1, they found that four- and five-year-old children responded with the implicature option at ceiling for the *ad hoc* implicature questions but around 40% for the quantity implicature questions. Foppolo et al. (2021) found similar results in children aged three- to six-years-old. Children derived *ad hoc* implicatures at a higher rate than scalar implicatures (78% *vs* 57%). Because the two sorts of implicature involve the same communicative processes and differ only on lexical content, Horowitz et al. (2018) and Foppolo et al. (2021) argued that children's difficulties with quantity implicatures must have a semantic basis (*e.g.* the link between *some* and *all*), consistent with the lexical alternatives account.

The lexical alternatives account has experimental support from studies that have tested *ad hoc* implicatures. Nonetheless, studies demonstrating that children derive scalar implicatures to adult-like levels when pre-exposed to alternatives (*e.g.*, Guasti et al., 2005; Pouscoulous et al., 2007; Skordos & Papafragou, 2016) raise questions about the generality of the lexical alternatives account. For example, Skordos and Papafragou gave children a sentence-picture matching task with underinformative *some* sentences (*e.g.* "Some of the blickets have an X" when in fact all did) and manipulated when they were exposed to *all* sentences ("All of the blickets have X"). When children processed *all* sentences before underinformative sentences, rejection of the underinformative sentences was higher than when they heard them after. The difficulty for the lexical alternatives account is how to explain why children were able to derive scalar implicatures in the pre-exposure condition. If children had no knowledge that *all* is an alternative to *some*, as the lexical alternatives account maintains, why would making *all* more salient elevate implicature rates? *All* should be no different to other expressions unconnected with *some*, yet children appear to recognise that when *all* is more salient, it should be used to derive an implicature.

One way of reconciling the pre-exposure results with the lexical alternatives account is to argue that children had partial knowledge of the relationship between scale mates but not complete knowledge. In other words, children were able to access the lexical alternatives to some extent, but only at low probability relative to adults. The results of Barner et al. (2011) and others require that scalar alternatives are *less* accessible than those of *ad hoc* alternatives, but not that they are completely inaccessible. A definitive test of the lexical alternatives account would therefore require a control condition involving *ad hoc* implicatures. If the probability of retrieving *all* from *some* was lower than the probability of retrieving *ad hoc* alternatives from their triggers, the effects of pre-exposing the alternative on scalar expressions should be smaller than on *ad hoc* expressions.

Another approach to explaining the pre-exposure results is to allow that children are able to derive scalar implicatures as *ad hoc* implicatures when they do not have appropriate lexical knowledge. For example, Barner et al. (2011) suggested that when children were trained to derive implicatures (*e.g.* Guasti et al., 2005), they did so by applying *ad hoc* reasoning; namely, they derived more informative sentences from the general context and negated them as appropriate (see Sullivan, Davidson, Shirlene, & Barner, 2019, for a similar suggestion). This extends the lexical alternatives account because it assumes children can still derive scalar implicatures with non-lexical alternatives (with prompting). Moreover, the difficulty with this explanation is why an *ad hoc* strategy is successful for *ad hoc* implicatures but not for scalar implicatures (outside of pre-exposure conditions). Why do children fail to derive scalar implicatures in experimental contexts when they could apply an *ad hoc* strategy?

One answer is that scalar alternatives might be more difficult to retrieve from the context than *ad hoc* alternatives. If children cannot easily retrieve the alternative, they would fail to derive scalar implicatures, even if they were using an *ad hoc* strategy. However, it is unclear why children would find scalar alternatives more difficult to retrieve. In experimental contexts, *all* trials typically occur as often as *ad hoc* alternative trials, and indeed, *all* trials are often used as control trials to ensure that children understand the basic task and semantic terms (*e.g.* Barner et al., 2011; Katsos & Bishop, 2011; Noveck, 2001). Frequency of exposure to the respective alternatives does not seem to be the reason why scalar alternatives are less salient than *ad hoc* alternatives. Nor does the experimental stimuli makes it easier to access *ad hoc* alternatives than scalar alternatives. For example, in Barner et al. (2011), the sleeping cow, dog, and cat are in the picture so a child can easily see that the *ad hoc* alternative sentence ("the cow, the dog and the cat are sleeping") is true, but then again, the child can also easily see that the scalar alternative ("all the animals are sleeping") is true. Moreover, the lexical alternatives account maintains that children have an adult understanding of *all* and *some* – it is the link between them that is underdeveloped – hence there is no reason why children would have difficulty accessing the meaning of *all*.

While the *ad hoc* extension of the lexical alternatives account leaves some questions unanswered, it nonetheless remains a possibility. It also makes predictions about pre-exposure of the alternative, however. If scalar alternatives are more difficult to access than *ad hoc* alternatives, priming with the alternative should have less of an effect on scalar expressions than on *ad hoc* expressions. To see why, consider a model in which alternatives have varying degrees of activation, and an activity threshold must be exceeded to trigger an implicature (Rees & Bott, 2018). Assume further that when an alternative is less accessible, it has a lower baseline activation, and that an alternative prime increases the activation level of the alternative. Under this model, alternatives with lower baseline activation levels (*all*) will see less of an increase in implicatures following an alternative prime than those with higher baseline activation levels (*ad hoc* alternatives). This is because activation levels will exceed the implicature threshold in a lower proportion of trials in low baseline alternative conditions than in high baseline alternative conditions.

In this study, we test the hypothesis that scalar alternatives are less accessible than *ad hoc* alternatives in children. If they are, this provides support for the lexical alternatives theory. If not, another explanation would be required for why children fail to derive scalar implicatures on some occasions but not others. We used a form of pre-exposure – structural priming (Branigan & Pickering, 2018; Raffray & Pickering, 2010) – and tested whether there was equal priming between *some* and *all* and *ad hoc* triggers and their respective alternatives.

1.1. Experiment overview

Participants completed a sentence-picture matching task where they had to decide which of two pictures best matched the meaning of a sentence. There were prime trials and target trials (see Fig. 1). In prime trials, the interpretation of the sentence was guided by the configuration of the pictures such that one picture (interpretation) provided a much better fit to the sentences. In target trials, the configuration of the pictures allowed either interpretation. Participants therefore had a choice of interpretations in target trials but not prime trials. There were three types of prime trial: strong, weak, and alternative. Target trials immediately followed prime trials.

Strong and weak prime trials used sentences containing an implicature trigger, *e.g.*, "Some of the animals are dogs", whereas alternative prime trials used sentences that were more informative, "All of the animals are dogs". In strong prime trials, the sentence picture combination encouraged participants to make an implicature interpretation (a *strong* interpretation), *some but not all of the animals are dogs*. In weak prime trials, the sentence picture combination encouraged participants to make a literal interpretation (a *weak* interpretation), *some and possibly all of the animals are dogs*. In the alternative prime trials, one picture matched the alternative interpretation of the sentence, *all of the animals are dogs*. Thus the alternative prime trial made the alternative salient.

In target trials, the sentence used an implicature trigger, *e.g.* "Some of the animals are dogs". One picture was consistent with a weak interpretation of the sentence and the other card was a "better picture" option (Fig. 1). Participants were instructed to select the "better picture" option if they thought there was a different, better picture that would match the sentence (as in Bott & Chemla, 2016; see also Bill, Romoli, Schwarz, & Crain, 2016 and Huang, Spelke, & Snedeker, 2013, for hidden box implementations with children aged two- and three-years-old). The logic was that if participants derived an implicature then the picture consistent with the weak interpretation would not be an acceptable choice and they would select the "better picture" option.

We tested four- and five-year-old children, and adults, using scalar expressions (*some*, *all*) and *ad hoc* expressions ("There is an X", "There is an X and a Y"). Adult responses should follow patterns reported in previous literature (Bott & Chemla, 2016; Rees & Bott, 2018), namely higher rates of strong responses (implicature interpretations) after strong primes than after weak primes, and higher rates of strong responses after alternative primes than weak primes. The logic of the task was that the strong prime and the alternative prime both made the alternative more salient, explicitly so for the alternative prime, implicitly so for the strong prime. Since more salient alternatives increases the likelihood of deriving an implicature (Bott & Frisson, 2022; Chierchia, Fox, & Spector, 2012; Skordos & Papafragou, 2016; Van Tiel & Schaeken, 2016), higher rates of strong responses should be observed after strong and alternatives primes than after weak primes.

Uncontroversial predictions for children's responses can also be made from previous literature. Following Barner et al. (2011), Stiller et al. (2015) and others, we expected children to derive *ad hoc* implicatures without difficulty and to choose the strong interpretation on the strong prime trials. We also expected a lower rate of strong responses on the strong scalar prime in children compared to adults, consistent with the classic finding of a low rate of implicatures with quantifiers in children (*e.g.* Noveck, 2001).

The crucial test of our hypothesis was behaviour on the target trials. If children have only a weak connection between scalar trigger and alternative, there should be less priming after the alternative prime in scalar expressions than in *ad hoc* expressions (relative to the weak prime) *i.e.* an interaction between prime type (strong, weak, alternative) and expression type (scalar quantifier, *ad hoc*) on the rate of implicatures in the target trials.

2. Method

2.1. Participants

72 children aged 4;2 to 5;11 (mean 5;1 years; 40 male) were

recruited from primary schools in Rugby and Warwickshire. They were given a sticker for their participation. Data were excluded from two children who did not pass the familiarisation trials.

51 adult controls were recruited from Cardiff University ($N = 21$) and Prolific Academic, an online recruitment website ($N = 30$). All adult participants completed the study online and received either course credit or payment for their participation.

2.2. Design and materials

For children, the sentence picture-matching task was conducted in person using a set of physical A6 printed cards. The cards showed two pictures consisting of rectangles containing either cartoon images of animals or the text "Better Picture?" (See Fig. 1). There were two implicature categories: quantifier and *ad hoc*, and three prime types: strong, weak, and alternative. For each category-prime combination there were four examples resulting in 48 experimental trials (24 prime-target pairs) that were randomly presented within-participants. Table 1 shows the scalar terms used together with plausible alternatives and the subsequent implicature.

2.3. Quantifier trials

For quantifier trials, sentences were of the form "[Quantifier] of the animals are [animal]."

Strong prime trials had two pictures, one with 9 of the same animal and another containing 6 of that same animal and 3 new animals. The sentence predicate was the animal seen in the both pictures. For example, in Fig. 1, the sentence for the strong prime is, "Some of the animals are dogs," and there is one picture with 9 dogs and another picture with 6 dogs and 3 cats. Thus the partial set picture is consistent with the strong interpretation, *some but not all of the animals are dogs*. Thus, in strong prime trials, participants should select the partial set picture and derive the strong interpretation.

Weak trials had two pictures, each consisting of a set of 9 animals. The animals were different in both pictures. The sentence predicate was the animal seen in one of the pictures. Since neither picture involved a partial set of animals, participants were obliged to select a picture corresponding to a weak interpretation. In Fig. 1, the weak prime used the sentence, "Some of the animals are cats," and included one picture with 9 rhinoceroses and another with 9 cats. Participants should therefore select the picture with 9 cats, consistent with the weak interpretation of the sentence.

Table 1
Example expressions, alternatives, and corresponding implicatures.

Implicature category	Expression	Alternative	Implicature
Quantifier	Some	all	Some but not all
Ad hoc	There is an X	X and Y	There is an X and nothing more

Alternative trials had the same picture configuration as the weak trials but were accompanied by a sentence that used the alternative quantifier, *all*. The sentence therefore unambiguously identified one picture and made the alternative salient without requiring an implicature. In Fig. 1, the alternative sentence is, "All of the animals are sharks," and one picture contains 9 sharks and the other 9 meerkats. Participants would therefore select the shark picture.

Target trials contained one picture with a full set of 9 animals (the weak picture), and one "better picture" option. The accompanying sentence used the less informative quantifier (*some*) and referred to the animals in the picture. Thus if participants derived the weak interpretation, they should select the full set picture, but if they derived the strong interpretation, they should select the "better picture" option. In Fig. 1, the sentence is "Some of the animals are pigs", and the full set picture contains 9 pigs. Thus, the selection consistent with the weak interpretation, *some and possibly all of the animals are pigs,* is the picture with pigs, but the selection consistent with the strong interpretation, *some but not all of the animals are pigs*, is the "better picture" option.

2.4. Ad hoc trials

For *ad hoc* trials there were two sentence forms, either, "There is an [animal]," for strong, weak, or target trials, or the conjunction, "There is an [$animal_1$] and an [$animal_2$]," for alternative trials.

Strong prime trials had one picture with two animals and another picture with one animal. The single animal picture contained the same animal as one of the animals on the other picture. The sentence referred to the animal that appeared in both pictures. Participants could therefore reason that if the sentence had meant to refer to the picture with two animals, it would have included both animals, and consequently the sentence must refer to the picture with only one animal. For example in

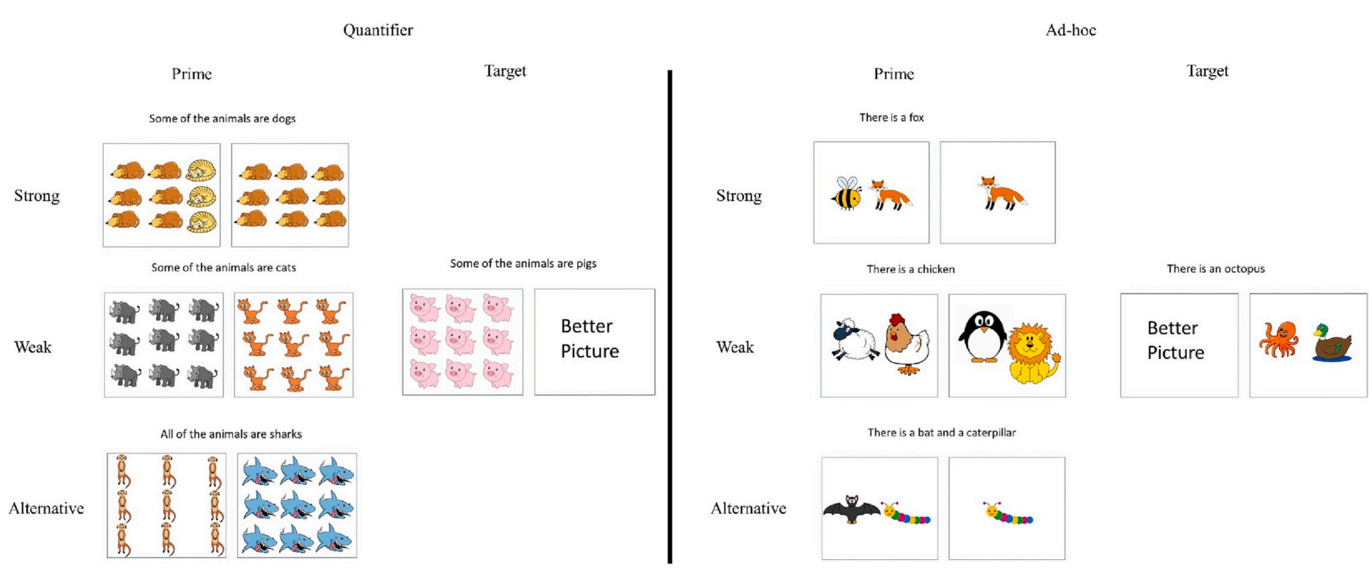

Fig. 1. Example prime and target trials. Left to right: quantifier and *ad hoc*. Primes top to bottom: strong, weak, and alternative. Each trial consisted of a sentence and two pictures. Participants selected the picture that best matched the sentence. *E.g.* for the quantifier alternative prime (bottom left), "All of the animals are sharks", participants should select the right hand picture.

Fig. 1, the strong prime trial contains the sentence, “There is a fox,” with one picture of a fox only and one with a fox and a bee. Participants can reason that since the sentence mentioned only the fox, and not the fox and the bee, the sentence must refer to the picture with only the fox. Strong primes encourage strong interpretations of the sentence, *e.g. there is a fox and nothing else*. Thus, in strong prime trials, participants should select the card with only one animal.

Weak trials had two unique animals in each picture. The sentence referred to one of the animals in the pictures. In Fig. 1, the weak sentence is, “There is a chicken,” and has one picture with a sheep and a chicken, and another with penguin and a lion. Here, the sentence-picture combination forces a weak interpretation of the sentence, *there is a chicken and possibly something else*.

Alternative trials had the same configuration as strong trials but used the more informative conjunction sentence. For example, in Fig. 1, the alternative sentence is, “There is a bat and a caterpillar,” and there is one picture with a bat and a caterpillar, and another with a caterpillar. The sentence unambiguously identifies one of the pictures but without invoking an implicature.

Target trials had one picture with two different animals (the weak picture), and one “better picture” option. The sentence referred to one of the animals in the picture. Thus a weak interpretation of the sentence was shown by selection of the animal picture, and the strong interpretation by the “better picture” option. In Fig. 1, the sentence is, “There is an octopus,” and the animal picture contains an octopus and a duck. Thus, the selection consistent with the weak interpretation, *there is an octopus and possibly something else,* is the octopus and duck picture, but the selection consistent with the strong interpretation, *there is an octopus and nothing else*, is the “better picture” option.

2.5. Procedure

For the child participants, testing took place in a quiet room at the participants' school. Before the main experiment, children had a familiarisation task where they were shown example cards with animals and asked to identify the animal. This was to ensure children were able to name all the animals in the experimental items and were comfortable interacting with the experimenter. Children were then shown five examples of “better picture” trials to get them comfortable with selecting that option. Children were instructed to select the “better picture” option if they thought that a different picture would match the sentence better. In these example trials, the spoken sentence did not match the items in the picture to try an encourage children to select the “better picture” option. If children failed to understand the “better picture” paradigm twice during familiarisation the experimenter ended the testing session, two participants were excluded for this reason. The main experimental session involved showing participants one card (two sets of pictures) and a corresponding spoken sentence. Children indicated which picture they thought matched by pointing and the experimenter took note of their responses.

For adults, the study was run as an online survey (*via* Qualtrics). The structure was the same as the main experimental session for children.

3. Results

3.1. Analysis procedure

We fitted a logistic mixed effects model in R (R Development Core Team, 2020) using lme4 (Bates, Maechler, Bolker, & Walker, 2015) and afex (Singmann, Bolker, Westfall, Aust, & Ben-Shachar, 2020). The model predicted participant's correct response as an interaction of prime (alternative, strong, or weak) and expression (quantifier or *ad hoc*) with random effects for participants. Like many developmental studies (*e.g.* Barner et al., 2011; Gotzner et al., 2020; Skordos & Papafragou, 2016), we had insufficient numbers of items (only 4 per cell) to include items as a random effect. To obtain convergence, we began with the maximal random effects structure supported by the design (Barr, Levy, Scheepers, & Tily, 2013; Gelman & Hill, 2006) and then simplified until convergence was obtained. Correlations between slopes and intercepts were set to 1 in all cases. Treatment coding was used throughout. Quantifier expression and weak prime type were reference levels for expression and prime respectively.

Main effects and overall interactions were established with likelihood ratio tests between complex and simplified models. Simple effects *p*-values were computed with the Kenward-Roger and Satterthwaite approximations to degrees of freedom (lmerTest(), Kuznetsova, Brockhoff, & Christensen, 2017).

We use Bayes Factors to interpret non-significant findings. Bayes factors indicate how strongly the data supports a hypothesis and can be used in the case of non-significant results to determine whether this is merely due to a lack of power (Dienes, 2011). We used the default JZS prior (0.707) for all analyses (Rouder, Speckman, Sun, Morey, & Iverson, 2009). The JZ prior minimises assumptions regarding expected effect sizes. Bayes factors were calculated using JASP (JASP Team, 2020). Bayes factors > 3 suggest ‘substantial’ evidence for the alternative hypothesis and Bayes factors < 0.33 indicate ‘substantial’ evidence for the null hypothesis (Dienes, 2011, 2014). Data and analysis scripts available on the Open Science Framework.[1]

3.2. Adults data

Prime trials. Adult responses to prime trials were at ceiling for all prime trials (alternative $M = 1.00$, strong $M = 0.96$, weak $M = 1.00$).

Target trials. The adult data replicated findings from Rees and Bott (2018) (Fig. 2). The rate of strong responses varied significantly across expression type (Table 2). There was a main effect of expression type ($\chi^2 = 308.04$ $p < .001$), with strong responses more likely for quantifiers than *ad hoc* expressions. There was also a main effect of prime ($\chi^2 = 29.67$ $p < .001$). Strong interpretations were higher following strong and alternative prime trials than following weak prime trials ($\beta = 1.15$, SE $= 0.23$, z $= 4.91$, $p < .001$; $\beta = 0.91$, SE $= 0.24$, z $= 3.89$, $p < .001$). There was no interaction between expression and prime type however ($\chi^2 = 0.82$, $p = .663$, BF $= 0.06$).

Simple effects analysis showed that strong responses were significantly more likely following strong primes than weak primes for *ad hoc* ($\beta = 1.00$, SE $= 0.33$, z $= 3.04$, $p = .009$) and quantifier expressions ($\beta = 1.29$, SE $= 0.33$, z $= 3.93$, $p < .001$). This was also found following alternative prime trials for *ad hoc* ($\beta = 0.98$, SE $= 0.33$, z $= 2.94$, $p = .009$) and quantifier expressions ($\beta = 0.85$, SE $= 0.33$, z $= 3.93$, $p = .028$). However, as in Rees and Bott (2018) there was no difference between strong and alternative primes for both *ad hoc* and quantifiers ($\beta = 0.03$, SE $= 0.31$, z $= 0.10$, $p = .99$, BF $= 0.15$; $\beta = 0.44$, SE $= 0.35$, z $= 1.25$, $p = .432$, BF $= 0.31$).

3.3. Children's data

Prime trials. Children's responses were at ceiling for all prime trials (M's $> 97\%$) except for quantifier strong primes[2] (M $= 81\%$). Consistent with previous literature, children were less likely to select the strong interpretation than adults ($t(452) = 5.02$, $p < .001$).

Target trials. As with adults, the rate of implicature responses varied as a function of prime type (Fig. 3, Table 3). There was a main effect of prime ($\chi^2 = 19.78$ $p < .001$). Participants were more likely to derive an implicature following strong ($\beta = 0.59$, SE $= 0.172$ z $= 3.40$, $p = .002$) and alternative ($\beta = 0.76$, SE $= 0.174$, z $= 4.35$, $p < .001$) prime trials

[1] https://osf.io/7mu8x

[2] We note performance on the strong primes is greater than performance on critical trials. This could be due to the visual presence of the alternative making the contrast between *some* and *all* more salient and thus the implicature easier to compute.

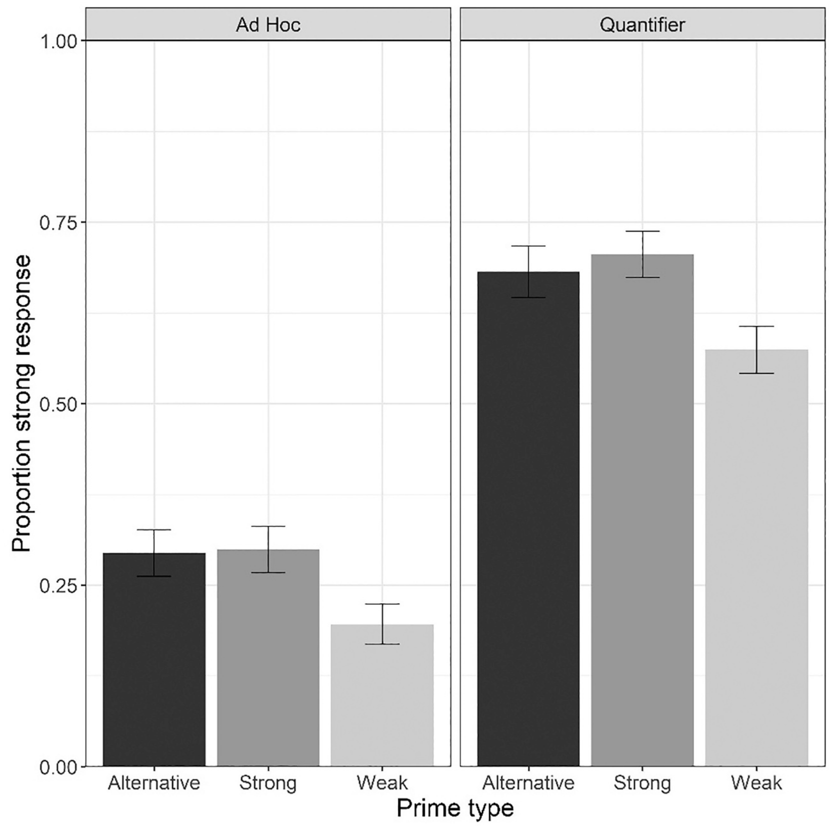

Fig. 2. Adult's strong responses to target trials. The rate of strong responses to target trials was higher after alternative and strong primes than after weak primes.

Table 2
Means and standard error of strong responses to target trials by expression and prime for Adults.

Expression	Prime	Mean (std. err)
Ad Hoc	Alternative	0.294 (0.032)
Ad Hoc	Strong	0.300 (0.032)
Ad Hoc	Weak	0.196 (0.028)
Quantifier	Alternative	0.683 (0.036)
Quantifier	Strong	0.706 (0.032)
Quantifier	Weak	0.574 (0.032)

than weak trials. Unlike in adults however, there was no effect of expression (χ^2 = 3.94 *p* = .268, BF = 0.10). Crucially, there was no evidence of an interaction between expression and prime type (χ^2 = 0.50, *p* = .780, BF = 0.06) and indeed the Bayes Factor demonstrates that the likelihood of there being no interaction is around 20 times the likelihood that there is. There is thus strong evidence against the prediction that the priming effect on quantifiers should be less than on *ad hoc* expressions.

We also analysed the data by expression. For *ad hoc* expressions, the rate of strong responses was significantly higher following strong and alternative primes when compared with weak primes (β = 0.70, SE = 0.24, z = 2.90, *p* = .004; β = 0.77, SE = 0.24, z = 3.16, *p* = .004) and there was no difference in priming between strong and alternative primes (β = 0.07, SE = 0.25, z = 0.28, *p* = .959, BF = 0.14).

Crucially, this pattern of results was also found in quantifier expressions. The rate of strong responses was significantly higher following strong alternative primes compared to weak primes (β = 0.68, SE = 0.24, z = 2.84, *p* = .004) and marginally significant following strong primes (β = 0.42, SE = 0.24, z = 1.81, *p* = .071) and there was no difference in priming between strong and alternative primes (β = 0.28, SE = 0.25, z = 1.12, *p* = .501, BF = 0.28).

4. Discussion

This study tested children's knowledge of the relation between an implicature trigger and its alternative. We found that children showed good understanding of *some* and *all* overall yet were reluctant to derive implicatures on prime trials, consistent with standard findings in the literature (*e.g.* Noveck, 2001). Conversely, *ad hoc* implicatures were at ceiling levels of proficiency. More importantly, children exhibited robust priming of scalar implicatures by the alternative, and at a level indistinguishable from those of *ad hoc* implicatures. Our data show that children have just as much knowledge of the relationship between scalar alternatives and their triggers as between *ad hoc* alternatives and their triggers, in contrast to the predictions of the lexical alternatives account.

4.1. Lexical alternatives account

In the Introduction we discussed results in which pre-exposure of the alternative elevated rates of implicatures. We argued that in order for a lexical alternatives account to explain these findings, it must assume either that children had partial lexical knowledge of the scalemate status of *some* and *all*, or, in an extension to the basic account, that children were able to compute scalar implicatures using alternatives retrieved from the context rather than lexically. In turn, these assumptions imply that lexical alternatives must be less accessible than *ad hoc* alternatives.

Our demonstration that the link between alternatives and triggers was the same for scalars and *ad hoc* expressions contrasts with this prediction. If there was a stronger link between scalar triggers and alternatives than between *ad hoc* triggers and alternatives, we should have observed greater priming from the alternative for the *ad hoc* expressions. This therefore argues against a lexical alternatives account that assumes children have an adult-like understanding of quantifiers but are unable to link the trigger with the alternative.

There may be other, related accounts that are more consistent with

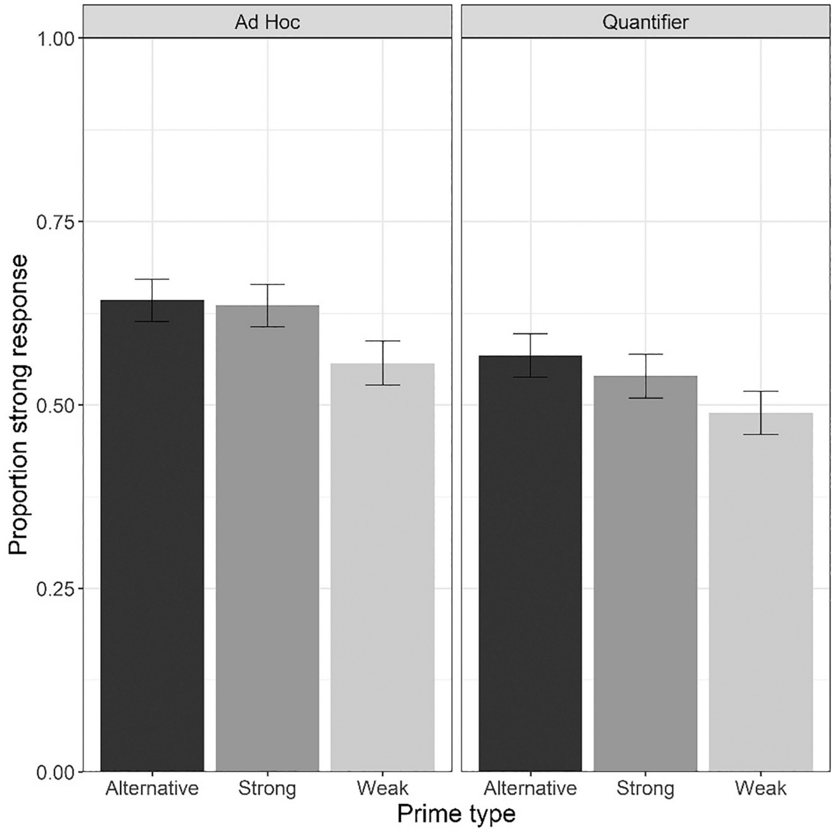

Fig. 3. Children's strong responses to target trials. The rate of strong responses to target trials was higher after alternative and strong primes than after weak primes.

Table 3
Means and standard error of strong responses to target trials by expression and prime for Children.

Expression	Prime	Mean (std. err)
Ad Hoc	Alternative	0.648 (0.029)
Ad Hoc	Strong	0.636 (0.029)
Ad Hoc	Weak	0.562 (0.029)
Quantifier	Alternative	0.572 (0.030)
Quantifier	Strong	0.634 (0.032)
Quantifier	Weak	0.496 (0.030)

our data, however. Relaxing the constraint that children understand quantifiers fully might explain why children were unable to apply *ad hoc* reasoning to scalar expressions but were also primed with the alternative in our task. For example, Horowitz et al. (2018) argue that children fail on scalar implicatures because they do not fully understand the class of quantifiers and that this interacts with their ability to retrieve alternatives.

It may also be that there are other concepts apart from accessibility that may explain why children did not use *ad hoc* reasoning when deriving scalar implicatures. For example, Skordos and Papafragou (2016) argue that children have difficulty computing the relevance of the scalar alternatives. However, if children find computation of relevance more difficult for scalar alternatives than for *ad hoc* alternatives, this effect should also have been present in our priming task: relevance priming should have been less effective for scalar implicatures than for *ad hoc* implicatures.

In summary, we have tested a prediction of the lexical alternatives account as we interpret it, but we appreciate that there may be other alternatives accounts that make different assumptions and that are more consistent with our findings.

4.2. *Ad hoc implicatures*

Children are reluctant to derive scalar implicatures (*e.g.*, Noveck, 2001) but are more ready to derive *ad hoc* implicatures (*e.g.* Foppolo et al., 2021; Horowitz et al., 2018; Stiller et al., 2015; Yoon & Frank, 2019). This effect is seen in our data. Children chose the strong scalar response less frequently than adults on prime and target trials. They also performed at ceiling on *ad hoc* prime trials. Interestingly however, they chose the *ad hoc* strong response at over twice the rate of adults in target trials (64% *vs* 30%). Thus if children are more logical than adults when deriving scalar implicatures, they are more pragmatic than adults when deriving *ad hoc* implicatures.

This effect has not previously been noted in the literature but our results are not inconsistent with others (*e.g.* Gotzner et al., 2020; Horowitz et al., 2018; Stiller et al., 2015; Yoon & Frank, 2019). Most authors (*e.g.*, Horowitz et al., 2018; Stiller et al., 2015) obtain ceiling level implicature responses for children and adults. One study that did not have ceiling effects, Gotzner et al. (Experiment 2), also found a greater rate of implicatures among children than adults, although not to the same degree as us. Adults derived conjunctive *ad hoc* implicatures at a rate of 5% and children at a rate of 14%; and adults derived disjunctive *ad hoc* implicatures at a rate of 45% and children at a rate of 55% (although the tasks were not identical across age groups).

One interesting explanation for the strong interpretation bias in children is that the strong interpretation is not pragmatic in nature, but instead is part of the semantics of the utterance, as has been proposed for *it*-clefts (Atlas & Levinson, 1981; Hedberg, 2000). Children might have an initial interpretation that is strong but then learn to apply the weak interpretation as they develop. If this is correct, it has implications for the conclusions of studies that have used *ad hoc* implicatures as a control condition against which to compare scalar implicatures (*e.g.*, Barner et al., 2011; Horowitz et al., 2018). The idea in these studies is that successful performance on the *ad hoc* implicatures demonstrates that children have the general pragmatic and cognitive skills necessary to derive implicatures *e.g.* combining the negated stronger expression with the basic meaning, and that poor performance on scalar implicatures must therefore be due to their scalar nature *i.e.* lexical storage of alternatives. However, if the strong interpretation of *ad hoc* expressions is developmentally prior, and some sort of pragmatic reasoning is required to derive the weak interpretation, then children can be considered pragmatically delayed on both *ad hoc* and scalar implicatures. General cognitive and pragmatic deficits may therefore play a role in explaining both deficits, thereby obviating the need for scalar specific explanations.

4.3. Weak or strong priming?

A potential limitation of our study is that we cannot say whether the strong and alternative prime biased participants away from the weak interpretation, as we have assumed, or whether the weak prime biased participants away from the strong interpretation. In other words, we do not know which interpretation was being primed. For scalars, our assumption was that the weak interpretation was the default and that the strong interpretation was primed. This is consistent with classical accounts of implicatures (Grice, 1989), developmental research concluding that children are biased towards the weak interpretation (*e.g.* Noveck, 2001), and adult work concluding that adults are faster to respond to weak interpretations (Bott & Noveck, 2004; Huang & Snedeker, 2018; although not always, see *e.g.*, Grodner, Klein, Carbary, & Tanenhaus, 2010). Our assumption may be incorrect however: the weak prime could have been doing the priming.

Recent conference proceedings relate to this question (Marty, Cowan, Romoli, Sudo, & Breheny, 2021; Waldon & Degen, 2020). These studies included a baseline prime trial that was unrelated to subsequent trials. Marty et al. included baseline trials at the start of the task, Waldon and Degen during the task, rotating with other experimental primes. Both studies tested only adults. The results were interesting but somewhat inconclusive with respect to whether participants were primed with the alternative, or with the weak interpretation for scalar triggers. Waldon and Degen's study was not directly concerned with this question but the proceedings appear to conclude that there was no evidence that the *all* alternative primed strong interpretations for scalar triggers. They nonetheless found that alternatives (both canonical and symmetric) primed responses across expressions generally. Marty et al. found that for participants who had high baseline rates of implicature, *i.e.* $> 50\%$ implicature rate, the weak prime lowered the implicature rate but for those who had low baseline rates, *i.e.* $< 50\%$, the strong prime/alternative raised them (Paul Marty, personal communication).

More importantly the question of which interpretation is being primed is irrelevant with respect to the lexical alternatives hypothesis. If the strong/alternative prime raised implicature rates, as we assumed throughout, then the alternative must be linked to the scalar trigger just as much as for the *ad hoc* expressions. If the weak prime suppressed implicature rates, the alternative must have been less accessible, which could also only be explained by assuming children understand the link between *some* and *all*. In both cases our data argue against the lexical alternatives account.

4.4. Role of the foil card

In Rees and Bott (2018), the alternative prime used a different picture configuration to that used here. In our task, the target card contained a complete set of predicate images, *e.g.* sharks, and the foil contained a complete set of images corresponding to a different predicate, *e.g.* monkeys. In Rees & Bott, the target card again contained a complete set of predicate images, *e.g.* sharks, but the foil contained a partial set of predicate images combined with other images, *e.g.* sharks and monkeys. The alternative prime cards were therefore identical to the strong prime cards, the difference being that the strong prime sentence referenced the partial set card, sharks and monkeys, and the alternative prime sentence referenced the complete set card, sharks.

The structure of the primes in Rees and Bott (2018) might be said to emphasise the difference between alternative and strong interpretation through comparison between target and foil (*all* in one card, *some-but-not-all* in the other). That we obtained a significant priming effect with the current configuration implies that the combination of linguistic expression and target card is sufficient to activate the alternative irrespective of the foil card. Quite possibly, however, the scalar priming effects would have been larger if we had used the configuration used in Rees & Bott. If so, this would have provided an even stronger demonstration of how children understand the relation between *some* and *all*.

5. Conclusion

The primary goal of this study was to investigate whether children's reluctance to derive scalar implicatures was due to a deficit in their knowledge of the relationship between *some* and *all.* To this end, we conducted a priming study in which we tested whether children could be primed to derive implicatures by making the alternative more salient. This yielded two major findings. First, children derived *ad hoc* strong interpretations at twice the rate of adults. While previous studies have consistently found that children derive strong *ad hoc* interpretations with ease, none have demonstrated that children exceed adults in the rate of strong interpretations. Children therefore have a deficit on *ad hoc* expressions as well as scalar expressions, albeit in different directions. Second, children displayed significant priming of scalar and *ad hoc* implicatures, both with the alternative and the strong prime, and at a level indistinguishable from each other. They also displayed poor performance on the scalar implicature primes. This suggests that the root cause of the scalar implicature deficit is not due to the absence of lexical knowledge of the relationship between *some* and *all*.

Data availability

Data is available on OSF. Link is included in methods.

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