

Children Interpret Disjunction as Conjunction: Consequences for the Theory of Scalar Implicature*

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December 7, 2013

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*We thank audiences at the Evelin Summer School at the University of Campinas, the ETI Workshop at McGill University, Carleton University, MIT, Stanford University, the Hebrew University of Jerusalem, and Tel Aviv University, as well as Alan Bale, Dave Barner, Emmanuel Chemla, Gennaro Chierchia, Noam Chomsky, Eve Clark, Herb Clark, Luka Crnić, Mike Deigan, Mike Frank, Noah Goodman, Martin Hackl, Irene Heim, Roni Katzir, Jorie Koster-Hale, Craig Leth-Steensen, John Logan, Jacopo Romoli, Philippe Schlenker, Benjamin Spector, Ida Toivonen, and especially Yossi Grodzinsky. DF and RS acknowledge support from the Department of Linguistics and Philosophy at MIT and the Office of the Provost Research Office at MIT, and RS acknowledges support from the Social Sciences and Humanities Research Council of Canada, Number 435-2012-1573.

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1 Introduction

We present evidence that there is a stage of development at which children (between the ages of 3;9 and 6;4, $M = 4;11$) assign disjunctive sentences a conjunctive interpretation (sections 3.3, 4.2.1). We explain this finding with two assumptions (section 4): (i) that children at this developmental stage have acquired the ‘inclusive disjunction’ meaning of *or* from their target grammar (following Chierchia et al., 2001; Gualmini et al., 2001; Crain, 2008; Crain and Khlentzos, 2010) and (ii) that whereas adults derive $\neg(A \wedge B)$ as the scalar implicature of $A \vee B$, children at this stage derive the opposite scalar implicature $A \wedge B$. A consequence of this characterization is that the implicatures computed by children are not a subset of the implicatures computed by adults.

Our proposal in (ii) is based on the combination of two assumptions that have been defended in the recent literature, one pertaining to the cognitive mechanisms that enter into the computation of scalar implicatures (SIs) by the adult (an assumption about the adult steady state), and the other pertaining to differences between children and adults with respect to the computation of SIs (an assumption about development).

The assumption about the steady state is that the algorithm that computes SIs can lead to a conjunctive interpretation for a disjunctive sentence when (and only when) the alternatives of the sentence are not closed under conjunction (Fox, 2007a; Chemla, 2009b; Franke, 2011). As we discuss in later parts of the paper (section 4), this explains why atomic disjunctive sentences $A \vee B$ do not give rise to conjunctive SIs $A \wedge B$ but disjunctive permission sentences like *you’re allowed to eat the cake or the ice-cream* ($= \diamond(A \vee B)$) do give rise to the conjunctive SI that you’re allowed to eat the cake and you’re allowed to eat the ice-cream ($= \diamond A \wedge \diamond B$).¹

The assumption about development is that children at this stage have acquired the same semantics and implicature computing mechanism as adults and differ only in the alternative sentences used in the computation (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Barner and Bachrach, 2010; Barner et al., 2011). We provide a precise statement of this difference by assuming Katzir (2007)’s characterization of alternatives in the steady state (sections 2.2 and 4). Katzir (2007) proposes that adults derive alternatives by replacing nodes in the parse of the ut-

¹As we discuss in sections 4.1 and 4.2.2, under standard assumptions about alternatives (e.g., Sauerland, 2004b; Katzir, 2007; Chemla, 2009b; Fox and Katzir, 2011), the alternatives to $A \vee B$ include A and B as well as $A \wedge B$, while the alternatives to $\diamond(A \vee B)$ include $\diamond A$ and $\diamond B$ but do not include their conjunction $\diamond A \wedge \diamond B$.

tered sentence with elements from three substitution sources: constituents of the node, linguistic elements explicitly mentioned in the context, and the lexicon. We propose that the child cannot access the lexicon but can access the other two substitution sources. Under this characterization the child's alternatives to $A \vee B$ include A and B but do not include their conjunction $A \wedge B$. Since these alternatives are not closed under conjunction, the theories of Fox (2007a), Chemla (2009b), and Franke (2011) predict the child should be able to produce $A \wedge B$ as an SI. The strengthening mechanism in Fox (2007a) in addition predicts the availability of an embedded conjunctive SI, a prediction that follows from the assumption that a covert exhaustive operator in the syntax is responsible for strengthening. The results of our experiment support this prediction (sections 3.1, 3.3), and thus are also relevant to broader debates about the existence of embedded SIs and to the division of labour between grammar and pragmatics in the computation of SIs.²

We are in effect proposing that $A \vee B$ is ambiguous for the child: with no exhaustive operator in the parse the sentence has its basic inclusive disjunction meaning, but the sentence can be strengthened to mean $A \wedge B$ if the exhaustive operator is added to the parse. The child, like the adult, thus faces the problem of deciding whether to come up with a parse containing this operator. We tentatively suggest natural parsing strategies that subjects may follow when such an operator is made available (section 4.2.1). These strategies in turn predict the existence of various idealized subpopulations that are arguably attested in our experimental sample (section 4.2.1). In particular, we follow Gualmini et al. (2008) in suggesting that among the many factors that enter into disambiguation there is a preference for a parse that settles the *question under discussion* (section 4.2.2). We show how this preference for a *complete answer* leads the child to prefer a conjunctive SI for atomic disjunctions as well as for disjunctions embedded under *every* (section 4.2.2). Given the close parallel that we propose exists between the child's conjunctive SI and the adult's free-choice SI (section 4.2.2), we argue that this preference in the child can be naturally unified with the attested preference among adults to compute free-choice SIs from disjunctive-permission sentences, including from those embedded under *every* (Chemla, 2009c; Chemla and Bott, 2012). The preference for a complete answer steers clear, however, of predicting a *general* preference for embedded SIs in the steady state (for relevant discussion, see e.g., Geurts and Pouscoulous, 2009; Panizza et al., 2009b,a; Sauerland, 2010;

²It is worth considering how to modify Chemla (2009b) and Franke (2011) to allow the operative principles to apply in embedded positions, or to modify the assumptions about global reasoning so as to mimic the effect of an embedded conjunctive SI (see note 9). We do not consider the form such modifications would have to take, nor their empirical or conceptual consequences.

Ippolito, 2010; Clifton Jr and Dube, 2010; Chemla and Spector, 2011; Chemla and Singh, 2013; Marty et al., 2013; Cremers and Chemla, 2013; Romoli and Schwarz, 2013).

2 Scalar Implicature: Child Development and Cognitive Architecture

2.1 Background on Implicature

Natural language sentences containing logical operators like *some* and *or* seem to be ambiguous between what is sometimes called a ‘basic meaning’ and a ‘strengthened meaning.’ The sentence *John ate some of the cookies* can either mean that John ate some, possibly all of the cookies (this is the basic meaning, \exists), or that he ate some but not all of the cookies (this is the strengthened meaning, $\exists \wedge \neg\forall$). The sentence *John ate cake or ice-cream* can either mean that John ate at least one of the cake or ice-cream, possibly both (this is the basic meaning, the inclusive disjunction \vee), or that he ate one of the cake or ice-cream, and not both (this is the strengthened meaning, the exclusive disjunction ∇).

There are good reasons for rejecting the idea that this ambiguity rests in the meanings of the lexical items *some* and *or*. For example, no known language has different morphemes representing both the basic and the strengthened meaning (e.g., Horn, 1972). Instead, it is commonly assumed that *some* and *or* unambiguously encode the basic meanings \exists and \vee , respectively, which sometimes get enriched to the strengthened meanings $\exists \wedge \neg\forall$ and ∇ , respectively (following Grice, 1967). The extra component of meaning involved in this enrichment is often called a ‘scalar implicature’ (SI).

The computation of SIs can be characterized by a function, f , which takes as input a sentence and a set of alternative sentences and returns the negation of some of the alternatives.³ There are two important components in the specification of the strengthening process. The first pertains to a specification of the input to f and in particular the set of alternatives, and the second pertains to a characterization of f itself. First, for any sentence S and context c there is a function ALT which returns the set of alternative sentences of S in c , $ALT(S, c)$ (e.g., Horn, 1972; Gazdar, 1979; Sauerland, 2004b; Katzir, 2007; Chemla, 2009b; Fox and Katzir,

³We will sometimes use f to refer to the function characterized here, as well as to the bit of cognition that implements f . We hope context will make our usage clear.

2011). Second, the strengthening function f takes the uttered sentence S and its alternatives $ALT(S, c)$ as arguments, and negates some of the alternatives. The negated members of $ALT(S, c)$ are the ‘scalar implicatures’ of S in c , and the conjunction of S and its scalar implicatures is the strengthened meaning of S in c . For example, one of the alternatives to $A \vee B$ is $A \wedge B$, which gets negated by f to produce $f(ALT(A \vee B))(A \vee B) \iff (A \vee B) \wedge \neg(A \wedge B)$. See (23) and (24) in the Supplementary Materials for algorithms for computing $ALT(S, c)$ and $f(ALT(S, c))(S)$ for any sentence S and context c . To reduce clutter in the main text we will sometimes write $ALT(S)$ or ALT in place of $ALT(S, c)$, and we sometimes write $f(S)$ as shorthand for the more articulated $f(ALT(S, c))(S)$, and we sometimes do not distinguish sentences and propositions when context makes our intended usage clear.

There is an ongoing debate concerning the cognitive mechanisms that implement f . On one view, f is shorthand for the output of domain-general systems of rational inference (e.g., Grice, 1967; Horn, 1972; Gazdar, 1979; Gamut, 1991; Levinson, 2000; van Rooij and Schulz, 2004; Sauerland, 2004b; Schulz and van Rooij, 2006; Russell, 2006; Spector, 2006; Franke, 2011). The competing view is that f belongs to a dedicated cognitive system, with different proposals concerning the nature of this domain-specificity. Under one domain-specific characterization of f , it is implemented in a module dedicated to conversational reasoning (e.g., Gazdar, 1979; Chemla, 2009b). Under another, f is implemented in the linguistic system itself (e.g., Cohen, 1971; Chierchia, 2004, 2006; Gajewski and Sharvit, 2012), and it is often argued to be a phonologically null variant of the word *only* (e.g., Fox and Hackl, 2006; Fox, 2007a,b; Chierchia et al., 2008; Magri, 2009, 2011). These debates about cognitive architecture are, of course, inextricably tied to debates about the specification of f .

2.2 Child Development

There is a stage of development at which children behave as if they know the meanings of logical operators yet do not (are unable or unwilling to) compute scalar implicatures; this finding seems most robust for children between the ages of 4-6, but has been found to hold for children as young as 3 and as old as 11 (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Noveck, 2001; Papafragou and Musolino, 2003; Guasti et al., 2005; Reinhart, 2006; Crain, 2008; Barner and Bachrach, 2010; Crain and Khlentzos, 2010; Barner et al., 2011; Stiller et al., 2011; Foppolo et al., 2012). Evidence for this characterization comes in two forms. First, in linguistic environments that are known to shut off SI computa-

tion in adults, such as when a sentence that normally gives rise to SIs is embedded in a downward-entailing environment, children are like adults in interpreting sentences containing logical operators like *some* and *or* with their basic meanings. For example, in a sentence like *every boy who is holding an apple or a banana is wearing a hat*, children and adults will judge the sentence to be true if and only if each boy who is holding at least one of an apple or a banana is wearing a hat (e.g., Chierchia et al., 2001 and Gualmini et al., 2001; see Crain, 2008 and Crain and Khlentzos, 2010 for similar results when disjunctions are embedded under negation). This result shows that when SI computation is not involved children behave as if they possess the basic meanings of the adult grammar.

Second, in those environments where adults compute scalar implicatures, such as in atomic sentences or in the nuclear scope of *every*, children differ from adults in that they do not typically strengthen \exists to $\exists \wedge \neg \forall$ (e.g., Smith, 1980; Noveck, 2001; Barner et al., 2011) and they do not typically strengthen \vee to ∇ (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Crain, 2008; Crain and Khlentzos, 2010). For example, in contrast with adults, children interpret sentences like *some dogs are animals* as true even though all dogs are animals, and they interpret sentences like $A \vee B$ as true even when they are shown a picture where A and B are both true. This means children are interpreting these sentences with their basic meanings \exists and \vee . If they had strengthened \exists to $\exists \wedge \neg \forall$ and \vee to ∇ , they would have judged the sentences to be false. This is a common adult response.

Taken together, the results suggest that children have acquired the basic meanings of the logical operators from the adult target, and are able to compositionally compute meanings even in complex sentences containing multiple logical operators, and to use the result of their semantic computation to guide their behavior (e.g., in giving truth-value judgments in experimental tasks). Where they differ from adults is that they do not compute SIs in those environments where adults do, raising the challenge of characterizing what the child is lacking from the target system that prevents them from performing the computation. Is the difference between children and adults located in the cognitive machinery necessary for applying f or in the cognitive machinery necessary for generating the set ALT ?

It has been claimed that children have knowledge of f but face difficulties with ALT . Specifically, it has been argued that children do not compute *lexical substitutions* in the generation of alternatives (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Barner and Bachrach, 2010; Barner et al., 2011). The generation of A and B as an alternative to the uttered sentence A or B requires substitution of the lexical item *or* with the lexical item *and*, and the generation of *all* X Y as an alternative to *some* X Y requires substitution of *all* for *some*. As noted above, children's

truth-value judgments suggest that they do not perform these scalar replacements. In a recent argument in favor of this claim, Barner et al. (2011) presented evidence that children judge sentences like *only some of the animals are sleeping* as true in contexts where all of the animals in a given picture are sleeping (see also Paterson et al., 2003). It seems that even in the presence of *only*, which like SI computation takes a set of alternatives as input and negates some of them (e.g., Rooth, 1992), children will perform like adults if and only if alternatives are contextually salient. For example, Barner et al. (2011) provided evidence that children reject sentences like *only the dog and the cat are sleeping* when they are explicitly given the information that the dog, the cat, and the cow are sleeping (see similar results in Chierchia et al., 2001; Gualmini et al., 2001; Papafragou and Musolino, 2003; Guasti et al., 2005; Miller et al., 2005; Verbuk, 2009; Minai and Fiorentino, 2010; Barner and Bachrach, 2010; Foppolo et al., 2012).

A rather clean picture is suggested by these studies. Children at the relevant stage of development know the basic semantics of logical operators and they know the strengthening function f , but they do not generate the alternatives that adults do. We can state this difference precisely by assuming Katzir's (2007) theory of alternatives. Under Katzir's (2007) approach, alternatives in the steady state are generated by substituting nodes in the parse of the uttered sentence with sub-constituents of the node, or with contextually salient linguistic elements, or with elements in the lexicon (see (23) in the supplementary materials for an explicit statement). For example, putting context-sensitivity aside for the moment, the relevant alternative for a sentence like *some of the animals are sleeping* is *all of the animals are sleeping*, derived by substituting *all* for *some*. The alternatives for *the boy is holding an apple or a banana* are the scalar alternative *the boy is holding an apple and a banana*, derived by replacing *or* with *and*, and the constituents *the boy is holding an apple* and *the boy is holding a banana*, derived by replacing *an apple or a banana* by *an apple* and by *a banana*, respectively. The studies discussed above suggest that children do not access the lexicon, so that for children at the relevant developmental stage there is no alternative for \exists and the only alternatives for $A \vee B$ are A and B , but crucially there is no conjunctive alternative $A \wedge B$. Assuming that the step of lexical substitution is indeed beyond the child's capacities, it is unsurprising that children interpret *some* with its basic meaning \exists , *or* with its basic meaning \vee , and so on. If the alternatives \forall and \wedge are not generated, they cannot be negated.

To summarize, the following picture suggests itself:

- (1) Child and adult comparison

- a. The child (at the relevant developmental stage) possesses the logical operators present in the steady state
- b. The child possesses the strengthening function f present in the steady state
- c. The child differs from the adult by not accessing the lexicon when generating ALT

2.3 The puzzle: children’s interpretation of disjunction

In the case of disjunctive sentences there is a somewhat overlooked result, found in Paris (1973, p. 285) and Braine and Romain (1981, pp. 57-58), which on the face of it is inconsistent with (1). Their finding is that when just one disjunct is true many children judge disjunctive sentences $A \vee B$ to be false. This result is unexpected given the assumptions in (1) that children know the meanings of logical operators but sometimes have difficulties with computing implicatures. (Adults judge disjunctive sentences to be true in such scenarios – this is expected on both an inclusive and exclusive reading of disjunction.) The conclusion that is suggested by Paris (1973) and Braine and Romain (1981) is that children sometimes assign a conjunctive meaning to disjunctive sentences. This conclusion receives further support from children’s interpretation of disjunctive sentences in imperative contexts: Suppes and Feldman (1971, pp. 313-314) found that when children between the ages of 4;6 and 6;0 were asked to *Give the things that are X or Y*, the most frequent response was to give the things that are both X and Y.⁴

If it is correct, then, that children sometimes interpret disjunctions as conjunctions, the assumptions in (1) would be hard-pressed to explain this difference between the child and adult. (The potential absence of a $\neg(A \wedge B)$ SI does not explain why $A \vee B$ should be judged false when just one of the disjuncts is true.) Our goal is to formulate proposals that are conservative (i.e., that adopt (1)) and are explicit enough to be tested experimentally and to apply to the theory of implicature in general and not just to atomic disjunctions.

As noted, one possibility is that the child is indeed interpreting disjunctive constructions as if they were conjunctive. We will turn to making this assumption

⁴There are additional puzzles raised by this finding, at least for our proposal that the child’s conjunctive reading is an SI. First, the strengthening would be happening in what is arguably a DE environment. Second, the strengthening is happening with *imperatives*, where it is not clear that strength relations are relevant (though see Huang and Snedeker, 2009 for evidence that SIs are computed in such environments; see Chemla and Singh, 2014 for discussion). We will not pursue these issues in detail here.

consistent with (1) momentarily. It will be instructive, however, to consider alternative explanations before accepting this somewhat radical conclusion. In particular, it is natural to explore the possibility that children’s judgments of pragmatic appropriateness influence their truth-value judgments (Clark and Amaral, 2010; Katsos and Bishop, 2011). What is needed from such a perspective is a pragmatic principle which, when coupled with the assumptions in (1), predicts that children should reject the disjunction when just one disjunct is true but should accept it when both are true.

When we look to independently motivated pragmatic principles, however, it is not immediately obvious which (if any) might be of use.⁵ Consider, for example, well-understood epistemic constraints on the utterance of disjunctive sentences. If pragmatically competent, the child would know that a disjunction (of the form $A \vee B$) should not be uttered when the speaker knows of one of the disjuncts (say A) that it is true. If pragmatically inappropriate utterances can sometimes be judged ‘false,’ this pragmatic requirement that the speaker be ignorant about the truth-value of each disjunct might lead the child to say ‘false’ when just one disjunct is true.⁶ But this pragmatic requirement also leads to the expectation, counter to fact, that the child should reject disjunctions when both disjuncts are true, and thus it leaves the puzzle as it was.

In addition to leaving the asymmetry unaccounted for, looking ahead to the results of our own experiment (section 3), appropriateness makes the wrong predictions about children’s truth-value judgments for sentences with embedded disjunctions like *every boy is holding an apple or a banana*. As we will see (section 3.3), children reject the utterance in contexts in which it is appropriate, for example as a description of the picture in Figure 1a, and children accept the utterance in contexts in which it is inappropriate, for example as a description of the picture in Figure 1b.

There might be ways of revising well-understood pragmatic principles that can respond to these challenges, but we will not speculate on what such revisions might look like. Instead, we will assume that the apparent conjunctive interpreta-

⁵The system of Chemla (2009b) does provide a principle, ‘similarity,’ but for reasons to be discussed shortly we classify his system under the ‘strengthening approaches’ in (2).

⁶Stated somewhat differently, utterance of a disjunction leads the hearer to infer that the speaker does not know whether A is true and the speaker does not know whether B is true (e.g., Gazdar, 1979; Sauerland, 2004b; Schulz and van Rooij, 2006; Spector, 2006; Fox, 2007a; Chemla, 2009b; Franke, 2011). When it is patently clear that the speaker does have an opinion on the truth-values of A and B , these ignorances inferences are misleading, and this might lead the hearer to reject the utterance.



(a) Children Reject; Sentence Appropriate (b) Children Accept; Sentence Inappropriate

Figure 1: Rejection and appropriateness of *every boy is holding an apple or a banana*

tion found in Paris (1973) and Braine and Romain (1981) is real. In fact, returning to (1) as our starting point, it turns out that some theories of implicature *predict* that a child at the relevant stage of development should be capable of strengthening a disjunction to a conjunction (Fox, 2007a; Chemla, 2009b; Franke, 2011). Specifically, these theories of the strengthening mechanism f mentioned in (1-b) predict that the difference between the child and adult alternatives specified in (1-c) should lead the child and the adult to strengthen $A \vee B$ in opposite ways: to $A \wedge B$ in the child's case and to $\neg(A \wedge B)$ in the adult's.⁷ Call this the 'strengthening' approach to the child's behavior:⁸

- (2) Strengthening approach:
- a. Share the assumptions in (1)
 - b. The child can strengthen the inclusive meaning of disjunction to a conjunction with f -application (Fox, 2007a; Chemla, 2009b; Franke, 2011)

By allowing the child to strengthen $A \vee B$ to $A \wedge B$, the strengthening ap-

⁷Standard neo-Gricean theories, such as Sauerland (2004b), do not yield this result. For such approaches, the only inferences that can be drawn from $A \vee B$ with the child's alternatives are the ignorance inferences that the speaker does not know whether A and that the speaker does not know whether B .

⁸More accurately, (2-b) is a consequence of (1) if f is identified with one of the strengthening mechanisms in Fox (2007a); Chemla (2009b); Franke (2011). We highlight (2-b) here for expository purposes, even though it is redundant under these approaches.

proaches in (2) provide a straightforward explanation for the Paris (1973) and Braine and Romain (1981) results: a child who rejects $A \vee B$ when just one disjunct is true and accepts it when both disjuncts are true does so because they have strengthened the disjunction to a conjunction. The statement in (2) is furthermore consistent with the observation that children interpret disjunctions inclusively in negative environments (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Crain, 2008; Crain and Khlentzos, 2010): such environments shut off the strengthening mechanism, and the child is thus predicted to interpret disjunctions in negative environments with their basic inclusive meaning only. Moreover, these strengthening mechanisms are independently motivated, for example by the need to derive free-choice inferences (we discuss the relation to free-choice in greater detail in section 4.2.2). The statement in (2) thus provides a general solution to the puzzle raised in Paris (1973) and Braine and Romain (1981).

If we furthermore identify f with the strengthening mechanism proposed in Fox (2007a), we predict that the child should be capable of strengthening disjunctions embedded under *every* to conjunctions, and thus we could explain the pattern of rejection in Figure 3. We discuss these points in greater detail in section 3, where we also highlight how the mechanism in Fox (2007a) derives these conjunctive readings for matrix and embedded disjunctions. Here we try to give the intuition behind the child’s proposed strengthening and its relation to strengthening in the adult.

Recall that we are assuming that the child and adult both encode an inclusive disjunction meaning for *or*, which can be represented with the truth-table in (3).

(3) Child and adult entry for *or*:

A	B	$A \vee B$
1	1	1
1	0	1
0	1	1
0	0	0

Strengthening of $A \vee B$ can be thought of as the conversion of some of the 1s in the table in (3) to a 0. The adult – who crucially has the conjunction as an alternative – excludes the conjunction by taking the 1 that results when both of the disjuncts are true and converting it to a 0. This is the $\neg(A \wedge B)$ SI, giving rise to the exclusive-disjunction strengthened meaning $A \nabla B$ represented by the truth-table in (4) (we highlight the row that gets converted with boldface).

(4) Adult Strengthening:

A	B	$f(A \vee B) \iff A \nabla B$
1	1	0
1	0	1
0	1	1
0	0	0

Under the proposal that we will advance, the child – who crucially lacks the conjunctive alternative – differs from the adult by excluding the individual disjuncts. That is, the child converts the complementary set of 1s to 0s, those 1s that result when just one of the disjuncts is true. This strengthening gives rise to the inference that ‘not just A and not just B ,’ which (together with the basic meaning in (3)) results in a conjunctive strengthened meaning $A \wedge B$, represented by the truth-table in (5).

(5) Child Strengthening:

A	B	$f(A \vee B) \iff A \wedge B$
1	1	1
1	0	0
0	1	0
0	0	0

We will show in section 4 how this difference in strengthening between the child and the adult follows as a consequence of the assumption that children do not perform lexical substitutions when generating alternatives (cf. (1-c)). Informally speaking, we might say that at some stage in the computation of strengthening – namely, at the recursive step in the application of f – the child will consider whether they can consistently negate ‘just A ’ ($= A \wedge \neg B$) and ‘just B ’ ($= B \wedge \neg A$). At this stage, given the alternatives to $A \vee B$ available to the child ($\{A \vee B, A, B\}$), it will turn out that they can, and this strengthening yields the table in (5). The adult, on the other hand, will be unable to consistently negate ‘just A ’ and ‘just B .’ Because their alternatives are different (they also include the conjunction $A \wedge B$), at the stage where they might consider negating ‘just A ’ and ‘just B ’ (again, at the recursive step in the application of f) the basic meaning in (3) will already have been strengthened to (4); from this table one can no longer consistently negate ‘just A ’ and ‘just B ’, for that would yield a contradictory meaning (a table with all 0s).

We note here again that under our proposal the child’s strengthening mechanism is identical to that of the adult. In fact, we will argue that the same principles governing the child’s strengthening of $A \vee B$ to $A \wedge B$ are at work in the adult’s strengthening of disjunctive permission sentences like *you’re allowed to eat the*

cake or the ice-cream to the conjunctive free-choice inference that the hearer is allowed to eat the cake and is allowed to eat the ice-cream. Note that the basic meaning of $\diamond(A \vee B)$ is equivalent to a disjunction of permission statements $\diamond A \vee \diamond B$, which thus yields a truth-table like the one in (3) with $\diamond A$ and $\diamond B$ as constituent disjuncts.

(6) Basic meaning of $\diamond(A \vee B)$:

$\diamond A$	$\diamond B$	$\diamond(A \vee B) \iff \diamond A \vee \diamond B$
1	1	1
1	0	1
0	1	1
0	0	0

The strengthening of this meaning in the adult state can be described, as in the table in (5), as exclusion of the individual disjuncts.

(7) Free-Choice Strengthening:

$\diamond A$	$\diamond B$	$f(\diamond(A \vee B)) \iff \diamond A \wedge \diamond B$
1	1	1
1	0	0
0	1	0
0	0	0

As we discuss more carefully in section 4.2.2, the relevant factor in governing the possibility of conjunctive SIs from disjunctive sentences, as in the child's strengthening of (3) to (5) and the adult's strengthening of (6) to (7), is closure of the alternatives under conjunction (Fox, 2007a): the child's alternatives for $A \vee B$ ($= \{A \vee B, A, B\}$) and the adult's alternatives for $\diamond(A \vee B)$ ($= \{\diamond(A \vee B), \diamond A, \diamond B, \diamond(A \wedge B)\}$) are not closed under conjunction, whereas the adult's alternatives for $A \vee B$ are (they include A, B and $A \wedge B$).

With this as background, we performed an experiment that aimed to see if the conjunctive interpretation of disjunction reported in Paris (1973) and Braine and Romain (1981) would reappear and, if so, to see if it would arise even in embedded positions.

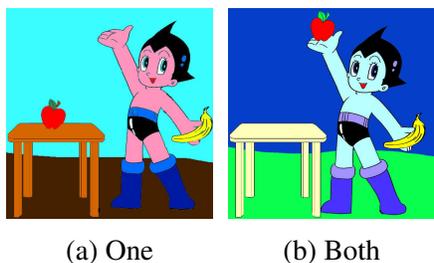


Figure 2: Sample of pictures for atomic disjunctions

3 Experiment

3.1 Design considerations

In this section we share some of the relevant choices we made in designing our experiment. We are concerned here with the general logic of the design; specific details concerning materials and methods are provided in section 3.2.

First, one of our goals was to see if the results from Paris (1973) and Braine and Romain (1981) would be replicated. To test this, we administered a truth-value judgment task (Crain and McKee, 1985) in which children heard an utterance of an atomic disjunction $A \vee B$ (e.g., *the boy is holding an apple or a banana*) intended as a description of a picture in which either one, or both, disjuncts were true (as in the pictures labelled ‘One’ in Figure 2a and ‘Both’ in Figure 2b, respectively).

We took for granted that children know the inclusive disjunction entry for *or* in (3), given their attested behavior in downward-entailing environments (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Crain, 2008; Crain and Khlentzos, 2010). Children, like adults, thus always have a principled route to accepting the utterance as a description of ‘One’ and of ‘Both,’ namely, by interpreting it with its basic meaning and ignoring the effects of any strengthening mechanisms that might interfere with this interpretation. What we were interested in finding out was whether children would nevertheless reject the disjunctive sentence as a description of ‘One’ but not as a description of ‘Both.’ Assuming the result from Paris (1973) and Braine and Romain (1981) to be real, we expected that this is what we would find. The goal, then, would be to understand what the additional mechanisms are that lead to this result.

In earlier sections we rejected the idea that the child is using pragmatic appropriateness as a proxy for truth. Instead, we assume with the strengthening

approach in (2) that the child can strengthen disjunctions to conjunctions (Fox, 2007a; Chemla, 2009b; Franke, 2011). Furthermore, if we assume the strengthening approach of Fox (2007a), it follows immediately that the child can strengthen embedded disjunctions to conjunctions. Thus, the proposal in Fox (2007a) makes clear predictions that we hoped to examine concerning the readings of a sentence like *every boy is holding an apple or a banana*: (i) among the set of readings is one in which the embedded disjunction gets strengthened because it gets parsed with an *f*, and (ii) the embedded strengthenings in the child and the adult go in opposite ways: the adult generates the reading ‘every boy is holding an apple or a banana and not both’ while the child generates the reading ‘every boy is holding both an apple and a banana.’⁹

⁹It is not clear to us whether the other strengthening approaches in (2) (Chemla, 2009b; Franke, 2011) can naturally accommodate embedded strengthenings. The main principle in Chemla (2009b), ‘similarity,’ predicts that for any disjunctive sentence $A \vee B$ embedded in ϕ , $\phi(A \vee B)$, the speaker believes $\phi(A)$ if and only if the speaker believes $\phi(B)$: $\Box_s \phi(A) \longleftrightarrow \Box_s \phi(B)$. In a subsequent stage, this ‘weak’ similarity inference can be strengthened to $\Box_s(\phi(A) \longleftrightarrow \phi(B))$ if the result is consistent with weak similarity inferences and other inferences formally specified in Chemla (2009b). For atomic disjunctions $A \vee B$, the weak similarity inference $\Box_s A \longleftrightarrow \Box_s B$ is derived. Together with the assumption $\Box_s(A \vee B)$ (the speaker believes what they assert), similarity predicts that the speaker is either (i) ignorant about both A and B ($\neg \Box_s A$ and $\neg \Box_s B$), or (ii) the speaker believes both A and B ($\Box_s A$ and $\Box_s B$). Adding the strengthening assumption $\Box_s(A \longleftrightarrow B)$ entails (ii), from which it follows that the speaker believes the conjunction of A and B . Someone with adult alternatives is prevented from making this conjunctive inference because they compute an SI – computed independently of the similarity-based inferences described above – that the speaker does not believe $A \wedge B$, $\neg \Box_s(A \wedge B)$; this SI prevents the hearer from strengthening the weak similarity inference to the conclusion that the speaker believes $A \wedge B$ (the result would be inconsistent). When disjunctions are embedded under universal quantifiers, e.g., *every boy is holding an apple or a banana*, the weak similarity-inference would be that the speaker believes that every boy ate an apple if and only if the speaker believes that every boy ate a banana. Someone with the child alternatives can strengthen this inference and conclude that the speaker believes that every boy ate an apple if and only if every boy ate a banana, but, so far as we can tell, this does not entail – together with other inferences specified in Chemla, 2009b – that the speaker believes that every boy ate an apple and a banana (e.g., the inferences are all true if in every one of the speaker’s epistemically accessible worlds every boy ate one or another of an apple and a banana, but each boy had only one, and some boys ate an apple and some boys ate a banana). The system in Franke (2011) derives SIs as a consequence of a solution concept (‘Iterated Best Response’) to signaling games that takes context models as input and outputs optimal behavior for speaker and hearer. What is important for the current discussion is that the context model for $A \vee B$ with the child alternatives is identical to the context model for free-choice; (Franke, 2011, pp. 55-56) shows that his system does not derive free-choice under *every*, and hence there can be no embedded conjunctive strengthening for the child.

- (8) Readings of *Every boy is holding an apple or a banana* in the adult target predicted by Fox (2007a)¹⁰
- a. Basic Meaning: for each boy x , x is holding at least one of an apple or a banana
 - b. Globally Strengthened Meaning: (8-a) and it is false that every boy is holding an apple and it is false that every boy is holding a banana¹¹
 - c. Locally Strengthened Meaning: for each boy x , x is holding an apple or a banana, but not both¹²
- (9) Readings of *Every boy is holding an apple or a banana* in the child predicted by Fox (2007a)
- a. Basic Meaning: same as in (8-a)
 - b. Globally Strengthened Meaning: same as in (8-b)
 - c. Locally Strengthened Meaning: that every boy is holding an apple and a banana

The possibility of an embedded conjunctive strengthening in (9-c) makes a surprising prediction. Consider assertion of a sentence like *every boy is holding an apple or a banana* as a description of: (i) a picture like ‘Every-one’ in Figure 3a in which there are three boys, two of whom are each holding an apple (and

¹⁰Here we assume that the adult does not prune the set *ALT*. If we allow pruning some additional readings may be generated, but these are irrelevant to anything we have to say here. See the supplementary materials for discussion of constraints on pruning, and especially Fox and Katzir (2011) and Crnic et al. (2013). See also note 24.

¹¹The term ‘global’ comes from the observation that this strengthening can be described as the result of applying f over the entire logical form for the sentence: $f(ALT(\textit{every boy } x, x \textit{ is holding an apple or a banana}))(\textit{every boy } x, x \textit{ is holding an apple or a banana})$. Assuming that the set of alternatives is $\{\textit{every boy is holding an apple or a banana, every boy is holding an apple, every boy is holding a banana, every boy is holding an apple and a banana}\}$ (Sauerland, 2004b; Katzir, 2007 – see (23)), the result is the meaning paraphrased in (8-b) (e.g., Sauerland, 2004b,a; Spector, 2006; Fox, 2007a – see the entry for f in (24)).

¹²The term ‘local’ comes from the observation that this strengthening can be described as the result of applying f in an embedded position: $\textit{every boy } x, f(ALT(x \textit{ is holding an apple or a banana}))(x \textit{ is holding an apple or a banana})$. The resulting meaning is described in (8-c). However, it has been pointed out that systems that remain committed to global reasoning can derive the locally strengthened reading by allowing the negation of merely non-weaker alternatives, and by allowing multiple scalar items in a single sentence to be replaced. This allows a new alternative to be derived, *some boy is holding an apple and a banana*, the negation of which (in conjunction with the basic meaning of the sentence) entails (8-c) (van Rooij and Schulz, 2004; Spector, 2005; Schulz and van Rooij, 2006; Spector, 2006; Chemla, 2009b; Chemla and Spector, 2011; Romoli, 2013).

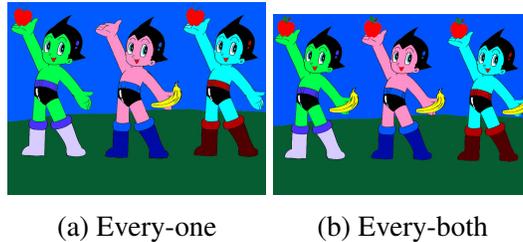


Figure 3: Sample of pictures for embedded disjunctions

nothing else), and one of whom is holding a banana (and nothing else), and (ii) a picture like ‘Every-both’ in Figure 3b in which each of three boys is holding both an apple and a banana. The strengthening mechanism in Fox (2007a) predicts that the child – because of the reading in (9-c) – has a basis on which to reject the utterance as a description of ‘Every-one.’ Note that unlike utterances of $A \vee B$ when just one disjunct is true, an utterance of (9) is entirely felicitous as a description of ‘Every-one’ (in the adult state). So far as we are aware, no other set of assumptions leads to this prediction. In addition to dissociating competing explanations of the child’s behavior on atomic disjunctions, then, the child’s behavior on embedded disjunctions might also provide a new way to examine whether embedded strengthenings are available and, as such, might help decide among competing theories of strengthening.

3.2 Materials and Methods

Participants for the present study were 63 preschool-aged children (recall from section 2.2 that studies on SI development often include samples with this age range). Four children were excluded from the sample: one child refused to finish the task and three did not speak English at home. The remaining sample consisted of 59 English-speaking children (36 girls) ranging in age from 3 years 9 months to 6 years 4 months ($M = 4;10$). Of these, another three failed to complete the task, leaving a sample of 56 children ($M = 4;11$, range = 3;9 to 6;4). All participants were recruited by contacting child care centres in the Ottawa area and we obtained informed consent from the centre coordinator, the parents of the children who participated, and the children themselves (verbal consent). The participants were tested either in a separate room or quiet area in the centre. Regardless of whether they completed the task, children were thanked and given stickers as a token of appreciation.

Participants were tested individually in one session approximately 15 minutes in length. Prior to beginning the task, children talked briefly with an experimenter to allow them the opportunity to get acquainted. The session involved looking at a picture book together, while the child interacted with the experimenter and a koala bear hand puppet.

The task used in the present study was created based on variations of the truth-value judgment task (Crain and McKee, 1985; Crain and Thornton, 1998) used in studies of children's understanding of disjunction (e.g., Paris, 1973; Braine and Romain, 1981) and implicature development (e.g., Chierchia et al., 2001, Gualmini et al., 2001, Noveck, 2001, Guasti et al., 2005, Barner et al., 2011). In this task, children were introduced to a puppet named Fuzzy and were told that their job was to help Fuzzy practice saying the right thing about pictures presented in a book. Prior to beginning test trials, children were first asked to identify each of the items used in the task to ensure they understood the labels being used. Furthermore, children also completed straightforward practice trials where the questions were similar to those in test trials but had obviously correct or incorrect responses. For example, the first practice trial depicted a picture of a boy holding a banana and Fuzzy stated *The boy is holding a banana*. Children were asked if Fuzzy was right or wrong about that picture. In the second practice trial the picture showed a monkey holding a flower and Fuzzy said *The monkey is holding an apple*. Again, children were asked if Fuzzy said the right thing or the wrong thing. They completed two more practice trials, one more correct and one more incorrect statement, before proceeding to test trials. Children who made errors during the practice trials were provided with feedback by the experimenter, and those questions were repeated up to two more times before moving onto the test trials. All children, including those who did not ultimately finish the task, were able to correctly respond to the practice trials by the third attempt, with most (47 out of 59) passing on their first attempt (11 passed on their second attempt, and 1 passed on his third attempt).

For each test trial, participants were shown a picture, heard a statement by Fuzzy, and were asked if Fuzzy said the right thing or the wrong thing about that picture. The order in which the experimenter asked if Fuzzy was right or wrong was counterbalanced between children. There were 40 test trials which consisted of eight conditions, with five trials per condition. In half of the conditions, Fuzzy made a disjunctive statement. In Condition 1 = 'One,' the character holds one item (e.g., there is a boy who is holding one item, such as a banana; see 4a in Figure 4), while in Condition 2 = 'Both' the character holds two items (e.g., the boy is holding two items, both an apple and a banana; see 4b). In both conditions



Figure 4: Sample of pictures for critical items

Fuzzy asserts a disjunctive sentence stating that the character is holding one or the other item (e.g., *the boy is holding an apple or a banana*). In Condition 3 = ‘Every-one,’ three characters (e.g., three boys) each hold one item, though they do not all hold the same item (e.g., two of the boys hold an apple while one of the boys holds a banana; see 4c), while in Condition 4 = ‘Every-both’ the three characters each hold two items (e.g., each of the three boys holds both an apple and a banana; see 4d). In both conditions, Fuzzy asserts a disjunctive sentence embedded under a universal quantifier stating that every character is holding one or the other item (e.g., *every boy is holding an apple or a banana*).

In the remaining conditions (Conditions 5-8), Fuzzy made an *and* statement instead of an *or* statement using the same pictures from Conditions 1-4. In Condition 5 subjects saw the picture from ‘One,’ in Condition 6 subjects saw the picture from ‘Both,’ in Condition 7 subjects saw the picture from ‘Every-one,’ and in Condition 8 subjects saw the picture from ‘Every-both.’ Conditions 5 through 8 were intended to be used as controls to ensure children understood the task and were paying attention to the questions being asked. After excluding participants who did not perform significantly above chance on these conjunctive controls (this required getting at least 16/20 correct responses on the items in Conditions 5 through 8, $p = .044$), 31 of the 56 child participants remained (23 girls). However, as we will see (note 14 in section 3.3), our main findings do not change if we include the whole sample.¹³ The children in the remaining sample ranged in age from 3

¹³We noticed several patterns among the group of subjects who failed to pass the conjunctive screener. Most prominent among them was a bias to say that Fuzzy was right. The conjunctive sentences are true in Conditions 6 and 8, and false in Conditions 5 and 7. Nevertheless, eight of the twenty-five excluded subjects said ‘true’ to Conditions 5 and 7 at least eight times out of ten trials (the mean number of ‘true’ answers this sample gave out of 40 critical and control items was 37.4). Another group of six subjects displayed a slightly weaker bias pointing in the same direction, saying ‘true’ to Conditions 5 and 7 five times out of ten trials (the mean number of ‘true’ answers this sample gave out of 40 critical and control items was 31.5). There was also a group of three subjects who displayed the opposite bias, saying ‘false’ to most conditions, and in particular to

years 9 months to 6 years 4 months, $M = 4;11$. A sample of the pictures was given above in Figure 4, and a characterization of the critical and control conditions is given in Table 1 below.

Conditions 6 and 8 at least nine times out of ten (the mean number of 'true' responses this sample gave out of 40 critical and control items was 4). Finally, there was a group of three subjects who seemed to have particular difficulties with Condition 7 only, incorrectly responding 'true' on each of the five trials. Condition 7 also gave particular trouble to two other subjects: one of them incorrectly responded 'true' four out of five times, and another one incorrectly responded 'true' three out of five times. Children have been shown to sometimes have difficulties with indefinites embedded under universal quantifiers (e.g., Inhelder and Piaget, 1964; see e.g., Philip, 1995; Crain et al., 1996; Drozd and van Loosbroek, 1998; Geurts, 2003; Gualmini et al., 2003 for more recent discussion), but the problem there has been that they say 'false' even when the sentence is true. It is not clear to us whether these issues are related, and we hope that the biases reflected in the samples discussed here do not affect our conclusions about the sample of 31 subjects who passed the conjunctive filter.

Condition	Picture Shown	Statement made by Fuzzy
One	There is one character (a boy), there are two items (an apple and a banana), and the boy is holding one of the items (e.g., the banana);	<i>The boy is holding an apple or a banana</i>
Both	There is one character (a boy), there are two items (one apple and one banana), and the boy is holding both items	<i>The boy is holding an apple or a banana</i>
Every-one	There are three characters (boys), there are three items (two bananas and one apple), one boy is holding one of the items (e.g., an apple) and nothing else, the other two boys are each holding one of the remaining two items (e.g., each is holding one of the remaining bananas) and nothing else	<i>Every boy is holding an apple or a banana</i>
Every-both	There are three characters (boys), there are three tokens each of two types of item (e.g., three apples and three bananas), and each boy is holding one token of each type of item (e.g., each boy is holding both an apple and a banana)	<i>Every boy is holding an apple or a banana</i>
5	There is one character (a boy), there are two items (an apple and a banana), and the boy is holding one of the items (e.g., the banana);	<i>The boy is holding an apple and a banana</i>
6	There is one character (a boy), there are two items (one apple and one banana), and the boy is holding both items	<i>The boy is holding an apple and a banana</i>
7	There are three characters (boys), there are three items (two bananas and one apple), one boy is holding one of the items (e.g., an apple) and nothing else, the other two boys are each holding one of the remaining two items (e.g., each is holding one of the remaining bananas) and nothing else	<i>Every boy is holding an apple and a banana</i>
8	There are three characters (boys), there are three tokens each of two types of item (e.g., three apples and three bananas), and each boy is holding one token of each type of item (e.g., each boy is holding both an apple and a banana)	<i>Every boy is holding an apple and a banana</i>

Table 1: Examples of test trials for critical (One, Both, Every-one, Every-both) and control (5-8) conditions

The task had five trials for each of the eight conditions. In addition to the boys with apples and bananas, we also showed children pictures of monkeys with flowers and books, trucks with pigs and tigers, horses with birds and crabs, and men with forks and spoons. The order in which the test trials were presented was randomized and three separate orders were produced to create three versions of the task. In all versions, a response that Fuzzy was right was coded as ‘one’ whereas a response that Fuzzy was wrong was coded as ‘zero.’ Total scores per condition were calculated.

Finally, we also recruited 26 adults from the Ottawa area. All were native English speakers, and all passed the conjunctive controls in Conditions 5-8 (25 of the 26 adults performed perfectly, and one adult made a single error).

3.3 Results

Here we report results for each of the child and adult samples as a whole. In section 4.2 we discuss individual child behavior in greater detail, which seems to reveal clusters of subpopulations in ways that we believe are of theoretical interest. Our main finding at the level of the entire sample of children, summarized in Table 2 and Figure 5 and Table 3 below, replicates the observation that children often interpret disjunctions as conjunctions (Paris, 1973; Braine and Romain, 1981), and extends this to embedding under *every*. Table 2 and Figure 5 summarize the mean scores on each condition, where the score is the number of times out of five items per condition that the child judged the statement to be ‘correct.’ In the conditions where just one character was present (‘One’ and ‘Both’), children were significantly more likely to judge a statement like *the boy is holding an apple or a banana* as correct when both disjuncts were true ($M = 3.81$) than when one disjunct was true ($M = 1.77$), $t(30) = 3.88$, $p = .001$. And in the conditions where three characters were present (‘Every-one’ and ‘Every-both’), children were significantly more likely to judge a statement like *every boy is holding an apple or a banana* as correct when each boy is holding both an apple and a banana ($M = 3.77$) than when each boy is holding only one of an apple or a banana ($M = 2.32$), $t(30) = 2.95$, $p = .006$.¹⁴

¹⁴The means and standard deviations for the four critical conditions for the entire sample of 56 children, reported here for each condition as $M(SD)$, are: (i) One: 2.45(1.94), (ii) Both: 3.80(1.91), (iii) Every-one: 2.93(1.82), (iv) 3.91(1.67). The comparison between ‘One’ and ‘Both’ remains significant ($t(55) = 3.84$, $p < .001$), as does the comparison between ‘Every-one’ and ‘Every-both’ ($t(55) = 3.36$, $p = .001$).

Table 2: Children’s mean number of ‘Fuzzy was right’ responses (out of 5 items) for test conditions ($n = 31$)

Condition	$M(SD)$
One	1.77(1.89)
Both	3.81(1.92)
Every-one	2.32(1.80)
Every-both	3.77(1.84)

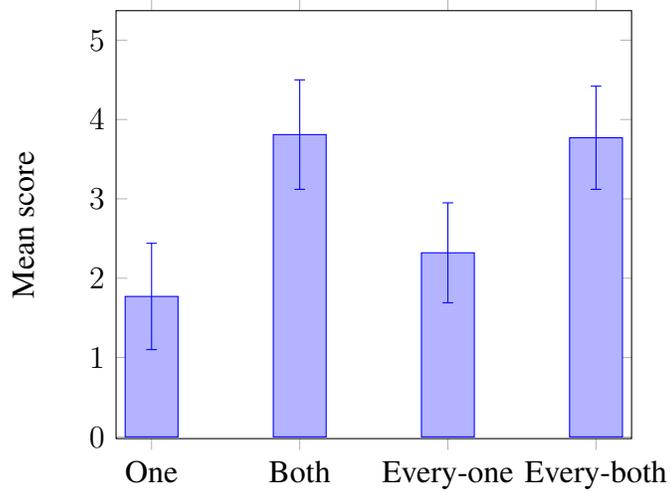


Figure 5: Children’s mean scores on critical conditions ($n = 31$; error bars indicate 95% confidence intervals)

To reduce the rate of Type I error when making multiple comparisons, as we did above, we applied the Bonferroni correction. For a desired significance level α , and n comparisons which were planned at the outset of the experiment, the correction sets the significance value of each comparison to α/n . In our case $n = 2$ ('One' vs 'Both' and 'Every-one' vs 'Every-both'), and our results remain significant at $\alpha = .05$ (note that our p -values are both below .025).¹⁵

Table 3 summarizes the percentages of 'Fuzzy was right' responses on the 155 trials on each condition (31 subjects, 5 items per condition). In the conditions where just one character was present, children were significantly more likely to judge the disjunctive statement as true in 'Both' than in 'One' (76 percent 'was right' responses in 'Both' vs 35 percent 'was right' responses in 'One'). And in the conditions where three characters were present, children were significantly more likely to judge the sentence as true in 'Every-both' than in 'Every-one' (75 percent 'was right' responses in 'Every-both' vs 46 percent 'was right' responses in 'Every-one').

Table 3: Children's percentage of 'was right' responses

Condition	Percent 'was right' responses
One	35
Both	76
Every-one	46
Every-both	75

We also considered the relation between children's tendency to judge the puppet as right or wrong when the single character held one item/both items and their tendency to judge the puppet as wrong when three characters each held one item/both kinds of item. There was a significant correlation between performance on these conditions: children who said the puppet was wrong in 'One' also had the tendency to say the puppet was wrong in 'Every-one' ($r = .47, p < .01$), and children who said the puppet was right in 'Both' also had the tendency to say the puppet was right in 'Every-both' ($r = .96, p < .01$).

We also examined whether there were any effects of age. We found no correlations between age and behavior in any of the 4 main conditions. This holds for the entire sample of 56 and for the group of 31 remaining after the screener. We

¹⁵We also evaluated our results with a one-way repeated measures ANOVA with four levels (corresponding to the four critical conditions), and the findings mirror the above, so we don't report them here.

also compared the age of children who passed the screener to those who did not, and again there was no effect of age.

Turning to our adult sample, recall that it is commonly assumed that in the steady state atomic disjunctions $A \vee B$ can have an inclusive or exclusive reading, while a disjunction embedded under *every* is commonly assumed to have the three readings identified in (8) in section 3.1. The prediction then is that there should be at least as many ‘true’ responses in ‘One’ as in ‘Both’ (the disjunction is true in ‘One’ on both an inclusive and exclusive reading but is true in ‘Both’ only on the inclusive reading), and there should be at least as many ‘true’ responses in ‘Every-one’ as in ‘Every-both’ (the sentence is true in ‘Every-one’ on each of the three readings in (8) but is true in ‘Every-both’ only on one of these readings ((8-a))). The sample’s mean responses on each condition, summarized in Table 4 and Figure 6, and the percentage of ‘true’ responses across all trials on each condition, summarized in Table 5, are consistent with this expectation.

Table 4: Adults’ mean number of ‘Fuzzy was right’ responses (out of 5 items) for test conditions ($n = 26$)

Condition	$M(SD)$
One	3.73(1.80)
Both	3.35(2.04)
Every-one	4.23(1.42)
Every-both	3.69(1.95)

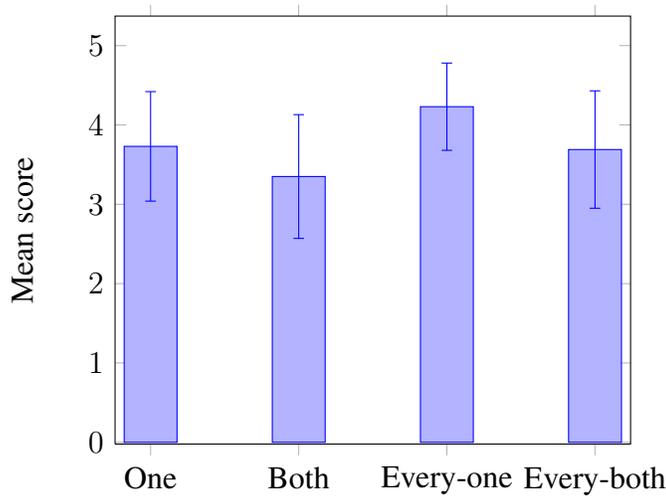


Figure 6: Adults’ mean scores on critical conditions ($n = 26$; error bars indicate 95% confidence intervals)

Table 5: Adults’ percentage of ‘was right’ responses

Condition	Percent ‘was right’ responses
One	75
Both	67
Every-one	85
Every-both	74

The scores on ‘One’ were numerically greater than the scores on ‘Both,’ and the scores on ‘Every-one’ were numerically greater than the scores on ‘Every-both,’ but these differences were not significant ($t(25) = 0.83$, $p = .42$ for ‘One’ vs. ‘Both;’ $t(25) = 1.24$, $p = .23$ for ‘Every-one’ vs. ‘Every-both’).¹⁶ The most likely explanation for the fact that the differences do not reach significance is that the subjects in our sample largely resisted computing SIs: 8 subjects always

¹⁶A quick glance at the means and at the upper and lower confidence limits in Figure 6 reveals a tendency for more rejection in ‘One’ and ‘Every-one’ than in ‘Both’ and ‘Every-both,’ respectively, but there is substantial overlap between the CIs of these conditions, which again does not support the conclusion that these differences are significant. One can show that less conservative methods than overlap on confidence intervals also do not warrant rejection of the null hypothesis. For example, the so-called ‘standard method’ (e.g., Schenker and Gentleman, 2001) sometimes rejects the null hypothesis when the overlap method does not, but this method does not allow us to conclude that the differences apparent in Figure 6 are significant.

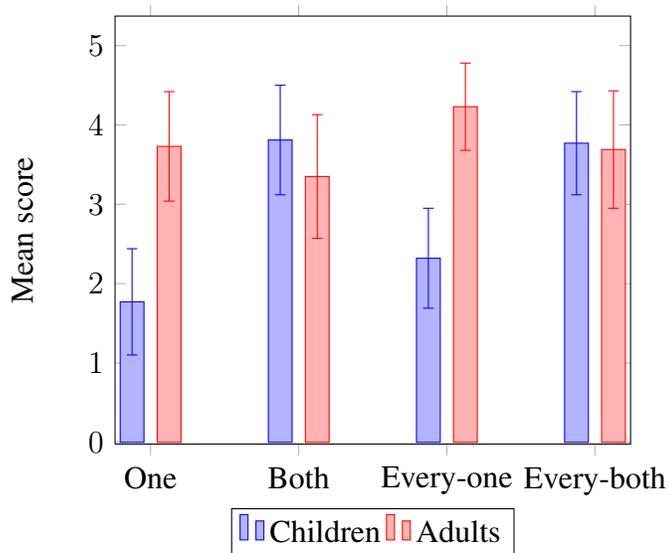


Figure 7: Comparing children ($n = 31$) and adult ($n = 26$) mean scores on critical conditions (error bars indicate 95% confidence intervals)

responded ‘true’ on each of the five items of the four conditions (20 out of 20 trials), two subjects responded true all but once (19 out of 20 trials), and three subjects responded true all but twice (18 out of 20 trials). There were only five subjects who behaved as if they often computed SIs (i.e., who mostly said ‘true’ to ‘One’ and ‘Every-one’ but ‘false’ to ‘Both’ and ‘Every-both’). While these results are consistent with common assumptions, it remains to be explained why the adults in our sample resisted computing SIs as much as they did.

When we compare the 31 children to the 26 adults in our sample, we find that their scores differ significantly on ‘One’ ($t(55) = 3.97, p < .01$) and on ‘Every-one’ ($t(55) = 4.47, p < .01$), but do not differ on ‘Both’ ($t(55) = 0.87, p = .39$) and do not differ on ‘Every-both’ ($t(55) = 0.16, p = .87$). We represent this comparison in Figure 7.

The lack of any significant difference between children and adults on ‘Both’ and ‘Every-both’ can be explained if we assume that children generally do not compute SIs and that the adults in our sample largely did not compute SIs. However, the significant difference between ‘One’ and ‘Every-one’ cannot be explained by these assumptions; under these assumptions there is no obvious rationale for why children should respond ‘false’ as much as they do.

4 Interpretation: The Conjunctive Inference is a Scalar Implicature

4.1 Conjunctive strengthening with a grammatical implementation of f

We suggest that the most natural explanation for the child’s relatively high rates of rejection in the ‘One’ and ‘Every-one’ conditions is that the child has the option to strengthen matrix and embedded disjunctions to conjunctions. As mentioned earlier, this strengthening follows from the strengthening system in Fox (2007a) together with the assumptions in (1) but does not follow from any other set of assumptions we are aware of.

We therefore take the data in section 3.3 as suggesting that there is a stage of development at which children strengthen the basic inclusive disjunction meaning of $A \vee B$ to $A \wedge B$ by applying a covert operator that realizes the strengthening function f in the grammar. This conjunctive scalar implicature is unavailable to the adult, and in fact is the opposite of the SI computed by the adult ($\neg(A \wedge B)$). This consequence is at odds with the common assumption that the set of SIs available to a child throughout development is a subset of the set of SIs available to the adult. We propose that children pass through stages of development at which some but not all components of the adult system have matured. In this case, what is missing is access to the lexicon in the generation of alternatives (cf. (1-c)). Together with the assumption that children compute implicatures (i.e., parse sentences and assign them meanings, with parses sometimes containing f), we might expect them to sometimes compute SIs that are different from the ones computed in the steady state. We suggest that children’s conjunctive interpretation of disjunction is a case of such an SI. In fact, we sometimes asked children (at the end of the experiment) to justify their ‘false’ responses to ‘One,’ and most of the justifications we received make sense only under a conjunctive interpretation. Representative justifications were responses like ‘because the boy is not holding the banana,’ or ‘the boy is holding just an apple,’ and minor variations thereof.

What remains is to characterize this stage of development, and to show how a conjunctive SI follows as a consequence of this partially matured SI system. This characterization will help explain the basis on which a child rejects the relevant disjunctive utterances in ‘One’ and ‘Every-one.’

Recall from (1) in section 2.2 that we adopt the assumption that children have acquired the inclusive disjunction meaning of *or* from their target grammar (e.g.,

Chierchia et al., 2001; Gualmini et al., 2001; Crain, 2008; Crain and Khlentzos, 2010), and have also acquired the strengthening function f (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Papafragou and Musolino, 2003; Guasti et al., 2005; Reinhart, 2006; Barner and Bachrach, 2010; Barner et al., 2011), but they differ in their *alternatives* ALT (see Chierchia et al., 2001; Gualmini et al., 2001; Barner and Bachrach, 2010; Barner et al., 2011).

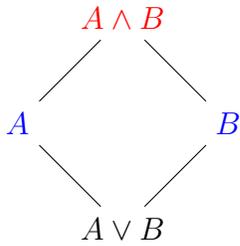
In characterizing this stage of development it will be useful to repeat some of our assumptions about the steady state. First, we assume that the adult alternatives for a sentence $A \vee B$ are: $ALT_{Adult}(A \vee B) = \{A \vee B, A, B, A \wedge B\}$ (e.g., Sauerland, 2004b; Fox, 2007a; Katzir, 2007; Chierchia et al., 2008; Chemla, 2009b; Fox and Katzir, 2011 – see (23) in the supplementary materials for a formal statement). The alternatives in the adult state are derived by successive application of the following operations (Katzir, 2007): (i) replacing nodes by their constituents (e.g., replacing $A \wedge B$ by A), (ii) replacing nodes with structures made salient in the context,¹⁷ (iii) replacing scalar terms (e.g., \vee) with related items in the lexicon (e.g., \wedge). Second, we assume with Fox (2007a) that f takes two arguments, the uttered sentence S and its alternatives $ALT(S)$, and attempts to negate as many of the alternatives as possible while maintaining consistency with S (see (24) in the supplementary materials for a formal statement). When f is applied to $A \vee B$ with alternatives $ALT(A \vee B) = \{A \vee B, A, B, A \wedge B\}$, the only alternative that f negates is $A \wedge B$. Why only $A \wedge B$? There are two maximal subsets of $ALT(A \vee B)$ such that all the alternatives in each subset can be negated while maintaining consistency with $A \vee B$: (i) $\{A, A \wedge B\}$, (ii) $\{B, A \wedge B\}$. Call each such set a ‘Maximal Consistent Exclusion’ (see (24) in the supplementary materials). A decision to negate the alternatives in (i) as opposed to (ii) (or vice-versa) would seem to be arbitrary (why negate A instead of B)? Fox (2007a) suggests that f is designed to negate only those alternatives whose negation would not involve arbitrary decisions of this sort; such alternatives are characterized as those that are in the intersection of all the Maximal Consistent Exclusions (MCEs). The intersection of (i) and (ii) is $\{A \wedge B\}$. Call those alternatives in the intersection of all MCEs ‘innocently excludable’ or simply ‘excludable,’ and call the rest ‘non-excludable.’ The strengthened meaning of a sentence S is the conjunction of the sentence and the negation of all the alternatives of S that are innocently excludable (see (24) in the supplementary materials). The strengthened meaning of $A \vee B$ in the adult state, $[[f(A \vee B)]]$, is thus $(A \vee B) \wedge \neg(A \wedge B) \iff A \nabla B$.

We can summarize the computation of strengthening with the diagram in (10)

¹⁷If all constituents of the asserted sentence are ‘salient,’ then (i) can be subsumed under (ii).

below. A visual representation might be useful in facilitating comparison between the child and the adult. In the diagram we locate alternatives as labelled vertices in the plane together with an ordering such that relative height corresponds to logical strength: node x is ordered ‘above’ node y (represented with a line connecting them) if and only if the alternative at node x asymmetrically entails the alternative at node y . Second, we color alternatives that are innocently excludable with red, and we color alternatives that are non-excludable blue.

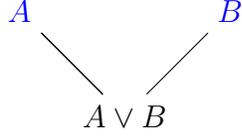
(10) Diagrammatic representation of $[[f(ALT_{Adult}(A \vee B))(A \vee B)]]$:



Returning to characterizing the relevant stage of development, we suggest, again building on Chierchia et al. (2001), Gualmini et al. (2001), Barner and Bachrach (2010) and Barner et al. (2011), that the critical difference between the child state and the adult state is that children at this stage do not perform scalar replacements. Specifically, children can access constituents of a node or other salient elements for substitution operations, but not the lexicon. Thus, the child’s alternatives will generally be a subset of the adult alternatives, and in this particular case are: $ALT_{Child}(A \vee B) = \{A \vee B, A, B\}$. Other than this we assume that children have assigned an inclusive disjunction meaning to *or*, like adults, and that they have acquired f and apply it in the same way as adults (cf. the ‘Modularity Matching Hypothesis’ of Crain and Wexler (1999)). What we should like to show is that this set of assumptions suffices to account for the child’s conjunctive interpretation of matrix and embedded disjunctive sentences if f is implemented in the grammar in the manner of Fox (2007a).

The application of f to $A \vee B$ with alternatives $ALT_{Child}(A \vee B) = \{A \vee B, A, B\}$ actually turns out to be vacuous. Note that the MCEs are: (i) $\{A\}$, (ii) $\{B\}$, and their intersection is empty. Thus, none of the alternatives are excludable. The corresponding diagram looks like this:

(11) Diagrammatic representation of $[[f(ALT_{Child}(A \vee B))(A \vee B)]]$:



With a grammatical implementation of f , however, it follows without further stipulation that f should be capable of applying recursively to its own output (Fox, 2007a), and one can show indeed that recursive application of f allows the child with its alternatives, but not the adult with its alternatives, to yield the desired conjunctive SIs. That is, if we let T be shorthand for the sentence $f(ALT_{Child}(A \vee B))(A \vee B)$ – the result of the first application of f – a second application of f on T yields a conjunctive interpretation with the child alternatives, $[[f(ALT_{Child}(T))(T)]] \iff A \wedge B$, but is vacuous with the adult alternatives, $[[f(ALT_{Adult}(T))(T)]] \iff A \nabla B \iff [[f(ALT_{Adult}(A \vee B))(A \vee B)]]$. We show how this result follows in greater detail in the supplementary materials. Here we try to present the core idea, which, recall from our high-level discussion of strengthening in terms of truth-tables from 2.2, concerns the properties of the alternatives at the recursive step in f -application and in particular whether the alternatives of the uttered sentence are closed under conjunction.

First, consider the child at the recursive step in the computation. The alternatives of $T = f(ALT_{Child}(A \vee B))(A \vee B)$ are $ALT_{Child}(T) = \{f(A \vee B), f(A), f(B)\} = \{A \vee B, A \wedge \neg B, B \wedge \neg A\}$.¹⁸ Because $f(A \vee B) \wedge \neg f(A) \wedge \neg f(B)$ is consistent, the application of f on T excludes the alternatives $f(A) \iff A \wedge \neg B$ (= ‘just A ’) and $f(B) \iff B \wedge \neg A$ (= ‘just B ’). The result is the conjunctive inference: $f(A \vee B) \wedge \neg f(A) \wedge \neg f(B) \iff A \wedge B$. We summarize this computation with the diagram in (12) and the description in (13).

(12) The child’s second application of f (visual summary):

¹⁸More pedantically, the set of alternatives is: $\{f(ALT_{Child}(A \vee B))(A \vee B), f(ALT_{Child}(A \vee B))(A), f(ALT_{Child}(A \vee B))(B)\} = \{A \vee B, A \wedge \neg B, B \wedge \neg A\}$. More generally, where C is the set of alternatives to S , and $f(C')(f(C)(S))$ is a logical form, $C' = \{f(C)(S') : S' \in C\}$. (By the algorithm in (23) in the supplementary materials, constituents of focus-marked constituents are substituted by elements from the substitution source for that constituent. Here this means that the sentential argument S of $f(C)(S)$ will be targeted for substitution, and $C = ALT(S)$.)

$$\begin{array}{ccc}
f(A) \iff A \wedge \neg B & & f(B) \iff B \wedge \neg A \\
& \searrow & \swarrow \\
& f(A \vee B) \iff A \vee B &
\end{array}$$

- (13) Child's second application of f (descriptive summary):
- Sentential argument: $f(ALT_{Child}(A \vee B))(A \vee B) \iff A \vee B$
 - Alternatives argument: $\{f(A \vee B), f(A), f(B)\} = \{A \vee B, A \wedge \neg B, B \wedge \neg A\}$
 - Result of f -application: $f((13-b))((13-a)) \iff f(A \vee B) \wedge \neg f(A) \wedge \neg f(B) \iff (A \vee B) \wedge \neg(A \wedge \neg B) \wedge \neg(B \wedge \neg A) \iff A \wedge B$

The second application of f works differently in the adult. Specifically, the possibility of excluding $f(A)$ (= 'just A ') and $f(B)$ (= 'just B ') is blocked by the presence of the conjunctive alternative $A \wedge B \in ALT_{Adult}(A \vee B)$. To see this, recall from (10) that $f(ALT_{Adult}(A \vee B))(A \vee B) \iff A \vee B \wedge \neg(A \wedge B) \iff A \nabla B$. But since $A \nabla B$ is equivalent to $f(A) \vee f(B)$ ('only A ' or 'only B '), neither $f(A)$ nor $f(B)$ can be innocently excluded at the second round of f -application, for the result would be inconsistent: $f(A \vee B) \wedge \neg f(A) \wedge \neg f(B) \iff (A \nabla B) \wedge (A \wedge \neg B) \wedge (B \wedge \neg A) \iff \perp$. In fact, it turns out that none of the alternatives are innocently excludable at this stage of the computation; the second application of f in the steady state is thus vacuous (as is any subsequent step; Fox, 2007a).

- (14) The adult's second application of f (visual summary):

$$\begin{array}{ccc}
f(A) \iff A \wedge \neg B & & f(B) \iff B \wedge \neg A \\
& \searrow & \swarrow \\
& f(A \vee B) \iff A \nabla B \iff f(A) \vee f(B) & \\
& & f(A \wedge B) \iff A \wedge B
\end{array}$$

- (15) Adult's second application of f (descriptive summary):
- Sentential argument: $f(ALT_{Adult}(A \vee B))(A \vee B) \iff A \nabla B$
 - Alternatives argument: $\{A \nabla B, A \wedge \neg B, B \wedge \neg A, A \wedge B\}$ ¹⁹

¹⁹The alternatives are derived by replacing $A \vee B$ in $f(ALT_{Adult}(A \vee B))(A \vee B)$

- c. Result of f -application: $f((15-b))((15-a)) \iff A \nabla B$ (i.e., f -application is vacuous)

We thus predict that strengthening yields an ambiguity for both the child and the adult, but that the strengthened meanings go in opposite directions. For children at the relevant stage of development atomic disjunctive sentences $A \vee B$ are ambiguous between an inclusive-disjunction (with no application of f , or with a single application of f) and a conjunction (derived by two applications of f). This ambiguity leads us to expect there to be at least as many true responses in ‘Both’ as in ‘One,’ which is what we saw in section 3.3. Recall that for adults $A \vee B$ is ambiguous between an inclusive disjunction (no application of f) and an exclusive disjunction (f -application), so that the reverse of children is expected: there should be at least as many true responses in ‘One’ as in ‘Both,’ and this is what we found in section 3.3. This difference is apparent in Figure 7 from section 3.3, repeated here in Figure 8 (scaled down in size): the child can say ‘false’ in the ‘One’ condition if they apply f , but the adult has no such mechanism available, and this explains the difference in scores apparent in ‘One.’

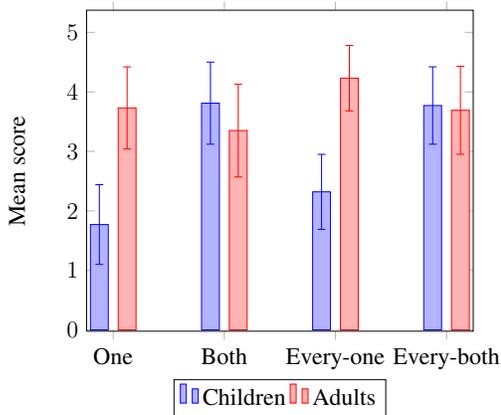


Figure 8: Comparing children ($n = 31$) and adult ($n = 26$) mean scores on critical conditions (error bars indicate 95% confidence intervals)

Turning to embedding under *every*, recall from (9) in section 3.1 that we predict that a sentence like *every boy is holding an apple or a banana* has three possi-

with members of $ALT_{Adult}(A \vee B)$ (see note 17 and the statement (23) in the supplementary materials): $\{f(ALT_{Adult}(A \vee B))(A \vee B), f(ALT_{Adult}(A \vee B))(A), f(ALT_{Adult}(A \vee B))(B), f(ALT_{Adult}(A \vee B))(A \wedge B)\}$.

ble readings for children at the given stage (we repeat (9) below as (16); compare with the adult’s readings in (8)):

- (16) Child’s Readings for $S = \textit{every boy is holding an apple or a banana}$
- a. **Basic Meaning** that for each boy x , x is holding at least one of an apple or a banana (no application of f anywhere)
 - b. **Global Strengthening** the conjunction of (16-a) and the scalar implicatures that not every child is holding an apple and not every child is holding a banana (parsing the sentence as $f(ALT(S))(S)$)²⁰
 - c. **Local Strengthening** that for each boy x , x is holding an apple and a banana (with recursive application of f beneath *every*: *every boy x , $f(f(x \textit{ is holding an apple or a banana}))$*).²¹

The child and adult thus both generate the basic meaning (16-a) and the globally strengthened meaning (16-b), but they differ in the locally strengthened meanings they generate. In particular, the child generates the conjunctive reading in (16-c), which gives them a route to false judgments in ‘Every-one,’ whereas for the adult all three readings in (8) are true in that condition. Again, as in the atomic case, it is the availability of different strengthenings that we take to be responsible for the difference between the child and the adult displayed in Figure 8. Note in particular that in the case of embedding under *every* the child and the adult ambiguity differs only in local strengthenings (embedded conjunction versus embedded exclusive disjunction), and it is this difference that explains the child’s deviance from adult responses. If this explanation is on the right track, it provides further support for the existence of embedded implicatures. Indeed, it is not clear how one could explain the child’s high rejection rates in ‘Every-one’ without appeal to an embedded conjunctive SI.

While the availability of an embedded conjunctive SI provides the child a route to ‘false’ judgments in ‘Every-one,’ it does not explain why there were relatively more rejections in ‘Every-one’ than in ‘Every-both.’ Two of the three readings in (16) are true in ‘Every-one’ (only (16-c) is false there), and two of the three

²⁰Following (23) and (26-a) in the supplementary materials, the alternatives of S for the child are $ALT_{Child}(S) = \{\textit{every boy is holding an apple or a banana}, \textit{every boy is holding an apple}, \textit{every boy is holding a banana}\}$, and application of f (given the entry for f specified in (24)) negates both of the simplified alternatives.

²¹The conjunctive interpretation of the embedded disjunction follows from the fact that double-application of f on a disjunction with the child’s alternatives yields a conjunctive interpretation, together with the assumption that f is a syntactic device, and hence can be recursively applied in embedded positions.

readings in (16) are true in ‘Every-both’ (only (16-b) is false there). Nevertheless, there were significantly more rejections in ‘Every-one’ than in ‘Every-both,’ suggesting that there is a preference for the conjunctive reading in (16-c). An account of this preference is clearly called for, but for the moment, since so little is known about disambiguation mechanisms (in general and when covert f is involved), there is not that much we can say with confidence. Nevertheless, there are a few observations about adult preference that lead to clear expectations for children, given our approach.

4.2 Disambiguation Strategies

We have provided evidence that children sometimes interpret disjunctive sentences conjunctively, and we have proposed an explanation of this finding that makes the following two assumptions: (i) children at the relevant developmental stage have acquired an inclusive disjunction lexical entry for *or* as well as a grammatical operator that realizes f , (ii) these children differ from adults in that they do not perform lexical substitutions in the generation of alternatives. The child and the adult thus both have the option of strengthening the basic inclusive meaning of $A \vee B$ with f -application: for someone with adult alternatives this results in the inference $\neg(A \wedge B)$, and for someone with child alternatives this results in the opposite inference $A \wedge B$. One question facing both the adult and the child, then, is whether or not they should strengthen the basic meaning by inserting f into the parse. Since there are potentially conflicting considerations that might enter into this decision, we might expect there to be different subpopulations that answer this question in different ways. We saw immediately above that there seems to be a preference in children to parse the sentence so as to yield a conjunctive meaning. Why, given f and a potential proliferation of considerations, should such a preference exist?

In this section we discuss the matter of disambiguation in greater detail. We begin in section 4.2.1 with some of the choice-points that arise for someone who has to decide whether to insert f into the input sentence. Different ways of making these choices give rise to different disambiguation-strategy profiles. When we take a closer look at individual behavior, we will suggest that these idealized profiles are arguably attested by subpopulations in our sample. One of these profiles displays the preference for conjunctive SIs discussed above, and is in fact dominant (in terms of membership numbers) among our subpopulations. In section 4.2.2 we relate this profile to populations in the steady state. Specifically, we highlight a formal property – closure of alternatives under conjunction (see (22))

– that regulates the possibility of conjunctive SIs for disjunctive sentences (following Fox, 2007a). We will show how this property predicts that children should generate conjunctive SIs using the same mechanism that adults use to compute conjunctive free-choice SIs in the adult state. We will further strengthen the parallel between the child and the adult by sketching a connection between CONJ and a disambiguation strategy that prefers parses that best answer the *question under discussion* (Gualmini et al., 2008). This relation predicts that children who follow the strategy should prefer conjunctive SIs even when disjunctive sentences are embedded under *every*, as our subpopulation of interest does, and that adults who follow the strategy should prefer free-choice SIs (see Chemla and Bott, 2012), even when disjunctive permission sentences are embedded under *every* (see Chemla, 2009c).

4.2.1 Predicted subpopulations

Several considerations might enter into any particular disambiguation decision: linguistic complexity (e.g., Miller and Chomsky, 1963; Frazier and Fodor, 1978; Ford et al., 1982; Gibson, 1998, 2000, *inter alia*), plausibility judgments (e.g., Crain and Steedman, 1985; Trueswell et al., 1994; Stolcke, 1995; Jurafsky, 1996; Goodman and Stuhlmuller, 2013, *inter alia*), preferences for parses that best answer the question under discussion (e.g., Gualmini et al., 2008), preferences for stronger meanings (possibly related to other interpretive strategies, e.g., Dalrymple et al., 1998), computation-storage tradeoffs (e.g., Johnson et al., 2007; O’Donnell et al., 2011), and many other factors that have been proposed in the parsing literature. Putting these underlying motivations aside for the moment, suppose that any given subject can be characterized as having either a preference to iteratively insert f to the parse until no further strengthening takes place (i.e., they exhaustify until they reach a fixed point), or to resist adding f to the parse entirely (i.e., they resist exhaustification). Call f -resistors ‘logicians’ (following Noveck, 2001’s evocative terminology), and call f -insertors ‘exhaustifiers’. When confronted with a complex sentence exhaustifiers face the additional problem of deciding *where* to exhaustify. For example, when there is one embedded constituent – as in *every boy is holding an apple or a banana* – an exhaustifier will have to decide whether to exhaustify locally at the embedded constituent or globally at the root. Suppose that any given exhaustifier is consistently either a local exhaustifier or a global exhaustifier.

Now if we assume more generally that any given subject is consistent in their preferences, we expect the existence of subpopulations that can be classified as

logicians, local exhaustifiers, or global exhaustifiers. Given these idealized subpopulations, it might prove interesting to look at our sample to see if they are attested. Here is what we will look for. Recall that each subject saw five items on each of the conditions ‘One,’ ‘Both,’ ‘Every-one,’ and ‘Every-both.’ Assuming consistent preferences, they should always give the same response (‘right’ or ‘wrong’) on each trial of any given condition. A logician, for example, should always say ‘true’ on each of the four conditions. An exhaustifier (whether local or global) with child alternatives will interpret *the boy is holding an apple or a banana* as ‘the boy is holding an apple and a banana,’ and thus will always say ‘false’ on ‘One’ and ‘true’ on ‘Both.’ In a complex sentence like *every boy is holding an apple or a banana*, a local exhaustifier will recursively insert *f* below *every* to yield the reading that ‘every boy is holding an apple and a banana,’ and thus will always answer ‘false’ on ‘Every-one’ and ‘true’ on ‘Every-both.’ A global exhaustifier will apply *f* at the root to yield the SI that not every boy is holding an apple and not every boy is holding a banana; such a subject should say ‘true’ to ‘Every-one’ and ‘false’ to ‘Every-both.’ Each of the four conditions thus gives each subject five chances to say ‘true.’ Putting the number of ‘true’ responses out of five for each condition in a vector (One, Both, Every-one, Every-both), a logician will be expected to have a (5,5,5,5) response profile (always ‘true’ on each condition), a local exhaustifier will be expected to have a (0,5,0,5) profile (always ‘true’ on ‘Both’ and ‘Every-both,’ always ‘false’ on ‘One’ and ‘Every-one’), while a global exhaustifier will be expected to have a (0,5,5,0) profile (always ‘true’ on ‘Both’ and ‘Every-one,’ always ‘false’ on ‘One’ and ‘Every-both’).

(17) Predicted subpopulations with child alternatives:

- a. Logicians: (5,5,5,5)
- b. Local exhaustifiers: (0,5,0,5)
- c. Global exhaustifiers: (0,5,5,0)

Of course in any given sample of children there might be some who have already matured into the steady state. Under our proposal, this amounts to considering those children who have acquired the adult alternatives (perform lexical substitutions). Among this population we can again consider logicians, local exhaustifiers, and global exhaustifiers – see the readings in (8). The reader can verify that the following profiles are predicted:

(18) Predicted subpopulations with adult alternatives:

- a. Logicians: (5,5,5,5)

- b. Local exhaustifiers: (5,0,5,0)
- c. Global exhaustifiers: (5,0,5,0)

The group in (18) only adds one additional subpopulation to (17), (5,0,5,0).²²

Given these idealized subpopulations, we were interested in exploring whether we could find them among our sample. It is of course difficult to say with confidence whether any given sample belongs to some predicted population. The difficulty for us was further compounded by the relatively small number of trials each subject saw. Nevertheless, we believe the results are suggestive and worth discussing here. In particular, we suggest – tentatively – that a large majority of children in our sample can with some justification be classified as belonging to one or another of these idealized populations. Using the same criterion we used for classifying children as having correctly understood conjunction (getting 16/20 according to the predicted pattern, see section 3.2), we were able to classify 23 out of 31 subjects as falling into one or another of these predicted subpopulations. Below we present tables that identify which of our participants were classified as belonging to each of the predicted profiles (we found no subjects in our sample who behaved like global exhaustifiers (cf. (17-c))). The tables show the participant number and the participant’s response rate (out of 5 chances to say ‘true’) on each of the four conditions. The most noteworthy group from our perspective are the subjects in Table 7, as these are the ones we claim are interpreting disjunctions conjunctively.

Table 6: Logicians (Predicted: (5,5,5,5))

ID Number	One	Both	Every-one	Every-both
18	5	4	5	4
27	5	5	5	4
56	5	5	5	5
58	5	4	4	4

²²Local and global exhaustification with adult alternatives leads to the same truth-value judgments in ‘Every-one’ and ‘Every-both,’ and the basic lexical entries for *or* and *every* are assumed to be the same between children and adults, so adult and child logicians are predicted to give the same truth-value judgments on all conditions.

Table 7: Child Local Exhaustifiers (Predicted: (0,5,0,5))

ID Number	One	Both	Every-one	Every-both
8	0	5	2	5
9	1	5	0	5
21	0	5	2	5
23	0	5	1	5
36	0	5	0	5
42	0	5	2	5
45	0	5	0	5
52	2	5	2	5
53	4	5	0	5
54	1	5	0	5
74	0	5	0	5

Table 8: Adult Exhaustifiers (Predicted: (5,0,5,0))

ID Number	One	Both	Every-one	Every-both
7	4	0	2	0
57	3	0	3	0
60	5	0	5	0

Within our sample there were additional participants who did not fall into any of our identified categories. It is unclear what to make of some of these participants' response patterns, but there were two subgroups of potential interest. First, there were two subjects who seemed to be rather close to a (0,5,0,5) profile: subject number 4 had response profile (2,5,2,4) and subject number 28 had response profile (2,4,2,5) (they both behaved according to the profile's predictions 15 times out of 20, one error away from reaching significance). Second, there was a group of five subjects who seemed to be following a (0,5,5,5) pattern.²³ It turns out that relaxing one of our parsing assumptions actually predicts the existence of a (0,5,5,5) pattern. Specifically, if we relax the assumption that subjects exhaustify at any given location until they reach a fixed point, it turns out that there is (only) one additional reading available to a subject with child alternatives: by parsing the sentence with a single f below *every* at the embedded disjunction as well as a single f at the root, $f(C')(every\ boy\ x, f(C)(x\ is\ holding\ an\ apple\ or\ a\ banana))$, the resulting meaning is that every boy is holding at least one of an apple or a banana – the literal meaning of the sentence – and that it is false that each boy is holding just an apple and it is false that each boy is holding just a banana.²⁴ Thus, by regrouping our subjects as exhaustifiers or not (logicians), and among exhaustifiers as either local (until fixed point), global (until fixed point), or everywhere-exhaustifiers, we get the following predicted profiles:

- (19) Predicted subpopulations:
- a. Logicians: (5,5,5,5) (with either child or adult alternatives)
 - b. Local exhaustifiers: (0,5,0,5) (with child alternatives)

²³The remaining subjects had the following profiles: subject number 12 had response profile (0,0,1,0); subject number 51 had response profile (0,0,3,0); subject number 15 had response profile (3,2,3,2); subject number 22 had response profile (2,4,1,3); subject number 75 had response profile (3,5,1,4); subject number 86 had response profile (0,1,0,3).

²⁴The alternatives C for the embedded occurrence of f are just the child alternatives for a disjunction *x is holding an apple or a banana*: $C = \{x\ is\ holding\ an\ apple\ or\ a\ banana, x\ is\ holding\ an\ apple, x\ is\ holding\ a\ banana\}$. Thus, the embedded occurrence of f is vacuous; as noted earlier, application of f on a disjunction with the child alternatives does not change the meaning of the disjunction. The embedded f does, however, affect the alternatives C' of the higher f : $C' = \{[every\ boy\ x, f(C)(x\ is\ holding\ an\ apple\ or\ a\ banana)], [every\ boy\ x, f(C)(x\ is\ holding\ an\ apple)], [every\ boy\ x, f(C)(x\ is\ holding\ a\ banana)]\} = \{that\ every\ boy\ is\ holding\ an\ apple\ or\ a\ banana, that\ every\ boy\ is\ holding\ an\ apple\ and\ not\ a\ banana, that\ every\ boy\ is\ holding\ a\ banana\ and\ not\ an\ apple\}$. We leave it to the reader to verify that $f(C')(every\ boy\ x, f(C)(x\ is\ holding\ an\ apple\ or\ a\ banana))$ with alternatives C' and C identified here gives rise to the meaning paraphrased in the main text. See Crnic et al. (2013) for parsing assumptions that make it natural to expect groups like (19-d), as well as for experimental evidence that such groups are attested among adult populations.

- c. Global exhaustifiers: (0,5,5,0) (with child alternatives)
- d. Everywhere exhaustifiers: (0,5,5,5) (with child alternatives)
- e. Adult exhaustifiers: (5,0,5,0) (local or global or everywhere)

The following participants get classified under the (19-d) profile:²⁵

Table 9: Child Everywhere Exhaustifiers (Predicted: (0,5,5,5))

ID Number	One	Both	Every-one	Every-both
5	0	5	4	5
19	1	5	4	5
26	0	5	4	5
31	1	4	4	4
55	1	5	5	5

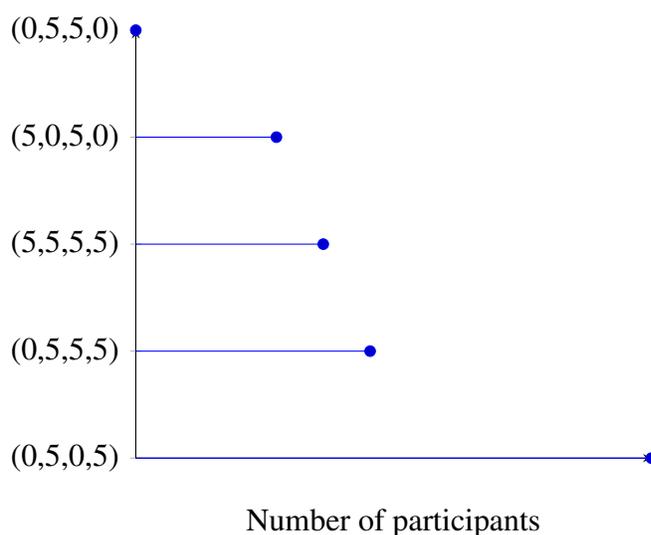
Out of the 31 subjects in our sample, then, we managed to find 23 who could be classified as falling under one or the other of the five predicted profiles in (19) (recall that all but the group in (19-c) were attested). It is worth noting that under alternative approaches to strengthening there is no obvious way to make sense of the groups in (19-b) and (19-d), which together make up more than half of our subjects (16 out of 31). These groups are quite natural, however, from the perspective of the grammatical theory of implicature, where f is realized in the grammar. At the same time, the existence of consistent sub-populations leaves several questions open, such as why different subjects follow different strategies. A related question is what the underlying factors are that govern the strategy profiles we have identified above (logician, local/global/everywhere exhaustifiers with child/adult alternatives).

We will not be able to say much about these general questions, but we will try to better understand the group of subjects in Table 7 (see Crnic et al., 2013

²⁵Under our classification criterion (16/20 according to the predicted profile), subjects 8, 21, 23, 42 from Table 7 would also be classified under this group. However, they are a better fit in the group of local exhaustifiers in Table 7. The important data point here is their relatively high number of ‘false’ responses on ‘Every-one.’ We examined our classification with a goodness-of-fit measure – the method of least-squares – which minimizes the sum of the square of residuals. In our case, the residuals were taken to be the difference between the subject’s observed value O_i on Condition i ($1 \leq i \leq 4$) – their observed number of ‘true’ responses out of five trials for the condition – and the predicted value P_i – the predicted number of true responses for condition i by the profile under consideration. The method of least-squares classified each of the subjects 8, 21, 23, and 42 as having a better fit (a lower sum of squares) with the local-exhaustifier profile than the everywhere-exhaustifier profile.

for detailed discussion of groups like (19-d)). Several questions arise. What lies behind their preference for a conjunctive reading? And why did so many subjects display this preference, even in embedded positions? The preference seems to be robust. For example, out of the 23 subjects we were able to classify into our predicted profiles, the majority fell into the (0,5,0,5) population.²⁶

(20) Observed distribution of subjects classified into predicted profiles



From (20) it looks like the (0,5,0,5) group (the local exhaustifiers with the conjunctive interpretation) attracted the greatest number of subjects. This looks different from what would be expected of a model in which subjects fall into one or another group by *chance*. Under such a model, with 23 subjects and 5 idealized profiles, we would expect 4.6 subjects in each profile. This is not what we found. The difference between the observed frequencies of profiles and that expected from chance is summarized in the table below.

(21) Expected (under chance) and observed frequencies of profiles

²⁶It is unclear to us whether there is any discernible pattern in the behaviour of the eight subjects who did not get classified. They certainly do not seem to be consistently following any of our idealized profiles. We could include a new category, 'other,' into which these subjects fall; if we do this, nothing of substance changes in our discussion (see note 27).

Frequencies	(0,5,0,5)	(0,5,5,5)	(5,5,5,5)	(5,0,5,0)	(0,5,5,0)
Expected	4.6	4.6	4.6	4.6	4.6
Observed	11	5	4	3	0

A chi square was computed comparing the frequencies of actual and expected occurrence of the different profiles, and a significant difference was found between the observed and expected values ($\chi^2(4, n = 23) = 14.17, p = .007$).²⁷

Thus, our sample displays a preference for a conjunctive interpretation of disjunction, even when the disjunction is embedded under *every*. This finding might be especially surprising given that there does not seem to be a preference for local exhaustification in the steady state when *some* and *or* are embedded under *every* (e.g., Geurts and Pouscoulous, 2009). At the same time, there does seem to be a preference in the adult for (embedded) free-choice (Chemla, 2009c; Chemla and Bott, 2012). We will suggest that the child’s preference for a conjunctive strengthening – matrix and embedded – is less surprising than it at first appears if we are right that children derive a conjunctive SI using the same mechanism used in the steady state to derive free-choice. In the next section we isolate a logical property that governs the availability of conjunctive inferences for disjunctive sentences (following Fox, 2007a), and we show how a preference for a conjunctive reading follows when we combine this logical property with a general pragmatic preference to resolve the *question under discussion*. We argue that the child’s preference for conjunctive SIs and the adult’s preference for free-choice inferences follow from this strategy. The strategy itself does not apply to adults’ readings of embedded scalars like *some* and *or*, and hence does not predict a general preference for embedded implicatures.

4.2.2 Free-choice and the preference for conjunctive SIs

We propose to explain the child’s preference for a conjunctive SI by connecting the child’s computation of conjunctive SIs to the adult’s computation of so-called ‘free-choice’ inferences. The puzzle of free-choice permission, recall, is that sentences like *you’re allowed to eat the cake or ice-cream* ($\diamond(A \vee B)$, which is equivalent to $\diamond A \vee \diamond B$) receive the free-choice interpretation that you’re allowed to eat the cake and you’re allowed to eat the ice-cream ($\diamond A \wedge \diamond B$). This inference has been argued to be a scalar implicature (e.g., Kratzer and Shimoyama, 2002;

²⁷The results remain significant if we include all 31 subjects and add a sixth category, ‘other,’ into which the subjects who do not follow our idealized profiles get classified ($\chi^2(5, n = 31) = 14.87, p < .002$).

Alonso-Ovalle, 2005; Schulz, 2005), and was shown by Fox (2007a) to follow from recursive application of f : $f(f(\diamond(A \vee B)))$ entails $\diamond A \wedge \diamond B$. Recursive application of f is the mechanism we have argued to be responsible for the child’s conjunctive SIs. This connection between the child’s developmental stage and the adult steady state follows from a general property that some sets of alternatives possess (Fox, 2007a – see also Chemla, 2009b; Franke, 2011; Meyer, 2013; Levin and Margulis, 2013):

- (22) Conjunctive SIs for disjunctive sentences
- a. Closure of the alternatives under conjunction: It is possible for S to yield a conjunctive SI $S_1 \wedge S_2$, with the parse $f(f(S))$, only if S_1 and S_2 are non-excludable stronger alternatives of S and their conjunction $S_1 \wedge S_2$ is not an alternative of S .
 - b. Non-excludable stronger alternatives: Let S be a sentence with two stronger alternatives S_1 and S_2 such that $S \wedge \neg S_1 \wedge \neg S_2$ is a contradiction. Then we call S_1 and S_2 *non-excludable stronger alternatives* of S .

As an example, consider a sentence $S = S_1 \vee S_2$. Under (22-b) the alternatives S_1 and S_2 are non-excludable stronger alternatives of S , and under (22-a) a conjunctive SI $S_1 \wedge S_2$ is available only if $S_1 \wedge S_2 \notin ALT(S)$ ((22-a)). In the supplementary materials we discuss why (22) holds for some important cases, and we discuss how the conjunctive SI $S_1 \wedge S_2$ might follow from recursive application of f when $ALT(S)$ is not closed under conjunction (see Fox, 2007a for a general characterization). For our purposes, what (22) allows us to do is predict whether a disjunctive sentence can give rise to a conjunctive SI merely by examining whether ALT is closed under conjunction. For example, the child’s alternatives to $A \vee B$ include A and B but do not include their conjunction $A \wedge B$. Similarly, the adult’s alternatives to $\diamond(A \vee B)$ include $\diamond A$ and $\diamond B$ but do not include $\diamond A \wedge \diamond B$. The prediction under (22) is that the child should be able to get a conjunctive SI $A \wedge B$ and the adult should be able to get a conjunctive SI $\diamond A \wedge \diamond B$. At the same time, the adult’s alternatives for disjunctions $A \vee B$ are closed under conjunction; (22) then predicts that adults should be unable to strengthen $A \vee B$ to $A \wedge B$.

If we are right to isolate (22) as the relevant factor governing the distribution of conjunctive SIs for disjunctive sentences, children assign a conjunctive interpretation to $A \vee B$ with the same mechanism adults use to derive free-choice: recursive application of f over a set of alternatives that is not closed under conjunction. For

the rest of the paper we will refer to sets of alternatives that allow a conjunctive SI as CONJ^+ alternatives, and we will refer to the parse with recursive application of f as the f^2 parse of the relevant sentences.

Assuming this formal parallel between the child and the adult to be correct, it allows us to address the question of disambiguation preferences raised earlier. Specifically, (22) might allow us to relate the child's preference for a conjunctive SI with the observation that free-choice inferences in the steady state are computed quickly, and are preferred among the readings available to the subject (e.g., Chemla, 2009c; Chemla and Bott, 2012). Of particular relevance is Chemla's (2009c) finding that this preference exists even when disjunctive permission sentences are embedded under *every*: the sentence *every boy is allowed to eat the cake or ice-cream* is preferentially interpreted as 'every boy is allowed to eat the cake and is allowed to eat the ice-cream.' Under a grammatical implementation of f this suggests that the preferred parse of these sentences is one that yields an f^2 parse of the embedded disjunction. If we are right to connect the child's conjunctive interpretation to the adult's free-choice inference, we might plausibly expect that whatever is behind the source of this preference in the adult is also responsible for this preference in the child.

What explains this preference for f^2 parses of sentences with CONJ^+ alternatives? As already noted, we would like to tentatively suggest, following Gualmini et al. (2008), that the readings of an ambiguous sentence can be ordered by how well they answer the (often implicit) *question under discussion* (QUD; cf. Groenendijk and Stokhof, 1984; Lewis, 1988). It follows from such an ordering that a complete answer will be preferred, if available.²⁸ It seems reasonable to construe a sentence like *the boy is holding an apple or a banana* as an answer to the question, *What is the boy holding?* Similarly, it is reasonable to construe a sentence like *the boy is allowed to eat an apple or a banana* as an answer to the question, *What is the boy allowed to eat?*²⁹ Finally, it is reasonable to construe a sentence like *every boy {ate/is allowed to eat} an apple or a banana* as an answer to the question, *what did every boy eat/what is every boy allowed to eat?* Focusing on

²⁸Following Groenendijk and Stokhof (1984), Lewis (1988) and others, the QUD is taken to be a partition of logical space or of the common ground, where the cells are the complete answers to the question. A *partial answer* to the QUD is a union of cells in the partition, and answers can be ordered in terms of goodness: an answer p is 'better' than another answer q if $p \subset q$. From this it follows that the speaker's best move is to identify for the hearer which cell of the partition is the true one.

²⁹This is most natural on the pair-list interpretation of the question, which asks for each boy what the boy ate/is allowed to eat.

children at the relevant developmental stage, these questions are best answered by the f^2 parse, for they provide the complete answer that the boy ate an apple and a banana in the atomic case, and that every boy ate an apple and a banana in the quantified case.³⁰ In the atomic case the other parses would leave open whether the boy ate an apple, and whether the boy ate a banana, and in the quantified case, the other parses would leave open what each boy ended up eating (though they would constrain it). Our tentative suggestion, then, is that parsing preferences might follow from the more general assumption that speakers provide the best answer to the QUD; this general preference leads, in the cases under consideration here, to a preference for an f^2 parse, and hence for a conjunctive SI.

5 Concluding Remarks

We replicated findings from Paris (1973) and Braine and Romain (1981) showing that children sometimes interpret disjunctions as conjunctions (see also Suppes and Feldman, 1971), and we extended this result to embedding under *every*. We used this result to advance the view that (i) children at the relevant stage of development have acquired the inclusive disjunction semantics of *or*, as shown in previous studies (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Crain, 2008; Crain and Khlentzos, 2010) and (ii) children have acquired the basic mechanism for computing implicatures (f) and differ from adults only in the alternatives they generate (e.g., Chierchia et al., 2001; Gualmini et al., 2001; Reinhart, 2006; Barner and Bachrach, 2010; Barner et al., 2011), and hence also in the SIs they compute. We localized the difference to lexical access in the generation of alternatives, and showed that this difference allows the child to generate a conjunctive scalar implicature using the same mechanism adults use to derive free-choice inferences, namely recursive application of a covert morpheme that realizes f (Fox, 2007a). We characterized this parallel between the developmental and steady state with (22), and the assumption that f^2 parses are available and are the source of the attested conjunctive inferences.

An immediate consequence of this parallel is that we should expect children (and adults) to generate conjunctive inferences with f^2 parses whenever their alternatives satisfy CONJ^+ . One notable prediction along these lines is that children should compute free-choice SIs, since their set of alternatives for $\diamond(A \vee B)$ is

³⁰None of these points change if there are other answers in the Hamblin denotation (e.g., that the boy ate/is allowed to eat a strawberry). These other propositions will all get negated.

CONJ⁺: under (1-c), $ALT_{Child}(\diamond(A \vee B)) = \{\diamond(A \vee B), \diamond A, \diamond B\}$. This expectation has been confirmed (see Zhou et al., 2013). Negated conjunctions $\neg(A \wedge B)$ are another case of this kind. Under our proposal the child’s alternatives for this sentence are: $ALT_{Child}(\neg(A \wedge B)) = \{\neg(A \wedge B), \neg A, \neg B\}$. Since these are yet another instance of CONJ⁺ alternatives (note that $\neg(A \wedge B) \iff \neg A \vee \neg B$), we again expect this sentence to receive the conjunctive interpretation $\neg A \wedge \neg B$. Jacopo Romoli, who pointed out this prediction (personal communication), reports a study by Anna Notley showing that children do indeed generate such ‘wide-scope conjunction’ interpretations. We would also expect children to assign free-choice interpretations under *every* in the same way that adults do (Chemla, 2009a); indeed our explanation for the child’s behavior on ‘Every-one’ and ‘Every-both’ relies on this assumption. It might also be interesting to examine the extent to which our analysis might apply to coordination in American Sign Language (ASL). Davidson (2013) reports that there is only a single coordinator in ASL which seems to allow both an inclusive disjunction interpretation and a conjunctive one, even in embedded positions. If this connective is encoded as an inclusive disjunction, then without a conjunctive alternative the alternatives will be CONJ⁺, and an f^2 parse would yield a conjunctive interpretation.

If we are right that children’s purported difficulties with implicature computation reduce to difficulties with accessing the lexicon, then children’s observed resistance to computing implicatures is a historical accident stemming from use of sentences whose implicatures require access to the lexicon (e.g., $\exists \rightsquigarrow \neg\forall$). By exploiting the current understanding of alternatives and implicatures in complex sentences, children are better described as being both willing and able to compute implicatures, sometimes resulting in inferences that are unavailable in the steady state. While this might make the child appear to be a supercomputer, one should bear in mind that under our proposal the computation of these implicatures amounts to nothing more than parsing the sentence and interpreting the result – computational operations that are known to be available to the child (for an overview, see e.g., Snedeker, 2009). Once the child has acquired the covert operator that realizes f , the only complication comes from having to decide whether to come up with a parse containing f . We tentatively suggested that this decision is sensitive to a general preference for a parse that provides a complete answer to the QUD (Gualmini et al., 2008).

6 Supplementary Materials: Definitions, Proofs, Summary of Claims

Let S be an arbitrary sentence uttered in an arbitrary context c , and let $[[S]]$ be the semantic interpretation of S .

- (23) Alternatives in the adult grammar (Katzir, 2007, Fox and Katzir, 2011):
- a. Formal Alternatives: The formal alternatives of S are derived by a function, ALT , such that $ALT(S, c)$ is the set containing sentences derived from S by successive substitution of focus-marked constituents of S from the substitution source of S in c , $SS(S, c)$.
 - b. Substitution Source: $Y \in SS(X, c)$ iff (i) Y is a constituent of a focus-marked constituent of X , (ii) Y has been explicitly mentioned in c , (iii) Y a lexical item.
 - c. Actual Alternatives: Where \mathcal{R}_c is the set of relevant sentences in c , the actual alternatives of S in c , $A(S, c) = \mathcal{R}_c \cap ALT(S, c)$
- (24) The semantics of f (Fox, 2007a): Where c is the context of assertion, $A(S, c)$ is the set of actual alternatives of S in c , and $f(A(S, c))(S)$ is the LF that is used in context c :
- a. $[[f(A(S, c))(S)]] = [[S \wedge \bigwedge \{\neg S_i : S_i \in IE(A(S, c))\}]]$
 - b. Innocent Exclusion: The set of innocently excludable alternatives of $A(S, c)$, $IE(A(S, c))$, is the intersection of the set of Maximal Consistent Exclusions of $A(S, c)$.
 - c. Maximal Consistent Exclusion: A Maximal Consistent Exclusion of $A(S, c)$ is a set B such that: (i) $B \subseteq A(S, c)$, (ii) $S \wedge (\bigwedge \{\neg S_i : S_i \in B\})$ is consistent, (iii) $S \wedge (\bigwedge \{\neg S_i : S_i \in B\}) \wedge S_j$ is inconsistent, for any $S_j \in A(S, c) \setminus B$.

The statement in (25) below is a special case of a general theorem from Fox (2007a), restricted to disjunctive sentences of the kind relevant to our discussion (proof sketch follows shortly). (What (25) says, roughly, is that a sentence ϕ containing a disjunction $A \vee B$, $\phi(A \vee B)$, will give rise to a conjunctive SI $\phi(A) \wedge \phi(B)$ with the parse $ff(\phi(A \vee B))$ if the alternatives are closed under conjunction; otherwise the recursive step will be vacuous)

- (25) (22) and the recursive step: Let ϕ be a sentence containing a disjunction $A \vee B$, $\phi(A \vee B)$, such that $\phi(A)$ and $\phi(B)$ each entail $\phi(A \vee B)$ and are

both members of $ALT(\phi(A \vee B))$, and that $\phi(A \vee B)$ entails $\phi(A) \vee \phi(B)$. Then assuming $ALT(\phi(A \vee B)) \subseteq \{\phi(A \vee B), \phi(A), \phi(B), \phi(A \wedge B)\}$ (cf. (23)):

$$[[f f(\phi(A \vee B))]] = \begin{cases} [[f(\phi(A \vee B))]] & \phi(A \wedge B) \in ALT(\phi(A \vee B)) \\ & \& \phi(A \wedge B) \equiv \phi(A) \wedge \phi(B) \\ \phi(A) \wedge \phi(B) & \text{otherwise} \end{cases}$$

(26) Claims:

- a. Children differ from adults only in that they do not use the lexicon as a substitution source (cf. Chierchia et al., 2001, Gualmini et al., 2001, Barner et al., 2011).
- b. The claim in (26-a), together with (25), predicts: (i) that children should be able to derive a conjunctive scalar implicature $A \wedge B$ from $A \vee B$ by recursive application of f (because these are CONJ^+ alternatives), (ii) that adults cannot compute a conjunctive scalar implicature $A \wedge B$ from assertion of $A \vee B$ (because these are not CONJ^+ alternatives; use ‘ CONJ^- ’ to refer to any set of alternatives that is not CONJ^+), and (iii) that both children and adults should be able to compute free-choice SIs $\diamond A \wedge \diamond B$ from disjunctive permission sentences $\diamond A \vee B$ (because these are CONJ^+ in both children and adults)).

Here we sketch a proof of (25). Together with (26-a) the claim in (26-b) will follow. There are three cases to consider: **(A)** CONJ^+ alternatives for which $\phi(A \wedge B) \notin ALT(\phi(A \vee B))$ (e.g., children’s disjunction), **(B)** CONJ^+ alternatives for which $\phi(A \wedge B) \in \phi(A \vee B)$ and $\phi(A \wedge B) \not\equiv \phi(A) \wedge \phi(B)$ (e.g., the adult’s alternatives for free-choice), **(C)** CONJ^- alternatives for which $\phi(A \wedge B) \in \phi(A \vee B)$ and $\phi(A \wedge B) \equiv \phi(A) \wedge \phi(B)$ (e.g., the adult’s alternatives for atomic disjunctions).

Consider first CONJ^+ alternatives like in **(A)**. Recall that $\phi(A \vee B)$ entails $\phi(A) \vee \phi(B)$ (by assumption, cf. (25)), which means neither $\phi(A)$ nor $\phi(B)$ will be innocently excludable. Thus, where $C = \{\phi(A \vee B), \phi(A), \phi(B)\}$, $[[f(C)(\phi(A \vee B))]] = \phi(A \vee B)$, i.e., f -application is vacuous. Now consider the second round of f -application. Let $T = f(C)(\phi(A \vee B))$, and consider the parse $f(C')(T)$, where $C' = ALT(T)$. By (23), this will be the set: $C' = \{f(C)(S) : S \in C\} = \{f(C)(\phi(A \vee B)), f(C)(\phi(A)), f(C)(\phi(B))\} = \{\phi(A \vee B), \phi(A) \wedge \neg\phi(B), \phi(B) \wedge \neg\phi(A)\}$. By the semantics of f in (24), $[[f(C')(T)]] = \phi(A \vee$

$B) \wedge \neg(\phi(A) \wedge \neg\phi(B)) \wedge \neg(\phi(B) \wedge \neg\phi(A)) \equiv \phi(A) \wedge \phi(B)$ (recall that $\phi(A \vee B)$ entails $\phi(A) \vee \phi(B)$).

Next consider CONJ^+ alternatives like in **(B)**. This differs from the previous case because the first round of f -application is not vacuous. Where $C = \{\phi(A \vee B), \phi(A), \phi(B), \phi(A \wedge B)\}$, $[[f(C)(\phi(A \vee B))]] = \phi(A \vee B) \wedge \neg\phi(A \wedge B)$ (neither $\phi(A)$ nor $\phi(B)$ is innocently excludable, as before, but $\phi(A \wedge B)$ is, because the Maximal Consistent Exclusions are $\{\phi(A), \phi(A \wedge B)\}$ and $\{\phi(B), \phi(A \wedge B)\}$, and $\phi(A \wedge B)$ is the only element in the intersection of these sets). Note that this strengthened meaning is consistent with $\phi(A) \wedge \phi(B)$ but does not entail it. Now consider the next round of f -application. Let $T = f(C)(\phi(A \vee B))$, and consider the parse $f(C')(T)$, where $C' = \text{ALT}(T)$. By the definition in (23), $C' = \{f(C)(S) : S \in C\} = \{f(C)(\phi(A \vee B)), f(C)(\phi(A)), f(C)(\phi(B)), f(C)(\phi(A \wedge B))\} = \{\phi(A \vee B) \wedge \neg(\phi(A \wedge B)), \phi(A) \wedge \neg\phi(B), \phi(B) \wedge \neg\phi(A), \phi(A \wedge B)\}$. As before, f will try to exclude as many of these alternatives as it can while maintaining consistency with its sentential argument, here T . The conjunctive alternative $\neg(\phi(A \wedge B))$ was already excluded in the first round (cf. T), and thus is irrelevant at this stage. And since T does not entail $f(C')(\phi(A)) \vee f(C')(\phi(B))$, both $f(C')(\phi(A))$ and $f(C')(\phi(B))$ will be excluded. Hence, $[[f(C')(T)]] = \phi(A \vee B) \wedge \neg\phi(A \wedge B) \wedge \neg(\phi(A) \wedge \neg\phi(B)) \wedge \neg(\phi(B) \wedge \neg\phi(A))$, which is equivalent to $\phi(A) \wedge \phi(B) \wedge \neg(\phi(A \wedge B))$ (recall that $\phi(A \vee B)$ is assumed to entail $\phi(A) \vee \phi(B)$).

Finally, consider CONJ^- alternatives like in **(C)**. After the first round of f -application the resulting meaning is the same as with the CONJ^+ alternatives in **(B)**: $[[f(C)(\phi(A \vee B))]] = \phi(A \vee B) \wedge \neg\phi(A \wedge B)$. What is important in comparison with **(B)** is that since $\phi(A \vee B)$ entails $\phi(A) \vee \phi(B)$, and $\phi(A \wedge B) \equiv \phi(A) \wedge \phi(B)$, we have the result that $f(C)(\phi(A \vee B)) \equiv f(C)(\phi(A)) \vee f(C)(\phi(B))$ (note that $f(C)(\phi) \equiv \phi(A) \wedge \neg\phi(B)$ and $f(C)(\phi(B)) \equiv \phi(B) \wedge \neg\phi(A)$). This makes it so that neither $f(C)(\phi(A))$ nor $f(C)(\phi(B))$ is innocently excludable, so no conjunctive SI is possible with a second round of f . (Note in fact that $\neg(\phi(A) \wedge \phi(B))$ already follows from the first round, since $\phi(A \wedge B) \equiv \phi(A) \wedge \phi(B)$).

The claim in (26-b) thus follows. However, there is a potential concern that we would like to briefly address. In general it is known that context can sometimes restrict the set of formal alternatives by eliminating all those formal alternatives that are irrelevant (Horn, 1972, Rooth (1992), Fox and Katzir (2011), cf. (23-c)). If context could arbitrarily prune alternatives, we might expect conjunctive SIs $A \wedge B$ to arise in the adult state by pruning $A \wedge B$ (this pruning would convert the adult alternatives from CONJ^- to CONJ^+). We assume that this pruning is impossible. Specifically, we assume following Fox and Katzir (2011) that pruning

involves the choice of a subset of relevant alternatives (see (23)) and that relevance is closed under conjunction (if A is relevant and B is relevant then $A \wedge B$ is relevant). This assumption about relevance follows from the idea that the set of relevant propositions is determined by a ‘partition’ of logical space (or of the common ground), and more specifically from the idea that a sentence is relevant if its denotation, a set of possible worlds, is a union of cells in the partition (Groenendijk and Stokhof, 1984; Lewis, 1988). The reader can verify that this closure condition prevents the adult from pruning $A \wedge B$ from $ALT(A \vee B)$, but does not prevent them from pruning $\diamond(A \wedge B)$ from the set $ALT(\diamond(A \vee B))$. The latter pruning does not prevent FC from arising (the set still satisfies $CONJ^+$).

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