Nat Lang Semantics (2016) 24:305–352
DOI 10.1007/s11050-016-9126-3

Children interpret disjunction as conjunction: Consequences for theories of implicature and child development

Raj Singh[1] · Ken Wexler[2,3] · Andrea Astle-Rahim[4] · Deepthi Kamawar[1,4] · Danny Fox[2]

Published online: 17 October 2016

Abstract We present evidence that preschool children oftentimes understand disjunctive sentences as if they were conjunctive. The result holds for matrix disjunctions as well as disjunctions embedded under *every*. At the same time, there is evidence in the literature that children understand *or* as inclusive disjunction in downward-entailing contexts. We propose to explain this seemingly conflicting pattern of results by assuming that the child knows the inclusive disjunction semantics of *or*, and that the conjunctive inference is a scalar implicature. We make two assumptions about implicature computation in the child: (i) that children access only a proper subset of the adult alternatives (specifically, they do not access the lexicon when generating alternatives), and (ii) that children possess the adult capacity to strengthen sentences with implicatures. As a consequence, children are expected to sometimes not compute any implicatures at all, but in other cases they are expected to compute an implicature that is *different* from the adult implicature. We argue that the child's conjunctive strengthening of disjunctive sentences realizes the latter possibility: the adult infers that the conjunction is false but the child infers that the conjunction is true. This behaviour is *predicted* when our assumptions about child development are coupled with the assumption that a covert exhaustive operator is responsible for strengthening in both the child and the adult. Specifically, children's conjunctive strengthening is predicted to follow from the same mechanism used by adults to compute conjunctive free choice implicatures in response to disjunctive permission sentences (recursive

✉ Raj Singh
raj.singh@carleton.ca

1 Institute of Cognitive Science, Carleton University, Ottawa, ON K1S 5B6, Canada

2 Department of Linguistics and Philosophy, MIT, Cambridge, MA 02139, USA

3 Department of Brain and Cognitive Sciences, MIT, Cambridge, MA 02139, USA

4 Department of Psychology, Carleton University, Ottawa, ON K1S 5B6, Canada

exhaustification). We furthermore argue that this parallel between the child and the adult extends to disambiguation preferences. In particular, we present evidence that children prefer to strengthen disjunctions to conjunctions, in matrix and embedded positions (under *every*); this result mirrors previous findings that adults prefer to compute free choice, at the root and under *every*. We propose a disambiguation strategy that explains the preference for conjunctive strengthening – by both the child and the adult – even though there is no general preference for exhaustification. Specifically, we propose that the preference for a conjunctive strengthening follows from a pragmatic preference for a complete answer to the Question Under Discussion.

Keywords Implicature · Exhaustivity · Alternatives · Free choice · Child development · Interpretation strategies · Ambiguity · Experiment

1 Introduction

1.1 The empirical challenge: children's conjunctive interpretation of disjunctive sentences

It is commonly assumed that children pass through a stage of development at which they know the meanings of logical operators but do not strengthen the basic meanings of sentences by computing scalar implicatures (e.g., Noveck 2001 and much work since). Consider the interpretation of sentences containing logical operators like *some* and *or*. An adult who understands *John ate some of the cookies* based on its basic (i.e., unstrengthened) meaning will conclude that the sentence is true if John ate one or more of the cookies. In a context in which John ate all of the cookies, the sentence is true under its basic meaning, but if the adult computes the sentence's scalar implicature (SI), that John did not eat all of the cookies, the sentence will be judged false. Similarly, the sentence *John ate cake or ice-cream* on its basic meaning is true as long as John ate at least one of cake or ice-cream. In a context in which John ate both cake and ice-cream, the sentence is true on its basic meaning, but if the adult computes the sentence's SI, that John did not eat both, the sentence is judged false.

Simplifying considerably for the moment, there are two steps in computing the implicature of a sentence S (e.g., Horn 1972, Gazdar 1979):

(1) Steps in implicature computation:

a. ALT (for 'alternatives'), which generates a set of alternative sentences, $ALT(S)$.

b. *STR* (for 'strengthen'), which strengthens the basic meaning of S by negating specific elements of $ALT(S)$ and conjoining the result with S.[1]

[1] That is, *STR* is sensitive to both the sentence and its alternatives: $STR(ALT(S), S) = S \bigwedge\{\neg S' : \text{for certain elements } S' \in ALT(S)\}$. We clarify our assumptions about ALT and the criteria for selecting the elements of $ALT(S)$ that get negated by *STR* in Sect. 4 and in the Appendix. We also put aside for now debates concerning whether *STR* is shorthand for domain-general principles of reasoning or is realized as a grammatical operator. We return to this question in later sections of the paper.

For example, suppose the uttered sentence is *John ate some of the cookies*, $\exists$. At step (1a), suppose that ALT in this particular case returns the singleton set {*John ate all of the cookies*} (= $\{\forall\}$).[2] At step (1b), *STR* negates $\forall$, and this is the scalar implicature of the sentence: that John did not eat all of the cookies. The overall strengthened meaning of the sentence is the conjunction of its basic meaning and its SI: that John ate some but not all of the cookies, $\exists \wedge \neg\forall$.

Now suppose the uttered sentence is *John ate cake or ice-cream*, $A \vee B$. Suppose for the moment that ALT returns {*John ate cake and ice-cream*}, $\{A \wedge B\}$ (we will revisit this assumption later in the paper). At step (1b), *STR* negates $A \wedge B$, and the SI is that John did not eat both cake and ice-cream. The strengthened meaning is thus that John ate cake or ice-cream but not both, $(A \vee B) \wedge \neg(A \wedge B)$; this of course is equivalent to an exclusive disjunction $A \veebar B$.

Evidence has been presented that preschool children do not compute SIs. For example, when presented with a picture or story in which John ate all of the cookies, a child – unlike the adult – will judge the sentence *John ate some of the cookies* to be true (e.g., Noveck 2001), and when presented with a picture or story in which John ate cake and ice-cream, a child – unlike the adult – will judge the sentence *John ate cake or ice-cream* to be true (e.g., Chierchia et al. 2001; Gualmini et al. 2001).

(2) Child vs. adult behavior:

State of affairs	Sentence	Adults	Children
$\forall$	$\exists$	F	T
$A \wedge B$	$A \vee B$	F	T

What (2) has been taken to show is that children pass through a stage of development at which they know the meanings of logical operators but do not compute scalar implicatures – they behave as if they are 'logicians' (cf. Noveck 2001).

(3) Common assumptions about the relevant developmental stage:
   a. *Basic semantics*: Children at this stage of development possess the adult meanings of logical operators.[3]
   b. *Strengthening*: Children at this stage of development do not compute scalar implicatures.

Note that the characterization in (3) leaves open whether the child's difficulties in (3b) are with ALT or *STR* or both (cf. (1)).[4]

[2] To reduce clutter, our notation will sometimes not distinguish between sentences and the propositions they denote; we hope no confusion arises.

[3] A further assumption that is often left implicit – but which is necessary to make sense of the child's 'logician'-type response patterns – is that children possess the adult principles of compositional semantics. These principles are used to compute the meanings of sentences based on the meanings of their primitive parts and their form. We will continue to share this presupposition, but we think it is worth noting explicitly that children appear to understand not just the meanings of logical words, but also the meanings of *sentences* in which logical words are contained, and this requires that children know how meanings compose.

[4] Certain contextual manipulations arguably facilitate SI computation in children (e.g., Papafragou and Musolino 2003; Barner et al. 2011, among others). We return to these in later sections of the paper and provide a way to make sense of this context dependence.

We present evidence that challenges this characterization of the relevant developmental stage. Specifically, we present evidence that many preschool children – the majority in our sample – understand disjunctive sentences like *The boy is holding an apple or a banana* as if they were conjunctions (that the boy is holding an apple and a banana). This finding is consistent with the earlier studies showing that a child will accept $A \vee B$ when both A and B are true; but our crucial finding, replicating a different set of previous results (e.g., Paris 1973; Braine and Rumain 1981; Chierchia et al. 2004), is that a child will *reject* $A \vee B$ when only one of the disjuncts is true. This is consistent with neither logician nor adult behaviour, but is instead suggestive of a conjunctive interpretation. In (4) below we provide a snapshot summary of children's and adults' deviance from inclusive disjunction interpretations of $A \vee B$, marking in boldface the 'extra' false judgments that each population gives. (In Sect. 2 we give a full report of our findings, as well as a more detailed description of Paris 1973; Braine and Rumain 1981; Chierchia et al. 2004.)

(4) Truth-value judgments for matrix disjunctions $A \vee B$ that deviate from inclusive disjunction:

State of affairs	Inclusive disjunction	Child	Adult
$\neg A \& \neg B$	F	F	F
$A \& \neg B$	T	**F**	T
$\neg A \& B$	T	**F**	T
$A \& B$	T	T	**F**

In fact, our data suggest that children generate conjunctive readings not only in matrix disjunctions, but also for disjunctions that are embedded under *every*. For example, we will see that many children understand *Every boy is holding an apple or a banana* to be asserting that every boy is holding both an apple and a banana.

The apparent conjunctive interpretation of disjunctive sentences found in previous studies has not received much attention. We wish to highlight these previous results, and to add our own findings to this set of studies. Taken together, these results have some general consequences for characterizing the relevant developmental stage. Specifically, they teach us that – whatever the explanation of the child's developmental stage – it cannot be one under which children are missing some capacity that in and of itself leads to rejection. For example, the assumption in (3) that children do not compute implicatures leads to the expectation that children will reject sentences in a subset of the conditions that adults reject, and in particular with disjunctions $A \vee B$ they will differ from adults only by not rejecting when both disjuncts are true. Counter to this expectation, children reject the disjunction when just one of the disjuncts is true, but adults accept it.

For similar reasons, other proposals that characterize the child as lacking some capacity that leads the adult to reject sentences will also be inadequate. For example, consider the assumption that children are 'pragmatically tolerant' (Katsos and Bishop 2011), that is, that children are less likely than adults to reject a sentence in a binary judgment task if the sentence is pragmatically inappropriate. This assumption does not predict the pattern of rejections in (4), for note that $A \vee B$ is an inappropriate description of both a scenario in which (the speaker knows that) one disjunct is true and one in which (the speaker knows that) both disjuncts are true (see also footnote 14). Nevertheless, the child rejects the disjunction in one of these conditions and the adult rejects in the other. In fact, we present evidence in Sect. 2 that many children reject sentences like *Every boy is holding an apple or a banana* even when, in the adult state, the sentence provides a true and otherwise pragmatically appropriate description. For example, consider a context in which two of three boys are holding just an apple and the third boy is holding just a banana; an example of such a context can be found in the picture in Fig. 1c in Sect. 2.2. In that context, the sentence *Every boy is holding an apple or a banana* is true whether or not the adult implicature is taken into account (that not every boy is holding an apple and not every boy is holding a banana; see (12) and footnote 19). Furthermore, the description is appropriate, and it is not obvious that there is any better way of describing Fig. 1c. Nevertheless, our results – described in Sects. 2 and 3 – show that children largely reject the sentence as a description of this picture. At the same time, they accept *Every boy is holding an apple or a banana* as a description of a picture in which every boy is holding both an apple and a banana (see Fig. 1d), even though this is clearly a bad description of the picture. Thus, for embedded disjunctions pragmatic tolerance predicts the opposite of what is observed. We are not here questioning the assumption that children are pragmatically tolerant (see also footnote 19); rather, we merely wish to point out that this assumption does not adequately describe children's behaviour for either matrix or embedded disjunctions, and in fact leaves it somewhat mysterious why children appear to reject disjunctive sentences precisely when a conjunctive interpretation of the sentence would make it false.

Paris (1973) and Braine and Rumain (1981) suggested that children at this stage of development might interpret $A \vee B$ by applying an ad hoc strategy that involves ignoring the operator and instead 'matching' disjuncts with parts of the picture. This assumption needs to be worked out, but we would like to argue that it is not necessary to account for the data, and most likely will turn out to be problematic given the observation that the child's deviant behaviour with *or* disappears in downward-entailing (DE) contexts;[5] in such contexts, there is evidence suggesting that preschool children understand *or* as inclusive disjunction, just like adults (e.g., Chierchia et al. 2001, 2004; Gualmini et al. 2001, 2003; Crain 2008; Crain and Khlentzos 2010; Crain et al. 2002; Goro et al. 2005; Gualmini and Crain 2002; Notley et al. 2012a).[6]

[5] Very roughly, DE contexts are environments that reverse entailment relations. The antecedent of *if*, the restrictor of *every*, and negation are examples of DE environments. For example, *Mary was born in Paris* entails *Mary was born in France*, but *Mary wasn't born in France* entails *Mary wasn't born in Paris*. Similarly, *Every one of these ten students who was born in France is here* entails *Every one of these ten students who was born in Paris is here*. Upward entailing (UE) contexts are contexts that preserve entailment relations. The nuclear scope of *every* is an example of an UE context: *Every one of these ten students was born in Paris* entails *Every one of these ten students was born in France*. Non-monotonic contexts are neither UE nor DE. For example, the nuclear scope of *exactly one* is such an environment: *exactly one of these ten students was born in Paris* neither entails, nor is entailed by, *exactly one of these ten students was born in France*.

[6] This result not only holds for English disjunctions embedded under a variety of DE operators, but it also holds across languages and language families (e.g., Chinese and Japanese). See Goro and Akiba (2004), Jing et al. (2005), Notley et al. (2012b), Su (2014), Su and Crain (2013), Su et al. (2012). Thanks to an anonymous reviewer for mentioning this point.

(5) Established empirical observation: DE contexts obliterate the difference between children and adults. In such contexts, children – like adults – understand disjunctive sentences as inclusive disjunction.

1.2 Outline

The goal of our paper is to give a detailed presentation of the data that give rise to the challenge described above, and to address the challenge by providing an explicit characterization of the relevant stage of development. Our proposal exploits the fact that implicature computation in the adult involves multiple steps (cf. ALT in (1a) and *STR* in (1b)), which raises the possibility that children might be missing just one of these steps. We will argue that the child generates a systematic subset of the adult alternatives but otherwise possesses all relevant adult capacities, including *STR*.

In Sect. 2 we present our experimental design and results, and relate our results to previous findings of a conjunctive interpretation in preschoolers. In Sect. 3, we present the results from each individual in our sample. We will see that individuals naturally clustered into various groupings based on their response profiles. However, we will argue that only some of these clusters can be made sense of with common assumptions. Specifically, we will see that the assumption in (3), together with the assumption that some of our children might have matured into the adult state, leaves most of our children unexplained. In Sect. 4 we give our own proposal, which we argue provides a better account of the data from Sect. 2 as well as of the clustering of individuals in Sect. 3. For readers not interested in the full details of our proposal but wishing to get a sense of the approach (or even an introduction to it), we will give a relatively non-technical summary of our account now, in Sect. 1.3. Readers who wish to skip this overview may jump ahead to Sect. 2.

1.3 Our proposal

1.3.1 Children compute implicatures

We propose that children's understanding of disjunctive sentences as conjunction in upward-entailing contexts and as inclusive disjunction in downward-entailing contexts is teaching us that this conjunctive interpretation is the result of a scalar implicature.[7] That is, the entries marked in boldface in (4) are due to strengthening by *STR*:

(6) Children and adults compute different scalar implicatures for $A \vee B$:
   a. The adult's SI denies $A \wedge B$.
   b. The child's SI denies both that just A and that just B.

[7] Implicatures are not computed for operators in DE contexts, at least not without marked accent (e.g., Geurts 2009; Fox and Spector 2015), because the logical strength of alternatives is reversed (see footnote 5). For example, the sentence *If the boy is holding an apple or a banana, the girl is holding a pear* is logically stronger than its alternative *If the boy is holding an apple and a banana, the girl is holding a pear*; thus, the sentence with the disjunctive antecedent can only be interpreted with its literal meaning.

If we are right, it is incorrect to characterize the child's developmental trajectory as one in which they transition from a 'logician' to the adult state, for here they *are* computing an implicature, one which just happens to be different from the one computed by adults. The divergence here is quite striking, for it leads children and adults to strengthen in opposite ways: adults conclude that $A \wedge B$ is false, while children conclude that $A \wedge B$ is true.

We will provide a precise characterization of the difference between the child and the adult that leads to this difference in implicatures. Specifically, we will argue that children at this stage of development share all the relevant adult capacities except for one specific parametric difference in alternatives:

(7) Our proposal about the relevant developmental stage [compare with (3)]:
   a. *Basic semantics*: The child possesses the adult meanings of logical operators (cf. footnote 3).
   b. *Strengthening*: The child possesses the adult capacity to compute scalar implicatures, *STR*.
   c. *Alternatives*: The child *does not* possess the adult alternatives. Specifically, the child does not access the lexicon in generating the alternatives of a sentence, and hence the child's alternatives are systematically a subset of the adult's alternatives.[8]

Our proposal in (7) explains why children in many instances appear not to compute any implicatures at all, and why in the case of disjunctions they do compute an implicature, but one that happens to be the opposite of what the adult computes. For example, in the adult, $\exists$ has the alternative $\forall$, generated by substituting *all* for *some*. Thus, $ALT_{Adult}(\exists) = \{\forall\}$, and *STR* ends up negating $\forall$, $\neg\forall$, resulting in a strengthened meaning $\exists \wedge \neg\forall$. However, because of (7c), children do not access the lexicon in generating alternatives, which in this case means that they cannot replace *some* by *all*. Thus, there is no alternative, and *STR* therefore has nothing to do. This explains the quantificational part of (2) (the first line): children say 'true' to $\exists$ when $\forall$ is true because there can be no implicature without an alternative to negate.

(8) Child–adult difference in implicatures for a sentence like $\exists$ (consequence of (7)):
   a. Adult:
      (i) $ALT_{Adult} = \{\forall\}$
      (ii) $STR(ALT_{Adult}, \exists) = \exists \wedge \neg\forall$
   b. Child:
      (i) $ALT_{Child} = \emptyset$
      (ii) $STR(ALT_{Child}, \exists) = \exists$

Note that for sentences like $\exists$, the proposals in (3) and (7) both predict that children will not strengthen $\exists$. However, they make strikingly different predictions for disjunctive sentences: (3) continues to predict no strengthening, so that only an inclusive disjunc-

[8] This assumption builds on Chierchia et al. (2001), Gualmini et al. (2001), Papafragou and Musolino (2003), Reinhart (2006), Crain (2008), and especially Barner and Bachrach (2010) and Barner et al. (2011).

tion reading is expected, whereas (7), when coupled with some theories of *STR* (Fox 2007, as well as Chemla 2009a; Franke 2011), predicts the possibility of a conjunctive strengthening.[9]

With disjunctions $A \vee B$, there are *two* mechanisms for generating alternatives in the adult. In addition to lexical replacements, there is also the possibility of deleting material to generate an alternative (Katzir 2007). These two mechanisms, when applied to $A \vee B$, operate as follows: (i) lexical replacements, in which *or* is replaced by *and*, yield the alternative $A \wedge B$; whereas (ii) deletion, which picks up subconstituents of the uttered sentence, yields the constituent disjuncts A, B as alternatives. Thus, $ALT_{Adult}(A \vee B) = \{A, B\} \cup \{A \wedge B\} = \{A, B, A \wedge B\}$. For reasons that we explain in detail in Sect. 4, when given this set of alternatives *STR* can only negate $A \wedge B$, resulting in the $\neg(A \wedge B)$ implicature found in the adult.

Under our proposal in (7), children cannot perform lexical replacements [cf. (7c)], so their alternatives are: $ALT_{Child}(A \vee B) = \{A, B\}$. As already noted, it turns out that under various characterizations of *STR* (Fox 2007; Chemla 2009a; Franke 2011), the application of *STR* to $A \vee B$ with these alternatives is *predicted* to result in a conjunctive strengthened meaning (see Sect. 4.2).[10] The possibility of a conjunctive strengthening of disjunction may seem somewhat exotic. However, we note that under our proposal, the conjunctive strengthened meaning follows from one of the parses of the sentence available to children, and parsing a sentence and computing its meaning are operations that are widely assumed to be available to children (e.g., Snedeker 2009 and see also footnote 3). Furthermore, conjunctive strengthenings of disjunctive sentences are familiar from the steady state attained by the adult. In particular, disjunctive permissions sentences like *You're allowed to eat cake or ice-cream* are strengthened in the adult to a conjunction, the so-called free choice inference 'You're allowed to eat cake and you're allowed to eat ice-cream' (e.g., Kamp 1973; Merin 1992). Free choice inferences have been argued to be scalar implicatures (e.g., Kratzer and Shimoyama 2002; Schulz 2005; Alonso-Ovalle 2005). As we discuss in more detail in Sect. 4, free choice inferences in the adult are possible because the alternatives of $\Diamond(A \vee B)$ are not closed under conjunction, and conjunctive strengthenings of $A \vee B$ in the adult are impossible because the alternatives of $A \vee B$ are closed under conjunction (Fox 2007; see also Chemla 2009a and Franke 2011). The generalization about the possibility of

[9] Note that this approach is consistent with the assumption that children are 'pragmatically tolerant' (Katsos and Bishop 2011; see Sect. 1.1). In an approach like Fox (2007), *STR* is identified with the application of a grammatical exhaustivity operator exh, essentially a covert variant of *only* (see Sect. 4). Thus, the capacity to strengthen is independent of quantity considerations; under this approach, the Maxim of Quantity (MQ) is active but – because it is sensitive to *everything* that's relevant, rather than a merely formally restricted subset of what's relevant as under the neo-Gricean variant – MQ only generates ignorance implicatures (see especially Fox 2007, 2014). Thus, even though children can only generate the unstrengthened meaning of $\exists$ (because $exh(\emptyset, \exists) = \exists$), it is conceivable that they can nevertheless detect that the utterance violates MQ when $\forall$ is true (MQ is insensitive to ALT, and therefore also to restrictions on ALT like the one in (7c)).

[10] To reduce clutter, we will sometimes talk as if *STR* is a one-place function that applies to a proposition and returns a (possibly) strengthened proposition. However, it should be kept in mind that *STR* takes two arguments (cf. footnote 1): a proposition p and a set of alternative propositions, $ALT(p)$. (Technically, ALT is a function from a sentence to a set of sentences, and propositions may be derived from these sentences; but as noted earlier (footnote 2), we will sometimes be sloppy about the sentence/proposition distinction when there is little chance of confusion.)

a conjunctive strengthening of a disjunctive sentence is stated in rough form in (9) (see (19) in Sect. 4.2 for a more careful statement):

(9) The closure of ALT under conjunction:

A conjunctive strengthening of a disjunctive sentence might be available when the alternatives of the sentence are not closed under conjunction (Fox 2007; see also Chemla 2009a and Franke 2011).

It follows from (9) that a population with $\{A, B\}$ as the alternatives to $A \vee B$ should be able to strengthen the disjunction to a conjunction in the same way that the adult derives free choice. We could test this prediction if we could find or create a population which has $\{A, B\}$ as the set of alternatives for $A \vee B$; our claim is that the child at this stage of development provides us with such a population.

(10) Child–adult difference in implicatures for a sentence like $A \vee B$ (consequence of (7) when *STR* is identified with the mechanism proposed in Fox 2007, Chemla 2009a, or Franke 2011):

a. Adult:
   (i) $ALT_{Adult} = \{A, B, A \wedge B\}$
   (ii) $STR(ALT_{Adult}, A \vee B)$ entails $\neg(A \wedge B)$

b. Child:
   (i) $ALT_{Child} = \{A, B\}$
   (ii) $STR(ALT_{Child}, A \vee B)$ entails $A \wedge B$

If the characterization in (10) is correct, English-speaking children at this stage of development are merely one among several populations that realize the underlying cognitive state of having an ALT which returns $\{A, B\}$ when given $A \vee B$ as input; for such populations $A \vee B$ is ambiguous between an inclusive disjunction (basic meaning) and a conjunction (strengthened meaning). As we discuss in later sections of the paper, there is recent evidence that children across languages and language families interpret disjunctions as conjunctions: relevant data have come from Mandarin-speaking children (Tieu et al. 2016), as well as Japanese-speaking and French-speaking children (Tieu et al. 2015). Furthermore, adult interpretations of disjunctive sentences in Warlpiri and American Sign Language seem to be quite similar in crucial respects: these languages have been characterized as having a single binary connective which denotes inclusive disjunction, but sentences containing this connective allow for a conjunctive interpretation (Bowler 2014; Davidson 2013; see Sect. 5 below). The possibility of a conjunctive interpretation is expected under (9) because in such languages $ALT(A \vee B) = \{A, B\}$: there is no conjunctive connective in the language and thus no sentence $A \wedge B$ that could serve as an alternative to $A \vee B$.[11] Our proposal unifies all these populations under the prediction that *any* population that lacks a conjunctive

[11] See also Meyer (2015) for adult data from other disjunctive constructions in English that support (9). The sentences of interest to Meyer (2015) are interpreted conjunctively; this is so, she argues, because the conjunctive alternative is ill-formed and thus not a real alternative. In the domain of quantification, there are arguments quite similar to the one we propose here that some apparently universal readings follow from strengthening of an existential (Spector 2007; Levin and Margulis 2013; Magri 2014).

alternative but is otherwise like the English adult will allow a conjunctive interpretation of disjunctive sentences.

We note that, under our proposal, no new cognitive machinery is needed to account for the child other than what is already needed to account for the adult: the child – like the adult – has an inclusive lexical entry for *or*; the child – like the adult – has *STR*; and the child has a specific subset of the adult alternatives, namely those that do not involve lexical access. Other than this difference in alternatives, we assume that the child's competence is the same as the adult's in all relevant respects (e.g., prohibition of *STR* in DE environments). In particular, children and adults are both expected under (9) to derive conjunctive readings for disjunctive sentences when the disjuncts are alternatives but their conjunction isn't. Crucially, the prediction in (9) follows only for some theories of *STR* (Fox 2007; Chemla 2009a; Franke 2011). Various competing proposals about *STR* would not derive a conjunctive reading for $A \vee B$ with the alternatives $\{A, B\}$. For example, Sauerland's (2004) neo-Gricean proposal would only generate inferences that the speaker is ignorant about the truth value of each disjunct (see footnote 14), and 'minimal-worlds' approaches to exhaustivity (e.g., Spector 2005; van Rooij and Schulz 2004; Schulz and van Rooij 2006) would predict an exclusive-disjunction reading instead of a conjunctive one (see Spector 2015 for illuminating discussion). Furthermore, only Fox (2007) predicts the possibility of *embedded* conjunctive strengthenings in children and *embedded* free choice in the adult; our results lend support to this prediction (see also Chemla 2009b for results in the adult, as well as footnotes 39 and 40).

1.3.2 Preferences in interpretation: Exhaustivity and Questions Under Discussion

We assume with Crain and Wexler (1999) that the child's performance systems are similar to the adult's in relevant respects. This assumption will help us make sense of evidence we present that there is a tendency for children to disambiguate in favor of the conjunctive reading. That is, they prefer to understand disjunctions $A \vee B$ as strengthened, $STR(A \vee B)$. However, there does not seem to be any evidence that there is a general preference in the adult or the child to understand an arbitrary sentence as strengthened.[12] Clearly, something needs to be said about why a preference for *STR* is only sometimes attested.

It turns out that there are clear parallels in the adult state that might allow us to resolve this tension. Specifically, adults have been found to prefer free choice inferences (Chemla and Bott 2014), even when the relevant sentences are embedded under *every* (Chemla 2009b). For example, adults prefer to understand *Every boy is allowed to eat cake or ice-cream* as asserting that every boy has free choice. Recall that under our proposal, the child's conjunctive strengthening and the adult's free choice inference are both the result of applying *STR* to a disjunctive sentence. Thus, it

[12] We put aside for now arguments that sentences are always exhaustified (Magri 2009, 2011). Magri's view shifts optionality in parsing to optionality in the pruning of alternatives. Thus, questions about structural preferences would be reformulated in his system as questions about preferences in domain restriction. See Crnič et al. (2015) for relevant discussion.

seems that *STR* is preferred when it can turn a disjunctive statement into a conjunctive one. The challenge, then, is to account for why these conjunctive strengthenings of disjunctive sentences are preferred in a way that standard 'some but not all' or 'A or B but not both' type strengthenings are not (see also Chemla and Singh 2014a, b).

We tentatively follow Gualmini et al. (2008) and suggest (Sect. 4.3) that this preference for conjunctive SIs – active in the child and the adult – might follow from a general preference to provide a *complete answer* to the Question Under Discussion (QUD) (Groenendijk and Stokhof 1984; Lewis 1988; Roberts 1996). For example, consider the (possibly implicit) question 'Which of John and Mary, if any, came to the party'? In the adult state, the strengthened meaning of the answer *John or Mary came to the party* would convey that exactly one of them came to the party, but would leave open whether it was just John or just Mary that came. Thus, the question remains unresolved even when *STR* is applied. In the child, however, the strengthened reading of the answer is that John and Mary both came to the party – a complete answer to the question. For expository purposes, in Sect. 4.3 we implement our proposal about parsing preferences in an Optimality-Theoretic constraint system; the resulting system correctly demarcates those SIs that end up dispreferred and costly (partial answers) from those that end up preferred and computed fast (complete answers).

2 Experiment

2.1 Motivation: previous findings of conjunctive interpretations of disjunction in children

There is a fair amount of evidence that children understand *or* as inclusive disjunction in downward-entailing (DE) contexts (e.g., Chierchia et al. 2001; Gualmini et al. 2001; Chierchia et al. 2004; Crain 2008; Crain and Khlentzos 2010). There also seems to be evidence that children understand *or* as conjunction in matrix disjunctions. Here we briefly summarize the experimental results that show this latter tendency. Our own experiment, discussed in Sect. 2.2, was designed to examine whether these results are replicable and whether they would be affected by embedding in upward-monotone environments.

The first report of a conjunctive interpretation that we know of is in Paris (1973). Second-graders were shown a slide presentation and given a verbal description (e.g., "The bird is in the nest or the shoe is on the foot"), and they were asked to decide whether the verbal description was true or false. Paris (1973) found that when A and B were both true, participants responded 'true' to $A \vee B$ almost 98 % of the time, and when A, B were both false, participants responded 'false' to $A \vee B$ roughly 98 % of the time. This is consistent with an inclusive disjunction. However, when only one of A, B was true, participants responded 'true' to $A \vee B$ only around 30 % of the time (see Table 3 in Paris 1973, p. 285). While one could imagine a variety of explanations for this latter result, we would like to note that it is expected if roughly 70 % of responses were based on a conjunctive interpretation and the rest were based on an inclusive disjunction interpretation.

Another study showing an apparent conjunctive interpretation is Braine and Rumain (1981). Here the methodology was slightly different: children (5–6 year-olds) were shown boxes with toys in them, and a puppet made a statement about the scene (e.g., "Either there's a horse or there's a duck in the box"). The child was asked to say whether the puppet was right. Again, as with the Paris (1973) study, participants mostly responded 'right' to $A \vee B$ when both A, B were true, and 'false' to $A \vee B$ when both disjuncts were false: around 95 % of participants displayed this behaviour. However, when only one disjunct was true, only 18 % of participants responded 'true' (see Table 3 in Braine and Rumain 1981, p. 58). This result is expected if most of the participants interpret $A \vee B$ as something other than inclusive disjunction. Of this majority, 32 % clearly gave a pattern of responses consistent with conjunction, and the others had a complex mix of 'true', 'false', and 'partly right' responses to these so-called 'mixed truth forms.' Although it is not clear how to interpret the 'partly right' response, we can take this pattern of behavior to argue that a considerable number of the children in Braine and Rumain (1981) understood $A \vee B$ as conjunction.[13]

More recently, Chierchia et al. (2004) presented children with a story together with a disjunctive statement $A \vee B$ describing the story. When A, B were both true, children accepted $A \vee B$ 95 % of the time, but when only one of A, B was true, they accepted $A \vee B$ only 78 % of the time. This result would be expected if roughly 17 % of responses were based on a conjunctive understanding of $A \vee B$.

What we have, then, is three different studies – using different methodologies and different sets of children – that found more rejections of a disjunction when just one disjunct is true than when both disjuncts are true. This makes sense if a conjunctive interpretation of disjunction is available to many of these children, but is somewhat mysterious otherwise.[14]

Conjunctive interpretations have also been found in imperative contexts. Children have sometimes been found to understand sentences like *Give me A or B!* as 'Give me

[13] We will propose that children derive a conjunctive reading with a scalar implicature that 'not just A' and 'not just B;' the 'partly-right' response might thus be reporting the view that the sentence is true on its basic meaning but false if its SI is taken into account. See also footnote 9.

[14] It is well known that, for the adult, disjunctions $A \vee B$ typically lead to the inference that the speaker is ignorant about the truth value of each disjunct (e.g., Gazdar 1979; Sauerland 2004; Fox 2007; Chemla 2009a). As emphasized to us by Jesse Snedeker (p.c.), the adults in Paris's (1973) study rejected $A \vee B$ when just one disjunct was true and when both were true at roughly the same relatively high rate, around 25 %. Older children (grades 5 and 8) also had relatively high rejection rates when just one disjunct was true and when both were true. Many of these rejections might be due to misleading ignorance inferences. One might thus try to explain the second-grade children's rejection of $A \vee B$ when just one disjunct is true as the result of an implausible ignorance inference. This seems unlikely to us, because it would not explain why children accept the disjunction when both disjuncts are true. Furthermore, as we will see, this line of explanation would not account for the conjunctive readings of disjunction under *every* that children produced in our experiment; in such embeddings ignorance implicatures are not computed (e.g., Sauerland 2004; Fox 2007). Embedding under 'every' also controls for other possible strategies, such as rejection when there is an object in the picture which does not get acted on (thanks to a reviewer for stressing this point). For example, suppose that there are three boys, and that two of them are holding one banana each and the third boy is holding an apple. Then *Every boy is holding an apple or a banana* is felicitous, and there is no object that is not participating in the 'hold' relation (see our 'Every-One' condition in Sect. 2.2).

A and B' (Neimark and Slotnick 1970; Suppes and Feldman 1971).[15] However, this result is not as robust as for matrix disjunctions (Johansson and Sjolin 1975; Hatano and Suga 1977). This is not very surprising if the conjunctive interpretation is the result of a scalar implicature. Note that in the adult state, *Give me some of the cookies!* is a demand to give the speaker some of the cookies, with a global implicature that the hearer is not required to give the speaker all of the cookies. However, the sentence is not readily interpreted as a demand to give the speaker some but not all of the cookies. Thus, embedded implicatures seem to be dispreferred in imperatives. Most importantly, embedded free choice inferences seem to be dispreferred as well under imperatives. For example, *Make sure that they're allowed to eat cake or ice-cream!* is not to our ears preferably interpreted as a command that the referent of 'they' have free choice (likewise for the imperative *Allow them to have cake or ice-cream!*). The observation that children who otherwise have a conjunctive reading of disjunctions get it less robustly in imperatives might thus follow from whatever it is that disprefers embedded implicatures under imperatives. In fact, this dispreference follows from our QUD-based approach to parsing preferences (see Sects. 1.3.2 and 4.3), for note that a non-conjunctive disjunction can be a reasonable, complete answer to a question like 'What are we required to do?' For example, matrix exhaustification of "We're required to read *Syntactic Structures* or *Aspects*" – which entails that we're not required to read *Syntactic Structures* and we're not required to read *Aspects* – is no worse as an answer than the proposition that we're required to read both *Syntactic Structures and Aspects*. For this reason, we think imperatives are not the ideal environment in which to look for a conjunctive strengthening.[16]

Taken together, the results suggest the following picture. Assuming that interpretations in DE contexts reveal literal meanings that are guarded from implicatures, the child can be assumed to know that *or* denotes inclusive disjunction. In matrix disjunctions many children seem to be strengthening the basic inclusive disjunction meaning to a conjunction. This strengthening might also be available, though not very robust, in imperative contexts.

This background guided the design of our own study. We were specifically interested in children's truth value judgments for matrix disjunctions when at least one of the disjuncts is true, for this is precisely where children and adults seem to differ. Furthermore, we embedded disjunctions under *every* to examine the robustness of children's apparent conjunctive interpretations. First, embedding under *every* would

[15] Other studies from that period also identified particular problems with disjunction, but it is hard to discern whether the difficulty was due to a conjunctive inference (e.g., Furth et al. 1970; Sternberg 1979). As far as we know, the possibility of a conjunctive inference was not taken very seriously in the literature. For example, Sternberg (1979) cites and discusses the Paris (1973) study, but nevertheless assumes that children's developmental trajectory takes them from a stage at which they understand *or* as inclusive disjunction to one in which they understand it as exclusive disjunction.

[16] Jesse Snedeker (p.c.) suggests that the experimental *task* might be relevant to how robust the conjunctive reading is: truth value judgment tasks seem to facilitate the conjunctive interpretation, whereas action tasks do not. As noted, the QUD-based approach explains the contrast, and it is unclear whether anything else about the task is relevant. Christine Bartels (p.c.) notes that speaker and hearer interests might also be relevant to how imperatives/permission sentences get interpreted; this might provide another incentive to use other quantificational environments to investigate the possibility of conjunctive readings of disjunctive sentences. We thank both Jesse Snedeker and Christine Bartels for very helpful discussion.

overcome the problem with imperatives: in this environment, the basic unstrengthened meaning of a sentence like *Every boy is holding an apple or a banana* would not provide a complete answer to a question like ‘What is each boy holding?’, but a conjunctive strengthening – if available – would settle the question. Second, and relatedly (as we discuss in Sect. 4.3), if the parallel between adult free choice and children’s conjunctive interpretations is correct, we would expect the embedded disjunction to be strengthened to conjunction in children, given that adults readily compute free choice meanings under *every* (Chemla 2009b). Finally, embedding under *every* might help control for various artificial strategies that might conceivably be applied to matrix disjunctions (see footnote 14).

2.2 Materials and methods

Participants for the present study were 63 preschool-aged children from the Ottawa area. 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 native-English speaking children (36 girls, 23 boys) 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 in a quiet area in their 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 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); similar tasks have been used in studies of children’s understanding of disjunction (e.g., Paris 1973; Braine and Rumain 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 our 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. We used pictures instead of stories to reduce the amount of time spent on each trial, so that more data points could be collected. We also assumed that a picture would impose fewer demands on a child’s memory than a story.[17]

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

[17] A reviewer points out that the decision to use pictures rather than stories has potentially negative consequences, such as loss of control over relevant contextual features like what participants take the Question Under Discussion to be. We agree that it would be best if our results could be replicated under various methodologies. But note that Tieu et al. (2015) performed a study that more closely followed the story-based truth value judgment task (in prediction mode), and found results similar to ours.

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: "Was Fuzzy right or wrong about this 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 had said the right thing or the wrong thing. They completed two more practice trials, involving 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 on to the test trials. All children, including those who did not ultimately finish the task, were able to respond correctly 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: "Was Fuzzy right or wrong about this 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 Fig. 1a), 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 Fig. 1b). In both conditions 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 Fig. 1c), 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 Fig. 1d). In both Conditions 3 and 4, 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), participants were presented with the same pictures as in Conditions 1–4, but now Fuzzy made an *and*-statement instead of an *or*-statement. 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 under-

(a) One **(b)** Both **(c)** Every-One **(d)**Every-Both

Fig. 1 Sample of pictures for critical items stood the task and were paying attention to the questions being asked. Prior to running the experiment, we had decided to exclude participants from analysis who did not perform significantly above chance on these conjunctive controls. This stringent criterion required getting at least 16/20 correct responses on the items in Conditions 5 through 8 ($p = .044$). After we excluded participants who failed this criterion, 31 of the 56 child participants remained (23 girls, 8 boys). However, our main findings do not change if we include the whole sample (see footnote 21 in Sect. 2.4 below).[18] The children in the remaining sample ranged in age from 3 years 9 months to 6 years 4 months, $M = 4;11$.

The task had five trials for each of the eight conditions. In addition to the boys with apples and/or bananas, we also showed children pictures of monkeys with flowers and/or books, trucks with pigs and/or tigers, horses with birds and/or crabs, and men with forks and/or spoons. There were three fixed orders of the task, and each fixed order was determined by randomizing the presentation of the trials. 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 on the conjunctive control).

2.3 Basic predictions of commonly assumed developmental trajectory

Recall from (3) that under the commonly assumed developmental trajectory, children at this stage (i) possess the meanings of logical operators in the steady state, and (ii) unlike adults, do not compute implicatures. Thus, children at the relevant stage of development are expected to only access reading (11a), whereas anyone who has matured into the steady state might access either of (11a) or (11b).

[18] We noticed several patterns among the group of participants 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 25 excluded subjects said 'true' to Conditions 5 and 7 on at least eight 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 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; for more recent discussion, see e.g. Philip 1995; Crain et al. 1996; Drozd and van Loosbroek 1998; Geurts 2003; Gualmini et al. 2003), 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.

(11) Readings of *A or B*:

a. Logician reading: $A \vee B$ (inclusive disjunction)

b. Strengthened reading: Logician reading + SI = $(A \vee B) \wedge \neg(A \wedge B)$ (exclusive disjunction)

Now consider a disjunction embedded under *every*, as in (12). Under the developmental assumption in (3), children will be expected to access only the reading in (12a), whereas adults will be expected to access either (12a) or (12b), with the choice between the two dependent on whether they choose to compute an SI.[19]

(12) Readings of *Every X is A or B*:

a. Logician reading: $[\forall y : Xy][Ay \vee By]$

b. Strengthened reading: Logician reading + SI
$= [\forall y : Xy][Ay \vee By] \wedge \neg[\forall y : Xy][Ay] \wedge \neg[\forall y : Xy][By]$ ('Every X is A or B and not every X is A and not every X is B')

Children will thus be expected to accept the disjunctive sentences in all four of our critical conditions, because the sentence on its logician reading is true in all of these conditions. The adult – because of the possibility for computing SIs – might sometimes reject 'Both' and 'Every-Both' but will have no reading which would warrant rejection of 'One' or 'Every-One.' Thus, assuming that our sample included both children at the relevant stage of development as well as some who had matured into the adult state, the following prediction is made, under the assumption that participants' acceptances/rejections of test sentences track their truth value judgments:

(13) Basic prediction of commonly assumed child and adult strategies:

Participants are expected to have at least as many acceptances on 'One' as on 'Both,' and participants are expected to have at least as many acceptances on 'Every-One' as on 'Every-Both.'[20]

[19] We ignore embedded implicatures for the moment; the reading 'Every X is an ((A or B) and not both)' would give the same truth values as (12b) in both the 'Every-One' and the 'Every-Both' condition. Another issue we put aside for the moment is whether the SI in (12b) is even available in the adult state. There is experimental evidence that the reading is not available, and that the distributive inference that some X is an A and some X is a B is derived through a different parse of the sentence (Crnič et al. 2015). See footnote 41 in Sect. 4.2 below. So far as we can tell, nothing crucial in our work hinges on the specific nature of strengthening associated with (12).

[20] Rejecting a sentence if it is pragmatically odd might provide an additional route to 'false' judgments, but the availability of this strategy does not change the basic prediction in (13), for note that the disjunctive test sentences are odd on 'One', on 'Both', and on 'Every-Both'. We discuss this in greater detail when we turn to individual behaviour in Sect. 3.

2.4 Results

Our results suggest that children behave neither like logicians nor like adults: Table 1 shows that children accepted 'One' and 'Every-One' *less* than they accepted 'Both' and 'Every-Both.'[21]

Indeed, a repeated-measures ANOVA showed that the within-subjects factor Condition was significant, $F(1.58, 47.39) = 10.92$, $p < .001$.[22] Of particular note are the following significant pairwise differences (all $ps < .01$, with Bonferroni corrections for multiple comparisons): (i) 'One' was accepted less than 'Both': M(One)$-M$(Both) $= -2.032$ (95 % CI of difference = [−3.51, −.55]); (ii) 'One' was accepted less than 'Every-Both': M(One)$-M$(Every-Both) $= -2$ (95 % CI of difference = [−3.5, −.5]); (iii) 'Every-One' was accepted less than 'Every-Both': M(Every-One)$-M$(Every-Both) $= -1.45$ (95 % CI of difference = [−2.84, −.06]); (iv) 'Every-One' was accepted less than 'Both': M(Every-One)$-M$(Both) $= -.148$ (95 % CI of difference = [−2.88, −.09]).

The participants who rejected 'One' and 'Every-One' did so systematically: 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 were somewhat surprised to find no correlations between age and behaviour in any of the four main conditions.

Furthermore, rejections of 'One' and 'Every-One' are not the result of a handful of outliers. For each condition, recall that each of the 31 participants received a score out of 5 based on the number of items they accepted per condition. We ranked the 31 scores on each condition from highest to lowest and identified (i) the median score, *MED*, which splits the measurements in half (this is the score at rank 16); (ii) the first quartile, Q_1, which is the data point above which three-quarters of the measurements are ranked and below which one-quarter of the results are ranked (this is the score at

Table 1 Children's mean number of 'Fuzzy was right' responses (out of 5 items) for the test conditions (95 % confidence interval, $n = 31$)

Condition	$M(SD)$	95 % CI
One	1.77(1.89)	[1.08, 2.46]
Both	3.81(1.92)	[3.51, 4.51]
Every-One	2.32(1.80)	[1.66, 2.98]
Every-Both	3.77(1.84)	[3.10, 4.44]

[21] The results are similar when the whole sample of 56 children is included. The scores (reported as $M(SD)$) for the entire sample on each condition are: (i) 'One': 2.45(1.94), (ii) 'Both': 3.80(1.91), (iii) 'Every-One': 2.93(1.82), (iv) 'Every-Both': 3.91(1.67).

[22] We violated the assumption of sphericity ($p < .001$), but we corrected for this using the Huynh-Feldt correction. Roughly speaking, sphericity assumes that there is no subject-by-factor interaction – that is, that participants' relative standing does not change much across the conditions. As we will see in Sect. 4, there were individual differences in interpretive strategies; this might in part be responsible for the deviation from sphericity, since different individuals react differently to the different conditions.

rank 24); and (iii) the third quartile, Q_3, which is the data point above which one-quarter of the measurements are ranked and below which three-quarters of the results are ranked (this is the score at rank 8). The measurements bounded by Q_1 and Q_3 contain the ‘middle-fifty’ percent of responses, and are thus less likely to contain extreme values. *MED* locates the central value in each condition, and the difference $Q_1 - Q_3$, the *Interquartile Range* (IQR), gives a measure of the spread of data on each condition (see e.g. Mosteller et al. 1983).

The boxplot in Fig. 2 displays the values Q_1, *MED*, Q_3 on each condition. The median score on each condition is marked with boldface (only two values are visible on ‘Both’ and ‘Every-Both’ because in these cases $MED = Q_3 = 5$).[23]

There are a few things the boxplot reveals. First, the bulk of participants in Condition ‘One’ had lower scores than those in ‘Both’. In particular, the median score for ‘One’ was 1 and the median score for ‘Both’ was 5. Similar contrasts are evident between ‘Every-One’ and ‘Every-Both’ (the median score for ‘Every-One’ was 2 and the median score for ‘Every-Both’ was 5). Note also that there is more spread in the responses in ‘One’, ‘Every-One’ than in ‘Both’, ‘Every-Both’: $Q_3 - Q_1 = 3$ on ‘One’ and ‘Every-One,’ but $Q_3 - Q_1 = 1$ on ‘Both’ and $Q_3 - Q_1 = 2$ on ‘Every-Both.’ We will return to individual response patterns in greater detail in Sect. 3, where we suggest ways of making sense of this pattern. For now, the important point is that these results are totally unexpected if the child differs from the adult only by not computing the strengthened meanings that adults compute in (11b) and (12b).

Turning to our adults, we see in Table 2 that their behaviour was consistent with expectations (recall that adults are characterized as having either a ‘logician’ reading or a strengthened reading; see (11) and (12)).

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 (note that there is overlap in the CIs). The most

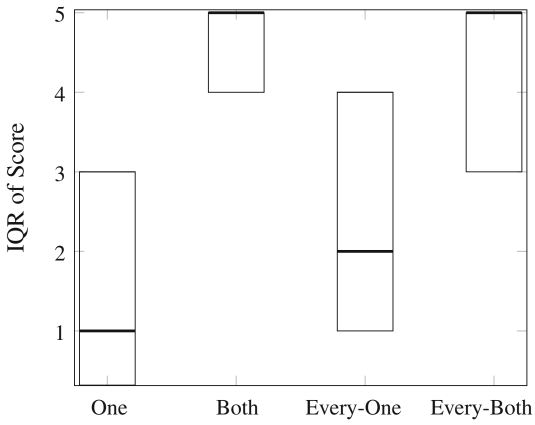


Fig. 2 Boxplot of interquartile range of children’s scores on each condition (the median score on each condition is marked with boldface)

[23] The min score on each condition was 0, and the max score on each condition was 5, so we leave that information out of the plot, and show only Q_1, *MED*, and Q_3.

Table 2 Adults' mean number of 'Fuzzy was right' responses (out of 5 items) for the test conditions (95 % confidence interval, n = 26)

Condition	$M(SD)$	95 % CI
One	3.73(1.80)	[3.00, 4.46]
Both	3.35(2.04)	[2.53, 4.17]
Every-One	4.23(1.42)	[3.66, 4.80]
Every-Both	3.69(1.95)	[2.90, 4.48]

likely explanation is that the subjects in our sample largely resisted computing SIs.[24] Fifteen of our participants accepted each condition most of the time. Of these fifteen participants, eight participants always responded 'true' on each of the five items of the four conditions (20 out of 20 trials), two participants responded 'true' all but once (19 out of 20 trials), three participants responded 'true' all but twice (18 out of 20 trials), one participant responded 'true' on 17 out of 20 trials, and one participant responded 'true' on 16 out of 20 trials. There were only seven participants who behaved as if they often computed SIs (i.e., who rejected 'Both' and 'Every-Both' at least five out of ten times while accepting 'One' and 'Every-One' most of the time).[25]

When we compare the 31 children to the 26 adults in our sample, we find that their scores differ significantly on 'One' and on 'Every-One', but do not differ on 'Both' or on 'Every-Both'; see Fig. 3 below.

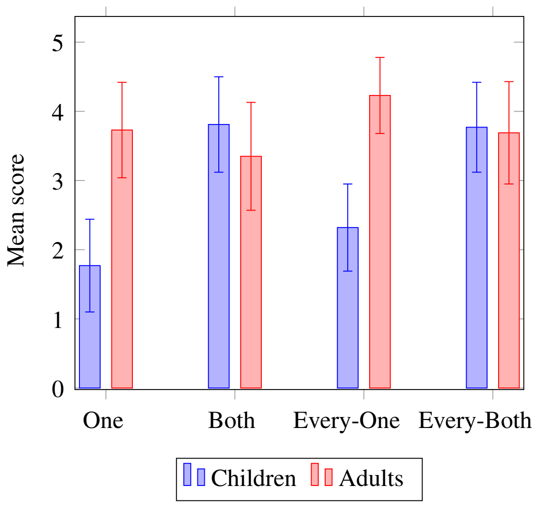


Fig. 3 Comparing children's (n = 31) and adult (n = 26) mean scores on critical conditions (error bars indicate 95 % confidence intervals)

[24] Some of the adults in our sample might have resisted computing implicatures because they were told that their responses would be compared with those of children. We suspect that this may have led them to overthink the question and become more risk-averse than they otherwise might have been (many of our adults hesitated before responding; unfortunately, we did not record these systematically). Thanks to a reviewer for raising the question of our adults' performance.

[25] The remaining four participants had no obviously discernible pattern to their responses. These participants may have used a combination of strategies; note that the quantified sentences are potentially many-ways ambiguous (cf. footnotes 39 and 41).

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 either. However, the significant difference between children and adults on 'One' and on 'Every-One' cannot be explained by these assumptions; for there is no obvious rationale for why children should respond 'false' on these conditions as much as they do.

3 Interpretive strategies and individual behaviour

It is clear that the children in our study, presumably like the children in previous studies (e.g., Paris 1973; Braine and Rumain 1981; Chierchia et al. 2004), are employing some interpretative strategies to disjunctions in upward-entailing contexts that deviate from the 'logician' strategy. The goal of this section is to try to illuminate these strategies by examining participants' *individual* behavior and relating this behavior to interpretation strategies that have prior motivation.

As we discussed in Sect. 1.1, two other plausible strategies with independent motivation include rejecting a sentence when it is pragmatically odd – say, because it generates misleading ignorance inferences – and rejecting a sentence when its strengthened meaning is false.[26] There are interesting differences between these strategies that we will soon discuss, but for current purposes we would like to recall from (13) in Sect. 2.3 a prediction they share in common with the 'logician' strategy: participants are expected to have at least as many acceptances on 'One' as on 'Both,' and participants are expected to have at least as many acceptances on 'Every-One' as on 'Every-Both.'[27] Call a subject that satisfies this prediction an 'expected' participant, and call a subject that does not satisfy this prediction an 'unexpected' participant. In our sample, only 10 of 31 participants (roughly 32 %) are 'expected.' A 95 % confidence interval extends this from 17 to 51 % (Clopper-Pearson Exact CI for binomial proportions). Under this model, then, even in the best-case scenario a large proportion of preschoolers would not be accounted for. Something is amiss.

3.1 Predicting clusters from commonly assumed strategies

Our main goal is to argue that the bulk of the participants in our sample came up with conjunctive readings of the critical disjunctive sentences. We also hope to argue that the conjunctive reading is expected when our proposal in (7) is assumed along with some current theories of strengthening (Fox 2007; Chemla 2009a; Franke 2011). In this section, we cluster individuals together based on their response profiles, and we relate these profiles to idealized profiles motivated by independent considerations. For the moment, we will assume that the correct characterization of children's developmental stage is not the one we propose in (7), but rather the commonly assumed one that

26 See Katsos and Bishop (2011) and Chemla and Singh (2014a, b) for discussion of some of the challenges of dissociating these strategies in experimental settings. See also footnotes 9, 14, and 28.

27 Note that the basic meaning of the sentence is true in all four conditions and that, in the adult state, the critical test sentences are odd on 'One', 'Both', and 'Every-Both'; the adult strengthened meanings (11b) and (12b) are false on 'Both' and 'Every-Both'.

posits that children do not strengthen (see (3)). In addition, we assume that some of the participants in our sample had already matured into the adult state, and thus might have been pragmatically intolerant (rejecting when the sentence is odd) or rejected the sentence when its strengthened meaning was false. We have already noted that these strategies explain the individual behaviour of only a small number of our subjects – at best the ten participants we just mentioned above. We will identify the response profiles of these ten participants, and we will then (Sect. 3.2) try to make sense of the remaining twenty-one participants.

Participants had five chances to say ‘true’ or ‘false’ on each of four conditions (‘One’, ‘Both’, ‘Every-One’, ‘Every-Both’). Suppose – as an idealization motivated by previous results (e.g., Noveck and Posada 2003; Guasti et al. 2005; Katsos and Bishop 2011) – that subjects are consistent in the interpretation strategy they pursue (e.g., whether or not they strengthen the meaning by *STR*, and similarly for other relevant choices). Then a ‘logician’ is expected to always say ‘true’ on each condition, (5,5,5,5). In our sample of 31 children, we found four participants who behaved like ‘logicians’; their profiles are displayed in Table 3.

An ‘adult strengthener’ is expected to always say ‘true’ to ‘One’ and ‘Every-One’ and to always say ‘false’ to ‘Both’ and ‘Every-Both,’ (5,0,5,0). We found four participants who might be ‘adult strengtheners’. Their profiles are displayed in Table 4.

Finally, an ‘oddness-based’ strategy would accept a sentence if it is both true and felicitous and reject it otherwise (e.g., Katsos and Bishop 2011; Clark and Amaral 2010). Thus, taking adult judgments as representative, *The boy is holding an apple or a banana* is odd in both ‘One’ and ‘Both,’ and *Every boy is holding an apple or a banana* is odd in ‘Every-Both’ but not in ‘Every-One’. Perhaps this pattern of oddness is rooted in the fact that the disjunctive sentence leads to misleading inferences

Table 3 ‘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
Mean	**5**	**4.5**	**4.75**	**4.25**

Table 4 ‘Adult strengtheners’ [predicted: (5,0,5,0)]

ID Number	One	Both	Every-One	Every-Both
7	4	0	2	0
15	3	2	3	2
57	3	0	3	0
60	5	0	5	0
Mean	**3.75**	**0.5**	**3.25**	**0.5**

in 'One', 'Both', and 'Every-Both', but not in 'Every-One'.[28] Under a strategy that penalizes oddness, then, the expected profile is (0,0,5,0). We found two participants that could perhaps be viewed as approximating this strategy; their profiles are shown in Table 5.[29]

The strategies outlined here account for at most 10 of 31 participants: 4 'logicians', 4 'adult strengtheners', and 2 who penalize oddness. Even if we assume the classification in Tables 3, 4, and 5 to be reasonable, we are still left with 21 out of 31 subjects who resist classification under common assumptions.

3.2 Conjunctive readings through strengthening

Suppose we admit the possibility that some children have a strategy at hand that allows them to interpret disjunctive sentences conjunctively. Indeed, participants' justifications for their rejection of $A \vee B$ when just one disjunct was true (A, say) systematically indicated a conjunctive interpretation. We collected 45 such justifications from participants at the end of the experiment, and after excluding uninformative responses (e.g., "because Fuzzy [the puppet] was wrong"), 23 responses were of the form "because only/just A", 10 were of the form "because not B", and 5 were of the form "because A" (where A seemed to mean 'A and not B'). These justifications make sense if these children are interpreting the disjunctive test sentences conjunctively.

For reasons that will become clear in the next section, call the group of participants generating a conjunctive reading 'Child Free Choice' (CFC). The predicted profile of CFC subjects is (0,5,0,5). The CFC strategy allows 16 of the remaining 21 participants to be classified as 'signal' rather than 'noise'; the response profiles of these CFC participants are displayed in Table 6.

We expect that an analysis of individual behavior would reveal CFC groups in Paris (1973), Braine and Rumain (1981), and Chierchia et al. (2004). Indeed, a recent study of French and Japanese preschool children found CFC profiles for both simple and

Table 5 'Oddness-based' [predicted: (0,0,5,0)]

ID Number	One	Both	Every-One	Every-Both
12	0	0	1	0
51	0	0	3	0
Mean	**0**	**0**	**2**	**0**

[28] The sentence with matrix disjunction suggests that the speaker does not know whether the boy is holding an apple and does not know whether the boy is holding a banana, while the sentence with embedded disjunction suggests that the speaker does not believe that every boy is holding an apple and does not believe that every boy is holding a banana. See also footnote 14.

[29] Participant 12's score on 'Every-One' seems far from the idealized score of 5, but note that the overall profile is quite accurate, and in fact, out of all theoretically motivated clusters Participant 12 fits best into the one displayed in Table 5 (see footnote 31). Whether the classification is appropriate or not is not entirely germane to our main point. We could just as well posit another category, 'unclassifiable,' into which Participant 12 would fall; this would merely increase the difficulty for the classical analysis, for it would add yet another unexplained participant.

Table 6 'Child Free Choice' [predicted: (0,5,0,5)]

ID Number	One	Both	Every-One	Every-Both
4	2	5	2	4
8	0	5	2	5
9	1	5	0	5
21	0	5	2	5
22	2	4	1	3
23	0	5	1	5
28	2	4	2	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
75	3	5	1	4
86	0	1	0	3
Mean	**1.06**	**4.63**	**0.94**	**4.63**

complex disjunctions (Tieu et al. 2015).[30] What is needed is a way to make sense of the CFC strategy. Ideally, what we should like is a general strategy which outputs conjunction when applied to disjunctive sentences in upward monotone environments, and returns the basic meaning when a disjunction is in the scope of a DE operator or when the strategy applies to other logical operators like *some*.

We will argue in the following section that this pattern can be explained without positing ad hoc strategies for the case at hand. Instead, we propose a conservative explanation of the child's behaviour that merely reuses existing assumptions about strengthening in the adult steady state and clarifies assumptions about child development. The assumption about the steady state, roughly stated in (9), is that *STR* derives conjunctive inferences for disjunctive sentences whenever the disjuncts are alternatives but their conjunction isn't (Fox 2007; see also Chemla 2009a; Franke 2011, and (19) for a more precise statement). The assumption we make about development is the one from (7): children at the relevant stage of development access a specific subset of the adult alternatives (which we clarify in (16) below), but otherwise they are like the adult in that they already possess the adult lexical entries for logical operators as well as the adult strengthening mechanism, *STR*. We will see that with these assumptions, together with some auxiliary assumptions about parsing, the above strategy profiles follow from different choices of parsing preferences. In addition to those profiles, we

[30] In Japanese, simple disjunctions have the form '*A ka B*' and complex disjunctions have the form '*ka A ka B*'. In French, simple disjunctions are '*A ou B*' and complex disjunctions are '*soit A soit B*'. In the adult state complex disjunctions are exclusive (see Spector 2014 for a proposal), but Tieu et al. (2015) found that children treated both simple and complex disjunctions as ambiguous between inclusive disjunction and conjunction.

will see that an additional strategy profile is predicted. Call it ‘CFCII’. Five CFCII participants were attested; these are displayed in Table 7 below.[31]

The 21 out of 31 participants that could not be explained under common assumptions all fall into either CFC (16/21) or CFCII (5/21). The goal of the rest of this paper is to explain how these groups arise, and to account for the obvious preference for CFC behavior.

4 An explanation of CFC and CFCII: ambiguity and free choice

4.1 Alternatives

We assume that alternatives in the steady state are generated by a sequence of the following operations (a simplified version of Katzir 2007):

(14) Generating alternatives in the adult state:
a. Replace nodes with their sub-constituents or other salient constituents.
b. Replace terminals with other lexical items.

Under this assumption, the alternatives for $A \vee B$ in the steady state are:

(15) Adult alternatives for disjunction (consequence of (14)):
$ALT_{Adult}(A \vee B) = \{A, B, A \wedge B\}$

It has been argued that children are limited in their ability to generate alternatives, and in particular that they do not perform scalar replacements (Barner and Bachrach 2010; Barner et al. 2011; see also Chierchia et al. 2001; Gualmini et al. 2001; Reinhart 2006; Stiller et al. 2011). For example, with the focus-sensitive operator *only*, children will accept *Only some of the animals are sleeping* as a description of a picture in which all of the animals are sleeping (Barner et al. 2011). This can be explained if children are unable to perform lexical replacements; with this assumption, *All of the animals are sleeping* cannot be generated, and thus *only* is vacuous. However, Barner et al. (2011)

Table 7 ‘Child Free Choice II’ [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
Mean	**0.6**	**4.8**	**4.2**	**4.8**

[31] We subjected our data, the individual child vectors, to the ‘k-means clustering’ algorithm to examine which clusters would be found. The algorithm optimizes an objective function: it clusters points so as to minimize distance *within* each cluster, with an initialization of k clusters together with their centroids. We initialized with the five theoretically motivated ideal clusters highlighted above (‘oddness-based’, ‘logician’, ‘CFC’, ‘CFCII’, ‘adult strengthener’). The algorithm produced exactly our clusters identified above, with cluster centres corresponding to the means of each cluster.

provide evidence that when the alternatives are explicitly provided, children reject *Only the dog and the cat are sleeping* when the dog, the cat, and the pig are all sleeping.

What this suggests is that the child cannot yet perform lexical replacements but can access explicitly mentioned material. We propose that this is the only relevant difference between the child and the adult; once the child starts making lexical replacements, his or her strengthening system will have matured into the adult target.[32]

(16) Generating alternatives in the child:

a. Replace nodes with their sub-constituents or other salient constituents.
b. ~~Replace terminals with other lexical items.~~

Under this assumption, the child's alternatives for $A \vee B$ are:

(17) Children's alternatives for disjunction (consequence of (16)):
$ALT_{Child}(A \vee B) = \{A, B\}$

The child thus lacks the conjunctive alternative $A \wedge B$ that is available in the adult state, but nevertheless has a nontrivial set of alternatives.

This points to an important difference between disjunctions and $\exists$ that might be worth highlighting again (cf. (8) and (10) in Sect. 1.3). Suppose that $ALT_{Adult}(\exists) = \{\forall\}$. Under our proposal, the child could not produce this alternative because it can only be generated with lexical replacement. Thus, no strengthening is possible with $\exists$, even if the child possesses *STR*.[33] However, because the set of alternatives for $A \vee B$ in the child is non-empty, there is in principle the possibility of some kind of strengthening. Our claim is that the child exploits this possibility: it uses the constituents A and B and concludes (by a method we introduce below) that both must be true.

4.2 The connection to free choice in the adult

We propose that the child's conjunctive inference can be derived by the same mechanism responsible for so-called free choice inferences in the adult. Consider the sentence in (18), together with its standard LF in (18a) and the free choice inference it receives in (18b).

[32] A reviewer asks whether the child's difficulty with lexical replacements is due to performance limitations (e.g., memory limitations), rather than lack of knowledge that lexical substitution is a step in alternative-generation. This is a difficult question to answer – here as in other cases where a child's deviance might be due to either limited knowledge or limited processing capacities. Nevertheless, we think this is a case of limited knowledge. A processing-based view would predict that under memory load or fatigue or time pressure, adults might access a conjunctive reading for disjunctive sentences. So far as we can tell, this does not happen, and it would in fact violate constraints on pruning of alternatives that have been proposed in the literature (see the Appendix, and Fox and Katzir 2011; Katzir 2013; Crnič et al. 2015; Trinh and Haida 2015). Adults do sometimes access a conjunctive interpretation of disjunctive sentences, but this only seems to happen when the competence system itself creates an environment in which the alternatives to the sentence are not closed under conjunction. This is what we take to be the relevant precondition for allowing conjunctive strengthenings of disjunctive sentences; see Sects. 1.3, 4.2, and 5.

[33] The point remains even if $ALT(\exists)$ has other alternatives, so long as they are generated by lexical replacement (e.g., *most*).

(18) You're allowed to eat the cake or ice-cream.

a. LF: $\Diamond(A \vee B)$ ($\Longleftrightarrow$ $\Diamond A \vee \Diamond B$)

b. FC inference: You're allowed to eat the cake and you're allowed to eat the ice-cream ($\Diamond A \wedge \Diamond B$)

The free choice inference does not follow from the semantics of (18a) under standard assumptions about the meanings of *allowed* and *or* (that *allow* is an existential quantifier over possible worlds and *or* denotes an inclusive disjunction, though cf. Geurts 2000; Zimmerman 2000; Simons 2005; Aloni 2007; Barker 2010). Furthermore, a free choice meaning is unavailable in downward-entailing contexts. For example, *No one is allowed to eat the cake or ice-cream* does not mean (merely) that no one has free choice; instead, it means that the cake and the ice-cream are both off limits for everyone, which is what is expected from the basic lexical semantics of *no*, *allow*, and *or*. For these and other reasons, it has been argued that free choice inferences are the result of SI computation (Kratzer and Shimoyama 2002; Schulz 2005; Alonso-Ovalle 2005; see also footnotes 6 and 7).

4.2.1 Free choice computation in the adult

Fox (2007) proposes a strengthening mechanism in the adult state that outputs the free choice inference in (18b) as a strengthened meaning of (18) while maintaining a classical semantics for *allowed* and *or*. At the same time, the mechanism produces the exclusive disjunction strengthened meaning for matrix disjunctions. Thus, under Fox's proposal it is possible for a disjunctive sentence to be strengthened to a conjunction, and it is also possible for a disjunctive sentence to be strengthened so as to deny a conjunction. We already noted in (9) that the possibility of a conjunctive strengthening of a disjunctive sentence depends in part on whether the set of alternatives to the sentence is closed under conjunction; in (19) below we give a somewhat more complete characterization.

(19) Closure and conjunctive strengthenings:

Suppose p is a sentence that entails $q \vee r$, and that p does not entail $q \wedge r$ and $q, r \in ALT(p)$. Then:

a. If $q \wedge r \in ALT(p)$, then p can never be strengthened to entail $q \wedge r$, but under certain circumstances p could be strengthened to deny $q \wedge r$: $STR(p)$ could sometimes entail $\neg(q \wedge r)$.

b. If $q \wedge r \notin ALT(p)$, then under certain circumstances p could be strengthened to $q \wedge r$: $STR(p)$ could sometimes entail $q \wedge r$.[34]

[34] The statement 'could sometimes entail' in (19) becomes a more definitive 'entails' if the sets of alternatives used by *STR* are restricted to the 'canonical' ones we consider in this paper. Let ϕ be a sentence containing disjunction $A \vee B$, $\phi(A \vee B)$, and consider the alternatives of the sentence, $ALT(\phi(A \vee B))$. By targeting the disjunction for the substitution operations in (14), we get three new sentences: $q = \phi(A)$, $r = \phi(B)$, $s = \phi(A \wedge B)$, and thus $ALT(\phi(A \vee B)) = \{q, r, s\}$ (the result is the set in (15) when the disjunction is matrix). For sets of this kind, $STR(p)$ entails $\neg s$ if $s \equiv q \wedge r$, and $STR(p)$ entails $q \wedge r$ if s asymmetrically entails $q \wedge r$ (i.e., if $s \vDash q \wedge r$ and $q \wedge r \nvDash s$). We momentarily discuss the reasoning that supports this statement. For a more general characterization, see Fox (2007), and see also Chemla (2009a) and Franke (2011), who derive this result with different architectural assumptions.

Here we try to illustrate the reasoning that supports (19); see the Appendix and Fox (2007) for more detailed and careful discussion.

Fox (2007) proposes the existence of a covert exhaustive operator exh, essentially an unrealized variant of *only*, and suggests that the strengthening mechanism *STR* should be identified with grammatical exhaustivity – that is, with (possibly recursive) application of exh (see also Chierchia 2006; Chierchia et al. 2012, and much other work). Under this approach, the strengthening of sentence p, $STR(ALT(p), p)$, is computed by parsing the sentence as $exh(ALT(p), p)$ (cf. footnote 1). The possibility of such an analysis follows from the assumption that, like *only*, exh is an *alternative-sensitive* operator, and that sentences p can be given a syntactic representation $exh(ALT(p), p)$. This representation – call it p^+ – could itself be exhaustified, yielding a new representation $p^{++} = exh(ALT(p^+), p^+)$, which in turn could be further exhaustified to yield p^{+++}, and so on.

The semantic effect of adding exh to the parse of sentence p – like that of adding *only* – is to 'strengthen' p by conjoining it with the negation of various elements of $ALT(p)$.[35] Specifically, exh negates those elements of $ALT(p)$ that are 'innocently excludable'. The core intuition behind innocent exclusion is that exh aims to negate as many alternatives in $ALT(p)$ as it can while maintaining consistency with p, but it will not negate alternatives arbitrarily. One way in which the negation of an alternative $q \in ALT(p)$ would be arbitrary is if q were 'symmetric' with another alternative r. Roughly speaking, q and r are symmetric alternatives of p if – given that p is true – the negation of one of q and r entails the truth of the other ((20) adapts the notion of symmetry from Fox and Katzir 2011):

(20) Symmetric alternatives:

$q \in ALT(p)$ and $r \in ALT(p)$ are *symmetric alternatives* of p if $p \wedge \neg q \vDash r$ and $p \wedge \neg r \vDash q$.

For example, q and r are symmetric alternatives of $p = q \vee r$. When q and r are symmetric alternatives of p, we will sometimes say that q and r are symmetric with each other. Terminology aside, what is relevant is that symmetric alternatives cannot be negated by exh: negating both q and r would result in a contradiction ($p \wedge \neg q \wedge \neg r$ is a contradiction if q and r are symmetric), and selecting one of q and r for negation instead of the other would seem to be arbitrary. For our purposes, an alternative of sentence p will be considered to be innocently excludable if it is not symmetric with any of p's other alternatives; the conjunction of p with the negation of each of its innocently excludable alternative is the strengthened meaning of p.[36] In

[35] The motivating idea is that the strengthened meaning of a sentence S can often be paraphrased by adding *only* to S and focusing the scalar item. For example, the strengthened meaning of *John ate some of the cookies* can be paraphrased by the sentence *John ate only SOME of the cookies*, and the strengthened meaning of *John ate cake or ice-cream* can be paraphrased by the sentence *John ate only cake OR ice-cream*. See the '*Only* Implicature Generalization' in Fox (2007).

[36] Not being symmetric with any other alternative is not sufficient for satisfying the more general notion of innocent exclusion we assume is needed (see (37) in the Appendix for a more adequate statement of innocent exclusion). As motivation for the more general notion, consider the question 'Which of John, Bill, Tom, Sue, and Mary came to the party?', and consider the response *Some boy*. Suppose that *(John/Bill/Tom) came to*

(21) we briefly summarize relevant properties of the syntax and semantics of exh; we turn to issues in pragmatics and processing in Sect. 4.3.

(21) Syntax and semantics of exh:

a. *Syntax*: It is possible to parse sentence p as $exh(ALT(p), p)$. We will sometimes use p^+ to refer to this parse of sentence p.

b. *Semantics*: The meaning of $exh(ALT(p), p)$, which we will also sometimes refer to as p^+ (cf. footnotes 2 and 10), is the conjunction of p with the elements of $ALT(p)$ that are innocently excludable (if there are any).

c. *Innocent exclusion* (roughly): $q \in ALT(p)$ is innocently excludable if it is not symmetric with any alternative $r \in ALT(p)$ (see (20)).

With this as background, let us return to (19) and the relevance of closure of the alternatives under conjunction. Consider the sentence $p = q \vee r$ and consider one of its possible representations $exh(ALT(p), p)$. Recall from (15) that in the adult state, $ALT(p) = \{q, r, q \wedge r\}$. Note that this set is closed under conjunction: q and r are in $ALT(p)$, and so is their conjunction $q \wedge r$. Thus, (19) predicts that no conjunctive strengthening is available, and in fact, the prediction is that the adult should compute the opposite inference, that the conjunction is false (cf. (19)). Under Fox's (2007) proposal, this follows because neither q nor r is innocently excludable (each is symmetric with the other). However, $q \wedge r$ is innocently excludable: $(q \vee r) \wedge \neg(q \wedge r)$ does not entail that q must be true and it does not entail that r must be true. Thus, $q \wedge r$ is the only innocently excludable alternative in $ALT(p)$, and $exh(ALT(p), p)$ in this case therefore returns the exclusive disjunction $(q \vee r) \wedge \neg(q \wedge r)$ as the strengthened meaning of p: $p^+ = exh(ALT(p), p) = q \veebar r$.

In contrast, consider $p = \Diamond(A \vee B)$, which is equivalent to $\Diamond A \vee \Diamond B$ and has $q = \Diamond A$ and $r = \Diamond B$ as alternatives. The conjunctive alternative to p is $s = \Diamond(A \wedge B)$, which is derived from p by substituting *and* for *or*. Thus, $ALT(p) = \{q, r, s\} = \{\Diamond A, \Diamond B, \Diamond(A \wedge B)\}$. Note that $ALT(p)$ in this case is *not* closed under conjunction: $q \in ALT(p)$ and $r \in ALT(p)$, but $q \wedge r \notin ALT(p)$ (importantly: $s = \Diamond(A \wedge B)$ asymmetrically entails $q \wedge r = \Diamond A \wedge \Diamond B$; $s \vDash q \wedge r$ but $q \wedge r \nvDash s$). Because of this, (19) predicts that a conjunctive strengthening of $p = \Diamond(A \vee B)$ to $\Diamond A \wedge \Diamond B$ should be possible [cf. (19)]. Under Fox's (2007) proposal, what differentiates this case from matrix disjunctions is that here the negation of s – the alternative derived by replacing *or* with *and* – is consistent with the conjunction of q and r. As the reader can verify, $s = \Diamond(A \wedge B)$ is the only innocently excludable element in $ALT(p)$, and hence $p^+ = exh(ALT(p), p) = \Diamond(A \vee B) \wedge \neg\Diamond(A \wedge B)$. This does not entail free choice, but it is consistent with it: p^+ ($= p \wedge \neg s$) is consistent with $q \wedge r$ (free choice), it is

Footnote 36 continued

the party are all alternatives. Note that no alternative is symmetric with any of the others. Nevertheless, the response is not understood as denying any of the alternatives. Note in particular that (21) as it stands predicts that all of these alternatives are innocently excludable, and hence the sentence should be contradictory. This is clearly a bad prediction. What is needed is a notion of innocent exclusion that would not negate any of these alternatives. The formulation in (37) meets this requirement while handling all the data discussed in this paper. For the examples that we consider here, however, not having a symmetric alternative happens to satisfy the more general notion of innocent exclusion in (37); we employ the symmetry-based notion here merely for expository simplicity. See Fox (2007) for detailed discussion.

consistent with $q \wedge \neg r$, and it is consistent with $r \wedge \neg q$ (recall that p entails $q \vee r$, and hence p^+ does, too). As we now briefly highlight, another layer of exhaustification ends up negating the latter two possibilities, so that p^{++} entails $q \wedge r$.

To see this, note that $p^{++} = exh(ALT(p^+), p^+)$ strengthens p^+ by negating the innocently excludable elements in $ALT(p^+)$. What is $ALT(p^+)$? This is the set derived by exhaustifying the elements of $ALT(p)$:

(22) Alternatives of $p^+ = exh(ALT(p), p)$:
$ALT(p^+)$
$= ALT(exh(ALT(p), p))$
$= \{exh(ALT(p), p'): p' \in ALT(p)\}$[37]
$= \{exh(ALT(p), q), exh(ALT(p), r), exh(ALT(p), s)\}$
$= \{q \wedge \neg r, r \wedge \neg q, s\}$.

There are no symmetric alternatives of p^+ in this set, so all of the alternatives are innocently excludable: p^+ already entails $\neg s$, and $p^+ \wedge \neg(q \wedge \neg r) \wedge \neg(r \wedge \neg q)$ is consistent and in fact entails $q \wedge r$ (recall that $p^+ \Leftrightarrow (p \wedge \neg s) \Leftrightarrow (q \vee r) \wedge \neg s$).

Thus, results from the adult – characterized in (19) – teach us that disjunctive sentences can get strengthened in strikingly different ways depending on whether the set of alternatives is closed under conjunction. If it isn't, recursive exhaustification could strengthen the sentence to a conjunction, and if it is, a single application of exh will deny the conjunctive alternative. The statement in (19) thus has the added benefit of providing a computational shortcut for checking whether a disjunctive sentence can be strengthened to a conjunction: knowing whether its alternatives are closed under conjunction will in many cases be enough to tell you whether a conjunctive strengthening is possible (cf. footnote 34). In (23) below we summarize and highlight the relevant distinctions in the adult state between matrix disjunctions and those embedded under an existential modal:

(23) Strengthening of disjunctive sentence in the adult:[38]

a. $p = q \vee r$
  (i) $ALT(p) = \{q, r, s\} = \{q, r, q \wedge r\}$
  (ii) $ALT(p)$ is closed under conjunction ($s \equiv q \wedge r$)
  (iii) p^+ entails $\neg(q \wedge r)$

b. $p = \Diamond(A \vee B)$
  (i) $ALT(p) = \{q, r, s\} (= \{\Diamond A, \Diamond B, \Diamond A \wedge B\})$
  (ii) $ALT(p)$ is *not* closed under conjunction ($s \not\equiv q \wedge r$)
  (iii) p^{++} entails $q \wedge r$

[37] This is computed by targeting the prejacent p in $exh(ALT(p), p)$ for the operations in (14). Note that exh is a focus-sensitive operator, and we assume that the operations in (14) target focused constituents. See (36) in the Appendix.

[38] Here and in what follows we assume that $s = p[or/and]$, by which we mean s is the sentence created by substituting *or* in p by *and*. The alternatives q and r are derived by substituting each disjunct for the disjunction in which it is contained.

4.2.2 Strengthening of disjunctive sentences in the child

The analysis of strengthening of disjunctive sentences in adults has consequences for the characterization of children. In Sect. 4.1, we proposed that the alternatives produced by children at the relevant developmental stage are a specific subset of the alternatives generated by the adult. Specifically, children do not perform lexical replacements (cf. (16)). Thus, their alternatives to the disjunctive sentences in (23a) and (23b) will be like adults', except that they will lack the alternative derived by replacing *or* with *and*:

(24) Child–adult differences in alternatives for disjunctive sentences (consequence of (14) and (16)):

a. $p = q \vee r$
  (i) $ALT_{Adult}(p) = \{q, r, q \wedge r\}$
  (ii) $ALT_{Child}(p) = \{q, r\}$

b. $p = \Diamond(A \vee B)$
  (i) $ALT_{Adult}(p) = \{q, r, s\} = \{\Diamond A, \Diamond B, \Diamond(A \wedge B)\}$
  (ii) $ALT_{Child}(p) = \{q, r\} = \{\Diamond A, \Diamond B\}$

Importantly, neither (24a.ii) nor (24b.ii) is closed under conjunction. If children are assumed to possess exh, then it follows from (19) that children should be capable of strengthening both (24a) and (24b) to $q \wedge r$. The prediction of a conjunctive understanding of (24a) has been confirmed here by our CFC group, as well as in other studies (e.g., Paris 1973; Braine and Rumain 1981; Chierchia et al. 2004; Tieu et al. 2015). The prediction of a conjunctive understanding of (24b) has been confirmed in Tieu et al. (2016). Children's conjunctive strengthening of disjunctive sentences, like adults', follows from two applications of exh: p^{++} entails $q \wedge r$. We work this out in the Appendix for (24a), but the logic straightforwardly extends to (24b) as well. Briefly, the basic idea is similar to the adult computation of free choice. The first application of exh to $p = q \vee r$ is vacuous, because q and r are the only alternatives and they are symmetric with each other. Symmetry gets broken in the next application of exh. The sentence $exh(ALT(p^+), p^+)$ denotes the conjunction of p^+, which is equivalent to $q \vee r$, with the innocently excludable members of $ALT(p^+) = \{exh(ALT(p), q), exh(ALT(p), r)\} = \{q \wedge \neg r, r \wedge \neg q\}$. The reader can verify that these are not symmetric alternatives: the negation of one does not entail the truth of the other (given $q \vee r$), and in fact the conjunction of $q \vee r$ with the negation of both alternatives is consistent and is equivalent to the conjunctive inference produced by the child ($q \wedge r \Leftrightarrow (q \vee r) \wedge \neg(q \wedge \neg r) \wedge \neg(r \wedge \neg q) \Leftrightarrow exh(ALT(p), p) \wedge \neg exh(ALT(p), q) \wedge \neg exh(ALT(p), r) = exh(ALT(p^+), p^+) = p^{++}$).

Here we summarize the strengthened meanings of (23a) and (23b) available to children and adults;

(25) Child–adult similarities and differences in strengthening of disjunctive sentences (consequence of (24) + the assumption that children and adults both possess exh):

a. $p = q \vee r$
  (i) Adult: p^+ entails $\neg(q \wedge r)$
  (ii) Child: p^{++} entails $q \wedge r$

b. $p = \Diamond(A \vee B)$
(i) Adult: p^{++} entails $q \wedge r$
(ii) Child: p^{++} entails $q \wedge r$

4.2.3 Back to our CFC and CFCII clusters

We now have all the theoretical background needed to make sense of the existence of the CFC and CFCII clusters (Tables 6, 7). We assume that the child is like the adult in that they have the inclusive disjunction entry for *or* and that they have exh. They differ from the adult only in their alternatives: ALT_{Child} is a specific subset of ALT_{Adult} (cf. (16)). The statement in (25) clarifies that in both children and adults, the conjunctive strengthening of a disjunctive sentence p follows from the representation p^{++} when $ALT(p)$ is not closed under conjunction.

The CFC group in our sample realized the prediction in (25a.ii). Crucially, the CFC group assigned conjunctive meanings not only to matrix disjunctions, but also to disjunctions embedded under *every*. This embedded strengthening is possible because – under our proposal – *STR* is realized in the grammar as an unpronounced operator exh, and thus should apply in embedded positions as well. Recursive application of exh below *every* but above disjunction captures the embedded conjunctive strengthening: the logical form 'Every boy x, $exh(exh(x$ is holding an apple or a banana))' is equivalent to 'Every boy is holding an apple and a banana' when the alternatives for the embedded disjunction are the child's alternatives (we have left the alternatives implicit here to reduce clutter).[39] Again, the parallel to the adult is clear: *Every boy is allowed to hold a banana or an apple* is readily interpreted as asserting that every boy has free choice (Chemla 2009b), and this embedded free choice strengthening follows from recursive application of exh below *every*: 'Every boy x, $exh(exh(x$ is allowed to hold a banana or an apple))'.[40]

What about the CFCII group? This differs from CFC only in the 'Every-One' condition: children in CFC reject 'Every-One' and children in CFCII accept it. At the

[39] For Chemla (2009a) and Franke (2011), *STR* is not grammatical but is shorthand for a sequence of inferences computed globally. The conjunctive reading thus cannot be explained if the disjunction is truly embedded under *every*. The conjunctive reading can be explained, however, if children are assumed to prefer a 'wide-scope' construal of disjunction, such that *Every X is A or B* is parsed as 'Every X is A or every X is B'. Under this construal, the child's alternatives are {*Every X is A*, *Every X is B*} if the child cannot perform lexical replacements. With this parse and these alternatives, (19) becomes relevant, and in particular (19b) with the restriction in footnote 34 predicts that the conjunctive inference 'Every X is A and every X is B' ($\Leftrightarrow$ 'Every X is A and B') is produced (thanks to Emmanuel Chemla and Jacopo Romoli for suggesting this possibility). Note that the assumed LF goes against the common assumption that children have a preference for surface scope. Wide-scope readings for disjunction have been found in children of some languages (e.g., Japanese), but these seem to be connected to the PPI status of disjunction in these languages (e.g., Goro and Akiba 2004). See also footnote 40.

[40] Embedded free choice readings in the adult argue against a globalist approach to free choice (see footnote 39). For example, *Most of the boys are allowed to eat cake or ice-cream* suggests that most of the boys have free choice, and *Every boy is allowed to eat either cake or ice-cream* suggests that every boy has free choice (*either* is used here to fix the scope of disjunction (e.g., Larson 1985; Schwarz 1999) and hence to make the intended embedded free choice reading salient). The possibility of embedded free choice is why we suspect we need *exh* to make sense of the child's embedded conjunctive readings, though see van Rooij (2010) for suggestive remarks from a globalist perspective.

same time, given CFCII's rejection of 'One,' they must be strengtheners. As pointed out by Crnič et al. (2015) and explored there in detail both empirically and conceptually, it is possible in Fox's (2007) system for someone with the child's alternatives to be a strengthener and to accept the sentence in 'Every-One' and in 'Every-Both' by parsing it with a single embedded exh and a single exh at the root. The meaning of this sentence is the conjunction of the literal meaning with 'Not every X is just an A' and with 'Not every X is just a B'.[41] This interpretation is true in both 'Every-One' and 'Every-Both.'

Thus, we see that prior theoretical proposals give rise to five natural interpretation strategies. 'Logicians' are those individuals – child or adult – who choose not to exhaustify. 'Adult strengtheners' are those individuals who have matured into the adult state and who exhaustify and reject the sentence when its strengthened meaning is false. 'Oddness-based' individuals are those children or adults who reject a sentence if it is pragmatically odd. The CFC group corresponds to those children who choose to recursively exhaustify matrix and embedded disjunctions. The CFCII group corresponds to those children who exhaustify once at each scope site. All five of these predicted strategies were attested in our sample (Tables 3, 4, 5, 6, 7), and no other strategy profiles are predicted to be available.[42] Recall that 21/31 individuals in our sample

[41] As identified by Crnič et al. (2015), if the sentence is something like *Every boy is holding an apple or a banana*, the required logical form (LF) is the one in (i), and the sets of alternatives for each occurrence of exh in the LF are in (ia.1) and (ib.1). Here we follow the syntax assumed in Crnič et al. (2015): exhaustification of p creates the representation $exh(ALT(p))(p)$ (we've been assuming a representation $exh(ALT(p), p)$ to highlight the way exh realizes *STR* (cf. note 1); the difference between the two LFs is immaterial to our current purposes).

(i) LF of sentence: $exh(C')$(every boy x, $exh(C)$(x is holding an apple or a banana)).

a. Analysis of exhaustification at nuclear scope of *every*:
   1) $C = ALT$(x is holding an apple or a banana) ={x is holding an apple, x is holding a banana}
   2) [[$exh(C)$(x is holding an apple or a banana)]] = [[x is holding an apple or a banana]] (exh is vacuous because neither element in C is innocently excludable)
   3) Thus, [[T]] = [[every boy x, $exh(C)$(x is holding an apple or a banana)]] = [[every boy x, x is holding an apple or a banana]]. Although the embedded exh is vacuous here, we will see below that its presence has consequences for the alternatives of the higher exh.

b. Analysis of matrix exhaustification:
   1) $C' = ALT(T) = ALT$(Every boy x, $exh(C)$(x is holding an apple or a banana))
   = {[every boy x, $exh(C)$(x is holding an apple)], [every boy x, $exh(C)$(x is holding a banana)]}
   = {that every boy is holding an apple and not a banana, that every boy is holding a banana and not an apple}
   2) [[$exh(C')(T)$]] = that every boy is holding an apple or a banana and not every boy is holding just an apple and not every boy is holding just a banana. (We leave it to the reader to verify this.)

See Crnič et al. (2015) for parsing assumptions that make it natural to expect groups like CFC II (cf. Table 7), as well as for experimental evidence that such groups are attested among adult populations.

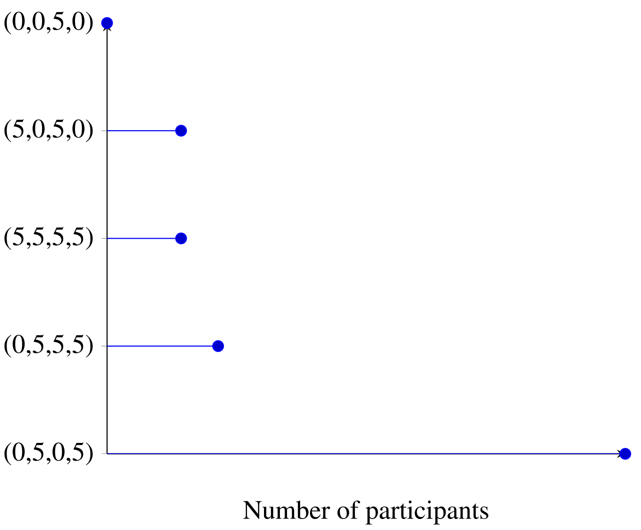
[42] Note that although we've exhausted the space of motivated strategy profiles, there remains uncertainty within certain profiles about which of the predicted form–meaning pairs were selected by the participants in the group. For example, the 'adult strengthener' group in Table 4 is consistent with a parse with matrix exh under both child and adult alternatives, as well as a parse with local exh with adult alternatives. And the CFCII group in Table 7 is consistent with child and adult alternatives for the form–meaning pair discussed in

belonged to one of the CFC and the CFCII groups, and that it was precisely these groups that prior proposals could not account for. The assumption that the child possesses *exh* makes these groups readily accessible. However, when we examine the clusters, we find that the CFC cluster is dominant; 16/31 participants ended up in that cluster. Why?

4.3 A note on preferences

Language comprehension is a complex task, and a variety of considerations might be at play when clear preferences are attested among competing interpretations of a linguistic stimulus. Such considerations might include linguistic complexity (e.g., Miller and Chomsky 1963; Frazier and Fodor 1978; Ford et al. 1982; Gibson 1998, 2000, among others), plausibility judgments (e.g., Crain and Steedman 1985; Trueswell et al. 1994; Stolcke 1995; Jurafsky 1996; Goodman and Stuhlmüller 2013; Bergen and Grodner 2012, among others), preferences for parses that best answer a 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 psycholinguistic literature. Our present concern is that, of the five theoretically motivated strategies discussed above, one – the Child Free Choice (CFC) strategy – was clearly dominant.

(26) Observed distribution of subjects classified into predicted profiles:



Footnote 42 continued
footnote 41 (see especially the discussion in Crnič et al. 2015, as well as our footnote 19). We hope nothing crucial hinges on our uncertainty about the precise form–meaning pairs selected by members of these groups. Note that no other readings are generated within our framework of assumptions; our uncertainty is only about which of the theoretically predicted readings were actualized in some cases.

The plot in (26) shows that the (0,5,0,5) group (the CFC group) attracted the greatest number of participants. 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 31 participants and 5 idealized profiles, we would expect something around 6.2 participants in each profile. The difference between the observed frequencies of profiles and those expected from chance is summarized in (27) below.

(27) Expected (under chance) and observed frequencies of profiles:

Frequencies	**(0,5,0,5)**	**(0,5,5,5)**	**(5,5,5,5)**	**(5,0,5,0)**	**(0,0,5,0)**
Expected	6.2	6.2	6.2	6.2	6.2
Observed	16	5	4	4	2

A chi square was computed comparing the frequencies of actual and expected occurrences of the different profiles, and an extremely significant difference was found between the observed and expected values ($\chi^2(4, n = 31) = 20.13$, $p = .0005$). Recall that the CFC group computes matrix and embedded conjunctive strengthened meanings. It might thus be unsurprising that a preference for matrix (Chemla and Bott 2014) and embedded (Chemla 2009b) free choice – a kind of conjunctive strengthened meaning – has been found in adults as well. We can thus state a generalization for both children and adults: for disjunctive sentences that *can* be strengthened to a conjunction (cf. (19)), there is a preference to strengthen these disjunctive sentences to conjunctions in matrix position and when they occur embedded under *every*.

The question we would like to ask is why there should be this preference for conjunctive strengthened meaning. As pointed out by Chemla (2009b), this preference is puzzling since there is no general preference for exhaustification (see Geurts and Pouscoulous 2009; Chemla and Spector 2011; Potts et al. 2015; Chemla et al. 2016; Franke et al. 2016 for quantitative information about the distribution of strengthened meanings in the scope of various operators). Furthermore, there is evidence that exhaustification is costly in certain matrix positions (for reviews, see e.g., Noveck and Reboul 2008; Katsos and Cummins 2010; Chemla and Singh 2014a, b), as well as in certain embedded positions (Chemla et al. 2016). It is thus surprising that adults and children should sometimes prefer to exhaustify twice, both in matrix and in embedded positions, and that they do so without the cost normally associated with exhaustification (see Chemla and Bott 2014 for complexity measures of adult free choice inferences). One of the goals of this section is to provide a way of thinking about the relevant preference that would make sense of this otherwise puzzling state of affairs.

We would like to tentatively suggest, following Gualmini et al. (2008), that a given reading of an ambiguous sentence is preferred if it provides a complete answer to the QUD (cf. Sect. 1.3.2 above). Building on this approach, we propose that exhaustification will be costly/dispreferred only if it does not lead to a complete answer to the QUD.

Following Groenendijk and Stokhof (1984), Lewis (1988), Roberts (1996), and others, the QUD can be thought of as a partition of logical space (or of the common ground) where the cells are the complete answers to the question and unions of cells are partial answers. To this we could add a general conversational preference for complete answers. We propose that this conversational preference for complete answers is reflected in parsing preferences. If a sentence generates a reading that provides a complete answer to the QUD, that reading will be preferred, and the sentence will be correspondingly easy to process. On the other hand, suppose that there is no parse of the sentence that leads to a complete answer. This might itself cause some difficulty for the hearer, for they would then have to compute a (presumably costly) pragmatic inference that, for each of the remaining cells, the speaker is ignorant about whether the cell is true (Fox 2007; see footnote 9). This ignorance inference in turn means that the speaker will be of no further help in answering the question. Furthermore, when the sentence has no reading that yields a complete answer, the hearer has to select from dispreferred options, and it is natural to assume that other factors become relevant in governing the choice. In particular, it is natural to assume that in such a case $exh(S)$ will be costlier to process than S: $exh(S)$ requires more syntactic and semantic computation per terminal item. Thus, we expect difficulties with exhaustification to be detected only when exhaustification does not lead to a complete answer.[43]

Returning to disjunctive sentences, it seems reasonable in the context of the picture-matching task in our experiment 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, in many contexts 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?' 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 pair-list meaning of the question, 'What did every boy eat/what is every boy allowed to eat?' Focusing on children at the relevant developmental stage, these questions are best answered by the doubly-exhaustified parse selected by the CFC group, for this parse provides the complete answer that the boy ate an apple and a banana in the case of matrix disjunctions, and that every boy ate an apple and a banana in the case of disjunctions embedded under *every*.[44] In the

[43] Some evidence in favour of a binary preference for complete over incomplete answers, rather than a finer-grained preference for better over worse answers, comes from the overt realizations of complete vs. incomplete answers. Specifically, complete or exhaustive answers are expressed with falling pitch movement, whereas partial answers are not (e.g., Zimmerman 2000). Importantly for us, intonation does not mark how close to a complete answer a partial answer is; it simply marks complete vs partial. This suggests that the competence system is insensitive to distinctions among partial answers.

[44] It is not obvious that anything changes if there are other possible answers to the question (e.g., that the boy ate/is allowed to eat a strawberry). Much will depend on what is assumed about how QUDs affect the construction of formal alternatives. Suppose the (possibly implicit) question is 'Which of C is the boy holding?', where C is a free variable whose value – a set of individuals – is determined by a contextually given assignment function. There are two questions that remain to be answered. First, it is unclear whether C includes elements other than what is in the picture. Second, it is unclear how whatever the value of C is affects the output of ALT. To see this, suppose that $C = \{a, b, c\}$, and suppose the speaker's answer is *The boy is holding* a. Clearly, in such a context we would want the answer to be understood exhaustively, which means *The boy is holding* b and *The boy is holding* c should also be in the set output by ALT. If these alternatives are generated by *lexical replacement* of a by b and by c, then – based on our assumed ban on lexical replacement (following Barner and Bachrach 2010 and Barner et al. 2011) – these alternatives would not be available to the child and the sentence would not be strengthened. However, if these alternatives are already salient – because of the question – then they might already be available to the child (because we assume the child can access salient material for replacement operations). In cases of disjunctions like *The boy is holding* a *or* b, where a and b are both in the picture and 'extra' elements like c, d, etc. are not, it is not clear whether any of this matters: if the extra elements are in the set of alternatives ALT and in C,

case of matrix disjunctions a parse without *exh* would leave open whether the boy ate an apple and whether the boy ate a banana, and in the case of disjunctions embedded under *every*, a parse without *exh* would leave open what each boy ended up eating. Note that strengthening in the adult does not lead to a complete answer to either of these questions. An exclusive disjunction reading of matrix disjunctions still leaves open which of the two disjuncts is true, and the adult's strengthened meaning of *Every boy is holding an apple or a banana* – whether global or embedded – still leaves open what each boy is in fact holding.[45]

One concrete way to implement our proposal is to assume that the parser ranks candidate form–meaning pairs according to an Optimality-Theoretic constraint system. Under such a system, ranking is governed by *Strict Domination*: any number of violations of lower-ranked constraints are tolerated if they allow you to satisfy a higher-ranked constraint. For example, suppose that X and Y are two constraints such that X outranks Y, $X \gg Y$, and suppose that A and B are candidates such that A does not violate X but incurs five violations of Y, and B incurs a single violation of X and a single violation of Y. Then A will be preferred to B. In fact, any candidate would be preferred to B no matter its number of violations of Y, so long as it did not incur any violations of X. (See e.g., Blutner and Zeevat 2003 and van Rooij and Franke 2015 for introductions to Optimality Theory and its application to studies of language use, as well as references to further literature.)

Thus, suppose that the parsing mechanism selects from the form–meaning pairs $<f, m>$ generated by the grammar. We propose that, among the many constraints that guide this selection, the following two are active: (i) *INC, which penalizes any form-meaning pair that fails to provide a complete answer to the QUD; and (ii) *EXH, which penalizes each occurrence of *exh* in the parse.[46] We furthermore assume that *INC $\gg$ *EXH. Finally, we assume that the parser carries along a set of candidate form–meaning pairs, and that the highest ranked pair is the most easily accessible at any given stage of processing.[47]

With these assumptions in place, the tableaux in (28) and (29) illustrate the child's and adult's processing of disjunctions *A or B*. The input in each case is a sentence of the form *A or B*, and the candidates are all the form–meaning pairs $<f, m>$ generated by the grammar consistent with the sentence *A or B*. We assume throughout that the QUDs posited by the listener are the ones discussed earlier.

Footnote 44 continued
they'll get negated by *exh*; if they're just in one of ALT and C and not in the other, it is not clear whether any inference is expected (see Fox and Katzir 2011 for relevant discussion); and if they're not in either C or ALT, they play no role in the computation. We hope to return to this in future work.

[45] This provides the adult with a further incentive not to strengthen (cf. footnote 24).

[46] *EXH is just a placeholder for what we expect is a more general principle that penalizes non-minimality – that is, any computations that are not strictly required in the analysis of the sentence. This should not be confused with hard constraints that have been proposed on the placement of *exh* in incremental processing (e.g., Singh 2008b, a; Gajewski and Sharvit 2012; Fox and Spector 2015); we assume that the candidates that enter into the parser's selection have already survived these and other hard constraints on well-formedness.

[47] We put aside for now questions about whether a Strict Domination approach to OT processing should be replaced by a weighted numerical measure (e.g., Gibson and Broihier 1998; for defence of Strict Domination, see Singh 2001 and Stevenson and Smolensky 2006).

(28) Adult processing of disjunctions:

		A or B	*INC	*EXH
a.	☞	$<\text{A or B}, A \vee B>$	*	
b.		$<exh(\text{A or B}), A \veebar B>$	*	*

(29) Child processing of disjunctions:

		A or B	*INC	*EXH
a.		$<\text{A or B}, A \vee B>$	*	
b.	☞	$<exh(exh(\text{A or B})), A \wedge B>$		**

For the adult, exhaustification does not lead to a complete answer and thus incurs a cost. For the child, exhaustification results in a complete answer, and thus the resulting reading is expected to be preferred to its unexhaustified competitor even though it incurs *EXH violations that the unexhaustified competitor does not.

For this reason, free choice readings of disjunctive permission sentences are also predicted to be preferred by both the child and the adult. As with matrix disjunctions, the readings available to the child are not the same as the readings available to the adult, but unlike the situation with matrix disjunctions, both the child and adult have a conjunctive reading available.[48]

(30) Adult processing of free choice:

		$\Diamond(A\ or\ B)$	*INC	*EXH
a.		$<\Diamond(\text{A or B}), \Diamond(A \vee B)>$	*	
b.		$<exh(\Diamond(\text{A or B})), \Diamond(A \vee B) \wedge \neg\Diamond(A \wedge B)>$	*	*
c.	☞	$<exh(exh(\Diamond(\text{A or B}))), \Diamond A \wedge \Diamond B>$		**

(31) Child processing of free choice:

		$\Diamond(A\ or\ B)$	*INC	*EXH
a.		$<\Diamond(\text{A or B}), \Diamond(A \vee B)>$	*	
b.	☞	$<exh(exh(\Diamond(\text{A or B}))), \Diamond A \wedge \Diamond B>$		**

Our suggestion, then, is that parsing preferences might follow in part from a preference for complete answers to the QUD; this general preference leads, in the cases under consideration here, to a preference for conjunctive interpretations of disjunctive sentences when the alternatives are not closed under conjunction. This leads to conjunctive inferences in the child, and to free choice inferences in both the child and the

[48] The child and adult share the basic meaning and the free choice reading, but the adult also has a third reading available: $exh(\Diamond(A \vee B))$ entails $\Diamond(A \vee B) \wedge \neg\Diamond(A \wedge B)$ when $\Diamond(A \wedge B)$ is not pruned from the set of alternatives. The child does not have $\Diamond(A \wedge B)$ as an alternative, and thus does not generate the reading $\Diamond(A \vee B) \wedge \neg\Diamond(A \wedge B)$ (which, notably, is the lowest-ranked reading of the ones available to the adult). In the adult, $\neg\Diamond(A \wedge B)$ is also an entailment of the free choice reading if $\Diamond(A \wedge B)$ is not pruned from the set of alternatives, but to reduce clutter we have left this entailment out of the free choice line in (30). See the Appendix for more discussion of pruning.

adult. We leave for future work the question of how our proposed constraints interact with other constraints that guide parsing decisions, as well as the question of how to identify and constrain what the QUD at a stage of conversation really is.

5 Concluding remarks

We replicated findings from Paris (1973), Braine and Rumain (1981), and Chierchia et al. (2004) showing that children sometimes interpret disjunctions as conjunctions, and we extended this result to embedding under *every*. We used these experimental findings 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, *STR*. Under our proposal, children 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 implicatures 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 (Fox 2007; Chemla 2009a; Franke 2011). The possibility of conjunctive strengthenings in embedded positions in both the child and the adult suggests the need for a grammatical exhaustivity approach to strengthening (Fox 2007; see footnote 40). We characterized the parallel between the developmental and adult state with the general prediction that a disjunctive sentence might be understood as a conjunction when the disjuncts are alternatives but their conjunction is not (cf. (19)). It seems that whenever this possibility is realized, the child and the adult prefer to take the option to strengthen the sentence to a conjunction, a preference that we tentatively suggested might follow from a general preference to resolve the Question Under Discussion. This is to be understood as a strictly conversational preference that is not specific to exh.

An immediate consequence of this parallel is that we should expect children (and adults) to have the possibility of generating conjunctive inferences of disjunctive sentences when the alternatives are not closed under conjunction. One notable prediction along these lines is that children should compute free choice scalar implicatures, since their set of alternatives for $\Diamond(A \vee B)$ is not closed under conjunction: under (16), $ALT_{Child}(\Diamond(A \vee B)) = \{\Diamond(A \vee B), \Diamond A, \Diamond B\}$. As we noted in Sect. 4.2, this expectation has been confirmed (see Tieu et al. 2016). Negated conjunctions $\neg(A \wedge B)$ are another case of this kind. Note that $\neg(A \wedge B) \Leftrightarrow (\neg A \vee \neg B)$, and that under our proposal the child's alternatives for this sentence are $ALT_{Child}(\neg(A \wedge B)) = \{\neg A, \neg B\}$. Thus, because of (19), 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 2009b); indeed, our explanation for the children's behavior on our 'Every-One' and 'Every-Both' conditions relies on this assumption.

The connection between the child and the adult through (19) – the possibility of a conjunctive strengthening when the disjuncts are alternatives but the conjunction isn't – seems to be transparently realized in other languages. Specifically, American Sign Language (Davidson 2013) and Warlpiri (Bowler 2014) have been analyzed as encoding a single binary connective that is ambiguous between inclusive disjunction and conjunction. Bowler (2014) moreover shows that under negation only the inclusive disjunction meaning is available. This description sounds a lot like what we and others have observed about preschool children, and is exactly what is expected if the connective in these languages is indeed lexicalized as an inclusive disjunction which gets strengthened to a conjunction.[49] The strengthening here is expected because, without *and* in the language, no conjunctive alternative can be formed, and from (19) it follows that in such a language a single connective should do double duty between inclusive disjunction and conjunction, much like the way English *or* seems to do double duty between inclusive and exclusive disjunction in the steady state attained by the adult.

Aside from conjunctive strengthenings, we predict that children should be able to strengthen like adults when access to the lexicon is not involved. For example, Katzir (2007) points out that sentences like *Every one of these ten students who is wearing a hat was born in Paris* implicates that not every one of these ten students was born in Paris. The inference follows from the assumption that *Every one of these ten students was born in Paris* is an alternative of the sentence, derived by deletion of the relative clause *who is wearing a hat*. Because this alternative is stronger than the utterance itself (cf. footnotes 5 and 7), it can be negated and conjoined with the uttered sentence. No lexical substitutions are involved, and thus children should be able to strengthen like adults in such environments.

If we are right that children's purported difficulties with implicature computation reduce to the single operation of lexical replacement, 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., $\exists \rightsquigarrow \neg\forall$). Exploiting the current understanding of alternatives and implicatures in complex sentences, we conclude that children are better described as being both willing and able to compute implicatures, sometimes resulting in inferences that are unavailable in the steady state. Although children and adults sometimes compute different implicatures, the underlying strengthening mechanism is the same (adding exh to the parse of a sentence), as are the pragmatic pressures that lead to the preference for conjunctive SIs. It might seem counter-intuitive that children and adults prefer to recursively exhaustify without there being a general preference for exhaustification. We proposed to resolve this puzzle by suggesting that there is no preference for exhaustification, but rather a pragmatic preference for a complete answer to the Question Under Discussion, which is sometimes but not always satisfied by exhaustification. When it is, exhaustification will be

[49] Bowler (2014) provides evidence of this interpretation of the Walpiri facts (following our account of the English child data). Davidson (2013) provides a different interpretation of the ASL facts. Whether our interpretation can be extended to ASL is something that we will have to leave to future research (see Podlesny 2015). See also Meyer (2015) for an argument that conjunctive entailments in certain English *or-else* constructions follow for similar reasons (the conjunctive alternative is missing; see also footnote 11).

preferred, and when it isn't, exhaustification will be dispreferred (by an underlying, but lower-ranked, dispreference for complicated structures).

Appendix

Appendix 1: Sample computation

Here we highlight important steps in the computation of a conjunctive meaning for $A \vee B$ with the child alternatives $C = \{A, B\}$. Formal definitions that support these computations are given in (36) and (37) below. Here we follow the syntax and semantics assumed in Fox (2007).

The conjunctive reading in children is derived with two applications of exh:

(32) Parse of sentence: $exh_2(C_2)(exh_1(C_1)(A \vee B))$

The set of alternatives C_1 for exh_1 is $\{A, B\}$. When exh is appended to a sentence it tries to negate as many of the sentence's alternatives as it can while maintaining consistency with the sentence. In (32), it tries to negate as many elements of C_1 as it can while maintaining consistency with $A \vee B$. However, the elements of C_1 can't both be negated, because the result would be inconsistent and negation of one would force you to accept the other. Hence, neither A nor B is 'innocently excludable' (see (37) below), and hence nothing can be negated at this stage: the meaning of $exh_1(C_1)(A \vee B)$ is just the inclusive disjunction.

(33) Summary of computation for first layer of exhaustification:

a. Parse: $exh(C_1)(A \vee B)$
b. $C_1 = \{A, B\}$
c. Meaning of (33a): $A \vee B$ (because no member of C_1 is innocently excludable)

At the second level of exhaustification, exh_2, the alternatives are: $C_2 = \{exh_1(C_1)A, exh_1(C_1)B\}$. This set is derived by replacing $A \vee B$ with its alternatives A, B in the sentence $exh(C_1)(A \vee B)$. Thus, $C_2 = \{exh_1(C_1)A, exh_1(C_1)B\}$ = $\{A \wedge \neg B, B \wedge \neg A\}$. exh_2 tries to negate as many alternatives in C_2 as it can while maintaining consistency with $exh_1(C_1)(A \vee B)$ ($\Leftrightarrow A \vee B$), and it turns out it can negate both alternatives at once: $(A \vee B) \wedge \neg(A \wedge \neg B) \wedge \neg(B \wedge \neg A)$ is equivalent to $A \wedge B$. (What the sentence asserts, therefore, is '$A \vee B$ and not just A and not just B'; recall that the most prominent justification children gave for rejection was 'just A').

(34) Summary of computation for second layer of exhaustification:

a. Parse: $exh(C_2)(exh(C_1)A \vee B)$
b. $C_2 = \{exh(C_1)(p) : p \in C_1\} = \{exh(C_1)A, exh(C_1)B\} = \{A \wedge \neg B, B \wedge \neg A\}$
c. Meaning of (34a): $A \wedge B$ (both members of C_2 are innocently excludable: $(A \vee B)\neg(A \wedge \neg B) \wedge \neg(\neg A \wedge B)$ is consistent and is equivalent to $A \wedge B$)

Thus, when the set of alternatives for $A \vee B$ is $\{A, B\}$, two applications of exh strengthen the disjunction to a conjunction.

Things are different when $C = ALT_{Adult}(A \vee B) = \{A, B, A \wedge B\}$. With these alternatives, the parse $exh(C)(A \vee B)$ is equivalent to $(A \vee B) \wedge \neg(A \wedge B)$. This is because $exh(C)(S)$ always entails S, and in this case there are two 'maximal consistent exclusions' (see (37) below for formal definitions): (i) $\{A, A \wedge B\}$, and (ii) $\{B, A \wedge B\}$. The intersection of these sets is $\{A \wedge B\}$; thus $A \wedge B$ is the only 'innocently excludable' alternative (see (37) below), and this is the SI. Further exhaustification is vacuous (Fox 2007).[50]

(35) Summary of computation of exhaustification in the adult:

a. Parse: $exh(C)(A \vee B)$
b. $C = \{A, B, A \wedge B\}$
c. Meaning of (35a): $(A \vee B) \wedge \neg(A \wedge B)$ ($A \wedge B$ is the only member of C that is innocently excludable)

Appendix 2: Formal definitions

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

(36) 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 either
(i) Y is a constituent of a focus-marked constituent of X;
(ii) Y has been explicitly mentioned in c; or
(iii) Y is 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, $A(S, c)$, are $\mathcal{R}_c \cap ALT(S, c)$.

(37) The semantics of 'exh' (Fox 2007): Where c is the context of assertion, $A(S, c)$ is the set of actual alternatives of S in c, and $exh(A(S, c))(S)$ is the LF that is being interpreted in context c:

a. $[[exh(A(S, c))(S)]] = [[S \wedge \bigwedge\{\neg S_i : S_i \in IE(A(S, c))\}]]$
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:

[50] At the second application of exh, the alternatives are $\{exh(C)A, exh(C)B, exh(C)A \wedge B\} = \{A \wedge \neg B, B \wedge \neg A, A \wedge B\}$. The prejacent – an exclusive disjunction – already entails $\neg(A \wedge B)$, and the other two alternatives are symmetric with each other.

(i) $B \subseteq A(S, c)$;
(ii) $S \wedge (\bigwedge\{\neg S_i : S_i \in B\})$ is consistent; and
(iii) $S \wedge (\bigwedge\{\neg S_i : S_i \in B\}) \wedge \neg S_j$ is inconsistent, for any $S_j \in A(S, c) \setminus B$.

Appendix 3: A possible concern about pruning

It is known that context can sometimes restrict the set of formal alternatives by excluding certain members from consideration (Horn 1972; Rooth 1992; Fox and Katzir 2011; cf. (36c) above). If context could arbitrarily prune alternatives, we might expect conjunctive SIs $A \wedge B$ to arise in the adult state by pruning $A \wedge B$. 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 (36)) 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 adults 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 free choice; the set of alternatives isn't closed under conjunction either way. For alternative constraints on pruning that would have the same effect, see Katzir (2013) and Crnič et al. (2015).

Acknowledgments This is a revised version of a manuscript that was posted in the *Semantics Archive* on 8 Dec 2013 (see http://semanticsarchive.net/Archive/mUzODEyY/Disjunction-Acquisition-SI.pdf). The ideas presented here have been developing since 2009. The data and our interpretation were firmly in place in 2011, and they were presented in talks in 2012 at Carleton University, Stanford University, the Evelin Summer School at the University of Campinas, and the 'Language and the brain, linguistics and neuroscience, McGill-Jülich dialogue'. We thank those audiences, as well as Alan Bale, Dave Barner, Susan Carey, Gennaro Chierchia, Noam Chomsky, Eve Clark, Herb Clark, Mike Deigan, Mike Frank, Noah Goodman, Martin Hackl, Irene Heim, Jorie-Koster-Hale, Craig Leth-Steensen, Jo-Anne Lefevre, John Logan, Philippe Schlenker, Jesse Snedeker, Benjamin Spector, Alasdair Urquhart, as well as audiences at the University of Toronto, MIT, the University of Ottawa, the ETI Workshop on Alternatives at McGill University, and Tel Aviv University and the Hebrew University of Jerusalem. We are especially grateful to Yossi Grodzinsky, Luka Crnič, Emmanuel Chemla, Roni Katzir, Jacopo Romoli, and Ida Toivonen, and to two anonymous reviewers for *Natural Language Semantics* and the editor Angelika Kratzer. Christine Bartels carefully read the paper and made many valuable suggestions that improved the result. Building on the circulated version of the manuscript, several studies have found the conjunctive reading reported here using somewhat different methodologies, and they cite and extend our proposal (see, e.g., Bowler 2014; Tieu et al. 2015, 2016). We discuss the connection to these papers in the current manuscript. 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.

References

Aloni, Maria. 2007. Free choice, modals, and imperatives. *Natural Language Semantics* 15(1): 65–94.
Alonso-Ovalle, Luis. 2005. Distributing the disjuncts over the modal space. In *Proceedings of NELS 35*, ed. Leah Bateman and Cherlon Ussery, 75–86. Amherst. Mass.: GLSA.

Barker, Chris. 2010. Free choice permission as resource-sensitive reasoning. *Semantics and Pragmatics* 3(10): 1–38.
Barner, David, and Asaf Bachrach. 2010. Inference and exact numerical representation in early language development. *Cognitive Psychology* 60: 40–62.
Barner, David, Neon Brooks, and Alan Bale. 2011. Accessing the unsaid: The role of scalar alternatives in children's pragmatic inference. *Cognition* 118: 87–96.
Bergen, Leon, and Daniel Grodner. 2012. Speaker knowledge influences the comprehension of pragmatic inferences. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 38(5): 1450–1460.
Blutner, Reinhard, and Henk Zeevat (eds.). 2003. *Optimality theory and pragmatics*. New York: Palgrave Macmillan.
Bowler, Margit. 2014. Conjunction and disjunction in a language without 'and'. In *Proceedings of SALT 24*, ed. A. Chereches, 137–155. Washington, D.C.: LSA.
Braine, Martin D.S., and Barbara Rumain. 1981. Development of comprehension of 'or:' Evidence for a sequence of competencies. *Journal of Experimental Child Psychology* 31: 46–70.
Chemla, Emmanuel. 2009a. Similarity: Towards a unified account of scalar implicatures, free choice permission, and presupposition projection. Manuscript, ENS, Paris.
Chemla, Emmanuel. 2009b. Universal implicatures and free choice effects: Experimental data. *Semantics and Pragmatics* 2: 1–33.
Chemla, Emmanuel, and Lewis Bott. 2014. Processing inferences at the semantics/pragmatics frontier: Disjunctions and free choice. *Cognition* 130: 380–396.
Chemla, Emmanuel, and Raj Singh. 2014a. Remarks on the experimental turn in the study of scalar implicature. Part I. *Language and Linguistics Compass* 8(9): 373–386.
Chemla, Emmanuel, and Raj Singh. 2014b. Remarks on the experimental turn in the study of scalar implicature. Part II. *Language and Linguistics Compass* 8(9): 387–399.
Chemla, Emmanuel, and Benjamin Spector. 2011. Experimental evidence for embedded scalar implicatures. *Journal of Semantics* 28: 359–400.
Chemla, Emmanuel, Chris Cummins, and Raj Singh. 2016. Training and timing local scalar enrichments under global pragmatic pressures. *Journal of Semantics*. Advance online access (first published online 29 May 2016). doi:10.1093/jos/ffw006.
Chierchia, Gennaro. 2006. Broaden your views: Implicatures of domain widening and the 'logicality' of language. *Linguistic Inquiry* 37(4): 535–590.
Chierchia, Gennaro, Stephen Crain, Maria Teresa Guasti, Andrea Gualmini, and Luisa Meroni. 2001. The acquisition of disjunction: Evidence for a grammatical view of scalar implicatures. In *Proceedings of BUCLD 25*, 157–168. Somerville, MA: Cascadilla Press.
Chierchia, Gennaro, Maria Teresa Guasti, Andrea Gualmini, Luisa Meroni, Stephen Crain, and Francesca Foppolo. 2004. Semantic and pragmatic competence in children's and adults' comprehension of *or*. In *Experimental pragmatics*, ed. Ira A. Noveck and Dan Sperber, 200–283. New York: Palgrave.
Chierchia, Gennaro, Danny Fox, and Benjamin Spector. 2012. Scalar implicature as a grammatical phenomenon. In *Handbook of semantics*, vol. 3, ed. Paul Portner, Claudia Maienborn, and Klaus von Heusinger, 2297–2331. New York: Mouton de Gruyter.
Clark, Eve V., and Patricia Matos Amaral. 2010. Children build on pragmatic information in language acquisition. *Language and Linguistics Compass* 4: 445–457.
Crain, Stephen. 2008. The interpretation of disjunction in Universal Grammar. *Language and Speech* 51: 151–169.
Crain, Stephen, and Drew Khlentzos. 2010. The logic instinct. *Mind & Language* 25(1): 30–65.
Crain, Stephen, and Cecile McKee. 1985. The acquisition of structural restrictions on anaphora. In *Proceedings of NELS 15*, 94–110. Amherst, MA.: GLSA.
Crain, Stephen, and Mark Steedman. 1985. On not being led up the garden path: The use of context by the psychological syntax processor. In *Natural language parsing: Psychological, computational, and theoretical perspectives*, ed. David R. Dowty, Lauri Karttunen, and Arnold Zwicky, 320–358. Cambridge: Cambridge University Press.
Crain, Stephen, and Rosalind Thornton. 1998. *Investigations in universal grammar: A guide to experiments in the acquisition of syntax and semantics*. Cambridge, MA: MIT Press.
Crain, Stephen, and Kenneth Wexler. 1999. Methodology in the study of language acquisition: A modular approach. In *Handbook of child language acquisition*, ed. William C Ritchie and Tej K Bhatia, 387–425. New York: Academic Press.

Crain, Stephen, Rosalind Thornton, Carole Boster, Laura Conway, Diane Lillo-Martin, and Elaine Woodams. 1996. Quantification without qualification. *Language Acquisition* 5(2): 83–153.
Crain, Stephen, Amanda Gardner, Andrea Gualmini, and Beth Rabbib. 2002. Children's command of negation. In *Proceedings of the 3rd Tokyo Conference on Psycholinguistics*, ed. Yukio Otsu, 71–95. Tokyo: Hituzi Publishing Company.
Crnič, Luka, Emmanuel Chemla, and Danny Fox. 2015. Scalar implicatures of embedded disjunctions. *Natural Language Semantics* 23(4): 271–305.
Dalrymple, M., M. Kanazawa, Y. Kim, S. Mchombo, and S. Peters. 1998. Reciprocal expressions and the concept of reciprocity. *Linguistics and Philosophy* 21: 159–210.
Davidson, Kathryn. 2013. 'And' and 'or': General use coordination in ASL. *Semantics and Pragmatics* 6: 1–44.
Drozd, Kenneth, and Erik van Loosbroek. 1998. Weak quantification, plausible dissent, and the development of children's pragmatic competence. *Proceedings of the 23rd Boston University Conference on Language Development*, 184–195. Somerville, MA: Cascadilla Press.
Ford, Marilyn, Joan Bresnan, and Ronald M. Kaplan. 1982. A competence-based theory of syntactic closure. In *The mental representation of grammatical relations*, ed. Joan Bresnan, 727–796. Cambridge, MA: MIT Press.
Fox, Danny. 2007. Free choice disjunction and the theory of scalar implicature. In *Presupposition and implicature in compositional semantics*, ed. Uli Sauerland and Penka Stateva, 71–120. New York: Palgrave Macmillan.
Fox, Danny. 2014. Cancelling the Maxim of Quantity: Another challenge for a Gricean theory of scalar implicatures. *Semantics & Pragmatics* 7: 1–20.
Fox, Danny, and Roni Katzir. 2011. On the characterization of alternatives. *Natural Language Semantics* 19: 87–107.
Fox, Danny, and Benjamin Spector. 2015. Economy and embedded exhaustification. To be published by *Natural Language Semantics*.
Franke, Michael. 2011. Quantity implicatures, exhaustive interpretation, and rational conversation. *Semantics and Pragmatics* 4(1): 1–82. doi:10.3765/sp.4.1.
Franke, Michael, Fabian Schlotterbeck, and Petra Augurzky. 2016. Embedded scalars, preferred readings and prosody: An experimental revisit. To appear in *Journal of Semantics*.
Frazier, Lyn, and Janet D. Fodor. 1978. The Sausage Machine: A new two-stage parsing model. *Cognition* 6: 291–325.
Furth, Hans G., James Youniss, and Bruce M. Ross. 1970. Children's utilization of logical symbols: An interpretation of conceptual behavior based on Piagetian theory. *Developmental Psychology* 3(1): 36–57.
Gajewski, Jon, and Yael Sharvit. 2012. In defense of the grammatical approach to scalar implicature. *Natural Language Semantics* 20(1): 31–57.
Gazdar, Gerald. 1979. *Pragmatics*. New York: Academic Press.
Geurts, Bart. 2000. Buoyancy and strength. *Journal of Semantics* 17: 315–333.
Geurts, Bart. 2003. Quantifying kids. *Language Acquisition* 11: 197–218.
Geurts, Bart. 2009. Scalar implicature and local pragmatics. *Mind and Language* 24: 51–79.
Geurts, Bart, and Nausicaa Pouscoulous. 2009. Embedded implicatures?!? *Semantics and Pragmatics* 2: 1–34.
Gibson, Edward. 1998. Linguistic complexity: Locality of syntactic dependencies. *Cognition* 68: 1–76.
Gibson, Edward. 2000. The dependency locality theory: A distance-based measure of linguistic complexity. In *Image, language, brain*, ed. Y. Miyashita, A. Marantz, and W. O'Neil, 95–126. Cambridge, MA: MIT Press.
Gibson, Edward, and Kevin Broihier. 1998. Optimality theory and human sentence processing. In *Is the best good enough? Optimality and competition in syntax*, ed. Pilar Barbosa, Danny Fox, Paul Hagstrom, Martha McGinnis, and David Pesetsky, 157–191. Cambridge, MA: MIT Press.
Goodman, Noah D., and Andreas Stuhlmüller. 2013. Knowledge and implicature: Modeling language understanding as social cognition. *Topics in Cognitive Science* 5: 173–184.
Goro, Takuya, and Sachie Akiba. 2004. The acquisition of disjunction and positive polarity in Japanese. In *Proceedings of WCCFL 23*, ed. G. Garding and M. Tsujimura, 101–114. Somerville, MA: Cascadilla Press.
Goro, Takuya, Utako Minai, and Stephen Crain. 2005. Bringing out the logic in child language. In *Proceedings of NELS 35*, ed. Leah Bateman and Cherson Ussery, 245–256. Amherst, MA: GLSA Publications.

Groenendijk, Jeroen, and Martin Stokhof. 1984. Studies on the semantics of questions and the pragmatics of answers. Doctoral dissertation, University of Amsterdam.

Gualmini, Andrea, and Stephen Crain. 2002. Why no child or adult must learn De Morgan's laws. In *Proceedings of the 24th Annual Boston University Conference on Language Development*, eds. S. Catherine Howell, Sarah A. Fish, and Thea Keith-Lucas, 367–378. Somerville, MA: Cascadilla Press.

Gualmini, Andrea, Stephen Crain, Luisa Meroni, Gennaro Chierchia, and Maria Teresa Guasti. 2001. At the semantics/pragmatics interface in child language. *Proceedings of SALT 11*, 231–247.

Gualmini, Andrea, Luisa Meroni, and Stephen Crain. 2003. An asymmetric universal in child language. In *Proceedings of Sinn und Bedeutung 7*, ed. Matthias Weisgerber, 136–148. Konstanz: Universität Konstanz.

Gualmini, Andrea, Sarah Hulsey, Valentine Hacquard, and Danny Fox. 2008. The question–answer requirement for scope assignment. *Natural Language Semantics* 16: 205–237.

Guasti, Maria Teresa, Gennaro Chierchia, Stephen Crain, Francesca Foppolo, Andrea Gualmini, and Luisa Meroni. 2005. Why children and adults sometimes (but not always) compute implicatures. *Language and Cognitive Processes* 20(5): 667–696.

Hatano, Giyoo, and Yasuko Suga. 1977. Understanding and use of disjunction in children. *Journal of Experimental Child Psychology* 24: 395–405.

Horn, Laurence R. 1972. On the semantic properties of logical operators in english. Doctoral dissertation, UCLA.

Inhelder, Barbel, and Jean Piaget. 1964. *The early growth of logic in the child*. London: Routledge.

Jing, Chunyuan, Stephen Crain, and Ching-Fen Hsu. 2005. The interpretation of focus in Chinese: Child versus adult language. In *Proceedings of the 6th Tokyo Conference on Psycholinguistics*, ed. Yukio Otsu, 165–190. Tokyo: Hituzi Publishing Company.

Johansson, Bo S., and Barbro Sjolin. 1975. Preschool children's understanding of 'and' and 'or'. *Journal of Experimental Child Psychology* 19: 233–240.

Johnson, Mark, Thomas L. Griffiths, and Sharon Goldwater. 2007. Adaptor grammars: a framework for specifying compositional nonparametric Bayesian models. In *Advances in neural information processing systems*, vol. 19, ed. B. Schölkopf, J. Platt, and T. Hoffman, 641–648. Cambridge, MA: MIT Press.

Jurafsky, Daniel. 1996. A probabilistic model of lexical access and disambiguation. *Cognitive Science* 20: 137–194.

Kamp, Hans. 1973. Free choice permission. *Aristotelian Society Proceedings* 74: 57–74.

Katsos, Napoleon, and Dorothy V.M. Bishop. 2011. Pragmatic tolerance: Implications for the acquisition of informativeness and implicature. *Cognition* 120: 67–81.

Katsos, Napolean, and Chris Cummins. 2010. Pragmatics: From theory to experiment and back again. *Language and Linguistics Compass* 4: 282–295.

Katzir, Roni. 2007. Structurally defined alternatives. *Linguistics and Philosophy* 30: 669–690.

Katzir, Roni. 2013. On the role of markedness and contradiction in the use of alternatives. In *Semantics, pragmatics, and the case of scalar implicatures*, ed. Salvatore Pistoia Reda. Basingstoke: Tokyo: Hituzi Syobo, Palgrave.

Kratzer, Angelika, and Junko Shimoyama. 2002. Indeterminate pronouns: The view from Japanese. In *Proceedings of the 3rd Tokyo Conference on Psycholinguistics*, ed. Yukio Otsu, 1–25. Tokyo: Hituzi Syobo.

Larson, Richard K. 1985. On the syntax of disjunction scope. *Natural Language and Linguistic Theory* 3: 217–264.

Levin, Moshe, and Daniel Margulis. 2013. Universal quantifiers as existentials undercover: Evidence from Hebrew *kol*. Presented at Sinn und Bedeutung 18, Vitoria-Gasteiz, 2013.

Lewis, David. 1988. Relevant implication. *Theoria* 54: 161–174.

Magri, Giorgio. 2009. A theory of individual level predicates based on blind mandatory scalar implicatures. *Natural Language Semantics* 17: 245–297.

Magri, Giorgio. 2011. Another argument for embedded scalar implicatures based on oddness in downward entailing environments. *Semantics and Pragmatics* 4(6): 1–51.

Magri, Giorgio. 2014. An account for the homogeneity effects triggered by plural definites and conjunction based on double strengthening. In *Pragmatics, semantics, and the case of scalar implicatures*, ed. Salvatore Pistoia Reda, 99–145. Basingstoke: Palgrave Macmillan.

Merin, Arthur. 1992. Permission sentences stand in the way of Boolean and other lattice-theoretic semantics. *Journal of Semantics* 9(2): 95–162.

Meyer, Marie-Christine. 2015. Generalized free choice and missing alternatives. *Journal of Semantics*. Advance online access (first published online 4 November 2015), doi:10.1093/jos/ffv010.

Miller, George, and Noam Chomsky. 1963. Finitary models of language users. In *Handbook of mathematical psychology*, vol. 2, ed. R.D. Luce, R.R. Bush, and E. Galanter, 419–491. New York: Wiley.

Mosteller, Frederick, Stephen E. Fienberg, and Robert E.K. Rourke. 1983. *Beginning statistics with data analysis*. Reading, MA: Addison-Wesley.

Neimark, Edith D., and Nan S. Slotnick. 1970. Development of the understanding of logical connectives. *Journal of Educational Psychology* 61(6): 451–460.

Notley, Anna, Rosalind Thornton, and Stephen Crain. 2012a. English-speaking children's interpretation of disjunction in the scope of 'not every'. *Biolinguistics* 39: 484–522.

Notley, Anna, Peng Zhou, Britta Jensen, and Stephen Crain. 2012b. Children's interpretation of disjunction in the scope of 'before': A comparison of English and Mandarin. *Journal of Child Language* 39(3): 484–522.

Noveck, Ira. 2001. When children are more logical than adults: Investigations of scalar implicature. *Cognition* 78: 165–188.

Noveck, Ira, and Andres Posada. 2003. Characterizing the time course of an implicature: An evoked potentials study. *Brain and Language* 85(2): 203–210.

Noveck, Ira, and Anne Reboul. 2008. Experimental pragmatics: A Gricean turn in the study of language. *Trends in Cognitive Sciences* 12: 425–431.

O'Donnell, Timothy J., Jesse Snedeker, Joshua B. Tenenbaum, and Noah D. Goodman. 2011. Productivity and reuse in language. In *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*, eds. L. Carson et al., 1513–1518. Austin: The Cognitive Science Society.

Papafragou, Anna, and Julien Musolino. 2003. Scalar implicatures: Experiments at the semantics-pragmatics interface. *Cognition* 80: 253–282.

Paris, Scott. 1973. Comprehension of language connectives and propositional logical relationships. *Journal of Experimental Child Psychology* 16: 278–291.

Philip, William C. H. 1995. Event quantification in the acquisition of universal quantification. Doctoral dissertation, University of Massachusetts at Amherst.

Podlesny, Olivia. 2015. Investigating disjunction in American Sign Language: The importance of nonmanual signals and the influence of English. Master's thesis, Carleton University.

Potts, Christopher, Daniel Lassiter, Roger Levy, and Michael C. Frank. 2015. Embedded implicatures as pragmatic inferences under compositional lexical uncertainty. *Journal of Semantics*. Advanced Online Access (first published online 18 December 2015): doi:10.1093/jos/ffv012.

Reinhart, Tanya. 2006. *Interface strategies*. Cambridge, MA: MIT Press.

Roberts, Craige. 1996. Information structure and discourse: Towards an integrated formal theory of pragmatics. In *OSU working papers in linguistics*, vol 49, ed. J.H. Yoon and Andreas Kathol, 91–136. Columbus, OH: The Ohio State University.

Rooth, Mats. 1992. A theory of focus interpretation. *Natural Language Semantics* 1: 75–116.

Sauerland, Uli. 2004. Scalar implicatures in complex sentences. *Linguistics and Philosophy* 27: 367–391.

Schulz, Katrin. 2005. A pragmatic solution for the paradox of free choice permission. *Synthese* 147(2): 343–377.

Schulz, Katrin, and Robert van Rooij. 2006. Pragmatic meaning and non-monotonic reasoning: The case of exhaustive interpretation. *Linguistics and Philosophy* 29: 205–250.

Schwarz, Bernhard. 1999. On the syntax of *either...or*. *Natural Language and Linguistic Theory* 17: 339–370.

Simons, Mandy. 2005. Dividing things up: The semantics of *or* and the modal/*or* interaction. *Natural Language Semantics* 13(3): 271–316.

Singh, Raj. 2001. A study of Optimality Theory and the human sentence processing mechanism. Master's thesis, University of Amsterdam.

Singh, Raj. 2008a. Modularity and locality in interpretation. Doctoral dissertation, MIT.

Singh, Raj. 2008b. On the interpretation of disjunction: Asymmetric, incremental, and eager for inconsistency. *Linguistics and Philosophy* 31: 245–260.

Snedeker, Jesse. 2009. Children's sentence processing. In *The handbook of child language*, ed. Edith L. Bavin, 331–338. Cambridge: Cambridge University Press.

Spector, Benjamin. 2005. Scalar implicatures: Exhaustivity and Gricean reasoning. In *Questions in dynamic semantics*, ed. Maria Aloni, Alastair Butler, and Paul Dekker, 225–249. Amsterdam: Elsevier.

Spector, Benjamin. 2007. Aspects of the pragmatics of plural morphology: On higher order implicatures. In *Presupposition and implicature in compositional semantics*, ed. Uli Sauerland, and Penka Stateva, 243–281. Basingstoke: Palgrave Macmillan.

Spector, Benjamin. 2014. Global positive polarity items and obligatory exhaustivity. *Semantics and Pragmatics* 7(11): 1–61.

Spector, Benjamin. 2015. Comparing exhaustivity operators. Accepted for publication in *Semantics and Pragmatics*.

Sternberg, Robert J. 1979. Developmental patterns in the encoding and combination of logical connectives. *Journal of Experimental Child Psychology* 28: 469–498.

Stevenson, Suzanne, and Paul Smolensky. 2006. Optimality in sentence processing. In *Toward a calculus of the mind/brain: Neural network theory, optimality, and universal grammar*, ed. Paul Smolensky and Geraldine Legendre, 307–338. Cambridge, MA: MIT Press.

Stiller, Alex, Noah D. Goodman, and Michael C. Frank. 2011. Ad-hoc scalar implicature in adults and children. In *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*, ed. L. Carlson et al., 2134–2139. Austin: The Cognitive Science Society.

Stolcke, Andreas. 1995. An efficient probabilistic context-free parsing algorithm that computes prefix probabilities. *Computational Linguistics* 21: 165–201.

Su, Yi (Esther). 2014. The acquisition of logical connectives in child Mandarin. *Language Acquisition* 21(2): 119–155.

Su, Yi (Esther), and Stephen Crain. 2013. Children's knowledge of disjunction and universal quantification in Mandarin Chinese. *Language and Linguistics* 14(3): 599–631.

Su, Yi (Esther), Peng Zhou, and Stephen Crain. 2012. Downward entailment in child Mandarin. *Journal of Child Language* 39: 957–990.

Suppes, Patrick, and Shirley Feldman. 1971. Young children's comprehension of logical connectives. *Journal of Experimental Child Psychology* 12: 304–317.

Tieu, Lyn, Kazuko Yatsuhiro, Alexandre Cremers, Jacopo Romoli, Uli Sauerland, and Emmanuel Chemla. 2015. *On the role of alternatives in the acquisition of simple and complex disjunctions in French and Japanese*. Manuscript, ENS (Paris), ZAS (Berlin), and the University of Ulster.

Tieu, Lyn, Jacopo Romoli, Peng Zhou, and Stephen Crain. 2016. Children's knowledge of free choice inferences and scalar implicatures. *Journal of Semantics* 33(2): 269–298.

Trinh, Tue, and Andreas Haida. 2015. Constraining the derivation of alternatives. *Natural Language Semantics* 23(4): 249–270.

Trueswell, John C., Michael K. Tanenhaus, and Susan M. Garnsey. 1994. Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language* 33: 285–318.

van Rooij, Robert. 2010. Conjunctive interpretation of disjunction. *Semantics and Pragmatics* 3(11): 1–28.

van Rooij, Robert, and Katrin Schulz. 2004. Exhaustive interpretation of complex sentences. *Journal of Logic, Language, and Information* 13: 491–519.

van Rooij, Robert, and Michael Franke. 2015. Optimality-theoretic and game-theoretic approaches to implicature. In *The stanford encyclopedia of philosophy (Winter 2015)*, ed. Edward N. Zalta. http://plato.stanford.edu/archives/win2015/entries/implicature-optimality-games/.

Zimmerman, Thomas Ede. 2000. Free choice disjunction and epistemic possibility. *Natural Language Semantics* 8: 255–290.