# Priming implicatures in young children

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# Priming implicatures in young children

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**Abstract**

Children struggle to derive scalar implicatures. Initially this was thought to relate to a lack of cognitive resources required for the computation. More recently however, there has been a shift towards the alternatives (what a speaker could have said but did not). The argument is that children struggle to make the scalar implicature associated with *some* because they are unaware of its relationship with the stronger alternative *all*. We present a priming study that investigates this. We show that children's implicatures can be primed equally by alternatives in quantifier and ad hoc expressions. This suggests that children are aware of the scalar relationship between *some* and *all*, even if they choose not to derive the implicature.

**Keywords:** Structural priming; Scalar implicature; Alternatives; Child language

## Introduction

Children's acquisition of language is not as straightforward as simply learning words and how to combine them. Utterances typically convey more than is explicitly encoded in their utterance; there is a distinction between a speaker's intended meaning and what is said (Grice, 1975). For example:

A. "Did you eat my cookies?"
B. "I ate some of them"

From this exchange, A is licensed to infer that B ate some *but not all* of the cookies. This is an example of a quantity inference known as a scalar implicature (Grice, 1975). Scalar implicatures are derived through reasoning about what a speaker could have said but didn't i.e. the *alternatives*. *Some* is a member of a logically ordered lexical scale <*some, most, all*> and its use can be taken to mean *not all* (e.g. Horn, 1972). In the example above, B could have been more informative and said "I ate all of them", but since they did not, A is entitled to infer that B ate *some but not all.* Crucially, the listener needs to be aware that the speaker could have said *all* and infer that since they did not say *all* they do not mean *all.* Previous research shows that making the alternatives more salient to a listener facilitates implicature computation (Rees & Bott, 2018; Skordos & Papafragou, 2016).

It is commonly reported in the literature that children draw scalar implicatures far less frequently than adults (e.g. Huang & Snedeker, 2009; Noveck, 2001; Papafragou & Musolino, 2003). One explanation for this is that they cannot access the appropriate alternatives or that they do not know what an appropriate alternative is. When the appropriate alternatives are made available to children their implicature computation increases (Barner & Bachrach, 2010; Skordos & Papafragou, 2016; Stiller, Goodman, & Frank 2015). Known as *the alternatives hypothesis*, Barner, Brooks, and Bale (2011) suggest that children's difficulty with scalar implicature lies in a lack of understanding of the scalar relation between terms (*all* and *some*). In the present study we test children's understanding of the link between *some* and *all* through structural priming.

## Children's scalar implicatures

The general consensus for many years was that children are unable to compute scalar implicatures. Studies would regularly report that children accept underinformative uses of *some* in cases where the implicature *some but not all* was false (e.g. Foppolo, Guasti, & Chierchia, 2012; Huang & Snedeker, 2009; Noveck, 2001; Papafragou & Musolino, 2003). For example, when *all* horses jumped over the fence children would agree that *some* of the horses jumped over the fence (Papafragou & Musolino, 2003) whereas adults would not. A common explanation for this difficulty relates to a lack of cognitive resources (e.g. Chierchia, et al., 2001; Huang & Snedeker, 2009; see also Papafragou & Tantalou, 2004). In adults, there is evidence that computing scalar implicatures is costly (e.g. Bergen & Grodner, 2012; Tomlinson, Bailey, & Bott, 2013). That implicatures are too costly for children to make has some support from findings that children's performance improves with training (e.g. Guasti et al, 2007; Papafragou & Musolino, 2003). However, there is growing evidence that children's difficulty may lie elsewhere; namely with the alternatives.

Barner et al. (2011) suggest that children struggle with scalar implicatures because they are unaware of the relationship between the scalar terms (*the alternatives hypothesis*). They use children's ability to compute scalar implicatures from numerals as evidence for this. Barner and Bachrach (2010; see also Papafragou and Musolino, 2003) show that children are able to compute scalar implicatures from numerical expressions but not from quantifiers. They suggest that since numbers are learnt as a scale the scalar relations between numerals is clear and thus accessing the appropriate alternatives is straightforward. For quantifiers however, these terms are not typically learnt as a scale. Thus, upon encountering *some* it is not clear that *all* is the appropriate alternative. Consequently children tend to not derive the scalar implicature.

This has been supported by findings from ad-hoc, or contextually based scales. Ad-hoc scales are contextually defined; the alternatives are dependent upon the context. Thus, the alternatives are clearer for children and this enables them to compute ad-hoc implicatures more easily than implicatures from quantifiers. Stiller, Goodman, and Frank (2015) showed children (aged 2-5) three characters wearing either: *glasses*, *a hat and glasses*, or *no accessories*. When asked to identify "the character with glasses" children tended to select the character with *only* glasses rather than the character with glasses and a hat, suggesting that children had interpreted the utterance as the character with the glasses *but not the hat*. It is likely therefore, that in previous investigations where children were unable to compute the inference this because the appropriate alternatives were not salient. Horowitz, Schneider, and Frank, (2018) found that children were deriving implicatures using ad-hoc scales at adult-like rates whereas for quantifiers children struggled to derive the implicature.

According to Barner et al., children are unable to compute scalar implicatures with quantifiers because they are unaware of the relationship between *some* and *all*. When the alternative is made accessible to children they show increased rates of implicature (Skordos & Papafragou, 2016). This is consistent with developmental findings from numbers and ad hoc scales (Horowitz, Schneider, & Frank, 2018; Papafragou & Musolino, 2003; Stiller, Goodman, & Frank, 2015; Yoon & Frank 2019). In the present study we test Barner et al.'s hypothesis using a structural priming paradigm based on Rees & Bott (2018).

## Experiment Overview

Participants completed a sentence-picture matching game where they were presented with two pictures and a sentence. The task was to decide which card the sentence was referring to. In prime trials, the interpretation of the sentence was guided by the configuration of the pictures. In target trials participants had a choice of interpretation. There were three types of prime trial: strong, weak, and alternative (Figures 1-3).

Strong and weak primes used sentences containing a scalar trigger term, e.g. *some*, whereas alternative prime trials used the more informative scalar term e.g. *all*. In strong prime trials, the sentence picture combination encouraged participants to make a strong (implicature) interpretation e.g. *some but not all*. In weak prime trials, the sentence picture combination encouraged participants to make a weak (non-implicature) interpretation. In the alternative prime trials, there was a picture that matched the more informative scalar term. In target trials (Figure 4) the sentence used the scalar trigger term. One picture was consistent with a weak interpretation of the sentence and the other card was a "better picture" option that participants could select if they thought there was a different, better picture that would match the sentence (as in Bott & Chemla, 2016 and the hidden box paradigm of Huang, Spelke, & Snedeker, 2013). The logic is that if participants derive an implicature they will select the "better picture" option since the other card is consistent with the non-implicature interpretation.

Rees and Bott (2018) demonstrated that, in adults, implicature interpretations could be primed. In priming paradigms, structural priming occurs when participants are exposed to or use a particular linguistic structure on one trial and then reuse this structure in a subsequent trial (see Branigan & Pickering, 2017 for a review). In order for a priming effect to occur the stimuli needs to share some attribute within the language system, for example a shared process or representation. Rees and Bott suggest that the locus of priming for implicatures is the alternative. Rees and Bott showed equivalent rates of priming following strong and alternative primes despite the two trials involving different processes (strong primes derive the implicature and alternative primes do not).

In the present study, we used two categories of expression, quantifiers and ad hoc. Children have been shown to successfully derive implicatures for ad hoc (context dependent) scales from an early age (Horowitz et al., 2018; Stiller et al., 2015; Yoon and Frank, 2019) and including these trials will allow us to compare performance across expression types (e.g. van Tiel et al., 2014). Rees and Bott (2018) found similar patterns of priming across expression categories (quantifier, ad hoc, and number) albeit at lower rates for ad hoc expressions.

### Predictions

For ad hoc items, since the alternatives are contextually defined the scalar relation between the items should be clearer than the relation between quantifiers (as suggested in Stiller et al., 2015 and Barner et al. 2011). Consequently we predict that following strong ad hoc primes children will compute more implicatures in the target trials than following weak ad hoc trials. Furthermore, we predict that compared to weak primes there will be greater implicature computation following alternative primes since these trials explicitly provide the alternative.

We expect children to struggle when deriving scalar implicatures in the quantifiers, as observed previously (e.g. Noveck, 2001). Most obviously, they will make fewer implicatures than adults in the prime trials. The crucial test of Barner et al.'s hypothesis will be whether we observe greater priming after the alternative prime trials than the weak prime trials. According to Barner et al., children who fail to derive scalar implicatures are unaware of the relationship between *some* and *all*. Consequently we would expect to find no priming after alternative trials, or at least less priming than after strong prime trials, since there is no link between the two quantifiers in the child's lexicon.

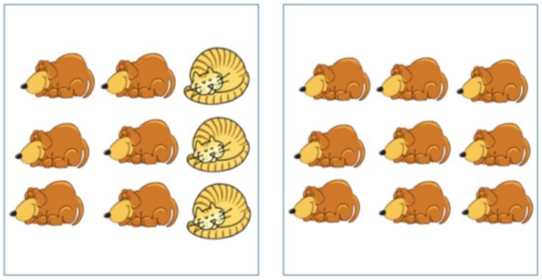

Figure 1: Example quantifier strong prime trial. The sentence "Some of the animals are dogs" favours left panel following the *some but not all* interpretation.

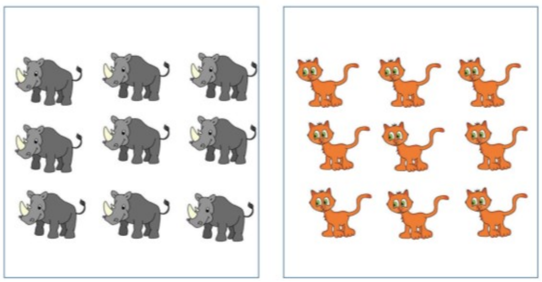

Figure 2: Example quantifier weak prime trial. The sentence "Some of the animals are cats" favours right panel following the *some and possibly all* interpretation.

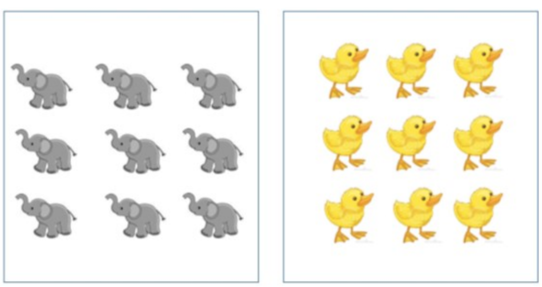

Figure 3: Example quantifier alternative prime trial. The sentence "All of the animals are elephants" favours left panel and raises the salience of *all* without the derivation of an inference.

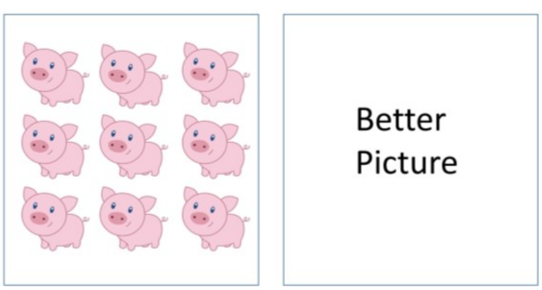


Figure 4: Example quantifier target trial. "Some of the animals are pigs" Participants have a choice in how they interpret the sentence. *Some but not all* interpretations are indicated by "better picture" selections whereas the left panel is consistent with *some and possibly all.*

## Method

**Participants.** 72 children aged 4;2 to 5;11 (mean 5;1 years; 40 male) were recruited from two Warwick primary schools. They were given a sticker for their participation. Data was excluded from two children who did not pass the familiarisation trials. 51 adult controls were recruited from [hidden for blind review] University and online.

**Design and Materials.** Each trial consisted of two pictures and a corresponding sentence. Participants had to select which picture matched the sentence. There were two expression types, quantifier and ad-hoc, and three prime types, strong, weak, and alternative.

Quantifier trials used sentences of the form "[Quantifier] of the animals are [animal]". Strong primes consisted of one picture with 9 of the same animal (dogs in Figure 1) and one picture with 6 of the animal on the first card and 3 new animals (6 dogs and 3 cats in Figure 1). The sentence encourages an implicature interpretation of the sentence; *some but not all of the animals are dogs*. It is expected that participants will select the partial set.

In weak trials each picture contains a set of 9 animals (9 rhinos and 9 cats in Figure 2). For the sentence *some of the animals are cats*, since only one picture has cats it is expected participants will make the non-implicature interpretation; *some and possibly all of the animals are cats.* Alternative primes have the same picture configuration as weak trials but are accompanied by a sentence using the *alternative*; *all of the animals are elephants* (Figure 3).

In target trials there is one picture with a full set of animals (9 pigs Figure.4) and one "Better picture" option. The sentence *some of the animals are pigs* is consistent with either options depending on the interpretation made.

Ad-hoc trials used two different sentence forms, either "There is an [animal]" or the more informative conjunction "There is an [animal] and an [animal]". Strong trials have one picture with two animals and one picture with a single animal (Figure 5). The single animal matches one of the animals on the other card. This configuration encourages an implicature interpretation of the sentence "There is a frog" to *there is a frog and nothing else*. Thus, in this trial it is expected that participants will select the single item card.

In weak trials both pictures contain two unique animals. Figure 6 shows a zebra and a monkey in one picture and a dinosaur and a goat in the other. Here the sentence "There is a dinosaur" disambiguates the target picture and is consistent with *there is a dinosaur and possibly something else.*

Alternative primes have the same configuration as strong trials but use the more informative conjunction. In Figure.7 this is "There is a horse and a cat" which is consistent with a single picture.

Target trials consist of one picture containing two animals and a "better picture" option (Figure.8). The sentence "There is a mouse" is consistent with either of the options depending on participants' interpretation of the sentence.

Figure 5: Example ad-hoc strong prime trial. The sentence “There is a frog” favours left panel following the *there is a frog and nothing else* interpretation.

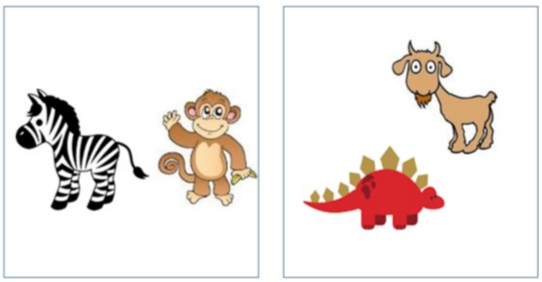

Figure 6: Example ad-hoc weak prime trial. The sentence “There is a dinosaur” favours left panel following the *there is dinosaur and possibly something else* interpretation.

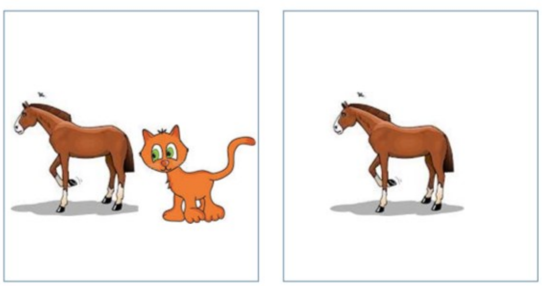

Figure 7: Example ad-hoc alternative prime trial. The sentence “There is a horse and a cat” favours left panel.


Figure 8: Example ad-hoc target trial. “There is a mouse” Participants have a choice in how they interpret the sentence. *There is a mouse and nothing else* interpretations are indicated by “better picture” selections whereas the left panel is consistent with *There is a mouse and possibly something else.*

**Procedure.** Before the main experiment children were familiarised with the task and the animals. They were shown example cards with animals and asked to identify the animal. Children were also shown examples of “better picture” 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 better represent the sentence. If children failed to understand the “better picture” paradigm twice during familiarisation the experimenter ended the testing session

**Analysis.** Responses to trials were removed if the preceding prime trial was not answered correctly which accounted for 5% of the data. The remaining data underwent a logit transformation and were analyses using a 2 x 3 ANOVA with expression (Ad-hoc and Quantifier) and prime type (strong, weak, and alternative) as within-subjects factor. We computed Bayes Factors in JASP using the JZS prior (JASP team, 2020) to interpret non-significant findings as in Rees and Bott (2018). 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).

## Results

### Adults

Figure 9 shows the proportion of implicature responses on target trials as a function of prime and expression. The overall rate of implicature responses varied significantly across expression type, ($F(1, 49) = 46.48$, $p < .001$). Participants’ responses to ad hoc expressions were biased towards the weak, non-implicature interpretation. Implicature interpretations were higher following strong and alternative prime trials than following weak prime trials ($F(2, 98) = 11.08$, $p < .001$). Rates of implicature were significantly higher following strong primes than weak primes for ad hoc ($t(49) = 3.22$, $p = .002$) and quantifier expressions ($t(50) = 3.90$, $p < .001$). There were also significantly higher implicature responses following alternative prime trials for ad-hoc ($t(50) = 3.22$, $p = .002$) and quantifier expressions ($t(50) = 2.12$ $p = .039$) compared with weak trials. There was no interaction between expression and prime type ($F(2,94) = 1.43$, $p = .244$, BF = 0.09). Overall, the results are consistent with Rees and Bott (2018) in magnitude and pattern.

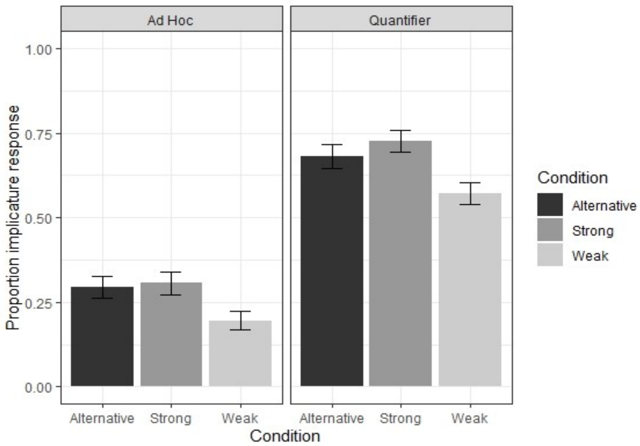


Figure 9: Adult implicature responses to target trials.

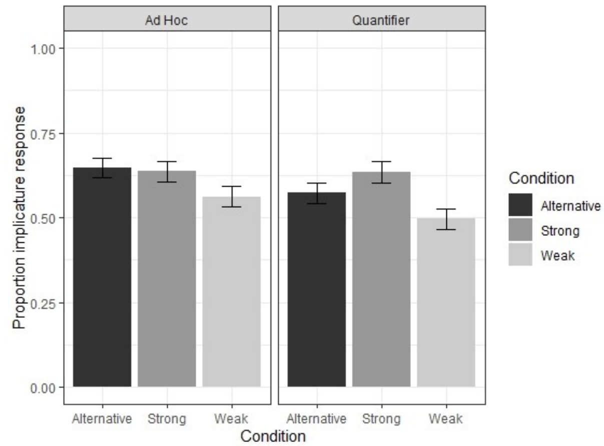


Figure 10: Children's implicature responses to target trials.

## Children

**Prime trials.** Children's responses were at ceiling for all prime trials (*M*> 97%) except for quantifier strong primes (*M* =81%). Consistent with previous literature, children had greater difficulty deriving the implicature (or failed to see the relevance of the implicature interpretation) for *some* sentences than *ad hoc* sentences.

**Target trials.** Figure 10 shows the rate of implicature derivation on target trials as a function as expression and prime type.

As predicted, for ad hoc expressions rates of implicature were significantly higher following strong and alternative primes ($t(69) = 3.11$, $p = .003$; $t(69) = 3.15$, $p = .002$) when compared with weak primes and there was no difference in priming between strong and alternative primes ($t(69) = .48$, $p = .634$, BF = .14).

Crucially, this pattern of results was also found in quantifiers. Rates of implicature were significantly higher following strong and alternative primes compared to weak primes ($t(69) = 2.28$, $p = .026$; $t(96) = 3.04$ $p = .003$) and there was no difference in priming between strong and alternative primes ($t(69) = .33$, $p = .741$, BF = .15). Thus children are aware of the relationship between alternatives and quantifiers just as much as they are aware of the relationship between alternatives and ad hoc triggers.

This demonstrates that children are able to derive an implicature when primed to do so. Moreover, children must be aware of the scalar relationship between *some* and *all*, even though they performed worse than adults on the scalar implicatures in the primes.

## Discussion

The present study investigated children's implicature computation using structural priming. Barner et al. (2011) suggested that children's difficulty with quantifier implicatures is due to a lack of awareness about the relationship between quantifiers and the alternative. If this were the case, priming with the alternative would not have primed the computation of implicatures. However, children in our study demonstrated robust priming of quantifier implicatures with the alternative. This is consistent with other developmental findings (e.g. Skordos & Papafragou, 2016; Stiller, Goodman, & Frank, 2016) that demonstrate that providing the alternative is salient, children can compute implicatures.

Our findings also speak to previous work on structural priming. Structural priming occurs throughout the language system and has been used to probe linguistic representation but typically focuses on syntax (Branigan, & Pickering, 2017). Previous work suggests that children have abstract syntactic representations which is the locus of the observed priming effects (e.g. Branigan & Messenger, 2016; Messenger, Branigan & McLean 2011). The present findings, along with previous work (Bott & Chemla, 2016), suggest there may also be pragmatic representations underlying scalar implicatures. One idea is that the locus of priming is a sentence level pragmatic representation [S¬S'] where S is the utterance and S' is the alternative (see Rees & Bott, 2019 for discussion).

Recent replications of implicature priming (Marty et al., 2021; Waldon & Degen, 2020) included a baseline in which participants respond to target trials in the absence of priming. Marty et al. showed that for some participants, the weak prime decreased implicature rates on the target relative to baseline, but the strong and alternative prime had little effect i.e. priming was caused by the weak prime and not the strong/alternative prime (cf. Rees & Bott, 2019). Could the same explanation apply to the priming effects seen in our study? We argue that this cannot account for all of our findings. 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, as described above, but for those who had low baseline rates, i.e. < 50%, the strong prime/alternative raised them (Paul Marty, personal communication). Thus there is considerable individual variation. While we did not include baseline trials, a similar measure can be obtained by considering the response rate on the first target trial of our experiment (although this is not a true baseline since it was preceded by a strong prime). We found that 45% of responses were weak. Thus, following the results of Marty et al., around 45% of children are "low baseline" and would consequently be primed by strong and alternative trials, not weak trials. These participants in particular present a challenge to Barner et al.'s theory. More generally, previous research has consistently found children to have a bias towards the literal interpretation (e.g. Noveck, 2001) and there is no reason to think our experiment is different (e.g. we found significantly lower implicature rates than adults on prime trials). Indeed, the converse finding, that children are biased towards the strong interpretation, would be highly noteworthy.

A surprising finding was that, unlike in adults, the implicature rate for children was similar for ad hoc and quantifier priming. Ad hoc expressions differ to quantifiers in the nature of their alternatives. Quantifier alternatives are context independent whereas ad hoc alternatives are contextually based. Since children have been shown to compute these ad hoc implicatures from an early age this has been taken as evidence that children's difficulty with quantifiers lies in their scalar knowledge (e.g. Horowitz, Schneider, & Frank, 2018; Stiller, Goodman, & Frank, 2015; Yoon & Frank, 2019). Arguably, the alternatives for ad hoc expressions are more accessible because they are present in the discourse rather than in the lexicon. Thus, the lack of a difference between quantifier and ad hoc implicatures in the present study is surprising. In adults, rates of priming in ad hoc expressions are typically far lower than for quantifiers (Rees & Bott, 2018). Adults tend to favour the weak, non implicature interpretation.

One potential explanation of our findings is that while children in our experiment did not have a lexical understanding of the relationship between *some* and *all*, they may have been able to compute the quantity implicatures in an ad hoc fashion. Perhaps children were able to recognize the entailment relation between *some* and *all* during the experiment. This would be consistent with Barner et al.'s (2011) theory, which stresses the lexical nature of the *some*/*all* relationship. However, there are a number of problems with this explanation. The first is that if children were able to extract the relationship between *some* and *all* in this task, it is not clear why they were not able to do so in Barner et al.'s task, which also employed images corresponding to *some* and *all*, or many other tasks that demonstrate a low rate of implicatures in children. The second is that there is no evidence that even adults have a lexical understanding of the entailment relationship between *some* and *all* (see Geurts, 2010, for a similar point). Ease of access certainly does not provide evidence of this: Non-lexical pragmatic reasoning can be computed quickly (e.g. Breheny et al., 2013), and supposed lexical implicatures e.g. with *some*, can take time (e.g., Tomlinson et al., 2013).

## Conclusion

The findings from this study demonstrate that children can be primed to derive implicatures. Making the alternative more salient results in more implicatures, regardless of the type of implicature. Moreover, this study demonstrates that children are aware of the relationship between *some* and *all*, even when they choose not to derive the implicature, contrary to the predictions of the alternatives theory (Barner et al., 2011).

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