

# The Semantics and Pragmatics of Logical Connectives: Adults' and Children's Interpretations of *And* and *Or* in a Guessing Game

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## Abstract

Logical connectives *and* and *or* have been a source of insight into the roles of semantics and pragmatics in children's linguistic development. Previous research has suggested that adults and children may differ in their interpretation of *or* in two ways. First, unlike adults, children may interpret *or* as *and*. Second, children interpret *or* as inclusive disjunction while adults interpret it as exclusive disjunction. We report the results of two experimental studies with truth value judgment tasks that agree with the latter but not the former claim. The results suggest that children do not interpret *or* as *and* but they do make fewer implicatures than adults.

**Keywords:** semantics; pragmatics; disjunction; conjunction; language development.

## Introduction

An airport sign reads “*If you see something, say something.*” Taken literally, this is a trivial request, but readers infer an interpretation that goes far beyond the literal meanings of the words. How much of what we interpret is due to literal meaning (semantics) and how much due to our general-purpose inferential abilities (pragmatics)? In this paper, we address this question by investigating adult and children's interpretation of logical words *and* and *or*.

Despite their simple appearance, *and* and *or* have been a major source of insight into the contributions of semantics and pragmatics to language interpretation. The meaning of *and* has always been unambiguously associated with logical conjunction. A conjunction is true when each individual conjunct is true. The meaning of *or*, however, has proven hard to capture. It has two possible interpretations: *inclusive* or logical disjunction and *exclusive* disjunction. An *inclusive* disjunction is true when either disjunct or both are true. On the other hand, an *exclusive* disjunction is true when only one of the disjuncts is true – not both. Until Grice (1975), it was generally assumed that *or* is ambiguous between an inclusive meaning and an exclusive one.

Grice (1975) argued against this ambiguity account. He maintained that the core meaning of *or* is inclusive disjunction. The exclusive interpretation of it is derived from the inclusive meaning via pragmatic reasoning. For example, “*there is a cat or a dog in the picture*” implies that not both animals are in the picture. This is called the *exclusivity implicature*. Grice argued that this implicature is derived via reasoning on what the speaker of the sentence could have said. If the speaker meant to communicate that both animals are in the picture, s/he could have used the connective *and*. He chose *or* instead, so he did not mean to communicate that both

animals are in the picture. In the Gricean account, the exclusivity implicature is not part of *or*'s meaning, but rather the result of our reasoning on why the speaker chose *or* instead of *and*.

The advent of Gricean pragmatics changed the landscape of research on children's development of *and* and *or* interpretations. The focus shifted to the differences between adults and children in semantic vs. pragmatic aspects of interpretation. In a series of influential studies, Stephen Crain and his colleagues argued that unlike adults who have an implicature-rich exclusive interpretation of *or*, children as young as three years old, interpret the meaning of *or* in its logical and inclusive sense. (Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Crain, 2008, 2012; Notley, Zhou, Jensen, & Crain, 2012) They argued that children develop the semantics of *or* before its pragmatics: they interpret *or* as inclusive disjunction but fail to enrich it with the exclusivity implicature the way adults do. Therefore, the main difference between children and adults is that children interpret *or* as inclusive, but adults interpret it as exclusive.

Recent investigations have added a new level of complexity to this line of research. Tieu et al. (2016) and Singh et al. (2016) argued that a substantial number of children in their studies (30-40% of the samples) interpreted *or* like a conjunction. In other words, these children do not differentiate between *and* and *or*. Based on previous studies that show children understand the meaning of *or*, they argue that this conjunctive interpretation of *or* is due to a non-adult-like pragmatic reasoning. Children interpret *A or B* as *A or B*, but not *only A and no only B*, resulting in *A and B*.

The current paper seeks to fill two gaps in the current literature. First, for theoretical reasons, previous research has focused on children's interpretation of *and* and *or* in complex sentences – for example with other logical words such as quantifiers *every* and *none*. In this paper we test children and adults' understanding of *and* and *or* in simple existential sentences like “*There is a cat or a dog.*” Second, previous research has tested children and adults using the binary truth value judgment task (Crain & Thornton, 1998). In such tasks participants are asked whether a puppet's statement is right or wrong. In this study, we allow participants to make use of three options: wrong, kinda right, and right. Katsos & Bishop (2011) showed that ternary judgment tasks are better suited for assessing children's pragmatic competence.

In this paper we address two main questions. First, do children (and adults) interpret *or* similar to *and*? Second, do they

understand *or* as inclusive disjunction, or exclusive disjunction? We conduct two experiments to answer these questions. Experiment 1 tests the adults' performance and sets the benchmark for children's performance in the task. Experiment 2 investigates children's interpretations. The results of our experiments suggest that the answer to the first question is **no** for both adults and children. For the second question, the results suggest that adults are more inclined to interpret *or* as exclusive than inclusive. On the other hand, children show judgments compatible with inclusive disjunction.

### Experiment 1: Adults

The goal of this study was to examine adults' interpretation of the connectives *and* and *or* as a benchmark for children's interpretations. We designed the study as a card game in which participants saw a picture card, read a description about the card, and had to evaluate the description. The descriptions contained the conjunction word *and* and the disjunction word *or*. This study found that adults interpret *and* and *or* differently and that adults are more likely to interpret *or* as exclusive than inclusive.

### Methods

**Participants** We recruited 52 English speaking adult participants online. The task took about 5 minutes on average to complete.

**Materials and Design** We used Amazon's Mechanical Turk (MTurk) for recruitment and the online platform Qualtrics for data collection and survey design.

The study included six cards with cartoon images of a cat, a dog, and an elephant. There were two types of cards. The cards with only one animal on them and the ones with two animals. We also used three types of descriptions as guesses for these cards: simple (e.g. *There is a cat.*), conjunctive (e.g. *There is a cat and a dog*), and disjunctive (e.g. *There is a cat or a dog*). Pairing the card-types with the guesses results in 6 types of card-guess scenarios (One Animal-Conjunctive, Two Animals-Disjunctive, etc.). In each scenario, the animal labels used in the guess and the animal images on the card may have no overlap (e.g. Image: dog, Guess: *There is a cat or an elephant*), a partial overlap (e.g. Image: Cat, Guess: *There is a cat or an elephant*), or a total overlap (e.g. Image: cat and elephant, Guess: *There is a cat or an elephant*). The number of animals on the card, the type of guess, and the overlap between the guess and the card results in 12 different trial types.

**Procedure** Participants read the consent form on Mturk and clicked on the study link to participate in the study. The link started a survey on Qualtrics with three phases: introduction, instruction, and test. In the introduction, participants saw the six cards and read that they will play a guessing game with these cards. They were then introduced to a blindfolded cartoon character, Bob. They were told that in each round of the game, they will see a card and Bob is going to guess what animal is on that card. We emphasized that Bob cannot see

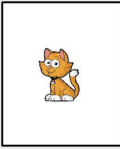
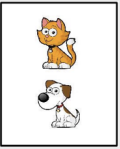
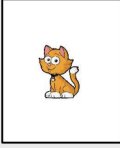

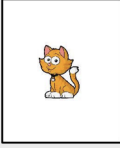

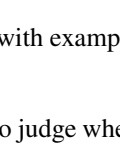
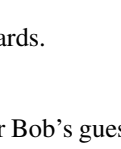
Guess		One Animal (1T)	Two Animals (2T)
AND	There is a cat and a dog.		
			
OR	There is a cat or a dog.		
			

Figure 1: Critical trials with example cards.

the cards. We asked participants to judge whether Bob's guess is *wrong*, *kinda right*, or *right*. In the instruction phase, participants saw an example trial where a card with the image of a dog was shown and the following was written above Bob's head: *Bob: There is a cat on the card*. All participants correctly responded with *wrong* and proceeded to the next phase.

In the test phase, participants saw one trial per trial type for the total of 12 trials. Within each trial type, the specific card-guess scenario was chosen at random. The order of trial types was also randomized for each participant. At the end of the study, participants received a 4 digit code to enter into Mturk and receive \$0.4 as compensation for their participation.

### Results

Here we focus on the results of the critical trial types. You can see the example scenarios of these trial types in Figure 1. These scenarios include conjunctive and disjunctive guesses with some overlap between the guessed animals and the animal(s) on the cards.<sup>1</sup> The number of animals in the critical trials of this study corresponds to the number of true conjunct/disjuncts: one animal is 1 conjunct/disjunct true (1T) and two animals, two conjunct/disjuncts true (2T) (Tieu et al., 2016).

Adult responses differed both by guess type and number of animals (Figure 2). First, the response patterns in the conjunctive and disjunctive trials are different. For conjunction, the responses were on the extremes of *right* and *wrong* while for disjunction, they were distributed on *kinda right* and *right*. This pattern suggests that adults interpret *and* and *or* differently. Second, the responses were different between the trials where one disjunct/conjunct is true (1T) and those where both disjuncts/conjuncts are true (2T). This difference was greater for conjunction than disjunction. Adults showed a small pref-

<sup>1</sup>Participants judged the trials with no overlap as *wrong* consistently.

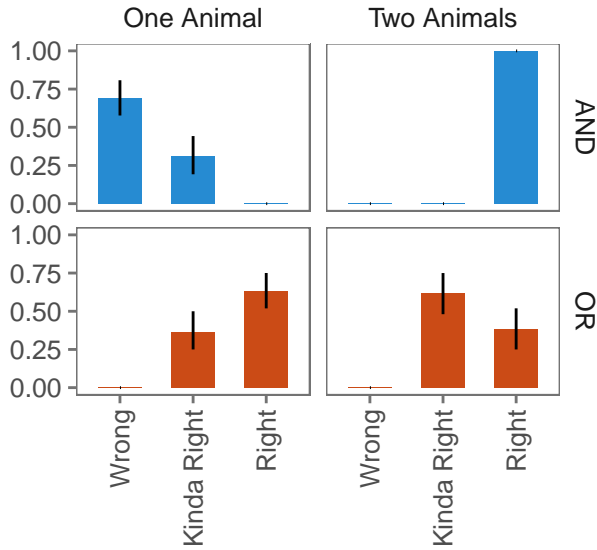


Figure 2: Adult judgments across trial types (panels), for critical trials of Experiment 1. Error bars represent 95% confidence intervals.

erence for the use of disjunction when only one disjunct is true rather than when both are true. This pattern suggests a small preference for an exclusive interpretation in the context of this experiment.

**Individual Responses** Tieu et al. (2016) and Singh et al. (2016) categorized participants as a function of their responses to the disjunctive trials. Here we perform a similar analysis on our disjunctive trials. Table 1 summarises the results. None of the participants considered a disjunctive guess *wrong* when one or both of the animals were on the card. However, participants divided into four different groups when interpreting disjunctive guesses for the one-animal and two-animal scenarios.

The majority of participants (23 out of 52) considered the disjunctive guess *right* when one animal was on the card (1T), but *kinda right* with two animals (2T). This pattern is consistent with an interpretation of “or” with an exclusivity implicature. The use of disjunction when both disjuncts are true is not *wrong* but it is nevertheless infelicitous and not completely *right*. For these participants, *kinda right* captures the violation of such a pragmatic expectation.

The other 29 participants were divided almost equally into the three remaining groups. 10 participants rated disjunctive guesses as *right* in both scenarios where one or two animals were on the card. This pattern is consistent with an inclusive interpretation of *or* with no exclusivity implicature. 9 other participants rated disjunctive guesses as only *kinda right* in both one-animal and two-animal trials. In other words, disjunctive guesses were dispreferred regardless of the outcome. This response pattern is consistent with the violation of another pragmatic expectation in the context of a guessing game: the guesser must choose the most specific

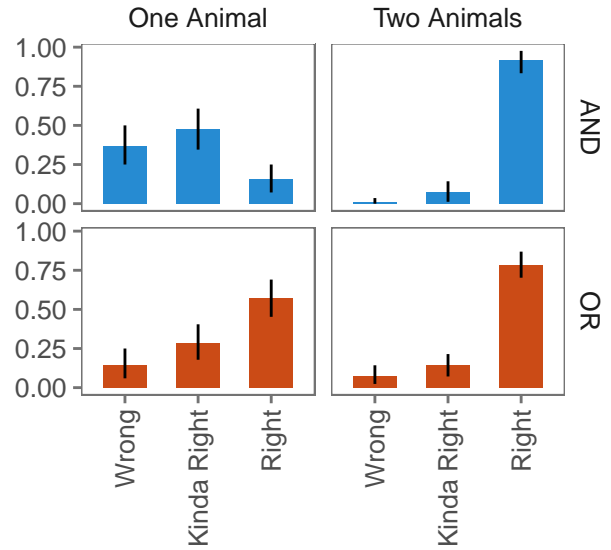


Figure 3: Children's judgments across trial types (panels), for critical trials of Experiment 2. Error bars represent 95% confidence intervals.

guess possible. Under this expectation, guesses that cover several possible outcomes are punished. A disjunctive guess never picks a specific outcome and for these participants, *kinda right* captures the violation of this specificity expectation.

Finally, 9 participants reported a disjunctive guess as *right* when both animals were on the card, but only *kinda right* when only one of the animals was on the card. In other words, these participants preferred the guess when both disjuncts were true rather than only one. It is possible that these participants expected a *right* guess to be one that brings up a relevant number of animals. When only one animal is on the card, bringing up a second animal violates this expectation. When two animals are on the card, bringing up both animals satisfies this expectation even though the *right* linguistic connective was not used. For these participants, the choice of the linguistic connective (*and* vs. *or*) did not play an important role in their judgments.

## Discussion

In this study, we tested adult interpretations of the connective words *and* and *or* in the context of a guessing game. Adult participants interpreted these words differently and depending on how many disjuncts/conjuncts were satisfied. Overall, a guess with *and* was considered *right* if both conjuncts were true and *wrong* if only one was true. A guess with *or* was not *wrong* in either case, yet adults were more likely to consider it as *right* when only one of the disjuncts was true. Grouping individuals based on their responses, we also found that some participants dispreferred disjunctive guesses whether one or both disjuncts were true, some considered them better when both disjuncts were true, and some others considered them *right* in either case.

The results are consistent with the dominant view on the division of labor between semantics and pragmatics in the interpretation of connective words. The semantics of *and* is captured by logical conjunction and *or* by inclusive disjunction. *And* is true when both conjuncts are true and false when only one is true. *Or* is true in both cases but not the best option as a connective when both disjuncts are true. In Experiment 2 we examine preschool children’s interpretation of these connectives in the context of the same guessing game.

## Experiment 2: Children

### Methods

**Participants** We recruited 42 English speaking children from the Bing Nursery School at Stanford University. Children were between 3;02 and 5;02 years old (Mean = 4;04).

**Materials and Design** We used the same set of cards and linguistic stimuli as the ones in Experiment 1. The study used 8 trial types and 2 trials per trial type for the total of 16 trials. The trials were balanced to include the same number of one-animal and two-animal cards, the same number of simple and connective guesses, and the same number of expected true vs. false judgments. However, we made a few changes to make the experiment more suitable for children. Instead of Bob, a puppet named Jazzy played the guessing game with the children. Jazzy had a sleeping mask on his eyes during the game. To introduce a three-valued scale, we placed a set of red circles, small blue stars, and big blue stars in front of the children. These tokens were used to reward the puppet after each guess. The use of tokens as rewards proved to be a more successful measure during piloting than hand gestures or only verbal feedback (e.g. *Jazzy you were right!*). One experimenter was involved in this study.

**Procedure** The experimenter and the puppet interacted with the children before the study. The experiment was carried out in a quiet room and the sessions were videotaped. There was a small table and two chairs in the room. Children sat on one side of the table and the experimenter and the puppet on the other side facing the child. The groups of circles, small stars, and big stars were placed in front of the child from left to right. A deck of six cards was in front of the experimenter. Similar to the previous study, participants sat through three phases: introduction, instruction, and test.

The goal of the introduction phase was to show the animal cards to children and make sure they recognize the animals and know their names. The experimenter showed the cards to the children and asked them to label the animals. All children recognized the animals and could label them as cat, dog, and elephant. In the instruction phase, children went through three example trials. The experimenter explained that he is going to play with the puppet first so that the child can learn the game. He removed the six introduction cards and placed a deck of three cards face-down on the table. From top to bottom (first to last), the cards had the following images: a cat, an elephant, a cat and a dog. He put the sleeping mask on

Jazzy’s eyes and explained that Jazzy is going to guess what is on these cards. He then picked the first card and asked the puppet: “*What do you think is on this card?*” Jazzy replied with “*There is a dog*”. The experimenter showed the cat-card to the child and explained that when Jazzy is *not right* he gets a circle. He then asked the child to give the puppet a circle. Rewards were collected by the experimenter and placed under the table to not distract the child. The second trial followed the same pattern except that the puppet guessed *right* and the experimenter invited the child to give the puppet a big star. In the final trial, the puppet guessed that there is a cat on the card when the card had a cat and a dog on it. The experimenter said that the puppet was *a little right* and asked the child to give him a little star.

In the test phase, the experimenter removed the three instruction cards and placed a deck of 16 randomized cards on the table.<sup>2</sup> The experimenter explained that it is the child’s turn to play with the puppet. The test phase followed the pattern described in the instruction phase.

**Measurement** In each trial, children were asked to give the puppet a circle if he is *wrong*, a small star if he is *a little right*, and a big star if he is *right*. During the analysis of the videos, children’s linguistic feedback to the puppet after each guess were categorized into four types: 1. None, 2. Judgments, 3. Descriptions, and 4. Corrections. The first category referred to cases where children did not provide any linguistic feedback. judgments referred to linguistic feedback such as *you are right!*, *yes*, *nope*, *you winned*. Such feedback only expressed judgments and mirrored the rewards. Descriptions were cases that the child simply mentioned what was on the card: *cat!*, *dog and elephant!*, *There is a cat and a dog!* etc. Finally, corrections referred to feedback that provided corrections to what the puppet had said. Examples include: *Just a cat!*, *Both!*, *The two are!*, *Only cat*, *cat AND dog* (with emphasis placed on *and*).

### Results

Figure 3 shows the results. Comparing the conjunction and disjunction trials (the figure rows), we see that children distinguish between *and* and *or* in cases where one animal is on the card, but not when both are. Given that the one-animal conjunction trials (top left) and the one-animal disjunction trials (bottom left) differ in truth conditions, the difference in response patterns suggests that children at this age have a different semantic knowledge for *and* and *or*. The two-animal conjunction and two-animal disjunction trials (top right and bottom right) do not differ in truth values, and the responses also show no difference.

In the one-animal and two-animal trials, children show different response patterns when the guess contains the conjunction word *and* (top right vs. top left) but not when *or* is used (bottom right vs. bottom left). Since the truth values of one-animal and two-animal trials differ for conjunc-

<sup>2</sup>The randomization code can be found in the github repository of this study

tive guesses but not disjunctive ones, the results suggest that children have different semantic knowledge for *and* and *or*. The similarity of the disjunctive guesses in one-animal and two-animal trials (bottom right vs. bottom left) can be interpreted as a lack of exclusivity implicatures in children. We will bring up a caveat to this interpretation in our analysis of children’s linguistic feedback.

**Statistical Modeling** We used the R package *{rstan}* for Bayesian statistical modeling. We fit separate ordinal mixed-effects logistic models for children’s and adults’ judgments. The response variable had three ordered levels: *wrong*, *kinda right*, and *right*. The trial types *One-Animals-OR*, *Two-Animals-OR*, *One-Animal-AND* constituted the (dummy-coded) fixed effects of the model with *Two-Animal-AND* set as the intercept. The model also included by-subject random intercepts. The priors over trial types and the random intercepts were set to  $\mathcal{N}(0, 10)$ . We also included parameters  $C_1$  and  $C_2$ , the two cutpoints delimiting the logistic for 1) *wrong* and *kinda right* and 2) *kinda right* and *right* responses, drawn with the prior  $\mathcal{N}(0, 1)$ .<sup>3</sup> All four chains converged after 3000 samples (with a burn-in period of 1500 samples)

We make inferences based on the highest-posterior density (HPD) intervals for the coefficients estimated from each model. Because predictors are dummy-coded, we can examine contrasts of interest by computing the difference between coefficients for pairs of conditions we wish to contrast (Figure 4). Overall, adults’ and children’s estimated coefficients are similar in sign to one another, though adults are more extreme. The one notable exception to this pattern is for the contrast *or*, 1T vs. 2T, which shows the comparison between the disjunctive trials: both disjuncts are true vs. only one disjunct is true. On average, children are more positive for disjunction on two-animal trials, while adults are more negative. These estimates reflect the implicature that we believe that adults compute, leading them to judge two-animal trials as more *kinda right*.

**Individual Responses** We searched for children that had the following response patterns: they responded with *wrong* when one disjunct was true but *kinda right* or *right* when both were true; as well as children that responded with *kinda right* when one disjuncts was true but *right* when both were true. We found 10 children with such response patterns.

**Linguistic Feedback** We next examined children’s linguistic feedback to the puppet (Figure 5). We performed chi-squared goodness-of-fit tests to compare the feedback distributions in each condition. Children’s linguistic feedback fell into three patterns. First, the one-animal conjunctive and two-animal disjunctive (top left and bottom right) trials show higher proportion of *Corrections* than the other trial types. These are trials that the guesses are either false or infelicitous. In the conjunction trials, a comparison of the

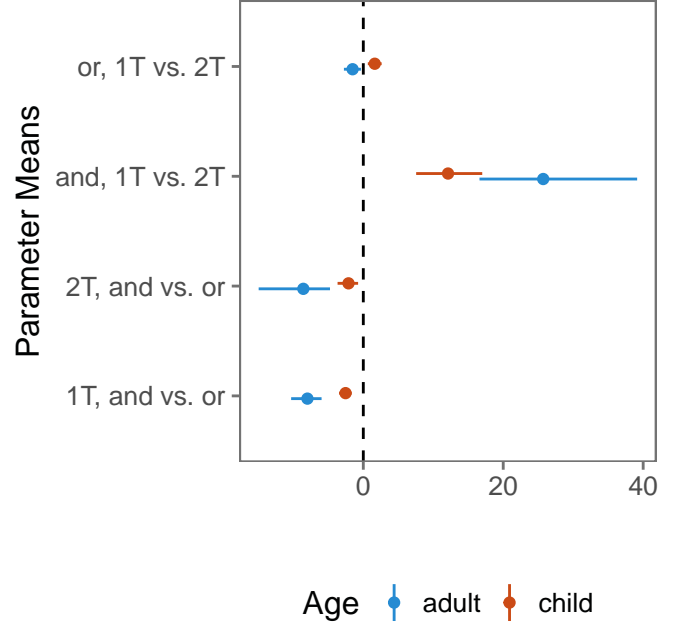


Figure 4: Coefficients capturing the relevant comparisons across conditions across the two experiments (see text). Error bars represent 99% regions of highest posterior density.

feedback distribution in one-animal and two-animal conditions was statistically significant ( $\chi(3, N = 83) = 201.65$ ,  $p = \text{round}(\text{chisq.and12}\$p.value, 2)$ ), indicating different feedback for false sentences. A similar numerical trend was present in the disjunction trials, but was not significant ( $\chi(9, N = 4) = 12$ ,  $p = \text{round}(\text{chisq.or12}\$p.value, 2)$ ).

Second, the one-animal disjunctive trials (bottom left) showed the highest proportion of *Descriptions*. These are trials in which the guess is correct but not specific enough: it leaves two possibilities open. These trials were significantly different than the one-animal trials for conjunction ( $\chi(3, N = 83) = 62.16$ ,  $p = \text{round}(\text{chisq.1andor}\$p.value, 2)$ ).

Finally, the two-animal conjunctive trials (top right) showed the highest proportion of *Judgments* such as *you are right!*. This is not surprising given that in these trials represent the most optimal guessing scenario. These trials had a significantly different feedback distribution from the matching disjunction trials ( $\chi(3, N = 84) = 184.98$ ,  $p = \text{round}(\text{chisq.or12}\$p.value, 2)$ ).

## Discussion

This study did not find evidence for the hypothesis that a large group of children interpret the disjunction word *or* similar to its conjunctive counterpart *and*. To the contrary, both children’s judgments and their linguistic feedback suggested that they differentiate these two connective words. Instead, children’s judgments largely mirrored those of adults. We took this as a sign of children’s adult-like semantics for *and* and *or*. However, children’s judgments differed from adults in the case of disjunction when both disjuncts were true, showing no signs of an exclusivity implicature in such trials. These

<sup>3</sup>We used a tight prior in this case to decrease posterior correlations between cutpoints and intercept.



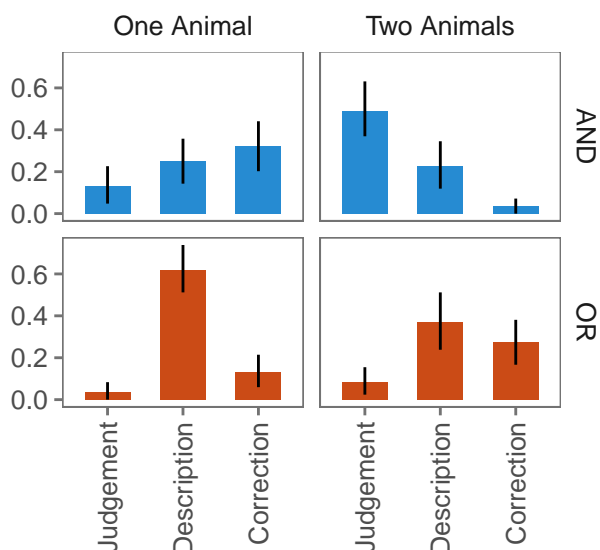


Figure 5: Children's Linguistic Feedback to Conjunction and Disjunction Trials. Error bars represent 95% confidence intervals.

results can be interpreted to show that children differ from adults in the pragmatics of disjunction words. Overall our data are most consistent with this hypothesis. We do however note the suggestive (though not statistically significant) increase in corrections in the two-animal disjunction case; anecdotally, these cases seemed to reflect corrections due to implicature. Further work could explore whether this numerical trend reflects implicature calculation, perhaps at a slower timescale or only in older children.

### General Discussion

We started our investigations with two questions: first, do adults and more importantly children interpret *and* and *or* differently? Second, do they interpret *or* as inclusive disjunction or exclusive disjunction? In this paper, we presented two experimental studies to address these questions. Experiment 1 showed that adults interpreted *or* as a disjunction and differentiated it from *and*. Judgments of *or* were split between an inclusive and exclusive interpretation, with a slight advantage for the exclusive interpretation. Experiment 2 showed that three-to-five-year old children showed very similar patterns of interpretation in the guessing game except for disjunction when both disjuncts are true. Overall, children were more likely to interpret *or* as inclusive disjunction. Therefore, the results of our truth value judgment studies suggest that both adults and children differentiate *and* and *or*. Yet, adults are more likely to interpret *or* as exclusive while children interpret it as inclusive. These results are most compatible with the ones reported in Crain (2012).

At this point, we would like to discuss two issues raised by Experiments 1 and 2 that we would like to address in the future. First, the analysis of individual adult responses in experiment 1 showed that adults interpret *or* in many different

ways, even though the majority stick to an exclusive interpretation. We suspect that this variation is due to participants' understanding of the goal of the game and ultimately what being *right* means in the context of the game. If this hypothesis is true, it should be possible to experimentally manipulate the goal of the game and assess the change in adult interpretations of *or*. Second, in our analysis of children's linguistic feedback we saw hints of children's sensitivity to exclusivity implicatures that might not be captured by the standard truth value judgment task.

Overall, our results point to the importance of assessing the semantics and pragmatics that children assign to connectives across a wide variety of contexts. Although individual experimental trial types can appear consistent with multiple interpretations, the profile of responses across trial types can be revealing of the underlying representations. More broadly, the investigation of how children acquire semantic representations for logical connectives – and in particular, how they infer an inclusive semantics for *or* – is an important puzzle for future investigations of early word learning.

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