LEARNING DISJUNCTION

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Abstract

To understand language, we rely on mental representations of what words mean. What constitutes these representations and how are they learned? To address this question, I investigate how children learn and interpret the disjunction word *or*. The highly abstract and context-dependent interpretation of or challenges word learning theories and provides an exceptional opportunity to better understand how words are associated with their meanings.

Or has several interpretations, including exclusive and inclusive disjunction. Inclusive disjunction, formalized as $A \vee B$ holds when A is true, B is true, or both. For example, a waiter may ask if you would like something to eat or drink, not excluding the possibility that you would like both. Exclusive disjunction, $A \oplus B$, is true when only A is true, or only B is true, but not both. If the waiter later asks whether you would like to see the dessert menu or have the check, his *or* is most likely interpreted as exclusive. He is suggesting that you should choose one or the other. Given these complexities in the interpretation of *or*, how do children interpret it and how do they learn its meaning?

I present the results of an experimental study which shows that children between the ages of three and five can interpret *or* as inclusive disjunction in positive declarative sentences, confirming previous findings. I also present the results of a study on parents' speech to children that shows that the exclusive interpretation is much more common in the examples children hear, again supporting previous results. These two findings fall into a current puzzle in the literature: How can children learn the inclusive interpretation of *or* if they rarely hear it?

I argue that this puzzle arises in models of word learning which directly map words to their meanings, thereby ignoring accompanying linguistic and conceptual cues. I present an in-depth annotation study demonstrating that exclusive interpretations correlate with interpretive cues in

children's input, such as intonation and the meaning of other words *or* combines with. Applying supervised learning techniques to the annotated data, I find that a learner who makes use of these interpretive cues can learn the inclusive as well as exclusive interpretation of disjunction from the language heard. These findings indicate that the representation of a word like or cannot be isolated from the linguistic and conceptual environment in which it appears. The linguistic and conceptual aspects of *or*'s environment can act as cues that aid its acquisition and interpretation. Together, these studies show that learning a function word like or requires richer lexical representations than currently assumed by our theories of word learning.

Dedication

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Introduction

In the literature on word learning, the story goes that one day, a linguist with great mastery of phonetics and phonology, heard of a people with an unknown language. She immediately packed her bags and traveled to learn about this new language. When she arrived, she saw a man walking down the road. Suddenly a rabbit scurried by. The man saw the rabbit and said “gavagai”. The linguist immediately pulled out her notebook. As an excellent phonetician with trained ears for detecting linguistic sounds, she wrote down the phonetic transcription of what she heard with great confidence. It was only when she tried to write the meaning that doubt and uncertainty seeped in. “Does *gavagai* mean rabbit?”, she whispered quietly. As a good scientist, she could see that her observation was compatible with a large number of hypotheses for the meaning of *gavagai*: “white-thing”, “furry thing”, “animal”, “fast”, “what was that?”, “oh gosh!”, “rabbit-on-the-road”, and even “undetached rabbit parts”! She shook her head and let out a sigh. She found this “referential uncertainty” challenging (Quine, 1960).

Unlike what most of us think, the story did not end there. The linguist continued with her observations and soon she learned the meaning of *gavagai* as well as many other words, mostly nouns, adjectives, and verbs. But soon she encountered a new challenge. One day when she was walking down the same road with the same man she met the first day, there was some movement in the nearby bushes. The man pointed to the bushes and said: “tonomi yok gavagai”. She now knew that *gavagai* meant rabbit. She also knew that *tonomi* is another animal. But she had never heard the word *yok* before. What did *yok* mean? “Maybe the man saw an animal and was not sure whether it was a gavagai **or** a tonomi”, she thought. However, the man did not sound uncertain. “What if he was trying to say that the animal was a gavagai **and not** a tonomi … or maybe he saw two animals and wanted to let me know that there was a gavagai **and** a tonomi in the bushes.” It was also possible that by that time, the man knew she was trying to learn their language and wanted to let her know that "gavagai" and "tonomi" are terms that apply to the same animal; something like: "this is called a gavagai **or** a tonomi". The linguist in our story sighed again. Even though she knew the meaning of words for things and actions, she needed to know the meaning of words that put them together to convey larger concepts. Legend has it that she did not go home until she discovered the meaning of every "function word" in this new language.

0.1 Word Learning

Learning the meaning of a word is often construed as mapping a linguistic form such as *gavagai* to a concept/meaning such as "rabbit". This mapping process is described in three stages: First the learner isolates the word form; then s/he isolates a meaning from a set of possible meanings; and finally s/he maps (or associates) the isolated word to the isolated meaning (E. V. Clark, 1993). A fundamental question in the acquisition of meaning concerns the second step of mapping: how do children select the right meaning of a word from a set of candidate meanings? Quine (1960)'s thought experiment with the linguist and the new language showed that this is not a trivial task. In any given context, a word is compatible with many possible meanings. The problem of selecting the right meaning for a given word is called the "mapping problem" or the "gavagai problem".

Solutions to the mapping problem often place constraints on either the hypothesis space or the structure of the lexicon to make word learning tractable (E. V. Clark, 1993). For example, the taxonomic constraint (Markman & Hutchinson, 1984) proposes that children generate semantic hypotheses for nouns that denote a set of taxonomically related entities and do not hypothesize meanings that capture sets of entities with thematic relations. For example, given the word *gavagai*, children hypothesize the meaning "rabbit" which denotes the set of rabbits (taxonomically related) but not "rabbit and carrot" (thematically related). Therefore, the taxonomic constraint limits the space of hypotheses that the learner entertains. On the other hand, the mutual exclusivity constraint (Markman & Wachtel, 1988) as well as the pragmatic principle of contrast (E. V. Clark, 1987) limit the structure of the lexicon such that two words are not mapped into the same meaning. This constraint on the lexicon makes the word learning task easier by removing hypotheses that are already associated with learned words.

Another solution to the mapping problem is to propose cues that bias the learner towards one hypothesis rather than another. For example, socio-pragmatic cues such as pointing and joint-attention (D. A. Baldwin, 1993; E. V. Clark, 2009; Tomasello, 2003) direct the learner to bias one hypothesis over others. For example, given a rabbit and a cat, the speaker pointing to the rabbit and saying *gavagai* biases the learner to map the meaning of *gavagai* to "rabbit" rather than "cat". Learning models can also integrate cues and constraints to develop a learning account that uses multiple cues to home in on the target meaning of a word (Hollich et al., 2000).

While there has been a large body of research on the set of cues and constraints that aid the acquisition of content word semantics, cues that assist the acquisition of function words have not received as much attention. This dissertation aims at advancing a multiple cue-based acquisition of functions words by investigating the acquisition of the disjunction word *or*. In the next section I explain the scope of this dissertation within a program of research that aims at developing a cue-based acquisition of function words.

0.2 Defining the Scope

The lexicon of a language can be divided into two groups of words: content words and function words. Content words consist of nouns (e.g. *cat*, *Bob*, *freedom*), verbs (e.g. *run*, *blink*, *imagine*), adjectives (e.g. *happy*, *red*, *fake*), and adverbs (e.g. *fast*, *quietly*, *quickly*). Function words include articles (e.g. *a*, *the*), quantifiers (e.g. *some*, *most*, *all*), prepositions (e.g. *in*, *on*, *at*), pronouns (e.g. *he*, *they*, *her*), auxiliary verbs (e.g. *did*, *can*, *am/is/are*), connectives (e.g. *or*, *if*, *because*), interrogatives (e.g. *who*, *what*, *when*), among others. Function words differ from content words in (at least) five crucial ways. First, function words are phonologically simpler than content words (Shi, 1996). Second, even though content words vastly outnumber function words, function words are a lot more frequent. Third, while content words frequently admit new members, function words rarely do so. This is why content words are considered an open class in the lexicon while function words are called a closed-class. Fourth, the common intuition is that content words carry more meaning and the concepts they denote are more tangible. The meanings of function words, however, are subtle and abstract. Finally, function words appear in children's speech later than content words.

Even though content words commonly steal the spotlight, the unique properties of function words make them a valuable resource to linguists and cognitive scientists. They are few in number, extremely frequent, and very abstract in meaning. They are the essential nuts and bolts that combine smaller concepts to form larger thoughts. They provide crucial information on the structure and inner workings of human language and mind. The crosslinguistic and psycholinguistic study of function words provides us with an exceptional window into structure and building blocks of the human thought and reasoning.

Within function words, logical connectives *and*, *or*, *not*, *if*, have received considerable attention in the linguistic and psychological literature due to the foundational role that the concepts of conjunction, disjunction, negation, and implication play in logic and mathematics. In linguistics and philosophy, a large body of research has investigated the connections between the meanings of these words and their corresponding operators in formal logics. Similarly in psychology, there has been substantial research on children's development and adults comprehension of logical concepts and logical reasoning. This dissertation focuses on the acquisition of the disjunction word *or* by preschool children. It proposes a learning account for *or* (and its counterpart *and*), that can be expanded in the future to linguistic connectives in general such as *but*, *because*, *yet*, *so*, *after*, *before*, *although*, *however*, etc.

0.3 The Structure of the Dissertation

This dissertation consists of four parts: literature review (Chapters 1 and 2), comprehension studies (Chapter 3), corpus studies (Chapter 4), and modeling (Chapter 4). Starting with the literature review, Chapter 1 provides an overview of the semantics and pragmatics of *or* in English. The main focus of the chapter is the empirical discoveries about the interpretations of disjunction in different linguistic and nonlinguistic contexts. The chapter shows that on the surface, a disjunction like "A or B" can be interpreted as inclusive disjunction, exclusive disjunction, or a conjunction. These interpretations are often accompanied by ignorance inferences (the speaker does not know which option is true) or indifference inferences (the speaker does not care which option is true). The chapter discusses the factors that affect the interpretation of *or* in a given context. These factors include conversational principles, entailment environment, modality, disjunct semantics, intonation, syntax, metalinguistic speech acts, and some specific constructions such as embedded imperatives and unconditionals. The chapter argues that these factors can act as cues for the acquisition and interpretation of disjunction.

Chapter 2 provides an overview of research on the acquisition and interpretation of disjunction in children. It discusses three accounts of children's acquisition of logical connectives: development of logical reasoning, usage-based account, and logical nativism. The first two consider logical concepts such as disjunction as emergent from more primitive concepts such as "choice". Logical nativism, however, proposes that humans are born with logical concepts necessary for linguistic interpretation, as part of their Universal Grammar. The first two accounts – development of logical reasoning and the usage-based account– predict that children start with an exclusive interpretation of disjunction and only later, around age 5 or 6, do they interpret *or* in its "logical" inclusive sense. The nativist account predicts that children interpret *or* as inclusive disjunction from the beginning and only later with the development of pragmatic reasoning, they derive the exclusive interpretation.

Chapter 3, presents three studies on adults' and children's comprehension of *or* in simple existential sentences ("there is A or B"). The first study tests adults comprehension of discussion using two and three-alternative forced-choice truth-value judgment tasks (2AFC and 3AFC TVJTs). The 2AFC task showed that adults interpret *and* as conjunction and *or* as inclusive disjunction. The 3AFC task showed that adults do not consider a disjunction completely felicitous when both disjuncts are true. The second study used a similar 3AFC task to test three-to-five year old children's comprehension of *and* and *or*. The study also analyzed and categorized children's open-ended spontaneous feedback in the task. Children's interpretations were similar to adults except in cases where both disjuncts were true. In such cases, children's forced choice responses showed no sign of infelicity while their spontaneous feedback showed such signs: children corrected the utterance with *or* and suggested that *and* should have been used instead. Study 3 used a two-alternative forced choice (2AFC) task and categorized children's open-ended feedback. The two-alternative forced choice task showed similar results to adults and the study replicated children's open-ended feedback in study 2: children provided corrections to the utterance when both disjuncts were true and offered the connective *and*. Overall the results suggested that three-to-five year old children's interpretations of disjunction do not substantially differ from those of adults.

Chapter 4 presents two corpus studies. First, it presents a large-scale analysis of parents and children's productions of *and* and *or*. The results show that children start producing *and* between the first and the second years of their lives and reach their parents rate of *and* production around their third birthday. For disjunction, children start producing *or* between two and three years of age and by the time they are four, they reach a constant rate of *or* production. This rate is slightly lower than that of their parents. Overall the results of this study support the findings of Chapter 3: by age four, children develop a good understanding of connectives *and* and *or*. The second study selected a subset of *and* and *or* in child-directed speech for children between the ages of one and three. The study annotated utterances containing *and* and *or* for seven cue categories: their interpretation (exclusive, inclusive, conjunction), intonation, utterance type (declarative, question, imperative), syntax, consistency (clean or dirty vs. clean or tidy), communicative function, and answer type (correct vs. incorrect answers to questions with *or*). The results showed that intonation, and consistency play a large role in determining the interpretation of a disjunction. The results also show that around age 2, children start providing appropriate answers to questions with disjunction. The findings of this chapter suggest that children develop their understanding of disjunction mostly between their second and fourth birthday.

Finally, in chapter 5.5, I report the results of applying random decision forests (Ho, 1995) to the annotation dataset. The modeling study uses the annotation categories in study 2 of Chapter 4 to learn a decision structure to successfully interpret conjunction and disjunction. The results show that using the cues proposed in Chapter 4, a random forest can reach above 85% accuracy in classifying the correct interpretation of a conjunction or a disjunction. Given the results of the annotation study and the computational modeling, Chapter **??** provides a learning account for connectives *and* and *or*.

Chapter 1

Interpretations of Disjunction

1.1 Introduction

Despite its modest appearance, the word *or* has been a major trouble maker for formal theories of meaning. Perhaps the main reason is that capturing its meaning has always seemed within the reach of formal accounts at the time, yet more examination has shown that *or* is much more complex than expected. Consequently, few words have managed to prove as influential as *or* in advancing formal semantics and pragmatics. This chapter is dedicated to the semantics and pragmatics of disjunction, and specifically *or* in English. My primary goal is to provide an overview of the empirical discoveries in the interpretation of *or* in adult language before moving to disjunction in child language acquisition.

In discussing linguistics meaning, often different words are used to refer to different types of meaning. Here I clarify my terminology. In what follows, I may use the terms "meaning", "implicature", "inference", "implication", and "interpretation". I use the term "meaning" to refer to "literal meaning": the meaning of words and word combinations in their most "literal", least context-dependent, and least enriched version. Most of the time my usage of "meaning" refers to "lexical meaning". I use "implicature" (conversational) when the meaning is considered to be derived from literal meaning via the Gricean cooperative principle and its associated conversational maxims (Grice, 1989). The term "inference" is used more generally to refer to any type of meaning that is derived from literal meaning using some form of reasoning. I use "implication" to refer to all linguistic meaning regardless of the source and theoretical status. Therefore, literal meanings, implicatures, and inferences are all implications. Finally, I use interpretation in the broadest and most theoretically neutral way to include all types of meaning; linguistic or non-linguistic.

In what follows, I start with the discussion of disjunction in logic and philosophy. Disjunction has enjoyed a great deal of investigation in these fields and it would not be possible to understand current semantics and pragmatics of disjunction without first understanding its logical background. Then I move to the discussion of disjunction in language, and more specifically *or* in English. I show that since the early linguistic investigations, two different approaches to the meaning of disjunction have co-existed: first lexical ambiguity accounts, and second Gricean accounts. I explain that lexical ambiguity accounts consider *or* ambiguous between several meanings or senses while the Gricean accounts propose a single meaning for *or* and derive different interpretations of a disjunction from other linguistic and conversational factors. Then I enumerate some of the factors that affect the interpretation of disjunction. I argue that these factors provide a starting point for a cue-based acquisition of disjunction.

1.2 Disjunction in Logic

The first explicit account of propositional connectives in logic was developed by Stoic philosophers (3BC - 3AD) (Bonevac & Dever, 2012). They divided logical propositions into simple (atomic) and complex (molecular) propositions. Complex propositions were made of simple propositions connected by connective such as conjunction and disjunction. Similar to logical systems today, they defined these connectives in terms of the truth conditions of the propositions they connect. A conjunction was considered true when all propositions are true and false otherwise. Disjunction, however, received two definitions: exclusive disjunction and inclusive disjunction. Exclusive disjunction is true when exactly one proposition is true and the rest are false. Inclusive disjunction is true when at least one proposition is true, the rest may be true or false. Table 1.2 shows the truth conditions for binary conjunction ($\wedge$), exclusive disjunction ($\oplus$), and inclusive disjunction ($\vee$)[1].

[1]Binary exclusive disjunction has an "odd property"" in that linking a sequence of exclusive disjuncts results in a disjunction that is true if and only if odd number of disjuncts are true. This is not the case for the Stoic version of disjunction which is not a binary operator.

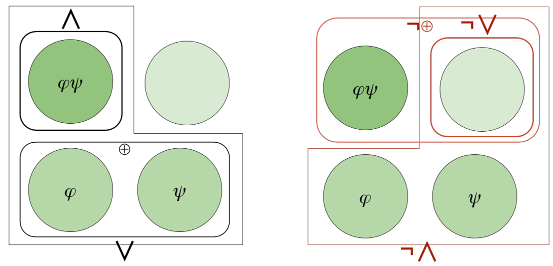

Figure 1.1: The relation betwen conjunction, inclusive disjunction, exclusive disjunction, and their negations.

Table 1.1: Truth conditions for conjunction and disjunction in classical logic

ϕ	ψ	$(\phi \wedge \psi)$	$(\phi \oplus \psi)$	$(\phi \vee \psi)$
T	T	T	F	T
T	F	F	T	T
F	T	F	T	T
F	F	F	F	F

It is important to note that there are entailment relations between the connectives in Table 1.2. A proposition ϕ entails another proposition ψ if in all situations that ϕ is true ψ is true as well. Conjunction of two propositions entails their inclusive disjunction but not the other way round. When the conjunction is true (row 1), the inclusive disjunction is also true but there are situations where inclusive disjunction is true but the conjunction is false (rows 2 and 3). Similarly, exclusive disjunction entails inclusive disjunction but not the other way round. This is because in every situation that exclusive disjunction is true, inclusive disjunction is also true but there is one situation where inclusive disjunction is true but exclusive disjunction is not. Conjunction and exclusive disjunction stand in contradiction to each other. If the conjunction of two propositions is true then the exclusive disjunction is false and if the exclusive disjunction is true then their conjunction is false. Figure 1.1 shows propositions as sets of situations in which they are true. The entailment relations can be seen as inclusion: a proposition that is contained within another proposition entails it. Exclusive disjunction and conjunction are both contained within inclusive disjunction and they both entail it. Negation in classical logic is a unary operator that flips the truth value of a proposition. Figure 1.1 also shows the negation of conjunction and two types of disjunction. Negated inclusive disjunction is contained within negated conjunction and negated exclusive disjunction; consequently it entails them. Table 1.2 shows the meaning of negative atomic propositions ($\neg\phi$, $\neg\psi$), negative inclusive disjunctions ($\neg(\phi \vee \psi)$), negative conjunctions ($\neg(\phi \wedge \psi)$), inclusive disjunction of negative propositions ($\neg\phi \vee \neg\psi$), the conjunction of negative propositions ($\neg\phi \wedge \neg\psi$), negative exclusive disjunction, and exclusive disjunction of negative propositions.

Table 1.2: Truth conditions for statements that involve the interaction of conjunction and disjunction with negation in classical logic.

ϕ	ψ	$\neg\phi$	$\neg\psi$	$\neg(\phi\vee\psi)$	$\neg(\phi\wedge\psi)$	$\neg\phi\vee\neg\psi$	$\neg\phi\wedge\neg\psi$	$\neg(\phi \oplus \psi)$	$\neg\phi\oplus\neg\psi$
T	T	F	F	F	F	F	F	T	F
T	F	F	T	F	T	T	F	F	T
F	T	T	F	F	T	T	F	F	T
F	F	T	T	T	T	T	T	T	F

Comparing the columns in Table 1.2 we can observe at least three equivalence relations. The first two are the ones named after the 19th-century British mathematician Augustus De Morgan[2]. The negation of an inclusive disjunction is equivalent to the conjunction of their negatives and the negation of a conjunction is equivalent to the disjunction of their negatives.

- De Morgan's Laws:
  - $\neg(\phi \vee \psi) \Leftrightarrow \neg\phi \wedge \neg\psi$
  - $\neg(\phi \wedge \psi) \Leftrightarrow \neg\phi \vee \neg\psi$

The third equivalence relation concerns exclusive disjunction. The exclusive disjunction of two propositions has similar truth conditions to the exclusive disjunction of their negatives. If exactly one disjunct is true and the other false, flipping the truth values using negation results in exactly one disjunct true and another false again. If the disjuncts have similar truth values, their negatives will also have similar truth values.

- Exclusive disjunction of negatives: $\phi \oplus \psi \Leftrightarrow \neg\phi \oplus \neg\psi$

[2]The so called De Morgan laws were known even to Stoics so the discovery of them certainly predate De Morgan's formulation.

Table 1.3 shows some other logical properties of exclusive and inclusive disjunction. Truth preservation refers to the property that if both disjuncts are true, then their disjunction is also true. Truth preservation holds for inclusive disjunction but not exclusive disjunction. Falsehood preservation is the opposite: the property that if both disjuncts are false then the disjunction is also false. Both inclusive and exclusive disjunction are falsehood preserving. Idempotency for disjunction refers to the property that the disjunction of a proposition with itself is equivalent in truth conditions to the original proposition. Inclusive disjunction is idempotent but not exclusive disjunction. However, both inclusive and exclusive disjunction are commutative and associative; meaning neither the order of the operands nor the order of the operations alter the outcome of the disjunctions. While inclusive disjunction distributes over conjunction, exclusive disjunction does not.

Table 1.3: Some logical properties of inclusive and exclusive disjunction.

Properties	Inclusive Disjunction $\vee$	Exclusive Disjunction $\oplus$
Truth Preservation	$a = T, b = T \Rightarrow a \vee b = T$	X
Falsehood Preservation	$a = F, b = F \Rightarrow a \vee b = F$	$a = F, b = F \Rightarrow a \oplus b = F$
Idempotency	$a \vee a \Leftrightarrow a$	X
Commutativity	$a \vee b \Leftrightarrow b \vee a$	$a \oplus b \Leftrightarrow b \oplus a$
Associativity	$(a \vee b) \vee c \Leftrightarrow a \vee (b \vee c)$	$(a \oplus b) \oplus c \Leftrightarrow a \oplus (b \oplus c)$
Disributivity	$a \vee (b \wedge c) \Leftrightarrow (a \vee b) \wedge (a \vee c)$	X
Monotonicity	$(a \rightarrow b) \Rightarrow (a \vee c) \rightarrow (b \vee c)$	X

Logical systems often pick one or the other definition of disjunction and give it more primacy. For example, Stoics considered exclusive disjunction as primary. Inclusive disjunction was considered "pseudo-disjunction" or merely the negation of a conjunction. It seems that the main reason for considering exclusive disjunction as primary was that unlike inclusive disjunction, it cannot be concisely redefined using conjunction and negation. Therefore, Stoics thought that exclusive disjunction must have an independent and primary status as an operator while inclusive disjunction is just a derivative. Unlike their Stoic colleagues, medieval philosophers defined disjunction as inclusive. Leibniz dispensed with both definitions of disjunction but later Bolzano (1781-1840) used

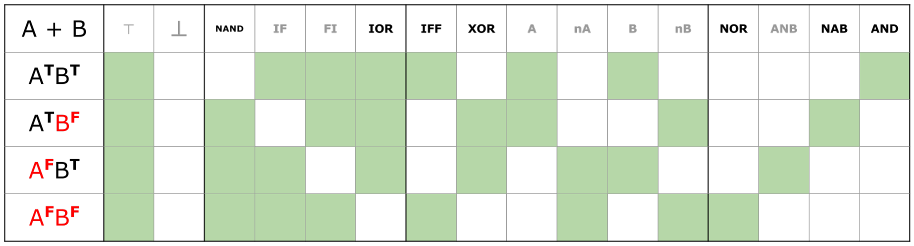

Figure 1.2: The truth table for the 16 binary logical connectives. The rows represent the set of situations where zero, one, or both propositions are true. The columns represent the 16 possible connectives and their truth conditions. Green cells represent true situations.

both. George Boole (1815 - 1864) gives more primacy to exclusive disjunction since it corresponds to addition modulo 2. Later Charles Sanders Peirce (1839-1914) changed Boole's system to use inclusive disjunction instead. Inclusive disjunction has enjoyed a primary role in modern logical systems since then.

The question of whether inclusive disjunction is "primary" in a logical system or exclusive disjunction depends on the goal of the system. The properties of exclusive disjunction make it ideal as an operator for some purposes but not others. When it comes to natural language semantics and modeling the meaning of the word *or*, we can similarly ask whether exclusive disjunction is primary (better represents *or*'s meaning) or inclusive disjunction. In the following sections we will discuss linguistic work that has addressed this issue but before I move to the discussion of disjunction in natural language, I would like to comment on two properties of exclusive disjunction that mismatch the properties of *or* in English.

First the lack of idempotency suggests that the exclusive disjunction of a proposition with itself ($\phi or \phi$) is necessarily false. Applied to the word *or* in natural languages, the prediction is that a sentence such as "Bob is happy or Bob is happy" should be judged as false regardless of whether Bob is happy or not. This intuition seems to be absent in judgments of such sentences with *or*. In fact, there is an intuition that such disjunctions are redundant and have the same truth value as the atomic proposition itself. For example, "the sky is blue or the sky is blue" is redundant and equivalent to "the sky is blue". This intuition is predicted if *or*'s meaning is represented by inclusive disjunction but not exclusive disjunction.

Second, exclusive disjunction of two propositions has the same truth values as the exclusive disjunction of their negatives ($\phi \oplus \psi \Leftrightarrow \neg\phi \oplus \neg\psi$). Considering the natural language *or*, this property suggests that the sentence "the door is open or the window is open" should have the same truth conditions as "the door is not open or the window is not open". However, the first seems false intuitively when both are closed while the second is false when both are open. Therefore, two essential properties of exclusive disjunction seem to mismatch the meaning of *or* in English. Inclusive disjunction on the other hand does not face these problems. However, many examples of English *or* such as "He is a basketball player or a soccer player" seem to exclude the possibility of both disjuncts being true. Therefore, exclusive disjunction seems to strong for the meaning of *or* and inclusive disjunction often falls short of the interpretation *or* receives. This tension has lead researchers in semantics and pragmatics to to consider inclusive disjunction as the primary meaning of *or* in English, and resort to other mechanisms that pragmatically strengthen the inclusive meaning of *or* to exclusive or conjunctive interpretations. In the next few sections, I briefly review the history and the current issues in the semantics and pragmatics of disjunction.

1.3 Disjunction in Language

In natural languages, disjunction and conjunction are types of coordination. Haspelmath (2007) defines coordination (or coordinate constructions) as: "syntactic constructions in which two or more units of the same type are combined into a larger unit and still have the same semantic relations with other surrounding elements." The example below shows several coordinate constructions in English.

(1)

a. The dog barked *and* the cat ran behind the sofa.
b. I will get some coffee *or* tea.
c. He went to bed *because* he was sleepy.
d. She was sick *but* she finished the homework.

The word or affix that marks coordination is called a coordinator. The coordinators are shown in italics in the example above. The units that are marked by the coordinator are called coordinands. "The dog barked" is a coordinand in the first example. In English, a conjunction is a coordination marked by the coordinator *and* and a disjunction one marked by *or*. The coordinands in conjunctions and disjunctions are called conjuncts and disjuncts respectively.

While there has been no report of a language that does not have ways to express conjunction and disjunction, several languages lack overt coordinators that mark conjunction or disjunction. In fact, Haspelmath (2007) reports that the mere juxtaposition of the conjuncts is a widespread strategy to convey conjunction crosslinguistically. For disjunction, often the juxtaposition is also accompanied by a marker of uncertainty or modality. For example, in Maricopa a sentence such as “John and Bill will come” is expressed as “John, Bill, will-come.” while the disjunction “John or Bill will come” is expressed as “John, Bill may-come.” (Gil 1991) Similarly in Dyirbal a disjunction such as “A or B” is expressed as “maybe A, maybe B” (Dixon 1972: 363). Similar effect of modals on the interpretation of coordination can also be found in English. Consider the English examples below.

(2) Here is what you will see on the table: a book, a pen, a calculator.

(3) Here is what you may see on the table: a book, a pen, a calculator.

A list of items with no overt coordinator such as “a book, a pen, a calculator” can be interpreted as a conjunction or a disjunction. In the first sentence, the list is interpreted as a conjunction: you will see a book, a pen, and a paper. In the second example, the list is interpreted similar to a disjunction: you may see a book, a pen, or a calculator. The sentences are identical except for the modal verbs. The sentence with a disjunctive interpretation uses the possibility modal *may*. Ariel (2014) reports a similar naturally occurring example with the modal *perhaps*, repeated below. Such examples point to a systematic connection between the notions of disjunction and modality.

(4) Practices of abortion, perhaps, pre-partum, perhaps postpartum (LSAC).

(5) Practices of abortion, pre-partum, or postpartum.

Languages that do mark coordination overtly do it in several ways. The most common pattern, at lest in European languages, is to place the coordinator in between the coordinands like “A and B” and “A or B” in English. However, other patterns such as “A B-and” where the coordinator appears after the coordination is also attested (see Haspelmath (2007) for more details). Another notable and common cross-linguistic pattern is the doubling of the coordinator on each coordinand. For example in Persian (Farsi), a disjunction can be expressed using the disjunction word *ya* like “A ya B” or it can be doubled on each disjunct like “ya A ya B”. Similar patterns have been attested in

Polish ("albo A albo B"), Dutch ("of A of B"), Basque ("ala A ala B"), Somali ("ama A ama B"), and French ("ou A ou B") among many others. In English the *either A or B* construction comes close to this pattern. In the next section, I focus on the interpretations of disjunction in English but the discussion is not limited to English and similar results have also been attested in other languages.

1.4 Disjunction in English

The use of the word *or* in English is informally observed to correlate with one or more of the following implications (Aloni, 2016):

1. Inclusivity (IOR): at least one of the disjuncts is true;
2. Exclusivity (XOR): exactly one disjunct is true;
3. Conjunctivity (AND): both disjuncts are true;
4. Ignorance: the speaker does not know which disjunct is true;
5. Indifference: which disjunct is true does not matter for the purpose of the conversation.

These five implications do not have equal status with respect to each other. The first three (inclusivity, exclusivity, and conjunctivity) are binary connective meanings discussed in section 1.2. The fourth, ignorance, is related to the knowledge state of the speaker, and the fifth, indifference, is related to the role of disjunction within the conversation.

These five implications are also not necessarily caused by the word *or* itself. They may directly stem from the meaning of *or*, or they may be the result of *or* interacting with several other factors that shape the overall communicative message of the utterance. The goal of semantic and pragmatic research on *or* is to separate the implication(s) contributed by *or* from those caused by other words or factors in the communication of meaning. Disentangling the contribution of *or* from the contribution of other communicative elements has proven difficult, yet extremely fruitful in advancing semantic and pragmatic theories. In what follows I try to provide a short overview of the difficulties that *or* poses to theories of meaning.

Table 1.4: Implications of *or* for three example sentences.

Example	IOR	XOR	AND	Ignorance	Indifference
Study today or tomorrow, to pass the exam!	✓	X	X	✓	✓
Bob studied yesterday or the day before.	X	✓	X	✓	X
Students, like Bob or Becky, will pass.	X	X	✓	X	X

Table 1.4 shows three example sentences with the disjunction word *or* and marks the presence or absence of each *or*-implication. A sentence such as "Study today or tomorrow, to pass the exam." implies that the addressee is asked to study today, tomorrow, or possibly both days. The overall message is that the addressee should study at least one of those two days to pass the exam. It does not rule out the possibility of the addressee studying both today and tomorrow, so there is no exclusivity implication. Furthermore, it is not asking the addressee to both "study today" **and** "study tomorrow", so a conjunctive implication is absent. It is also possible to infer that the speaker does not know or it does not matter to them whether the addressee studies today or tomorrow. The command is complied with as long as the addressee studies one of those two days. Compare this to a sentence like "Bob studied yesterday or the day before." The overall message is that Bob studied one day and that day may have been yesterday or the day before. It suggests that Bob did not study both yesterday and the day before, so there is an exclusivity implication and no conjunctivity implication. It is also implied that the speaker does not know which day exactly Bob studied so we have an ignorance implication, but it is not implied that the speaker is indifferent towards which day Bob actually studied. Now compare the previous sentences to a sentence such as "students like Bob or Becky will pass the exam." This sentence does not imply inclusivity or exclusivity. It does not communicate anything like "Either students like Bob will pass, or students like Becky will pass, or both." It does not exclude the possibility of students like both Bob and Becky passing at all. In fact to the contrary, the main message is that "both students like Becky **and** students like Bob will pass". In this example, *or* has a conjunctive implication. Even replacing *or* with *and* does not substantially alter the meaning of the sentence: "students like Bob and Becky will pass the exam". No ignorance or indifference implication accompanies this conjunctive implication.

Just looking at Table 1.4 one might conclude that there is no systematicity behind the use of *or* and the implications that accompany it. This was indeed the prevailing view among many logicians and philosophers that considered language messy, fraught with ambiguities, and illogical. For example, while discussing disjunction in his influential introductory book on logic, Alfred Tarski warns readers about the many interpretations of *or* in natural language and explains that there are "quite noticeable differences between the usage of it in everyday language and in logic."(Tarski, 1941). He first points out that "the word *or* in everyday language has at least two different meanings". A child may ask us to be taken to a hike in the morning and a theater in the afternoon, but we may respond: "No, we are going on a hike or we are going to the theater". He explains that the interpretation of *or* in this example is exclusive because "we intend to comply with only one of the two requests" and not both. However, a disjunction may also have an inclusive interpretation like the following example: "Customers who are teachers or college students are entitled to a special reduction". Tarski explains that *or* in this example is inclusive "since it is not intended to refuse reduction to a teacher who is at the same time a college student." He advises readers to avoid this exclusive vs. inclusive ambiguity by reserving the word *or* for the "logical" (inclusive) sense and use the construction "either ... or ... " for the exclusive one.

However, he immediately notes that there are other interpretations of *or* that go beyond the exclusive/inclusive distinction. I include his discussion here directly since in addition to addressing the ignorance implication of *or*, it foreshadows future developments in semantics and pragmatics initiated years later by Paul Grice.

> "In commmon language, two sentences are joined by the word *or* only when they are in some way connected in form and content. (The same applies, though perhaps to a lesser degree, to the usage of the word *and*) ... anybody unfamiliar with the language of contemporary logic would presumably be little inclined to consider such a phrase as"2+2=5 or New York is a large city" as a meaningful expression, and even less so to accept it as a true sentence. Moreoever, the usage of the word *or* in everyday English is influenced by certain factors of a psychological character. Usually we affirm a disjunction of two sentences only if we believe that one of them is true but wonder which one. If, for example, we look upon a lawn in normal light, it will not enter our mind to say that the lawn is green or blue, since we are able to affirm something simpler, and at the same time, stronger, namely that the lawn is green. Sometimes even, we take the utterance of a disjunction as an admission by the speaker that he does not know which of the

> members of the disjunction is true. And if we later arrive at the conviction that he knew at the time that one – and specifically, which – of the members was false, we are inclined to look upon the whole disjunction as a false sentence, even should the other member be undoutedly true. Let us imagine, for instance, that a friend of ours, upon being asked when he is leaving town, answers that he is going to do so today, tomorrow, or the day after. Should we then later assertain that, at that time, he had already decided to leave the same day, we shall probably get the impression that we were delibrately misled and that he told us a lie. The creators of contemporary logic, when introducing the word *or* into their considerations, desired, perhaps unconsciously, to simplify its meaning and to render the latter clearer and independent of psychological factors."

Tarski ended his discussion by saying that these linguistic and psychological factors should not enter logical considerations. The view that language is not amenable to the tools of logic remained prevalent but faced substantial challenges from philosophers that argued for more attention to ordinary language use. Finally, the work of two philosophers, Richard Montague, a student of Tarski, and Paul Grice, tilted arguments towards the "ordinary language" philosophers. Montague's focus was on quantification in logic and natural language while Grice focused on the logical connectives such as *or* and *if*. Grice (1989) argued that the perceived differences between the meaning of natural language words such as *or* and the operators in formal logic such as inclusive disjunction "arise from inadequate attention to the nature and importance of the conditions governing conversation." He set out to show that when we take conversational factors into account, the meaning of linguistic connectives are similar to the common definitions of their counterparts in formal logic.

An important contribution of Grice was his typology of meaning that lead to the establishment of semantics and pragmatics. He differentiated between "what is said" and "what is implied". "What is said" refers to the literal meanings of words; the conventional association between words and meanings that is independent of any particular context. "What is said" is the most primary type of meaning and not derived from any other process. The field of semantics is concerned with this type of meaning and all else that relies on context of use is relegated to pragmatics. On the other hand, "what is implied" (conversationally) or as he called them "conversational implicatures" refer to meanings that are created by using words and sentences in specific contexts[3]. Conversational

[3] I set aside conventional implicatures here since they do not come up in the semantics and pragmatics of disjunction.

implicatures are the result of refining the literal meanings of words (what was said) to suit the assumptions and purposes of the conversational context. As such, implicatures are derivative and not primary.

Grice was also influential because he pioneered the methodology of studying linguistic meaning. He viewed the interpretation of an utterance as the composite of many interacting factors. In order to understand the literal meaning of a word, a semanticist needs to examine it in different contexts and understand its interaction with other factors that shape the general interpretation of the utterance. Utterances containing a word like *or* may be interpreted differently in different contexts, giving the impression that the word is polysemous. However, it is possible that the word has one underlying meaning (i.e. its semantics) and that in interaction with other elements of the sentence and the conversation, it gives rise to a variety of interpretations. In such cases, the underlying meaning can be recovered by detecting the factors that influence interpretation and reversing their effects. In Grice's view, true polysemy is stable polysemy across a wide range of contexts.

In addition to context-sensitivity, Grice suggested cancellability and computability as other properties of pragmatic enrichment. Cancellability refers to the following observation: a speaker explicitly denying a pragmatic enrichment of what they said does not result in the speaker contradicting themselves. For example, if I say that "the chocolate box is in the fridge or the cupboard", you may infer that I do not know where it is (ignorance implication). But, I can continue by saying "I know where it is but I'm not going to tell you" without contradicting what I said before. According to Grice, this suggests that the ignorance implication is not part of the literal meaning of what I said. The idea is that my continuation cancelled the pragmatic inference that I do not know where the chocolate box is. With literal meaning on the other hand, a speaker explicitly denying what they literally said results in a contradiction. For example, if I say "the chocolate box is in the fridge or the cupboard", I cannot add "it is in neither place" without sounding contradictory. Grice also emphasized on calculability of non-literal (non-conventional) meaning (i.e. conversational implicatures). He believed that if researchers propose a certain interpretation to be non-literal (more accurately non-conventional), they should be able to explain the mechanism that gave rise to that interpretation. Finally, it is important to note that Grice did not mean to introduce an exhaustive and definite set of diagnostics to distinguish literal and implicated meaning. He emphasized that in many cases, our intuitions will be the guide on what is said literally and what is merely implicated by what is said.

1.5 Factors Involved in the Interpretation of Disjunction

This section presents a brief list of factors that influence the interpretation of disjunction in English. This list is not meant to be exhaustive; it only provides a window into the factors that an account of disjunction acquisition needs to consider. The factors discussed in this section include: conversational principles, entailment environment, modality, semantics of the disjuncts, metalinguistic communication (definitions and repairs), syntactic categories of the disjuncts, question intonation, embedded imperatives, and alternative unconditional constructions. I start this section with Grice's discussion of conversational principles that contribute to the overall interpretation of an utterance.

1.5.1 Conversational Principles

Grice's focus was on how conversational factors enrich utterance interpretation. He saw conversation as a cooperative social activity in which participants follow a certain set of rules or "maxims". Below I list the overarching "cooperative principle" as well as its maxims. Grice contended that these maxims further enrich the primary meaning of words and sentences in a given context. He used the term *conversational implicature* to refer to implications that are derived from the cooperative principle and the conversational maxims.

- **Cooperative Principle**: Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged.
  - **Maxim of Quality**: Try to make your contribution one that is true. Do not say what you believe to be false. Do not say that for which you lack adequate evidence. things for which you lack evidence.
  - **Maxim of Quantity**: Make your contribution as informative as required. Do not make your contribution more informative than is required.
  - **Maxim of Relation**: Be relevant.
  - **Maxim of Manner**: Be perspicuous. Avoid obscurity of expression. Avoid ambiguity. Be brief. Be orderly.

Grice's account provided some informal explanations for the divergences between the interpretation of *or* and inclusive disjunction in logic. For example, Tarski pointed out that sentences that are connected with *or* should be related with respect to their content. He reported that English speakers find a sentence like "2+2=5 or New York is a large city" very odd and hard to judge as true, even though one of the disjuncts is certainly true. Grice's "maxim of relation" provides an independently motivated explanation for this observation. In conversations, speakers are expected to provide relevant information to the topic of the conversation. It is extremely hard to think of a context where "2+2=5" and "New York is a large city" are relevant alternatives to the conversational topic. Tarski himself noticed, however, that this phenomenon is not limited to the word *or*. Other connectives face the similar problem: "2+2=4 and New York is a large city" or "if 2+2=4, then New York is a large city".

Tarski also pointed out that a disjunction such as "A or B" is often odd when the speaker knows which alternative is true. In other words, a disjunction often implies that the speaker is ignorant with respect to the truth of the disjuncts. The definition of disjunction in classical logic lacks this aspect. Grice's theory provides a separate mechanism that is responsible for the ignorance implication. The maxim of quality requires the speaker to say what they believe to be true and the maxim of quantity requires them to be as informative as required. In many contexts the speaker is expected to be maximally informative. If the speaker knows A then they should say "A". In Tarski's example, if the speaker knows that the grass is green, then the most informative statement would be "the grass is green." Saying that "the grass is green or blue" goes against the maxim of quantity. The speaker is providing less information even though it is clear they know more. However, as Grice points out, in some contexts there is a reason for being underinformative and in such cases there is no ignorance implication. For example, he mentions that in a treasure hunt with his children, he may say: "The prize is in the garden or the attic. I know that because I know where I put it, but I'm not going to tell you." In this context the speaker knows which alternative is true. However, the context does not require him to be maximally informative. In fact, given the rules of a treasure hunt, he is required to not divulge the whereabouts of the prize. Therefore, the speaker's underinfomative utterance is warranted. This way Grice shows that the ignorance implication is not part of what *or* means but rather the result of *or* interacting with conversational maxims. It is important to point out that a disjunction such as "A *or* B" is unacceptable when conversational participants already know which disjunct is true. In Grice's example, while Grice knows which disjunct is true (there is no speaker ignorance), the addressee does not. However, in Tarski's example, both the speaker and the addressee know whether the grass is green or blue.

Tarski discussed the exclusive and inclusive interpretations of *or* as well. He explained that even though in logic a disjunction is commonly defined as inclusive, a sentence like “we are going on a hike or we are going to the theater” has an exclusive interpretation. Grice’s account provides an explanation for this supposed “ambiguity” as well. In some contexts, the speaker knows whether both alternatives are true or not (Competence Assumption). If the speaker knows both alternatives to be true and the context requires maximal informativeness, then they should use the connective *and*. If they know that only one alternative is true, then they cannot use *and* because using it would violate quality (the speaker has said something false.) In such contexts using *or* instead of *and* implies that only one alternative is true and not both. The exclusive example provided by Tarski is similar to such contexts. The father knows (and in fact decides) whether both alternatives will be true or only one. If he intended for both to be true he could use the word *and*: “we are going on a hike and we are going to the theater”. Since he did not, we can infer that he does not intend to do both. In fact in Tarski’s original context, the father says the sentence with *or* in contrast to the child’s utterance with *and*.

The Gricean account has been developed and made more explicit by several authors. Here I present the current standard neo-Gricean account which is mostly due to U. Sauerland (2004). Assuming the speaker has uttered a disjunctive assertion such as “P or Q”, the reasoning proceeds as follows:

- **Utterance**: the speaker said “P or Q”.
- **Alternatives**: the speaker could have said: P, Q, or “P and Q”. Why didn’t s/he?
  1. **Ignorance**: The speaker is uncertain about the truth of P (i.e. $\neg B_S(P)$)
  2. **Ignorance**:The speaker is uncertain about the truth of Q (i.e. $\neg B_S(Q)$)
  3. **Ignorance**: The speaker is uncertain about the truth of P and Q (i.e. $\neg B_S(P \wedge Q)$)
- **Comeptence**: The speaker knows whether both propositions hold or not (i.e. $B_S(P \wedge Q) \vee B_S\neg(P \wedge Q)$)
  4. **Exclusivity**: Given ignorance inference 3 and speaker competence, the speaker believes that only one of the disjuncts is true (i.e. $B_S\neg(P \wedge Q)$).

Inferences 1-3 are ignorance implications. It is important to notice that the exclusivity inference in step 4 develops from the ignorance inference in step 3 and the the competence assumption. For the exclusivity implicature to arise, the context of the utterance must be one where the speaker should know whether both disjuncts hold or not, but s/he is not sure about which one holds. As Geurts (2006) argues, it is not clear how common such contexts are and what proportion of exclusivity implications are in fact implicatures derived via this type of pragmatic reasoning. Nevertheless, it is not impossible to think of such contexts. For example, if I say that "Bob went to the shop and bought a cardigan or a shirt", it is reasonable for the addressee to assume that I know whether one item was bought or two. At issue is not whether exclusivity implicatures exist at all but rather how common are they. The semantics and pragmatics literature seems to have an assumption that at least the majority of exclusivity implications are derived via the Gricean reasoning sketched above.

While ignorance, indifference, and exclusivity implications of *or* can be explained (at least partly) via the Gricean mechanism above, the conjunctive interpretation remains unexplained. Geurts (2010) revises the Gricean account to cover the conjunctive inferences of free-choice expressions like "you can have coffee or tea". Potts & Levy (2015) extend the Gricean account to cover definitional uses like "he is a wine lover or an oenophile". I will discuss free-choice inferences and definitional uses below. As far as I know, there are no Gricean accounts for conjunctive interpretations of discussion for sentences that provide examples such as "Students, like Bob or Becky, will pass." There are also no Gricean accounts for examples of self-repair with disjunction such as "Bob changed the font, or I mean, the size of the text." These cases will be discussed below as well.

Before moving on, I would like to add that in Gricean pragmatics, the notion of "alternatives" or "what the speaker could have said" plays a crucial role. In case of the ignorance implicature, the explanation relies on the assumption that instead of "A or B" the speaker could have said something simpler but more informative, namely "A". The Gricean explanation relies on the addressee reasoning about why the speaker did not just say "A". In case of the exclusivity implication, the Gricean approach relies on the assumption that instead of "A or B" the speaker could have used a different connective, namely *and* to say "A and B". The addressee reasoning about why the speaker did not do so derives the exclusivity implicature. Alternatives also play an important role in developmental accounts of pragmatics. Barner, Brooks, & Bale (2011) argue that children are not adult-like in their access to the linguistic alternatives and as a result, they show non-adult-like pragmatic inferences.

An active area of research in Gricean pragmatics is the question of what constitutes an alternative and how implicatures are computed given a set of alternatives to the asserted utterance. The alternatives to a lexical item were traditionally considered as a scale ordered by entailment. L. R. Horn (1972) proposed that words such as *or* and *and* as well as *some* and *all* form scales of alternatives represented as <*or*, *and*> and <*some*, *many*, *most*, *all*>. This is why the exclusivity implicature of *or* is also called a "scalar implicature". The basic idea is that asserting an utterance with the weaker lexical item on the scale (e.g. *or*) results on the inference that the corresponding utterance with the the stronger item (e.g. *and*) would have been false (violated the maxim of quality). However, using the scale <*or*, *and*> will only derive the exclusivity implicature and does not provide an account of ignorance implications. In the standard account provided above, the ignorance implications rely on including each disjunct in the alternative set as well. Due to this problem (among others), the notion of "scale" has been replaced by "the set of alternatives". Nevertheless the term "scalar implicature" is still used to refer to the implicatures of *some*, and *or*. A large body of literature suggests that children do not compute scalar implicatures at the rate that adults do. I discuss this issue more in the next two chapters.

1.5.2 Entailment Environment

The concept of "entailment" plays an important role in logic and semantics. The concept is often introduced as a relation among propositions such that P entail Q if and only if P being true necessarily makes Q true. Based on this, two other notions are defined: upward entailing environment and downward entailing environments.

- A linguistic environment ϕ is upward entailing if and only if for any two expressions a and b, if a entails b, then $\phi[a]$ entail $\phi[b]$.
- A linguistic environment ψ is downward entailing if and only if for any two expressions a and b, if a entail b, then $\psi[b]$ entail $\psi[a]$.

Let's consider a as "student", b as "human", ϕ as "Roxy is a []", and ψ as "Roxy isn't a []". Since "student" entails "human", and "Roxy is a student" entails "Roxy is a human", we can conclude that "Roxy is a []" is an upward entailing environment. On the other hand, "student" entails "human" but "Roxy isn't a human" entail "Roxy isn't a student". Therefore, we can conclude that "Roxy isn't a []" is a downward entailing environment. In short, upward entailing environments preserve entailment direction while downward entailing environments reverse it.

As explained earlier, exclusive disjunction entails inclusive disjunction. In an upward entailing environment, this entailment relation is preserved: "Roxy is a student or a teacher (but not both)" entails "Roxy is a student or a teacher (or both)." However, in a downward entailing environment this relation is reversed: "Roxy isn't a student or a teacher (neither)" entails "Roxy isn't a student or a teacher (but may be both or neither)" A common observation is that the exclusive interpretation of *or* is more common in upward entailing environments while the inclusive interpretation is more common in downward entailing environments. For example a disjunction like "he is a student or a teacher" is more likely to be interpreted as "exclusive" while its negative counterpart "not a student or a teacher" is more often interpreted as "neither", which is expected if *or* is inclusive. This is predicted by Grice's maxim of quantity. In an upward entailing environment, exclusive disjunction is stronger and conveys more information. In a downward entailing environment, this pattern is reversed; inclusive disjunction results in a stronger and more informative statement. If a listener expects the speaker to make their contribution as informative as possible, then we can expect a bias towards exclusive disjunction in upward entailing environments and inclusive disjunction in downward entailing ones.

As explained in the section on logic and disjunction, the interaction of negation with disjunction, and conjunction is captured by the so-called De Morgan laws repeated below. We can generalize from negation to all downward entailing environments and re-write the De Morgan laws with Δ representing a downward entailing environment.

- Generalized De Morgan's Laws:
  - $\Delta(\phi \vee \psi) \Leftrightarrow \Delta\phi \wedge \Delta\psi$
  - $\Delta(\phi \wedge \psi) \Leftrightarrow \Delta\phi \vee \Delta\psi$

It is sometimes argued that the interaction of downward entailing environments with disjunction and conjunction follow these rules in natural language. For disjunction the argument is that (not A or B) is interpreted as the conjunction of negatives (not A and not B). While this may be true in many and perhaps majority of cases, there are notable and systematic exceptions. This point is perhaps best illustrated by the negative phrase "not one or the other" in the following naturally occurring examples (5-9). In (5) below, "not one or the other" is used to mean "both". In example (6) it is used to mean "neither". In the (7) and (8) examples, the authors explicitly explain that by "not one or the other" they mean "neither or both". Finally (9) shows that these observations are not isolated to the expression “one or the other”.

(6) Speed or Quality? It’s Not One or the Other. It’s Both! (Online Blogpost title by Chris Manuel)

(7) There is no inâĂŚbetween: you’re either masculine or feminine because you’re either male or female, and if you’re not one or the other of these two genders, then there must by something wrong with you. In numerous other cultures, however, there are gender systems that are not binary.

(8) In the above example [containing this expression: $time =˜ /(\d+):(\d+)(:(\d+))?/], the third set of parentheses is used to associate both the colon and the digits with “?” - either both should be specified, or neither, but not one or the other. (Response to a programming exercise on an online forum)

(9) Everything is either physical or spiritual ... This is of course the root of the problem ... If things are either A or B, it actually makes sense to assume that once they’re not one, then they are the other. But what if they’re not A or B? what if, for instance, they’re neither? Or ... both? (Medium Article by Doc Ayomide: I’m Christian and I don’t believe mental illness is spritiual)

(10) The church of the Lord is not here or there, but everywhere. (online newsletter at newchurch.org)

The examples above suggest that in natural language, the negation of a disjunction is not necessarily the conjunction of negations. These examples are not presented here to suggest that the NOR and AND interpretations of not (A or B) are equally likely. The examples show the importance of linguistic and non-linguistic factors in shifting our biases one way or another. Entailment environment is simply one of these factors.

Nevertheless, research in semantics has shown that entailment environment is an important factor in the interpretation and distribution of lexical items (see Giannakidou (2011) for a discussion). Based on this, Crain (2012) has suggested that the entailment environment and its interactions with logical words such as *or* must be an innate property of the human mind. I will cover this nativist model of logical word acquisition in the next chapter. In the next section I discuss the role of modality in the interpretation of disjunction.

1.5.3 Modals

The interaction of *or* with modals, especially possibility modals such as *may* and *can* presented the biggest challenge for the proposal that *or* has the semantics of inclusive disjunction. The issue was first discussed by Kamp (1973) in the context of giving permissions. Consider a sentence like: "You may pay using cash or credit card." It has two main interpretations. One is the standard inclusive interpretation which is more accessible if it is followed by an expression of uncertainty: "you may use cash or you may use credit card, or possibly both but I'm not sure". This interpretation is predicted by the standard inclusive account. However, there is a second and often more prominent interpretation for this sentence which suggests customers are free to choose: they are allowed to use cash *and* they are allowed to use credit card. This so called "free choice" interpretation is not expected if *or* means inclusive disjunction and *may* acts like a standard possibility modal. "It is possible that A or it is possible that B" weaker and less informative than "it is possible that A and it is possible that B". However, it seems that in natural language when *or* appears with possibility modals it can have both interpretations. There have been many proposals to tackle this problem. Here I discuss two main proposals and expand on one that has made its way into acquisition research. In one approach, semanticists abandoned the truth-conditional inclusive semantics of *or* and proposed that *or* encodes the conjunction of two possibilities (Geurts, 2005; Zimmermann, 2000). In a second approach, they kept the standard semantics of *or* and treated the free choice inference as an implicature (Fox, 2007; Geurts, 2010).

First, Zimmermann (2000) made a departure from the truth-functional account of *or* and proposed that *or*'s meaning is inherently modal. "A or B" expresses the conjunction of two possibilities and can be paraphrased as "It is possible that A and it is possible that B," represented in modal logic as $\Diamond A \wedge \Diamond B$. For example, "Bob paid using cash or credit card" is equivalent to "It is possible that Bob paid using cash and it is possible that Bob paid using credit card." The modal account of *or* predicts a different logical structure for the free choice sentences. A sentence like "Bob is allowed to pay using cash or credit card" will have two layers of possibility modals: $\Diamond\Diamond A \wedge \Diamond\Diamond B$, roughly paraphrased as "it is possible that Bob is allowed to pay using cash and it is possible that Bob is allowed to pay using credit card." This is the interpretation without a free-choice implication. The free-choice interpretation is only derived when the speaker is assumed to be an "authority" on the subject. According to the "authority principle", if an authority considers it possible that Bob is allowed to pay in cash, then Bob is allowed to pay in cash ($\Diamond\Diamond A \to \Diamond A$). Assuming speaker authority, a statement like "it is possible that Bob is allowed to pay using cash and it is possible that Bob is allowed to pay using credit card" reduces to "Bob is allowed to pay using cash and Bob is allowed to pay using credit card" ($\Diamond\Diamond A \wedge \Diamond\Diamond B \to \Diamond A \wedge \Diamond B$). Therefore, the modal account of disjunction provides a straightforward answer to the puzzle of free-choice interpretations, yet it dispenses with the truth-functional account of disjunction.

The pragmatic approach strives to keep the truth-functional meaning of *or* and analyze the free-choice interpretation as an implicature. It takes two observations as its starting point. First, that the free-choice inference is cancellable. As explained before, "you are allowed to drink tea or coffee" can be followed with "but I'm not sure which", therefore not implying that the addressee has free choice between tea and coffee. Second, when we add negation to free-choice sentences, the interpretation is not the negative of the conjunctive free-choice interpretation, but rather the negative of the standard account in which disjunction is inclusive. For example, the main interpretation of a sentence like "you are not allowed to drink tea or coffee" is one where neither option is allowed. This interpretation is expected if negation is operating on the possibility modal and an inclusive disjunction ($\neg\Diamond(A \vee B)$). Proponents of the pragmatic approach argue that this behavior is not limited to negation and applies to downward entailing environments more generally. Consider a sentence like: if I'm allowed to drink tea or coffee, I'll be happy. We can infer that the speaker will be happy even if they are only allowed to drink tea. However, under a conjunctive interpretation of *or* with *allowed to*, one should expect that the speaker will only be happy if both are allowed. This is not the interpretation we intuit. The pragmatic approach keeps the semantics of *or* as inclusive disjunction and contends that similar mechanisms should explain exclusivity as well as conjunctive (free-choice) implication. (Chierchia, 2013; Fox, 2007; Geurts, 2010) In what follows I sketch Fox (2007)'s analysis of free-choice inferences of *or* which was later adopted by Singh, Wexler, Astle-Rahim, Kamawar, & Fox (2016) to explain why children sometimes appear to interpret disjunction similar to conjunction in simple declaratives.

Applying the ordinary pragmatic mechanism explained earlier to sentences with modals such as *may* and *allowed to* results in the wrong prediction. The problem lies in the alternatives considered for pragmatic computation. Consider the sentence "you are allowed to drink coffee or tea". The standard alternatives to this sentence are: you are allowed to drink coffee, you are allowed to drink tea, and you are allowed to drink coffee and tea. If we mechanistically apply the Gricean recipe, we derive nothing more than the standard interpretation: "you are allowed to drink coffee or tea; but the speaker is not certain that you are allowed to drink coffee, and the speaker is not certain that you are allowed to drink tea, and the speaker is not certain that you are allowed to drink both coffee and tea". This is not the free-choice inference we have been looking for.

Fox (2007) resolves this issue by changing the alternatives. As explained before, the standard set of alternatives to a disjunction like "A or B" is A, B, and "A and B". For the sentence "you are allowed to drink coffee or tea", the standard alternatives are "you are allowed to drink coffee" ($\Diamond A$), "you are allowed to drink tea" ($\Diamond B$), and "you are allowed to drink coffee and tea" ($\Diamond A \wedge \Diamond B$). Fox (2007) proposes that the alternatives are instead the following set: "you are only allowed to drink coffee" ($\Diamond A \wedge \neg \Diamond B$), "you are only allowed to drink tea" ($\Diamond B \wedge \neg \Diamond A$"), and"you are allowed to drink coffee and tea" ($\Diamond A \wedge \Diamond B$). What justifies the change of alternatives from "allowed to X" to "only allowed to X"? In Fox (2007)'s system this follows from the syntactic structure of these sentences. They contain a silent operator that has similar semantic effects as the word *only*. The process of applying this operator to a linguistic expression is called "exhaustification", and the operator is commonly abbreviated as EXH. In short, EXH(ϕ) asserts that ϕ is true and every alternative not entailed by ϕ is false. In Fox (2007)'s account, EXH applies to each disjunct, as well as the disjunction as a whole. The final product is the following implication: "you are allowed to drink coffee or tea; not **only** coffee, not **only** tea, and not both coffee and tea."

Geurts (2010) uses essentially the same solution as that of Fox (2007), but casts it in a pragmatic framework rather than a syntactic one. He suggests that pragmatic reasoning is intention based and even though linguistic alternatives are important, it the set of possible communicative intentions that play the key role in pragmatic computation. When a sentence such as "you are allowed to drink coffee or tea" is uttered, the listener considers four possible communicative intentions: (1) coffee and tea are both allowed, (2) coffee is allowed but tea isn't,(3) tea is allowed but coffee isn't, and (4) neither is allowed. He explains that intention (4) is ruled out because it is in contradiction with the basic meaning of the utterance. Options (2) and (3) are ruled out because if the speaker meant to convey them, they could have said something simpler, namely "you are allowed to drink tea" or "you are allowed to drink coffee". The only intention left that satisfies Gricean maxims is intention (1) which is the desired free-choice inference.

While the literature on the interaction of disjunction with modals has mostly focused on possibility modals such as *may* and the context of giving permissions, similar conjunctive inferences are present with preference/desire modals such as *want*, *like*, and *love*. If we say "Bob likes/loves going on hikes or climbing rocks or staying outdoors", it is clear that Bob likes all the activities listed. Therefore, it is possible to infer that "Bob likes/loves rock climbing." Similarly, we can infer from "Bob would like some coffee or tea" that "Bob **would like** some coffee" and "Bob **would like** some tea" (The inference is easier to access when *would like* is stressed). Similar inferences seem to be valid for "Bob wants some coffee or tea." However, it seems that the conjunctive inferences in such cases are not as strong as the case of permissions like "Bob is allowed to drink coffee or tea." Perhaps the strongest case of conjunctive inferences comes in the context of providing examples with the word "like". In a sentence such as "Students like Bob or Becky never fail", the disjunction word is almost equivalent to a conjunction: "Students like Bob and Becky never fail." These observations suggests that *or* receives conjunctive interpretations in a wider range of environments than commonly discussed in the literature.

1.5.4 Disjunct Semantics

Geurts (2006) points out that even though pragmatic reasoning may be the reason behind some exclusive interpretation of *or*, in many examples deriving the exclusivity interpretation via implicatures may be unnecessary because exclusivity is introduced by the semantics of the disjuncts themselves. Consider an example such as: "Bob is in the kitchen or the bathroom." In the ordinary world that we live in, both disjuncts in this sentence cannot be true. Bob cannot be in the kitchen and the bathroom at the same time. Given that the inconsistency of the disjuncts is common knowledge to discourse participants, no inclusive interpretation is possible. The only available interpretation of such disjunctions is exclusive but this has little to do with the meaning of *or*. It stems from the semantic relation between the disjuncts. In fact, the exclusive interpretation would be present even when *or* is absent. Suppose someone asks where Bob is and the speaker responds with "Not sure ... in the kitchen ... in the bathroom." The interpretation of this response is similar to exclusive disjunction.

More generally, our world knowledge provides us with likely relations between different propositions. For example, "Bob fell down" and "Bob hurt himself" are likely to co-occur and are interpreted as causally linked even though they do not have to be. The rich conceptual structure among different propositions can help the interpretation of linguistic connectives. Consider the following naturally occurring example from Ariel (2014): "You come ... you don' come ... it doesn't matter to me". In this example, the speaker uses no connectives between the main three sentences of the utterance, yet the interpretation of the relations among them is clear. The utterance can be paraphrased as "Whether you come or you don't come, it does not matter to me." The rich conceptual structure among coordinands often make it transparent what type of coordinator is required and this can subsequently help children's acquisition of connectives. With respect to disjunction, the disjuncts are often inconsistent in their meanings; only one can be true and not both. It is noteworthy that stoics described disjunction as "an operator for incompatibles", which points to the influence of disjunct semantics on the definition of disjunction in stoic logic.

1.5.5 Metalinguistic Communication

In two instances, disjunction is used to communicate about language itself. The first is when a speaker wants to communicate that two expressions have the same meaning (at least for the purposes of the conversation), and the second when a speaker wants to provide a repair; a signal that a linguistic error was made. I discuss these two cases below.

Definitions

Definitional or metalinguistic disjunction is the type of disjunction that I just used at the beginning of this sentence! The primary function of such a disjunction is to communicate that two expressions are equivalent in meaning or function, at least for the current purposes of the conversation. For example, a sentence such as "Bob is a wine lover or an oenophile" communicates that "oenophile" is another term for "wine lover" (Potts & Levy, 2015). Similar to what we saw with modals, definitional uses give rise to conjunctive interpretations of disjunction. If "Bob is a wine lover or an oenophile", then "Bob is a wine lover" and "Bob is an oenophile". Potts & Levy (2015) propose that the following sociopragmatic conditions should hold for the definitional interpretations of *or*: First, discourse participants have mutual interest in communicating about the language itself, in addition to interest in communicating about the world. Second, the participants can assume that the speaker has expertise in the relevant domain. Third, that the cost of using a disjunction must justify its verbosity given that a disjunction of A or B is always longer than B itself to communicate the same meaning.

Potts & Levy (2015) provide a Gricean account for definitional disjunctions in which “A or B” has the semantics of inclusive disjunction. The key innovation of the account is that conversational participants use language to convey information about the world as well as language itself. Potts & Levy (2015) argue that a disjunction can be used to communicate information about a speaker’s preferred lexicon, as well as the state of the world. Therefore, when the right sociopragmatic conditions for the definitional use hold, a disjunction such as “A or B” communicates two pieces of meaning: 1. “A” is true and 2. “A and B have the same meaning”. The equivalence of A and B in meaning derives the conjunctive interpretation in this account. Given that the speaker has communicated that A and B have the same meaning, they are either both true or both false. Since the speaker also asserted that A is true, then B must be true as well. Therefore, in Potts & Levy (2015)’s account the conjunctive interpretation of definitional uses is primarily the result of disjunct semantics and not *or* itself. In turn, disjuncts semantics in definitional uses are the result of sociopragmatic conditions governing the context of the utterance.

It is important to point out that child directed speech often satisfies all three sociopragmatic conditions of definitional interpretations proposed by Potts & Levy (2015). First, parents and children have mutual interest in communicating about the language itself given that children are active language learners. Second, in almost all areas, parents are experts with respect to the lexicon compared to children. Finally, it is reasonable to assume that the pedagogical goal of teaching a child the lexicon of a language justifies the verbosity of using a disjunction. Therefore, we may expect that definitional uses will show up commonly in child-directed and in fact, this is what we found in our corpus study presented in Chapter 4.

Repairs

A fairly unexplored area is the role of disjunction in conversational repairs. Often during casual speech, conversational participants notice a mistake either in their own speech or someone else’s. The utterance that signals this mistake and provides correction is called a “repair”. Repairs are often classified into “self-repair” and “other-repair”. Self-repairs are repairs that are provided by the speaker themselves while other-repairs are provided by discourse participants other than the speaker.

For example while discussing news on the flat earth society, a speaker may say "I can't believe there are people who still believe the earth is round" providing an immediate self repair ". . . I mean flat." Alternatively, someone else in the conversation may provide the repair with ". . . you mean flat." Repairs have the following three components: reparandum (the part of the original utterance that needs repair like "round"), editing term (a discourse marker like "I mean" that signals a repair), and alteration (the corrected section like "flat") (Heeman & Allen, 1999). Common editing terms include *oh*, *um*, *uh*, *I mean/I meant*, *well*, *sorry*, *no*, *or*, and *let's see*. Not all repairs are accompanied by editing terms, especially those that repeat a large part of the reparandum in the alteration and make a minor modification such as "The boy was ha . . . The man was happy."

The disjunction word *or* can be used as an editing term alone or along with other editing terms such as "I mean". The sentences below show a few examples of *or* as an editing term.

(10) "Engine two from Elmi(. . .) or engine three from Elmira." (example 14 of Heeman & Allen (1999))

(11) "Why can't I change font or I mean size of the typed letters?" (online example)

(12) "I promised to see Nadelka again," said he, "or, I mean she promised to see me." (Stash of the Marsh Country by Harold Waldo)

(13) "John picked us up in his car, or rather his dad's car which he'd borrowed." (online example)

(14) "I met him very late on Friday night, or rather, early on Saturday morning." (online example)

It is reasonable to use a coordinator for repairs given that the reparandum-term-alteration structure is similar to the structure of coordination. However, the communicated meaning in a repair is not what *or* often communicates. A repair commonly signals that the reparandum was not true or accurate and that the alteration is true and what the speaker is trying to communicate. A disjunction, on the other hand, commonly allows either disjunct to be true and does not rule out any disjunct. How come *or* is used as the connective for repairs?

It is important to note that while *or* does not carry the repair interpretation itself, its meaning – either as inclusive disjunction or exclusive – is not incompatible with a repair. The repair interpretation (the first disjunct is false, the second is true) is stronger and more specific but still compatible with the meaning of *or*. This is not the case for *and* since conjunction communicates that both conjuncts are true and this is not ideal for repairs. For example, in the repair sentences provided above, using *and* instead of *or* is infelicitous for communicating a repair. Since *or* is compatible with a repair reading but not strong enough, it is quite possible that similar to previous cases, the weak semantics of *or* (inclusive disjunction) is strengthened by external factors.

For example, it is possible that *or* simply contributes the meaning that at least one of the disjuncts are true. Then factors that commonly signal repairs such as pauses, intonation, significant overlap between reparandum and alteration, or co-occurring edit terms such as "I mean" can strengthen the inclusive meaning of *or* to communicate that "in fact it is the second disjunct that is true". This account is supported by the fact that *or* is often optional in repairs. In the examples recounted before, if *or* is dropped, other elements such as the pause, the intonation, the phrase "I mean", or the word "rather" can still signal the repair in the utterance. Therefore, it is possible that *or* contributes inclusivity but these repair factors strengthen the coordination to mean that the first disjunct is false while the second is true.

1.5.6 Syntactic Units

To my knowledge, there has been no systematic investigation of the effect of syntactic category on disjunction interpretation. However, there is some informal evidence suggesting that it may play a role in generating exclusivity inferences. Compare the following example sentence "He likes coffee or tea" (nominal disjunction) with "He likes coffee or he likes tea" (sentential disjunction). A common intuition is that the second disjunction with sentential disjuncts is more likely to be exclusive than the first disjunction with nominal disjuncts. The clausal vs. sub-clausal distinction also plays a role crosslinguistically. Haspelmath (2007) reports that Yapese (an Austronesian language of Micronesia) uses different words for sentential and nominal conjunction. He reports different conjunction words for nominal and event conjunction as a widespread typological phenomenon, especially in African languages. He also reports that in Koromfe (a Gur language of Burkina Faso) a disjunction is only allowed for events so a sentence like "do you want coffee or tea?" must be rephrased as "do you want coffee or do you want tea?" These observations suggest that the syntax of a disjunction may play a role in shaping its interpretation.

1.5.7 Question Intonation

Table 1.5: Intonation and interpretation of disjunction in polar and alternative questions.

Question	Intonation	Example	Answer	Interpretation
Polar	Rising	Would you like any tea(↑) or coffee↑?	yes/no	$\vee$
Alternative	Rise-Fall	Would you like tea↑, or coffee↓?	tea/coffee	$\oplus$

There are two types of questions with the disjunction word *or*: polar questions and alternative questions. These two types of questions differ in the type of intonation and the responses they receive. Table 1.5 provides a summary of the properties of polar and alternative questions. Disjunctions in polar questions are accompanied by an overall rising intonation, or by rising intonation on each disjunct. Disjunctions in alternative questions receive rising intonation on the non-final disjuncts and falling intonation on the last. Polar questions typically receive a yes/no answer followed by one of the alternatives if the alternative matters for the purpose of the conversation. For example, if a waiter approaches and asks "would you like any tea or coffee?" the appropriate answer is typically "yes, tea/coffee please" or simply "no thank you". On the other hand, in the context of asking someone out on a date, a simple "yes/no" response to the same question may suffice given that the choice of alternative does not matter for the purpose of the conversation. When the choice of alternative is extremely relevant, the yes/no part of the response may be left unsaid and simply implied by the mention of the alternative. For example, in response to the waiter's question "would you like any coffee or tea?", the addressee can say "coffee, please". When it comes to alternative questions, a yes/no response is infelicitous. The purpose of an alternative question is to find out which alternative is true and a yes/no response does not do that. The one exception is when the alternatives themselves are positive and negative. For example, the alternative question "would you like coffee or not?" can be felicitously responded with "yes/no" but in such cases the alternatives themselves are "yes" and "no" in a way.

Polar questions receive an inclusive interpretation (at least one disjunct is true) while alternative questions are interpreted exclusively (exactly one disjunct is true). Intonation plays a crucial role in the interpretation of polar and alternative questions with disjunction. Pruitt & Roelofsen (2013) recorded 24 disjunctive questions with both final rise intonation and final fall intonation. They asked 37 undergraduate participants to choose between two paraphrases: an inclusive paraphrase and an exclusive paraphrase. For example, a question like "did Sally bring wine or bake a dessert?" had the inclusive paraphrase "did Sally do any of these things: bring wine or bake a dessert?" and the exclusive paraphrase "which of these things did Sally do: bring wine or bake dessert?" They showed that the majority of responses (%80) considered a question with falling final intonation as exclusive and a question with rising final intonation as inclusive.

1.5.8 Embedded Imperatives

We can use *and* and *or* to connect imperative and declarative sentences. The two sentences below connect the same imperative and declarative sentences but use different connectives; the first uses *and* and the second *or*. An important observation with respect to the meaning of such utterances is that they can be paraphrased as conditionals. The first sentence with *and* can be paraphrased as "if you go home, you'll miss the fun." The second sentence with *or* can be paraphrased as "if you do not go home, you'll miss the fun." More accurately, the original sentences and their conditional paraphrases are biconditionals or perfected conditionals (Geis & Zwicky, 1971). The sentence with *and* implies that if the addressee does not go home they will not miss the fun. The sentence with *or* implies that if the addressee goes home they will not miss the fun.

(16) Go home *and* you'll miss the fun. (If you go home, you'll miss the fun.)

(17) Go home *or* you'll miss the fun. (If you do not go home, you'll miss the fun.)

If we consider the relevant propositions as "addressee going home" and "addressee missing the fun", the first sentence has a conjunction interpretation with respect to these propositions while the second carries an exclusive interpretation. The imperative-or-declarative structure suggests that the proposition inside the imperative and the one inside the declarative will not be true at the same time: "If you go home, you won't miss the fun and if you don't go home you will miss the fun."

1.5.9 Alternative Unconditionals

The alternative unconditional construction has the following general schema: "Whether X or Y, Z." When the alternatives are negatives of each other ("Whether X or not X, Z."), the shorter form "Whether or not X, Z" can also be used. Rawlins (2013) classifies alternative unconditionals as a subtype of unconditionals along with constituent unconditionals (e.g. "Whatever happens, we win.") and headed unconditionals (e.g. "No matter what happens, we win."). He points out that unconditionals share "a certain kind of not mattering" or an indifference implication. If we schematize an unconditional construction as "unconditional-adjunct + main-proposition", the main message of the construction is that the alternatives listed in the unconditional adjunct do not make a difference with respect to the truth of the main proposition. In other words, the truth of the main proposition does not depend on the truth of the alternatives in the unconditional adjunct.

An alternative unconditionals is considered to be equivalent to the conjunction of two conditional statements with the alternatives as their antecedents. This means that a construction such as "Whether X or Y, Z" is equivalent to "If X, Z, and if Y, Z." For example, "Whether it rains or snows, I won't go outside." can be paraphrased as "If it rains, I won't go outside, and if it snows I won't go outside." Notice that the unembedded connective used in the paraphrase is *and* rather than *or*. The paraphrase with *or* would be too weak: "if it rains, I won't go outside, or if it snows I won't go outside". The unconditional does not communicate that at least one of the conditional statements are true; it communicates that both are true. Therefore, the interpretation of *or* embedded under an unconditional adjunct surfaces as conjunction rather than disjunction.

Rawlins (2013)'s analysis of alternative unconditional has four important components. First that the whole construction is a conditional ($X \rightarrow Y$) such that the adjunct (X) restricts the modal base of the main clause (Y.) Second, the antecedent of this conditional is a disjunction (If A or B then Y.) Third a disjunction such as "A or B" denotes the set of propositions in the disjunction ($\{A, B\}$). Forth, the set of propositions provide sequential restrictions on the modal base in the main clause. The conjunctive interpretation of disjunction in alternative unconditionals follows from this sequential domain restriction.

1.6 Discussion

This chapter provided a brief introduction to disjunction in logic as well as previous approaches to the semantics of *or* in English. In logic, disjunction has always faced two alternate definitions: exclusive and inclusive. While different eras have assigned primacy to one or the other definition, logical systems in the past century or so have adopted the inclusive definition more often. In natural language, disjunction words like *or* are associated with (at least) five implications: inclusivity, exclusivity, conjunctivity, ignorance, and indifference. Table (1.6) shows 10 example sentences in different linguistic environments and marks the presence and absence of each implication. I discussed a range of factors that may affect the interpretation of *or* including conversational (Gricean) principles, entailment environment, semantic relation of the disjuncts, syntactic category of the disjuncts, question intonation, and a range of linguistic constructions such as the ones with possibility modals, embedded imperatives, repairs, definitions, and unconditionals.

Table 1.6: Implications of *or* for several example sentences.

Example	IOR	XOR	AND	Ignorance	Indifference
Have some food or drinks!	✓	X	X	X	✓
Bob studied yesterday or the day before.	X	✓	X	✓	X
Students like Bob or Becky will pass.	X	X	✓	-	-
I didn't see Bob or Becky study at all.	X	X	✓	-	-
Did Bob study yesterday, or Becky?	X	✓	X	✓	X
Did either Bob or Becky study yesterday?	✓	X	X	✓	X
Study hard or you will fail!	X	✓	X	X	X
Bob could study or play soccer.	X	X	✓	-	-
Bob studies language acquisition or language development.	X	X	✓	-	-
Becky studies phonetics or semantics; not sure which.	X	✓	X	✓	X

The chapter also discussed two approaches to lexical meaning: lexical ambiguity approaches and Gricean approaches. The crucial difference between them is their adherence to a principle of parsimony for meanings, namely Grice's "Modified Occam's Razor". Grice's razor proposes that lexical meaning should not be multiplied beyond necessity. Lexical ambiguity approaches are more relaxed about Grice's razor and may consider different interpretations of a word as different meanings of the word. Gricean approaches strive to only assign an interpretation as lexical meaning when it cannot be explained by other independently motivated interpretive factors. For example, a lexical ambiguity account considers *or* ambiguous between the five implications mentioned earlier and possibly more. Context of the utterance helps speakers disambiguate the intended meaning of *or*. The Gricean approach proposes a single meaning for *or* and derive its various interpretations from other interpretive factors.

How does research in semantics and pragmatics of disjunction inform accounts of disjunction acquisition? The literature on semantics and pragmatics of *or* provides a list of factors that affect the interpretation of a disjunction word like *or*. This list provides a set of candidate cues that children can potentially use to learn the interpretation and ultimately the meaning of a disjunction word. It is important to note that both lexical ambiguity and Gricean accounts rely on such cues to derive the intended interpretation. Ambiguity accounts use them to disambiguate among a set of learned lexical meanings while Gricean accounts need them as part of the reasoning process that derives the intended interpretation from a unified lexical meaning for *or*. Chapter 4 focuses on the role of these cues in the acquisition of *or* from child-directed speech.

Chapter 2

Acquisition of Disjunction

The rapid development of formal and logical semantics in the past 50 years, has brought renewed interest in children's interpretation and acquisition of connectives such as *or*. However, research on the development of linguistic connectives in children predates the advances in formal semantics and pragmatics in the 70s. In the late 1950s and early 1960s, many psychologists were conducting research on children's development of logical reasoning kicked off by Inhelder & Piaget (1958). Even though this line of research started by investigating the interpretation of linguistic connectives such as *and* and *or*, the main interest was the development of logical concepts and later investigations focused on non-linguistic logical reasoning. In late 90s, a separate line of research inspired by advances in formal semantics/pragmatics and language acquisition started which focused on the development of linguistic connectives rather than their associated concepts.

With respect to children's comprehension of *or*, these two research programs diverge both empirically and theoretically. Empirically, the early research on logical reasoning suggested that children first learn the exclusive interpretation of *or* ($\oplus$) and later they develop the inclusive (often called logical) interpretation. Furthermore, some children who struggle with the meaning of *or*, interpret this word like a conjunction. On the contrary, later research on semantic acquisition suggests that children learn the inclusive interpretation before the exclusive one. The existence of conjunctive interpretations was denied for a long time but it has resurfaced recently (Singh et al., 2016). Theoretically, the research on logical reasoning considered logical thinking as an abstract kind of thinking that is present only in late stages of development. The research in semantic acquisition considers logical concepts present early in development and some researchers even consider it innate.

These two research programs also diverge in their assumptions with respect to the learning process. Similar to many other areas of developmental research, the present accounts of children's acquisition of disjunction fall either closer to the nature side or the nurture side of the nativist-empiricist debate. In fact, the interpretation of *or* has become a stronghold for nativist theories of language acquisition in the past decade (Crain & Khlentzos, 2008). The nature side has not been as unified and vocal but it is possible to see it represented by the early work on logical reasoning as well as a usage based approach advocated by Morris (2008).

The nativist and usage-based positions differ on almost every major acquisition issue: the nature of the input data (poverty vs. richness), the cognitive mechanisms applied to the data (domain specific vs. domain general), and the nature of linguistic knowledge (abstract generative model vs. constructions and shallow generalizations). In the nativist account, linguistic knowledge is the result of the triggering effect of the poor and noisy input data on innate linguistic (hence domain specific) principles and parameters. The common metaphor is that of maturation, from an initial state of the language faculty to a final stage. In the usage-based approach, linguistic knowledge is the result of applying general purpose cognitive mechanisms and principles to the input linguistic data. The input data is rich and plays a major role in children's acquisition of language. Frequency in the input is an important component of the usage based theory's predictions on the acquisition pattern. More frequent constructions are predicted to be acquired earlier and faster.

The debate on children's acquisition of logical connectives mirrors this overarching nature-nurture debate. The nativist literature emphasizes the poverty of the stimulus and posits innate logical principles and parameters. The usage-based approach emphasizes the richness of the input and the predictive power of child direct speech on children's linguistic productions. In the next three subsections, I go over the existing literature on children's acquisition of logical connectives. I start with the research program on children's development of logical reasoning. Then I discuss the usage-based approach to the acquisition of logical connectives which can be considered as the true heir of the research on logical reasoning. In the third subsection I discuss the literature on semantic acquisition, specifically the logical nativist position that stands in sharp contrast to the first two.

2.1 The Development of Logical Reasoning

2.1.1 Theoretical Landscape

Investigations on children and adults' comprehension of logical words such as *or* started in the 60s with the work of Nitta & Nagano (1966) on Japanese and Neimark & Slotnick (1970) on English, and continued until mid 80s. These studies focused mainly on children's conceptual development and more specifically, children's development of logical reasoning. The theoretical paradigm behind them was Piaget's theory of cognitive development. There were four main stages of development in Piaget's theory: sensorimotor stage (ages 0-2;0), pre-operational stage (ages 2-7 years), concrete operational stage (ages 7-11 years), and formal operational stage (11 years and above). The operational stages (concrete and formal) were considered the period where children develop logical thinking (Inhelder & Piaget, 1958). The idea was that children start applying logical thinking or operations (rule-based thinking) around the age of 7. At first, they can only apply logical thinking to concrete objects (concrete operational stage) but later when they are about 11, they learn logical reasoning in an abstract and hypothetical fashion.

To test the predictions of this hypothesis, the majority of research on children's understanding of logical connectives in this period focused on children and adolescents between the ages of 6 and 18. With respect to the acquisition of logical connectives, the main claim was that while *and* is understood better than *or* they both improve as children move from the concrete operational stage to the formal operational stage. However, the meaning of *or* is not understood until late in the period of formal operations (Neimark & Slotnick, 1970). Later research such as Johansson & SjÃűlin (1975) and Braine & Rumain (1981) showed that the development of children's connective comprehension does not fully match the stages of the Piagetian theory. However, the idea that a full mastery of the "logical" (inclusive) meaning of *or* is acquired later survived and was inherited by the usage-based approach. The claim was that children's initial interpretation of *or* is simply a "choice" between two options (exclusive) and only later do they learn the inclusive meaning of *or*. In other words, these approaches predicted that the exclusive interpretation emerges before the inclusive interpretation in child language.

2.2 Empirical Landscape

Studies in this period used a variety of tasks to assess children's understanding of logical connectives. Studies like Nitta & Nagano (1966) and Neimark & Slotnick (1970) were designed as in-class tests and students had to simply circle all the items that were described by some statement (akin to current picture selection task). Paris (1973) explicitly asked the participants to provide truth value judgments for statements containing *and* and *or*. In Suppes & Feldman (1969), there were several wooden blocks with different attributes and the participants were asked to give the experimenter some of the blocks using the words *and* and *or* (akin to give-X tasks used with numerals and quantifiers; see Barner, Chow, & Yang (2009)).

Almost all of the studies in this period agree that children interpret *and* successfully. The main problem is posed by *or*. Table 2.1 summarizes the conclusions of 7 studies. A surprising finding in these studies is that some children interpret *or* as *and* in contexts where conjunctive readings are not to be expected. The results of the studies listed in Table 2.1 suggest that these conjunctive reading interacts with age and task. It is more common among younger groups and reduces until it is very rare among adults, but surprisingly, some adults still show these readings where they are not expected.

The conjunctive reading is also detected at a higher rate in some tasks rather than others. For example, Paris (1973) and the third task of Braine & Rumain (1981) that used truth value judgments report a high level of conjunctive readings while other studies that rely on participants performing an appropriate action with respect to the statement report a very low levels of conjunctive readings. A more detailed look at tasks 1 and 3 in Braine & Rumain (1981) show the task dependency of conjunctive readings better. In the first task, Braine & Rumain (1981) used the same paradigm as Suppes & Feldman (1969) and found only a few conjunctive readings and a strict majority of exclusive (choice) readings. In their third task on the same participants, they used a truth value judgement task in which the participants had to say whether a puppet was right or wrong in its description of the contents of a box. There is a substantial increase in the number of conjunctive readings in this task to the point that the youngest group produced more conjunctive readings than inclusive readings and did not show any pattern for an exclusive reading. Suppes & Feldman (1969) also noticed that children's errors had two interesting patterns: they either went for a conjunctive reading, or they simply answered with respect to the first mentioned disjunct or conjunct and ignored the second one completely. This emphasizes the possibility of children's non-linguistic strategies which has not been systematically investigated in the case of logical connectives. It is possible that the conjunctive reading is the result of some non-linguistic strategies in cases where the child does not know the meaning of the connective or fails at processing the task properly.

The nativist inquiry started by criticizing the research in the literature on logical reasoning for not choosing their stimuli such that *or* is embedded under the right contexts. Inspired by research in semantics and pragmatics, they argued that *or* is often accompanied by an exclusivity implicature. If we want to really understand children's semantic knowledge of *or*, we need to use it in contexts where the exclusivity implicature does not arise. Since the studies on logical reasoning did not control for the exclusivity implicature, they painted an inaccurate picture in which children interpret *or* as exclusive ($\oplus$). As we will see in the third subsection, most nativist research focuses on "implicature-canceling" contexts such as making predictions, or embedding the disjunction word under negation or the restriction of the universal quantifier. However, the claim that the literature on logical reasoning did not use *or* in such implicature-canceling environments is not completely accurate. For example, Johansson (1977) asked the participants to "circle all figures that are blue or square" or Braine & Rumain (1981) asked children to give them "all those things that are either blue or round". In these sentences, *or* is embedded in the restriction of the universal quantifier *all*. Both studies report that the inclusive reading is present only among a subset of adults. Younger participants interpret the disjunction word as exclusive. Similar nativist studies where *or* is in the restriction of the universal quantifier *every* or its counterpart in Mandarin report that children successfully interpret it as inclusive. However, the nativist studies differed in that they used the truth value judgement task.

Table 2.1: Summary of studies on children's interpretation of the disjunction word in the literature on children's cognitive development. K is short for kindergarten, G for grade, and C for college.

Study	Age	n	Language	Environment	Interpretation
Nitta & Nagano (1966)	K, G2,4,6,8	679	Japanese	Imperatives	$\wedge$, $\oplus$, $\vee$
Neimark & Slotnick (1970)	3-9G, C		English	Imperatives	$\wedge$, $\oplus$, $\vee$

Study	Age	n	Language	Environment	Interpretation
Suppes & Feldman (1969)	4;5-6;7	64	English	Imperatives	$\oplus$, $\wedge$
Paris (1973)	G2,5,8,11, C	200	English	Present Declarative	$\wedge$, $\oplus$, $\vee$
Johansson & SjÃűlin (1975)	2;0-7;6	60	English	Present Declarative	$\oplus$, (low $\wedge$)
				Imperative	$\oplus$, (low $\wedge$)
Beilin & Lust (1975)					
Ford (1976)			English		
Johansson (1977)	6-10, 12, 22	70	English	Imperative	$\oplus$
				Imperative, *all* restrictor	$\oplus$, ($\vee$ 2 oldest groups)
Braine & Rumain (1981)	5-10, C	88	English	Imperative	$\oplus$
				Imperative, *all* restriction	$\oplus$, ($\vee$ for C)
				Present Declarative	$\wedge$, $\vee$ ($\oplus$ for C)

2.3 The Usage Based Approach

Usage-based researchers have not been active in children's acquisition of logical words. There is only one paper by Morris (2008) that investigates children's acquisition of *and* and *or* by conducting a corpus study. Here I summarize the assumptions, claims, and hypotheses of this paper and often more generally the usage based approach to the acquisition of meaning.

2.3.1 Theoertical Landscape

The usage-based theory contends that "meaning is use" and "structure emerges from use" (Tomasello, 2009). Therefore communication is viewed as raison d'etre of language and it is used as an explanatory factor either in the study of adult language or children's acquisition of it. Most importantly, linguistic structure is viewed as a phenomenon emergent from communicative principles and conventions, and domain general cognitive mechanisms recruited to achieve communicative goals. In stark contrast to the nativist theories, the usage-based theory of language acquisition emphasizes children's reliance on their linguistic input. They consider the language children hear around them, especially child directed speech, as the main source of their linguistic knowledge. Under the usage-based approach, children's input language is a rich source of linguistic information for domain general cognitive mechanisms to analyze and learn their structure. Therefore, children's early language closely matches what they hear around them.

The usage-based approach contends that children's acquisition of language is item-based. Children acquire words and word uses (meanings) item by item and in an isolated fashion. Later they form generalizations over these isolated items and extract abstract information and use a word to convey a broader range of meanings (Akhtar, 1999; Lieven, Pine, & Baldwin, 1997).

In the usage based theory, meaning is represented as a usage protocol. In usage-based acquisition of meaning children form representations for use based on input from their natural language environments, which may best be described as a conceptual prototype associated with a usage script (E. Levy & Nelson, 1994; Tomasello, 2003).

One hypothesis regarding the development of meaning in this framework is the confirmed core-meaning hypothesis:

> "The initial meaning of a connective should be limited to a single, essential meaning (MacWhinney, 2002). Through increased attention to the productions of others and more heterogeneous functional contexts, children acquire additional meanings (i.e., logical uses) and rules for appropriate use (i.e., pragmatics), and generalize items to more abstract grammatical structures. This confirmed core should (a) have a prototypical meaning, (b) have the least interference with other meanings, and (c) require the least amount of additional cognitive resources (MacWhinney, 1989). A prototypical meaning likely covers the core function ascribed to a word. The likely prototypical meaning for

> *and* is conjunction (denoting the inclusion of two or more objects or phrases in a set) while choice (exclusive-or) is a likely candidate for *or*. These functions may help form the basis of word meanings and aid in their acquisition" (Morris, 2008).

The assumption here is that lexical items have multiple meanings or uses, and logical connectives are not exempt. Both *and* and *or* are considered polysemous. They express a variety of uses (interpretations). *And* has a conjunctive use (e.g. that's a mommy and two dogs.), an explanatory use (e.g. you hit him and that is not OK), a temporal use (e.g. He broke the window and then stole the television.), and an extension use (e.g. And who should this be?). *Or* has an exclusive (choice) use (e.g. You can go the table or to the free play area), an inclusive use (e.g. you can have apples or bananas), and a conditional use (e.g. stop hitting him or you will have to have a time out?)

The developmental predictions of the usage-based approach is that *and* starts from the core meaning of conjunction and later is associated with other uses such as the temporal interpretation and the causal interpretation. *or* starts with the core "exclusive" use but expands into the other uses such as "inclusive" and "conditional" (Exclusive-First Hypothesis). Children start with the exclusive meaning since it is more frequent in the input data and furthermore, it has less interference with the meaning of conjunction.

2.3.2 Empirical Landscape

In order to support the hypotheses mentioned in the previous section, Morris (2008) investigated the use of *and* and *or* in child-directed speech and children's production between the ages of 2;0 and 5;0, using 240 transcriptions of audiotaped exchanges obtained in the CHILDES database. Each connective was analyzed with respect to its frequency, syntactic frame, meaning, and formal/informal use. With respect to frequency, the study found that overall, *and* is approximately 12.8 times more likely to be produced than *or*. There were a total of 6,459 connective uses: *and* was produced 5,994 times whereas *or* was produced 465 times.

Considering syntactic frames, instances of the connective use were coded as appearing in *statements* or *questions*. The study reports that *and* appears predominantly in statements (more than %90 of the time) while *or* is extremely common in questions (more than %85 of the time). For the meanings and uses of *and* and *or*, the study reports that for both adults and children, the dominant meaning of *and* and *or* were "conjunction" and "exclusive disjunction" respectively. This is taken to confirm the confirmed core-meaning hypothesis. There was also a significant increase in the mean number of different uses for AND and OR. *And* started with only the core conjunctive meaning at 2;0-2;6 and around the ages 3;0 and 4;0, children increased that to two different uses on average. Only at 4;6-5 children were producing three different uses of *and*. The production of *or* starts at around 3;0-3;6 with the "exclusive" meaning and expands to 1.5 uses on average by 4;6-5;0.

However, the account above faces an important issue. The conjunctive *and* and temporal/explanation *and*s do not have the same syntactic status. The former often conjoins noun phrases while that latter two only conjoin sentences. We can have conjoined nouns phrases in utterances with 3 or 4 words while conjoined sentences require utterances longer than 4 words. How can a two-year-old with an average MLU of 1.5-2.5 words produce the temporal or explanation *and* which require conjoined sentences? It is possible that the increase in the number of word usage can be explained by syntactic development rather than semantic development. The absence of the non-conjunctive uses of *and* in the corpus data may only be a phenomenon in production and not comprehension. Even if children understand the meaning of temporal *and*, if they cannot yet produce conjoined sentences, we are not going to observe such uses in the corpus data. This question cannot be resolved by the corpus evidence alone.

Utterances were also coded as informal or formal. Formal uses of connectives were those with explicit truth-value judgments. For example, "Does the dog have a tennis ball and a hockey puck?" to which the child answered with "No" was coded as formal. However, "I'd like peanut butter and jelly" was considered informal. The study found that there are rare cases of formal use in child and child-directed speech. This is interpreted as evidence for the developmental claim that the connectives' logical meanings are acquired later in development and not part of the core meaning. However, the definition of formal vs informal use which is translated into logical versus non-logical meaning in Morris's analysis seems to differ substantially from that of logical nativism and more generally formal semantics.

2.4 Logical Nativism

2.4.1 The Theoretical Landscape

Logical nativism supposes that humans are biologically endowed with the tools for logical reasoning. The meanings of logical expressions in natural languages are captured by the semantics of logical operators in classical logic. The semantics of these logical operators along with some logical principles and parameters are hypothesized to be innate. The logical nativist position is extensively argued for in Crain (2008); Crain (2012); Crain & Khlentzos (2008); Crain & Khlentzos (2010). Here I summarize the main claims, assumptions, and hypotheses very briefly. I start with the nativist assumption on language processing in general.

According to the Modularity Matching Model, the human language faculty is modular and operations within the language faculty are hierarchically organized (syntax $\rightarrow$ semantics $\rightarrow$ pragmatics). Operations of the higher level components apply to the output of lower level components. The syntax module may propose several analyses of a string of which only some satisfy the input requirements of the semantics module and create a well-formed logical form. The semantics module may propose more than one logical form for a sentences while only one is deemed felicitous by the pragmatics module. (Crain & Thornton, 1998; Crain & Wexler, 1999)

The famous aphorism of the modularity matching hypothesis is that "syntax proposes and semantics disposes"; in turn semantics proposes and pragmatics disposes. Let's consider the nativist claim on the meaning of logical words such as *and* and *or* across languages. The claim is that the native speaker knowledge of the meanings of logical expressions in natural languages is captured by the semantics of logical operators in classical logic. For example, the meaning of *or* and similar logical words across languages correspond to $\vee$ (inclusive) and not $\oplus$ (exclusive). Let's call this the "logical meaning".

The above claim is one that logical nativists share, more or less, with many formal semanticists. Discrepancies between the meanings of logical words in natural languages and the logical operators are often attributed to either pragmatic enrichment or crosslinguistic differences in scope assignment. However, a formal semanticist may argue for the logical meaning claim while remaining agnostic with respect to how logical representations relate to psychological representations. This is not so for logical nativists. Implicit in the arguments of logical nativism is the assumption that the formal (logical) descriptions used in modeling linguistic meaning also have psychological reality.

In fact, the logical nativist position is even stronger. The main claim is that "the human genome contains a set of innate logical structures" (Crain, 2012, p. 76). This set of logical structures includes at least the semantics of logical operators in classical logic, downward entailment, and two scope parameters. I will investigate the elements of this set in more detail here.

First it is hypothesized that the meanings of logical operators such as $\neg, \wedge, \vee, \exists, \forall$ are part of the biological endowment of human beings. Let's call this hypothesis the "Innateness of Logical Meaning". This hypothesis strictly limits the hypothesis space for the meaning of logical words to only those provided by classical logic. The meaning of *or* is a good example here. While the meaning of $\vee$ is innate, the meaning of $\oplus$ is not. The innateness of logical meaning predicts that children do not assign the meaning of $\oplus$ to *or* and similar disjunctive expressions in other language at any stage in their development because the meaning of $\oplus$ is simply not provided to them by the Universal Grammar. This is also offered as an explanation for the claim that languages do not lexicalize the meaning of $\oplus$. In other words, if $\oplus$ is never available to humans for form-meaning mapping, it will never appear in world languages as the meaning of a lexical item.

At this point, a fair objection to the nativist position is the limitation of classical logic in capturing the meaning of L-expressions such as *most*, *many*, and *few*. There are no operators in classical logic that correspond to the meaning of these expressions and under the current formulation of the nativist position, we expect children to never learn them. This is clearly a false prediction. However, logical nativism can avoid this criticism by assuming that the human logical faculty is not completely modeled by classical logic and several operators provided by UG fall outside its scope. The nativist can argue that classical logic is a good approximation to the human logical faculty in many cases such as the meaning of *every*, *some*, *and*, and *or*.

Another prediction of the innateness of logical meaning hypothesis is that children acquire the meaning of *and* and *or* almost simultaneously. This prediction has not been explicitly acknowledged in the nativist literature but it is an inevitable prediction of the nativist account. The main reason is that the syntactic distribution of connectives make it clear that *and* and *or* should correspond to either $\wedge$ or $\vee$. Universal Grammar does not allow other possible connectives such as $\oplus$ to be considered. Once the child has figured out that *and* corresponds to $\wedge$, then the meaning of *or* comes for free since there are no other options provided by UG. This is on difference between the nativist approach and approaches that rely on domain general learning mechanisms.

Moving on to the next hypothesis, Crain (2012) suggests that the property of downward entailment is also innate. More specifically, he argues that the child is innately instructed that downward entailing environments license Negative Polarity Items (NPIs) and and generate a conjunctive reading of *or*. Below, Δ stands for a downward entailing operator such as negation, the restrictor of *every*, the meaning of *before*, or the antecedent of a conditional (Crain, 2008, Crain (2012)).

> Innateness of Downward Entailment: Downward entailment and the behavior of logical operators in such environments are innate. Example; The conjunctive entailment of disjunction: $\Delta(A \vee B) \Leftrightarrow \Delta(A) \wedge \Delta(B)$.

It is not clear why the property of downward entailment needs to be innate. One way to explain this is that downward entailment is a grammatical feature that is not learnable and needs to be part of UG. However, on purely semantic grounds, children's awareness of subset-superset relations along with the innateness of logical meaning may predict the DE behavior of operators or NPIs, without the need to resort to the innateness of downward entailment.

Logical nativism also claims that languages vary with respect to their scope taking properties of disjunction and conjunction with negation. Languages like English require disjunction and conjunction to scope under negation while those like Mandarin require disjunction and conjunction to scope above negation. Two scope parameters are proposed to explain this scope variation. One guides the scope of negation and conjunction and the other commands the scope relation of negation and disjunction: 1. $[\neg > \vee]$ vs. $[\vee > \neg]$ 2. $[\wedge > \neg]$ vs. $[\neg > \wedge]$.

I have written the default value of each parameter on the left. The default value for disjunction is $[\neg > \vee]$ and for conjunction $[\wedge > \neg]$. Children speaking any language in the world are expected to start with these default values and if the input data is consistent with the non-default value, then there will be a switch in the parameter setting. As a result, the pattern of children's early scope errors in different languages is attributed to the default settings of the scope parameters that happen to not match the target language, but are perfectly acceptable in many other languages of the world. According to nativists, these patterns of errors conform to the continuity hypothesis, namely that children's non-adult like linguistic behavior will consist of constructions that are attested in other human languages (Crain, 1991).

Let me point out a problem with the parametric scope claim and the innate scope claim here.

The nativist literature is not clear on whether one scope relation is more salient than the other in such languages or that only one scope relation is available. Given the modularity matching model, the claim seems to be that given the syntactic parameters of the language, only one logical form is available for *and* and *or* under negation. However, such an account will face empirical issues. In the following English example, the salient reading of *or* is one where it scopes above negation (contrary to the generalization in innateness of scope) :

(15)

A: Did you know that Mike Huckabee has been running for every presidential election since 2000?

B: No, he missed one. He didn't run in 2008 or 2012. I'm not sure which.

Below is a naturally-occurring example of Mandarin where disjunction scopes under negation, again contrary to the generalization presented in the nativist literature for Mandarin.

(16)

liang xueya qian, bu yao chi zaocan huo fu yao

measure blood-pressure before, NEG will eat breakfast or take medicine

"Before measuring blood pressure, do not eat breakfast or take medicine."

And finally in this example from Persian, both scope relations are available and are disambiguated by the context.

(17)

Ali ya Reza ro davat na-kon

Ali or Reza OM invite NEG-do

1. "Don't invite Ali and don't invite Reza"

2. "Either don't invite Ali or don't invite Reza"

It is not clear what the disjunction scope parameter setting should be for the Persian speaker. One way to remedy this is to add a third value to the parameters that makes both scope relations possible. Therefore, the correct setting for English, Mandarin, and Persian would be this third value. However, adding a third value to each parameter has consequences for the the nativist theory including on how to choose the default parameter. Currently, the choice of the default parameter is based on the semantic subset principle. Given a sentence with more than one interpretation such that the interpretations form a subset-superset relationship, learners are innately guided to initially choose the representation that is true in the smallest set of circumstances. (Crain, Ni, & Conway, 1994)

The hypothesis above is a semantic version of the more general "subset principle" for language learning (Berwick, 1985, K. Wexler & Manzini (1987)). The subset principle suggests that "the learner must guess the smallest possible language compatible with the input at each stage of the learning procedure" (R. Clark & Roberts, 1993). The subset principle aids the learner in situations where no negative evidence is present. However, the claim that children's input does not contain negative evidence has been a major source of contention in children's acquisition of syntax (see Marcus (1993), chouinard2003adult) and it is even more dubious whether it can extend to semantic acquisition. The main reason is that even those arguing for this claim acknowledge that adults do correct children on the content and semantics of their utterances. Therefore, the claim that there is no negative evidence with respect to the meaning of logical words and subsequently the semantic subset hypothesis need much more empirical support. Logical nativism also argues that children do not have sufficient evidence from experience to learn the meaning of logical expressions by observing how adult speakers use them. For example, *or* is rare in children's input data and it is more consistent with an exclusive meaning in its most frequent use.

Finally, the hypothesis that logical meaning is innate along with the claim that young children fail at adult-like computation of scalar implicatures leads to the formulation of the logical stage hypothesis. According to this hypothesis, children's acquisition of meaning for certain logical operators follow two stages. First, the logical stage in which they assign the basic logical meaning to the logical words and do not compute standard implicatures associated with them. Second, the pragmatic (adult-like) stage in which the basic semantics of these words is enriched with pragmatic implicatures.

The logical stage hypothesis along with the innateness of logical meaning hypothesis result in the prediction that children's initial interpretation of *or* should be inclusive and that only later when they reach the pragmatic stage they are capable of deriving the exclusive reading (Inclusive-First hypothesis). The prediction above is the opposite of the exclusive-first prediction made by the usage-based account of language acquisition.

2.4.2 The Empirical Landscape

Nativists have mostly investigated children's interpretation of disjunction words using experimental studies. Table 2.2 summarizes the nativist studies on the acquisition of disjunction words. There is not enough space to go over all the studies in detail here but I will discuss some overall themes and issues in the literature listed.

The nativist experimental investigations into children's interpretation of *or* started with Chierchia, Crain, Guasti, & Thornton (1998). This paper criticizes the semantic and pragmatic assumptions of the research on children's logical reasoning. The main argument is that in order to truly understand children's interpretation of logical expressions such as *some* and *or*, we need to test them in contexts where they are not accompanied by exclusivity implicatures. This reasoning is adopted by the majority of nativist studies since then and as a result, in most of these studies the disjunction word is embedded under some implicature-cancelling operator. Unfortunately, most of these studies have not tested for children's understanding of these operators separately and it is hard to know how much children's non-adult-like responses are due to their non-adult-like comprehension of the operators rather than the disjunction words.

Chierchia et al. (1998) argued that scalar implicatures are not generated when the speaker has uncertainty with respect to the outcome. So they tested children in two conditions: one in which the sentence with *or* was with a past tense verb and as a description, and another where the sentence had the modal *will* and was a prediction. They reported that when both disjuncts were true, children rejected the test sentence as a description but accepted it as a prediction. The conclusion was that contrary to the reports in the literature on children's logical reasoning, children understand *or* as $\vee$ and not $\oplus$. The culprit behind the previous findings was the exclusivity implicature that the experiments did not control for. Since Chierchia et al. (1998) did not report the children's age range, it is hard to compare the results with the current investigations of scalar implicatures. Chierchia et al. (1998) and subsequent studies up until Su (2014), rejected Paris (1973)'s suggestion that some children interpret *or* as a conjunction. However, recent studies of Singh, Wexler, Astle, Kamawar, & Fox (2015) and L. Tieu et al. (2016) have detected conjunctive readings again.

Since almost all nativist experiments use the Truth Value Judgement Task (TVJT) of Crain & Thornton (1998), let me briefly describe how TVJT works. It involves a storyteller, a story, and a puppet. One experimenter is in charge of narrating the story and the other experimenter is in charge of the puppet. The story creates the context for the evaluation of the target sentence and then the puppet utters the target sentence either as a description of what happened in the story (Description Mode), or as a prediction of what will happen next (Prediction Mode). In Prediction Mode, the story continues so that the child can see whether the prediction of the puppet was realized or not. Then the puppet repeats the prediction and either the puppet itself or the storyteller asks the child whether the puppet was right. Children can provide their judgments either by saying “Yes” or “No” (or other equivalent utterances) or sometimes by rewarding the puppet if it was right. When children say that the puppet is wrong, they are asked to explain why.

An advantage of TVJT is that it allows for an explicit truth value judgement from children rather than relying on implicit measures or behaviors. However, as Crain & Thornton (1998) acknowledge, children tend to accept utterances when they are confused as well. As a result, their rejections and explanations about their rejections are much more informative than their acceptances of the target sentence. This methodological issue with TVJT may have been neglected in a lot of later investigations of disjunction words where children’s acceptance of *or* when both disjuncts are true is argued as a sign of the inclusive meaning for *or*. It may be the case that children accept such cases due to the uncertainty they have with respect to the judgment.

Recent TVJT studies have reported a conjunctive interpretation of *or* in contexts where *or* commonly does not have a conjunctive reading (L. Tieu et al., 2016, Singh et al. (2015)). Singh et al. (2015) suggest that children who interpret *or* as a conjunction, differ from adults in the pragmatic operations they perform. Children perform an adult-like strengthening of meaning on non-adult-like set of alternatives which results in an $\wedge$ interpretation of $\vee$. In other words, children know that *or* has the meaning of $\vee$ but they do some non-adult-like pragmatic reasoning to interpret it as a conjunction. The main reason to reject an explanation based on incorrect or incomplete semantics is the previous nativist investigations of children’s comprehension of *or* which conclude that children know *or* as $\vee$. However, as I have argued above, the previous studies have several methodological issues and cannot be simply taken for granted.

Finally, I would like to add that the nativist investigations do not address the main nativist hypothesis that logical meaning is innate. The age column of Table 2.2 shows that most nativist studies have been conducted on children who are older than 4;0 or 4;6. It is hard to argue that some type of knowledge that exists at this age range is in fact innate. I assume that the nativist focus on older children is simply due to the demands of TVJT and that younger children would not be able to follow it properly. However, it is crucial for testing the nativist hypothesis that children at much younger age ranges are tested. This requires the development of simpler tasks than TVJT.

Table 2.2: The summary of nativist studies on disjunction words.

Study	Age	n	Languages	Environment	Interpretation
Chierchia et al. (1998)	Not Reported	23 + 10	English + Italian	Past Declarative	$\oplus$
				Future (*will*)	$\vee$
Gualmini, Meroni, & Crain (2000b)	4;1-6;1 (M=4;11)	16	English	*can*	$\vee$
Gualmini, Crain, & Meroni (2000a)	3;2-5;9 (M=4;8)	14	English	*if* (antecedent)	$\vee$
Crain, Gualmini, & Meroni (2000)	3;5-6;1 (M=4;1)	13	English	*will not*	$\vee$
Chierchia, Crain, Guasti, Gualmini, & Meroni (2001)	3;7-6;3 (M=4;11)	15	English	*every* restriction	$\vee$
	3;5-6;2 (M=5;2)	15	English	*every* nuclear scope	$\oplus$
Gualmini & Crain (2002)	3;10-5;10 (M=4;7)	30	English	*none* nuclear scope	$\vee$
Chierchia et al. (2004)	5;1-6;0 (M=5;5)	9	Italian	Future Tense	$\vee$
Goro & Akiba (2004)	3;7-6;3 (M=5;3)	30	Japanese	Negation (*nakat)	$\vee$
Notley, Zhou, Jensen, & Crain (2012)	3;4-5;1 (M=4;4)	24	English	*before*	$\vee$

Study	Age	n	Languages	Environment	Interpretation
	4;6-5;4 (M=4;7)	20	Mandarin	*before*	$\vee$
Notley, Thornton, & Crain (2012)	4;2-5;2 (M=4;8)	17	English	*not every* restriction	$\vee$
				not every nuclear scope	?
Su & Crain (2013)	3;11-5;11 (M=4;10)	31	Mandarin	*mei* (every restriction)	$\vee$
				mei (every nuclear scope)	$\oplus$
(DO construction)	4;1-5;8 (M=4;11)	34	Mandarin	*mei* (every restriction)	$\vee$
				mei (every nuclear scope)	$\oplus$
Su (2014)	2;6-5;0 (M=3;9)	32	Mandarin	*ruguo* (if antecedent)	$\vee$
				ruguo (if consequent)	$\vee$
	3;11-5;11, (M=4;11)	23	Mandarin	*ruguo* (if consequent)	$\vee$
				ruguo (if consequent)	$\vee$
Singh et al. (2015)	3;9-6;4 (M=4;11)	31 (+25 excluded)	English	Present Declarative	$\wedge$, $\vee$, $\oplus$
				every nuclear scope	
Lyn Tieu, Romoli, Zhou, & Crain (2015)	3;7-6;6 (M=4;5)	28	French	Past Declarative	$\wedge$, $\vee$, $\oplus$

Study	Age	n	Languages	Environment	Interpretation
	4;7-6;6 (M=5;5)	18	Japanese	Past Declarative	

Chapter 3

Comprehension of Disjunction

3.1 Introduction

I turn now to the differences between adults and children's interpretation of the connectives "and" and "or". Previous research has suggested that adults and children might differ in their interpretation of *or* in two ways. First, unlike adults, children might interpret *or* as logical conjunction, akin to *and* (Singh et al., 2016; L. Tieu et al., 2016). Second, children might interpret *or* as inclusive disjunction while adults interpret it as exclusive (Crain, 2012). In this chapter, I present three studies that assess adults and children's understanding of "and" and "or" using a guessing game paradigm. These studies show that four-year-olds' interpretation of conjunction and disjunction may not be as different from adults as previously supposed.

Study 1 tested adults' interpretations of logical connectives in the context of a guessing game using Two and Three-Alternative Forced Choice judgment tasks (2AFC and 3AFC). The results showed that adults interpret *and* and *or* differently. They interpreted *and* as conjunction and *or* as inclusive disjunction. However, in the task with three alternatives (3AFC) adults did not consider a disjunction felicitious when both disjuncts were true. Comparing the 2AFC and 3AFC results, we find that the felicity of disjunctive statements is sensitive to the measurement. 2AFC task systematically underestimated judgments of felicity and better approximated truth judgments compared to the 3AFC task. This finding is intuitive given that more options provide the opportunity to express more nuances of linguistic interpretation.

Study 2 investigated children's judgments in the same guessing game as study 1 using a 3AFC task. I used three alternatives to give children a better chance of expressing their pragmatic knowledge and judgments of felicity (Katsos & Bishop, 2011). The study also analyzed and categoried children's open-ended spontaneous feedback to the guesser. Both the 3AFC judgments and the categories of open-ended responses showed that four-year-olds differentiated *or* from *and*. While children's judgments in the 3AFC task showed no sign of infelicity for disjunctive guesses when both disjuncts were true, their open-ended feedback showed that children find such guesses infelicitous. In their open-ended feedback, children's comments showed that a conjunction in such cases would be more appropriate.

Study 3 used the same paradigm as study 2, but focused on replicating children's open-ended responses and contrasting them with the results of a 2AFC task. As in study 2, both truth judgments and open-ended feedback showed that children differentiated *or* from *and*. The 2AFC task showed no evidence that children find disjunctions with true disjuncts infelicitous. However, children's judgments did not differ significantly from those of adults in the 2AFC task of study 1. As in study 2, children's open-ended feedback suggested that when both disjuncts are true, children find a disjunctive statement infelicitous and the conjunctive alternative more appropriate. Overall, the results of study 2 and 3 show that forced-choice judgement tasks underestimate children's pragmatic competence. Therefore, using open-ended elicitation and analysis of children's feedback **along with** forced choice judgment tasks may provide a better understanding of children's true semantic and pragmatic knowledge.

The studies reported here also fill two gaps in the literature. First, previous research has focused on children's interpretation of *and* and *or* in complex sentences – for example with other logical words such as quantifiers *every* and *none*. Here I test children and adults' understanding of *and* and *or* in simple existential sentences like "*There is a cat or a dog*." Second, previous research has mostly tested children and adults using 2AFC truth judgment tasks (Crain & Thornton, 1998). Here I report adults and children's judgments on both 2AFC and 3AFC tasks. I also use children's open-ended spontaneous feedback to develop relevant analytical response categories and I replicate the findings in a following pre-registered study. Katsos & Bishop (2011) argued that 3AFC judgment tasks are better suited for assessing children's pragmatic competence. Here I show that even 3AFC tasks can underestimate children's pragmatic knowledge and children's open-ended elicited responses

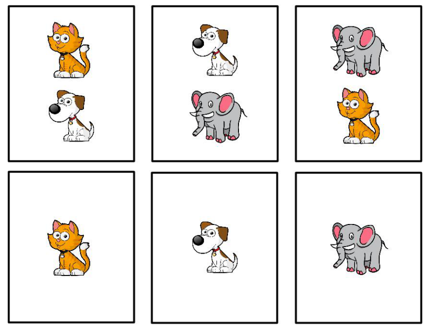

Figure 3.1: Cards used in the connective guessing game.

can provide valuable insights not available in forced choice judgment tasks.

3.2 Study 1: Adult Judgments

The goal of this study was to examine adults' interpretations of *and* and *or* in a guessing game used as a benchmark for children's interpretations. I designed the study as a card game in which participants saw a picture card, read a description about the card, and had to evaluate the description. In test trials, the descriptions contained the conjunction *and* and the disjunction *or*. I tested adults in both two-alternative and three-alternative forced choice tasks (2AFC and 3AFC). Adults interpreted *and* as a conjunction and *or* as an inclusive disjunction. They also considered *or*-statements infelicitous when both disjuncts were true. I also found that the 2AFC and 3AFC tasks register different aspects of adult interpretations: the 2AFC task captures adult intuitions on the basic semantics of the connectives while the 3AFC task is sensitive to pragmatic infelicities as well.

3.2.1 Methods

Materials and Design

The materials included six cards with cartoon images of a cat, a dog, and an elephant (Figure 3.1), and the questions were designed to focus on the type of cards participants saw and the guess they heard about each one. There were two types of cards: cards with only one animal pictured and cards with two animals. There were three types of guesses: simple (e.g. *There is a cat*), conjunctive (e.g. *There is a cat and a dog*), and disjunctive (e.g. *There is a cat or a dog*). In each guess, the animal

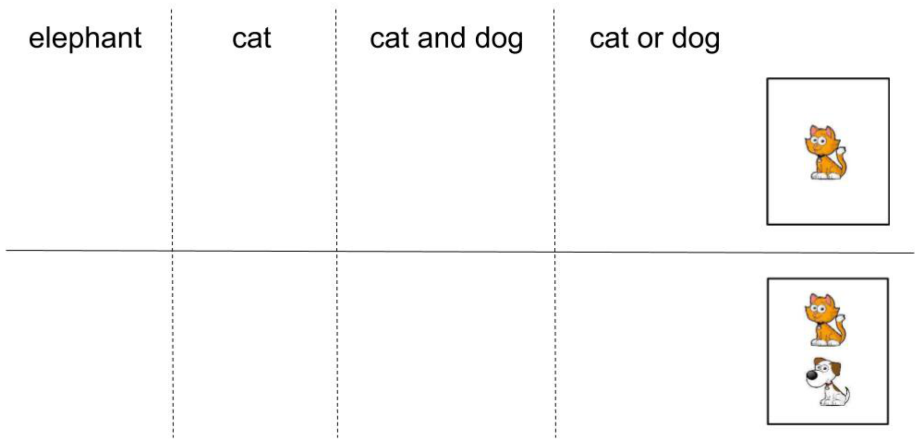

Figure 3.2: Trial types represented by example cards and example guesses.

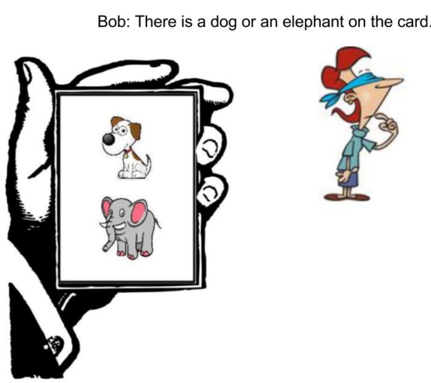

Figure 3.3: An example trial in the online study.

labels used in the guess and the animal images on the card could have no overlap (e.g. Image: dog, Guess: *There is a cat or an elephant*), partial overlap (e.g. Image: Cat, Guess: *There is a cat or an elephant*), or total overlap (e.g. Image: cat and elephant, Guess: *There is a cat or an elephant*). Crossing the number of animals on the card, the type of guess, and the overlap between the guess and the card yields 12 different possible trial types. I chose 8 trial types (Figure 3.2), to balance the number of one-animal vs. two-animal cards, simple vs. connective guesses, and expected true vs. false trials (as shown in Figure 3.1).

Participants and Procedure

I used Amazon's Mechanical Turk (MTurk) for recruitment and the online platform Qualtrics for data collection and survey design. The task took about 5 minutes on average to complete. 109 English speaking adults participated. 57 of them were assigned to a 2AFC judgment task and 52 to a 3AFC judgment task. In the 2AFC task, participants had to judge using the options *wrong* and *right*. In the 3AFC task they had to choose between *wrong*, *kinda right*, and *right*. The two conditions were otherwise identical.

The experiment had three phases: introduction, instruction, and test. In the introduction, participants saw the six cards and read that they would play a guessing game. Then a blindfolded cartoon character named Bob appeared on the screen and they were told that in each round of the game, they would see a card and Bob was going to guess what animal was on the card. I emphasized that Bob could not see anything. I asked participants to judge whether Bob's guess was right. In the instruction phase, participants saw an example trial where a card with the image of a dog was shown with the following sentence written above Bob's head: *Bob: There is a cat on the card*. All participants who correctly responded with *wrong* proceeded to the test phase.

In the test phase, participants saw one trial per trial type. Within each trial type, the specific card-guess scenario was chosen at random. The order of trial types was also randomized. At the end of the study, participants received $0.4 as compensation. Figure 3.3 shows an example test trial.

Table 3.1: Summary of Study 1 Methods

Study	N	Age	Mode	Response Options
Study 1 - Part 1	57	Adults	Online (Mturk)	Wrong, Right
Study 1 - Part 2	52	Adults	Online (Mturk)	Wrong, Kinda Right, Right

3.2.2 Results

In this section, I first present the results of the 2AFC and 3AFC tasks with adults. Then I discuss how these results can be interpreted with respect to the semantics and pragmatics of disjunction in the context of the guessing game.

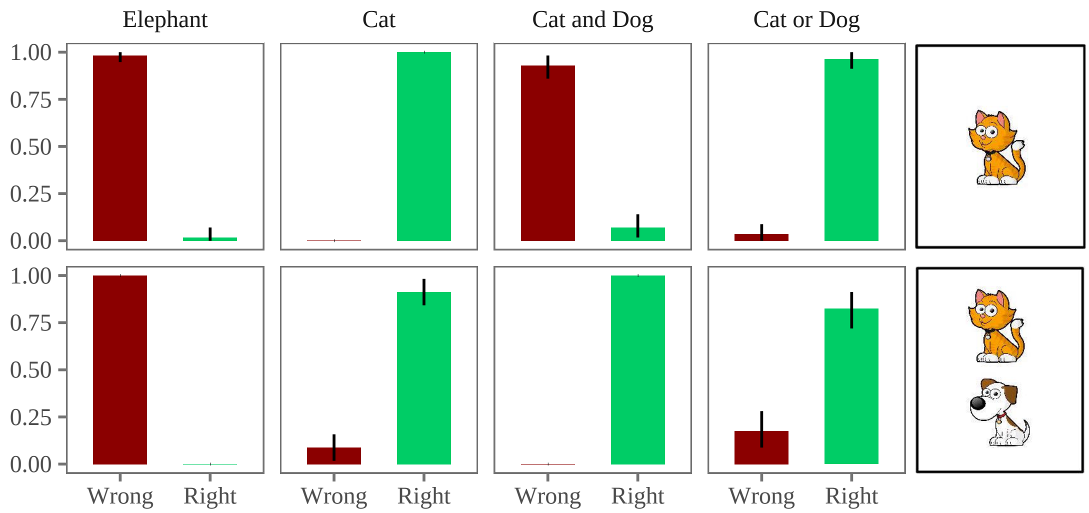

Figure 3.4: Adults' two-alternative forced choice judgments.

Two Alternative Judgments

Figure 3.4 shows the results for the adult 2AFC task. The two left columns show the simple guesses and serve as controls. The results show that if the animal mentioned in the guess was not on the card (e.g., elephant), participants judged the guess to be "wrong"; if the animal was on the card (e.g., cat), participants judged the guess to be "right". The next two columns of Figure 3.4 show how the results for the test conditions, namely conjunction and disjunction, match the expectations for logical conjunction and (inclusive) disjunction: An *and*-guess (e.g. cat and dog) is "wrong" if only one of the animals is shown on the card, and "right" if both are on the card. An *or*-guess (e.g. cat or dog) is "right" whether one or both animals are depicted on the card.

Three Alternative Judgments

Figure 3.5 shows the results for the 3AFC judgment task. For four trial types, the results are identical to the 2AFC task: if the animal mentioned in the guess was not on the card (e.g. elephant), participants judged the guess "wrong". If the animal mentioned (e.g. cat) was the only animal on the card, participants judged the guess "right". Finally, if there were two animals and the puppet mentioned them using *and* (e.g. cat and dog), all participants considered the guess "right".

The four remaining trial types showed different patterns of judgments than the ones in the 2AFC task. If the animal mentioned (e.g. cat) was only one of the animals on the card, participant

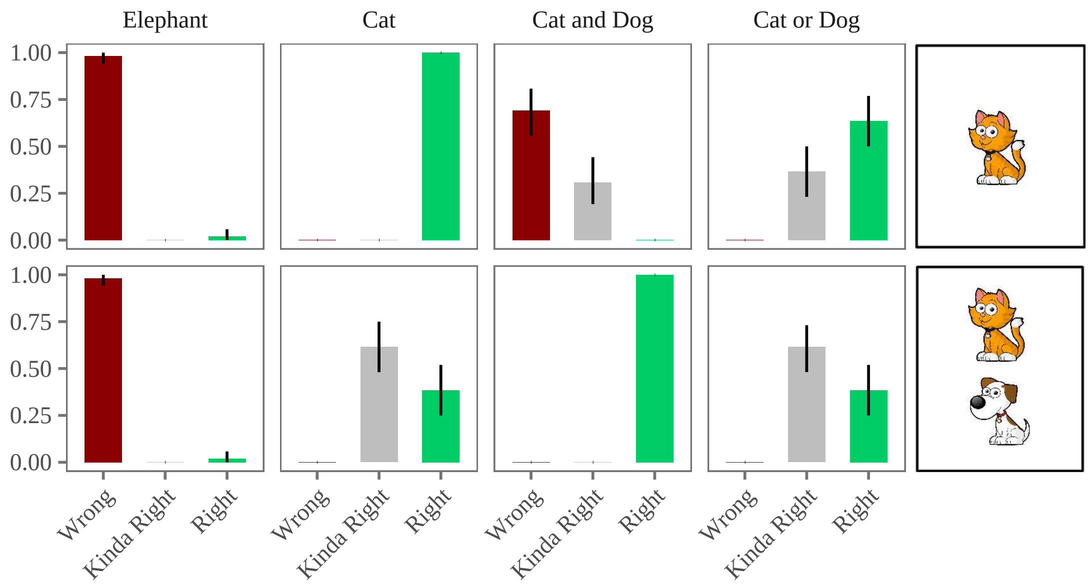

Figure 3.5: Adults' three-alternative forced choice judgments in the connective guessing game.

judgments were divided between "right" and "kinda right" (Table 3.2, row 1). Also, most adults considered a conjunctive guess (e.g. cat and dog) "wrong", when only one of the animals was on the card (Table 3.2, row 2). However, some considered it *kinda right*. When both animals were on the card everyone agreed that the guess was "right" – as in the results for such trials in the 2AFC task.

With respect to disjunctive guesses like "cat or dog", if the card had only one of the animals, most adults considers the guess "right" while some considered it "kinda right" (Table 3.2, row 3). It is possible that the adults who considered such guesses "kinda right" were sensitive to the under-informative nature of a disjunctive guess when a simple guess would have been more appropriate. If both animals were on the card, adults were split between "kinda right" and "right" responses (Table 3.2, row 4). The choice of "kinda right" over "right" in such trials can be interpreted as a sign that adults were sensitive to the infelicity of a disjunction when conjunction was more appropriate. However, the scalar reasoning with *and* and *or* is subtle and in section 3.2.3 I discuss the nature of this reasoning in the context of this guessing game.

Table 3.2: Exact One-Sided Binomial Test

Trial Type	n_{right}/n_{total}	$\hat{p}_{right}$	p_{null}	P-value	95% CI
Two Animals - Simple	32/52	0.62	0.5	0.06	0.49-1
One Animal - AND	16/52	0.69	0.5	0.004	0.57-1
One Animal - OR	19/52	0.63	0.5	0.04	0.51-1
Two Animals - OR	32/52	0.62	0.5	0.06	0.49-1

3.2.3 Discussion

The example sentences bellow show the common interpretations of conjunctive and disjunctive assertions (Aloni, 2016).

- Bob is sad *and* angry.
  - Both are true. (Truth Conditional Meaning)
- Bob is sad *or* angry.
  - At least one of the two is true. (Truth Conditional Meaning)
  - Speaker doesn't know which is true. (Ignorance Inference)
  - At most one of the two is true. (Exclusivity Inference)

A conjunctive assertion implies that both propositions are true while a disjunctive assertion implies that at least one is true. These two inferences follow from the classical truth-conditional account of conjunction and disjunction. They constitute the semantics of *and* and *or*. However, a disjunctive assertion often has two additional inferences: an ignorance inference and an exclusivity inference. These additional inferences are often classified as having pragmatic meaning. This section discusses the semantics and pragmatics of *and* and *or* in the context of study 1's guessing game.[1]

The Semantics of AND and OR

Let's assume that the semantics of *and* and *or* in simple declarative sentences like "there is a cat and/or a dog" is captured by the logical operators conjunction and inclusive disjunction respectively.

[1]See Gutzmann (2014) for a comprehensive discussion of the definitions and boundaries of semantics and pragmatics. Here my definitions and assumptions are close to those of Gazdar (1979).

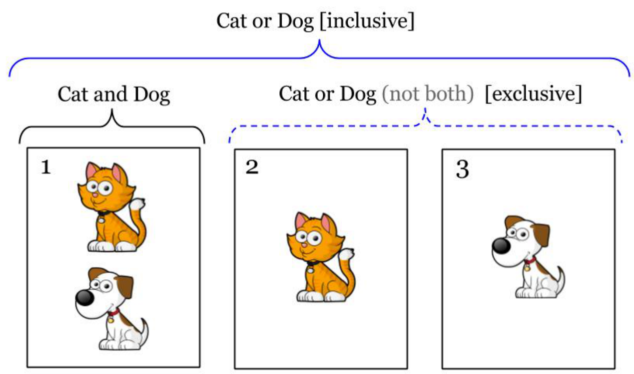

Figure 3.6: Example of cards referred to by a conjunction, inclusive disjunction, and exclusive disjunction.

A conjunction is true when both conjuncts are true and false otherwise. An inclusive disjunction is true when at least one disjunct is true and false otherwise. Let's also assume that a false statement is judged as "wrong" and a true statement as "right". In the context of study 1, this purely semantic (i.e. truth-conditional) account has two main predictions: 1. Conjunctive guesses like "cat and dog" are wrong when only one of the animals is on the card. 2. Disjunctive guesses are always right because in all such trials at least one of the animals is present on the card. Figure 3.4 shows that in 2AFC judgments, both predictions are borne out. In other words, judgments with two alternatives closely match the predictions of a purely semantic or truth conditional account of the connectives *and* and *or*. Adults interpreted "right" and "wrong" roughly as "true" and "false" in the 2AFC task.

However, in the 3AFC task, judgments deviated from a purely semantic account in four trial types: 1. disjunction trials with one animal 2. disjunction trials with two animals, 3. conjunction trials with one animal, and 4. the trials with simple guesses when two animals were shown on the card. Participants often used the third option *kinda right* in these trial types. Other trial types obtained identical results in 2AFC and 3AFC tasks. The comparison of forced choice judgments with two and three alternatives suggests that two alternatives better capture the truth-conditional meaning of the connectives, but underestimate adult pragmatics reasoning.

The Pragmatics of AND and OR

A disjunctive assertion like "cat or dog" gives rise to an ignorance inference and an exclusivity inference. The ignorance inference is the inference that the speaker does not know which disjunct actually holds. For example in figure 3.6, the speaker does not know whether the card has a cat on it or a dog - they are uncertain between cards 1, 2, and 3. The guessing game in this study controls for the ignorance inference by keeping the guesser blindfolded. Therefore, all the disjunctive guesses are evaluated in a context where participants know that the guesser is ignorant of the animals on the cards - both the number of them on the card and their identity. The exclusivity inference is the inference that only one of the disjuncts holds and **not both**. In figure 3.6, a disjunction like "cat or dog" only refers to cards 2 and 3 if it is accompanied by an exclusivity inference.

Since Grice (1989), this exclusive interpretation of "or" has been (at least partly) attributed to pragmatic reasoning about the speaker's connective choice. The reasoning goes like this: conversational participants are required to make their utterances as informative as possible. In the context of making predictions and guessing, a guesser is required to make their guess as specific (i.e. informative) as possible.[2] The conjunction word *and* is more specific and informative than the disjunction word *or* (L. Horn, 1989). For example in figure 3.6, "cat and dog" picks card 1 while "cat or dog" refers to cards 1, 2, and 3. If a speaker intends to refer to card 1, they should use *and* and say "cat and dog". They did not use *and*, so they probably do not intend to refer to card 1. Following this line of reasoning, I can **exclude** the possibility that the speaker intends to refer to card 1. The term **exclusivity implicature** captures this pragmatic reasoning that results in excluding the possibility of both disjuncts being true.

The goal in this section is to lay out the structure of pragmatic reasoning in the experimental setup and explain how they can be manifested in the results of the experimental studies. There are three main components to the pragmatic reasoning in the guessing game: 1. the assumptions of the game. 2. sensitivity to (under)informativity, and 3. the pragmatic reasoning about the speaker's choice of connectives. Following Katsos & Bishop (2011), I have considered **sensitivity to informativeness** as a precondition for **derivation of scalar implicatures**. I begin with the assumptions of the guessing game.

- **Guessing Game Assumptions**:
  - **Ignorance**: the guesser does not know the number or identity of the animals on the card.
  - **Specificity**: A guesser is required to be as specific as possible, ideally referring to a single card.

[2] When you ask someone to predict the outcome of a coin toss, a guess like "it will be heads or tails" does not count as a felicitous guess or prediction.

As explained before, ignorance of the guesser is explicitly explained to the participants. However, specificity is an assumption that was implicit in the game[3]. All the guesses used in the experiment can pick a single specific card except for disjunctive ones. Conjunctive guesses like "cat and dog" pick specific cards. The simple ones like "cat" can be strengthened pragmatically to mean "only a cat", and pick a specific card. However, Disjunctive ones like "cat or dog" pick two cards in their most specific (exclusive) sense. Therefore, they are always under-informative and violate the specificity assumption.

- **Sensitivity to Informativeness**: The guesser said "cat or dog" which is under-informative and picks card 1, 2, and 3.
  - **Violation Assumption**: the guesser is violating the specificity requirement.

Participants can detect the underinformativity of disjunctive guesses, notice the violation of specificity, and then decide whether they would like to tolerate this violation or punish it. It should be pointed out that it is hard to distinguish between "tolerating the specificity violation" and simply revising the specificity assumption of the game to avoid a violation. For example, participants may assume that the goal of the game is saying something true about the cards rather than being as specific as possible. In either case, the prediction is that adults who tolerate violation or revise specificity would judge disjunctive guesses as "right". However, if participants assume specificity and decide to not tolerate its violation, they will judge all disjunctive guesses to have some degree of infelicity. Since an under-informative guess is still technically correct, participants may not punish such a guess with a "wrong" response and prefer an intermediate option for like "kinda right". This is what I find in study 1 results. With two alternatives, not many adults judge infelicity with disjunctive guesses and I see almost no "wrong" responses. With three alternatives, "kinda right" responses pop up. Adults responses are split between "kinda right" and "right". If detecting and reacting to underinformativity is the whole story, then disjunctive guesses should show similar degrees of infelicity, regardless of how many animals there are on the card. However, the results of the 3AFC task suggest otherwise. A logistic mixed-effects model with the random intercepts and slopes for subjects and fixed effect of disjunction type found that when comparing disjunctive guesses in the 3AFC task, participants are more likely to choose *kinda right* than *right* when both animals

[3]Making this assumption explicit is both hard for young children and almost impossible when disjunctive guesses are used. Disjunctive guesses are always underinformative and never pick out a specific card.

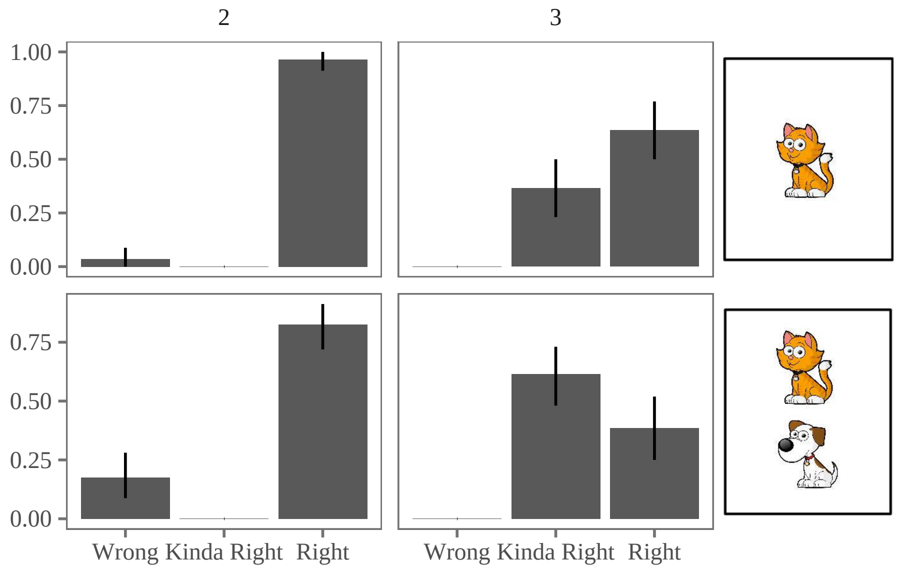

Figure 3.7: Adult responses to dicjunction guesses where both discjuncts where true with 2 and 3 options.

were on the card (β=-1.22, z=-2.25, p=0.02). In other words, participants judged further infelicity with disjunctive guesses that had both disjuncts as true. Therefore, it is reasonable to assume that when both disjuncts were true, some participants went through the following pragmatic reasoning.

- **Reasoning on Alternatives**: Why did the guesser choose the underinformative connective *or* rather than the more informative one *and*?
  - **Resolution Assumption**: speaker is trying to be as specific as possible by resolving the issue of how many animals are on the card.
    - **Exclusivity Implicature**: Given the resolution hypothesis, if the speaker had decided that two animals were on the card, they should have said "cat *and* dog". He did not, so he had decided that only one animal is on the card and **not both**.

How does the exclusivity implicature affect participant judgments in the experimental setting? One possibility is that excluding the correct response pragmatically is treated like cases of excluding the right response semantically. For example, guessing "elephant" when there is a cat on the card. The prediction is that disjunctive trials with true disjuncts should receive "wrong" responses. However, this prediction was not borne out. Such disjunctive trials are almost never judged as "wrong".

Alternatively, it is possible that adults differentiate incorrect pragmatics from incorrect semantics (i.e. falsehood) and punish incorrect pragmatics less than incorrect semantics. This conclusion is supported by the response patterns across trial types (figure 3.5). Trial types that have received a "wrong" response are those that are false. Pragmatically infelicitous trial types, namely simple guesses like "cat" or disjunctive guesses like "cat or dog" when both animals are on the card, receive "kinda right" responses. In other words, adults consider false utterances as "wrong" guesses but infelicitous utterances do not reach the level of being "wrong"; they are still right even though not completely right. This explains why the rates of infelicity (avoiding the "right" alternative) differ between 2AFC and 3AFC trials in disjunctive trials with true disjuncts (0.18 vs. 0.62).

3.3 Study 2: Children's three-alternative judgments and open-ended corrective feedback

The goal of this study was to examine children's interpretations of *and* and *or* in the guessing game and compare them to those of the adults. Since the 3AFC judgment task in study 1 proved better at capturing the nuances in adults' pragmatic reasoning, I decided to first test children using three alternatives. I also analyzed children's open-ended comments about the guesses in the experimental context. Both three-alternative judgments and the analysis of children's open-ended responses showed that children differentiate *and* and *or* statements. The judgment task suggested that children do not consider disjunctive guesses when both disjuncts are truly infelicitous. Yet, the analysis of their open-ended feedback showed that they did find such guesses infelicitous. I conclude that the 3AFC judgment task can underestimate children's pragmatic competence.

3.3.1 Methods

Table 3.3: Summary of Study 1 and Study 2 Methods

Study	N	Age	Mode	Response Option
Study 1 - Part 1	57	Adults	Online (Mturk)	Wrong, Right
Study 1 - Part 2	52	Adults	Online (Mturk)	Wrong, Kinda Right, Right

Figure 3.8: Jazzy with and without the sleeping mask.

Study	N	Age	Mode	Response Option
Study 2	42	3;1-5;2 (M = 4;3)	Study Room	Circle (wrong), Little Star (little right), Big Star (right)

Materials and Design

I used the same set of cards and linguistic stimuli as the ones in study 1. There were 8 trial types and 2 trials per trial type for a total of 16 trials. I made two changes to make the experiment more suitable for children. First, instead of the fictional character Bob, a puppet named Jazzy played the guessing game with the children. Jazzy had a sleeping mask on his eyes during the game (Figure 3.8). Second, a pilot study showed that a scale with three alternatives is better understood and used by children if it is presented in the form of rewards to the puppet rather than verbal responses such as “wrong”, “a little bit right”, and “right”, or even hand gestures such as thumbs up, middle, and down. Therefore, I placed a set of red circles, small blue stars, and big blue stars in front of the children. These tokens were used to reward the puppet after each guess. During the introduction, the experimenter explained that if the puppet is right, the child should give him a big star, if he is a little bit right, a little star, and if he is not right, the puppet gets a red circle.

Participants and Procedure

I recruited 42 English speaking children from the Bing Nursery School at Stanford University. Children were between 3;1 and 5;2 years old (Mean = 4;3). The experiment was carried out in a quiet room and all sessions were videotaped. There was a small table and two chairs in the room. Children sat on one side of the table and the experimenter and the puppet on the other side facing the child.

The groups of circles, small stars, and big stars were placed in front of the child from left to right. A deck of six cards was in front of the experimenter. As in study 1 with adults, the children sat through three phases: introduction, instruction, and test.

The goal of the introduction was to show the cards to children and make sure they recognized the animals and knew their names. The experimenter showed the cards to the children and asked them to label each animal. All children recognized the animals and could label them correctly. In the instruction phase, children went through three example trials. The experimenter explained that he was going to play with the puppet first so that the child could learn the game. He removed the six introduction cards and placed a deck of three cards face-down on the table. From top to bottom (first to last), the cards had the following images: cat, elephant, cat and dog. He put the sleeping mask on the puppet's eyes and explained that he is going to guess what animal is on the cards. He then picked the first card and asked the puppet: "*What do you think is on this card?*" The puppet replied with "*There is a dog*". The experimenter showed the cat-card to the child and explained that when the puppet is *not right* he gets a circle. He then asked the child to give the puppet a circle. Rewards were collected by the experimenter and placed under the table to not distract the child. The second trial followed the same pattern except that the puppet guessed *right* and the experimenter invited the child to give the puppet a big star. In the final trial, the puppet guessed that there is a cat on the card when the card had a cat and a dog on it. The experimenter said that the puppet was *a little right* and asked the child to give him a little star.

Table 3.4: Instruction Trials.

Card	Guess	Reward
CAT	there is a cat!	Circle
ELEPHANT	there is an elephant!	Big Star
CAT-DOG	there is a dog!	Little Star

In the test phase, the experimenter removed the three instruction cards and placed a deck of 16 randomized cards on the table. The experimenter explained that it was the child's turn to play with the puppet. The test phase followed the pattern described in the instruction phase. You can find the randomization code as well as the details of the methods on the online repository for this study.

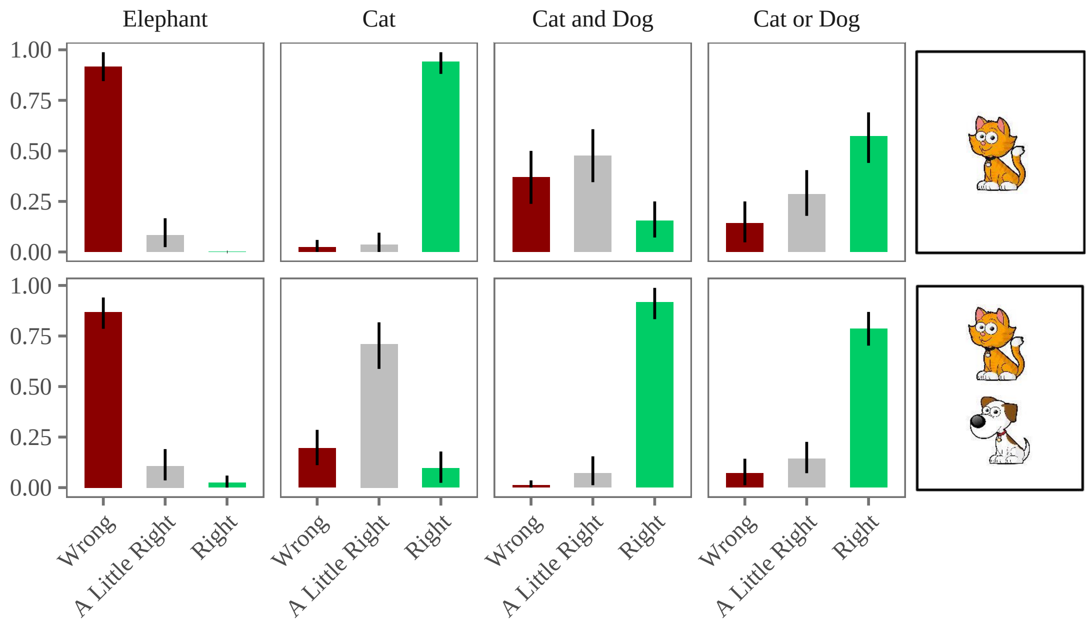

Figure 3.9: Children's ternary judgments in the connective guessing game.

Offline Annotations

During analysis of the videos, children's linguistic feedback to the puppet after each guess was categorized into four types: 1. None, 2. Judgments, 3. Descriptions, and 4. Corrections. The first category referred to cases where children did not say anything and only rewarded the puppet. Judgments referred to linguistic feedback such as *you are right!*, *yes*, *nope*, or *you winned*. Such feedback only expressed judgments and complemented the rewards. Descriptions were cases that the child simply mentioned what was on the card: *cat!*, *dog and elephant!*, *There is a cat and a dog!* etc. Finally, corrections referred to feedback that provided additional linguistic elements that acted like corrections to what the puppet had said. Examples include: *Just a cat!*, *Both!*, *The two are!*, *Only cat*, *cat AND dog* (with emphasis placed on *and*). In trials where the child provided both judgments as well as descriptions or corrections, I placed the feedback into the more informative categories, namely description or correction.

3.3.2 Results

Figure 3.9 shows the results for children's 3AFC judgments. Starting from the left column, we see that if the mentioned animal was not on the card (e.g. elephant), children judged the guess to be "wrong". If the animal mentioned (e.g. cat) was the only animal on the card, children judged the guess to be "right". Here I will ignore the results for trial types in which the animal mentioned was one of the animals on the card. The reason is that such trials were used in the instruction phase to introduce the "little bit right" guesses, and the results are potentially biased by the instructions.

In conjunctive guesses (e.g. *cat and dog*), when only one of the animals mentioned was on the card, children judged the guess as "wrong" or "a little bit right". However, if both animals were on the card, they judged the conjunctive guess as "right". In disjunctive guesses (e.g. *cat or dog*), when only one of the animals mentioned was on the card, children considered the guess "right" or "kinda right". If both animals were on the card, the disjunctive guess was considered "right".

Comparison of the conjunction and disjunction trials (last two columns of figure 3.9) shows that overall, children distinguished between *and* and *or* guesses in cases when one animal was on the card but not when both were. Given that the one-animal conjunction trials and the one-animal disjunction trials differ in truth conditions, the difference in response patterns suggests that children at this age have a different semantic knowledge for *and* and *or*. The two-animal conjunction and two-animal disjunction trials did not differ in truth values, and the responses also show no difference.

In the one-animal and two-animal trials (figure 3.9 rows), children gave different responses when the guess contained the conjunction word *and* but not when *or* is used. Since the truth values of one-animal and two-animal trials differ for conjunctive guesses but not disjunctive ones, the results suggest that children were sensitive to the difference in meaning between *and* and *or*. The similarity of the disjunctive guesses in one-animal and two-animal trials could also be interpreted as a lack of pragmatic reasoning in children. 3.10 compares the results for children and adults' 3AFC judgments in the conjunction and disjunction trials. The major difference between adults and children's responses here is visible in the disjunctive trials where both animals were on the card; in other words, trials where both disjuncts are true. In the next section, I use statistical modeling to compare adults' and children's three-alternative responses more systematically.

Analysis and Statistical Modeling

I used the R package {*rstan*} for Bayesian statistical modeling to fit separate ordinal mixed-effects logistic models for the children's and adults' judgments. The response variable had three ordered

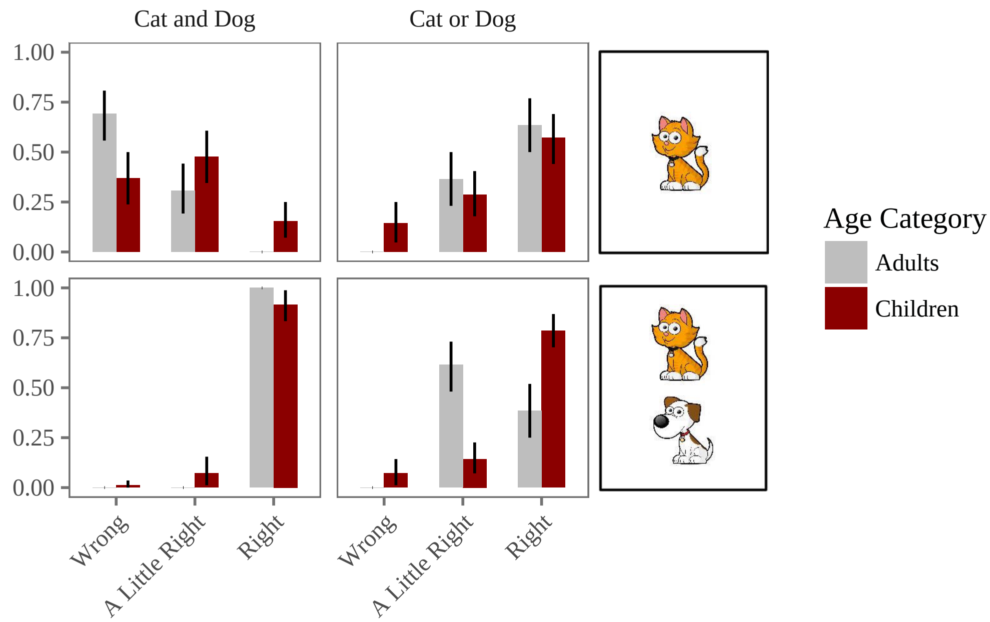

Figure 3.10: Comparison of Adults' and Children's ternary judgments.

levels: *wrong*, *kinda right*, and *right*. The trial types *One-Animal-OR*, *Two-Animals-OR*, *One-Animal-AND* constituted the (dummy-coded) fixed effects of the model with *Two-Animals-AND* set as the intercept. The model also included by-subject random intercepts. The priors over trial types and the random intercepts were set to $\mathcal{N}(0, 10)$. I also included parameters C_1 and C_2, the two cutpoints delimiting the logistic for 1) *wrong* and *kinda right* and 2) *kinda right* and *right* responses, drawn with the prior $\mathcal{N}(0, 1)$.[4] All four chains converged after 3000 samples (with a burn-in period of 1500 samples)

I made inferences based on the highest-posterior density (HPD) intervals for the coefficients estimated from each model. Because predictors are dummy-coded, it's possible to examine contrasts of interest by computing the difference between coefficients for pairs of conditions I wish to contrast. Figure 3.11 shows the contrasts of interest: *b(OR, 2)-b(OR,1)* represents the difference between the estimated coefficients for the disjunction trials with two animal on the card and those with only one; *b(OR, 2)* represents the difference between the estimated coefficients for the conjunction trials with two animals and the disjunction trials with two animals; and so on.

Overall, adults' and children's estimated coefficients are similar in sign to one another, though

[4] I used a tight prior in this case to decrease posterior correlations between cutpoints and intercept.

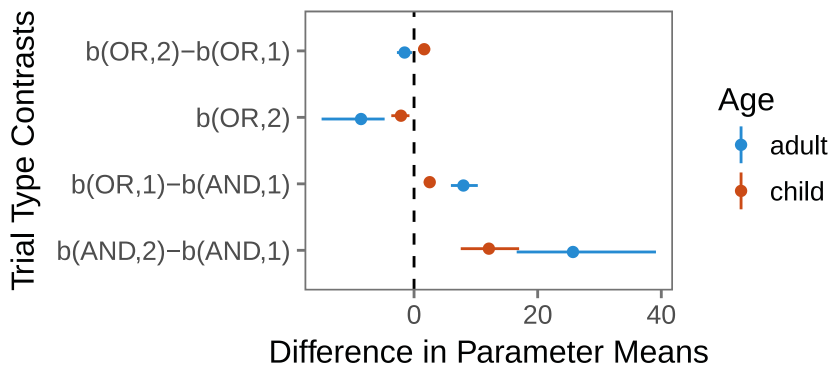

Figure 3.11: Coefficients capturing the relevant comparisons across conditions in ternary judgments in Study 1 and 2. Error bars represent 99% regions of highest posterior density.

adults' are more extreme. In the conjunction trials (*b(AND, 2)-b(AND,1)*), children and adults showed a strong preference for the cards with two animals rather than one. At the same time, given two animals on the card, children and adults showed a preference for *and* rather than *or* (*b(OR, 2)*). However, with only one animal on the card, children and adults preferred a disjunctive guess (*b(OR, 1)-b(AND,1)*). These results are compatible with the truth conditions of conjunction and disjunction.

The main difference between adults and children shows up in the contrast between the disjunctive trial types: two animals vs. only one (*b(OR, 2)-b(OR,1)*). On average, children rated disjunction trials with two animals higher than those with only one. Adults on the other hand showed the opposite pattern: they rated disjunction trials with two animals lower. This pattern is compatible with current accounts of pragmatic development that suggest an absence of implicatures in children's interpretations. The idea is that while adults strengthen the disjunctive guess "cat or dog" to "cat or dog but not both", children simply interpret it as "cat or dog or both". Adults are therefore going to rate trials where both disjuncts are true as lower.

The slight preference children show for cards with two animals when the guess is disjunctive is also compatible with the account proposed by Singh et al. (2016) and L. Tieu et al. (2016). However, the effect is much smaller here than they reported in their studies. The comparison with conjunction trials makes it clear that overall, children are not interpreting *or* as having a conjunctive meaning. The effect in this study can be more accurately described as a preference for both disjuncts being true rather than a conjunctive interpretation of disjunction. I will further discuss the nature of this preference in the General Discussion.

Children's open-ended feedback

Table 3.5: Definitions and Examples for the Feedback Categories.

Category	Definition	Examples
None	no feedback provided to the puppet, only reward	
Judgment	the child said yes/no, you are right, etc.	"No!" , "You are right Jazzy!"
Description	mentioned the animal(s) on the card	"elephant", "cat and dog"
Correction	used focus particles like "only"/"just", emphasized "and" or used "both"	"only cat", "just elephant", "Both!", "cat AND dog!"

As explained in section 3.3.1, I also categorized and annotated children's spontaneous and free form verbal reactions to the puppet's guesses. Table 3.5 summarizes the definitions and examples for each category and figure 3.12 shows the results. I should first point out that each trial type shows similar number of "None" cases, for feedback. Some children remained more or less silent throughout the experiment and only provided rewards to the puppet. In the next study I focus on children's open-ended feedback. In the discussion and analysis here I will not comment further on the "None" category but focus on the other three categories.

In the leftmost column, when the animal guessed (i.e. elephant) was not on the card, children either provided judgments like "No!" or described what was on the card like "cat" or "cat and dog". However, when the animal guessed was the only animal on the card (i.e. cat), most children provided a positive judgment like "Yes". When the animal guessed was only one of the animals on the card, children described what was on the card, say, "cat and dog". Corrections were rare for all these four control trial types.

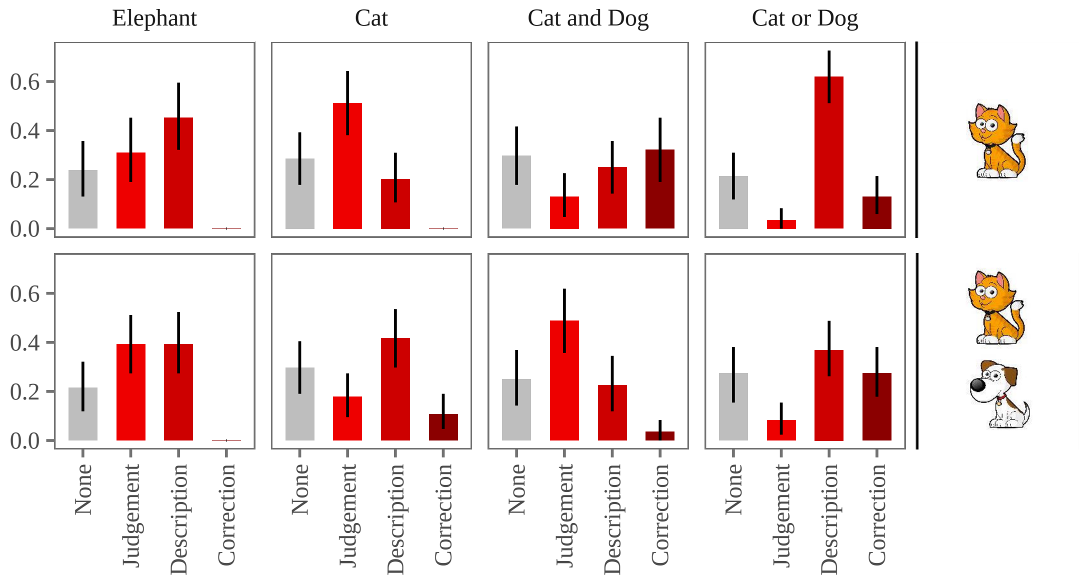

Figure 3.12: Children's open-ended Feedback. Error bars represent 95% confidence intervals.

In the critical trial types with conjunction and disjunction, children showed a high rate of corrections and description when the guess used "and" but there was only one animal on the card. In their corrections, children used the focus particles "just" and "only" like "just a cat" or "only a cat". However, in trial types where conjunction was used and both animals were on the card, children predominantly provided positive judgments like "Yes!" and "You are right". Considering disjunctive guesses like "cat or dog", when only one of the animals was on the card, most children simply described what was on the card, for example "cat". However, when both animals were on the card, children corrected the puppet by saying "both" or emphasizing "and" as in "cat AND dog".

I performed chi-squared goodness-of-fit tests to compare the feedback distributions in the critical conditions with "and" and "or". Here I focus on those trials (the four bar charts on the right of figure 3.12). Children's linguistic feedback showed three patterns. First, the one-animal conjunctive and two-animal disjunctive (top left and bottom right) trials contained a higher proportion of Corrections than the other trial types. These were trials where the guesses were either false or infelicitous. In the conjunction trials, a comparison of the feedback distribution in one-animal and two-animal conditions was statistically significant ($\chi(3, 83) = 201.65$, $p < .0001$), that children gave different feedback for false guesses. A similar numerical trend was present in the disjunction trials, but was not significant ($\chi(9, 4) = 12$, $p = 0.21$).

Second, the one-animal disjunctive trials (top right) showed the highest proportion of *Descriptions*. These are trials in which the guess is correct but not specific enough: it leaves two possibilities open. These trials were significantly different from the one-animal trials for conjunction ($\chi(3, 83) = 62.16$, $p < .0001$). Finally, the two-animal conjunctive trials (bottom left) showed the highest proportion of *Judgments* such as *You are right!*. This was not surprising given that in these trials represented the most optimal guessing scenario. These trials had a significantly different feedback distribution from the matching disjunction trials ($\chi(3, 84) = 184.98$, $p < .0001$).

3.3.3 Discussion

In study 2, I used a 3AFC judgment task to test children's comprehension of logical connectives *and* and *or*. I compared these results to those found in the 3AFC judgment task of study 1 with adults. The general comparison showed that adults and children had similar patterns of judgments, except when both disjuncts were true. In such cases, adults judged the disjunctive guess as not completely right while most children found it completely right. There was even a slight preference among children to rewarded the puppet more in such cases, compared to cases of disjunction when only one disjunct was true.

To consider another measure of children's comprehension, I also looked at children's spontaneous open-ended feedback in response to the guesses. My analysis suggested that children recognized false and infelicitous utterances with the connectives and provided appropriate corrective feedback. As expected from an adult-like understanding of connectives, children corrected the puppet most often when there was only one animal on the card and the guess was conjunctive, or when there were two animals on the card and the guess was disjunctive. Perhaps the most important finding was that children increased their corrective feedback in disjunctive guesses where both disjuncts were true, compared to those with only one true disjunct. These findings difer from the the results of the 3AFC judgment task which suggested that children did not find any infelicity with disjunctive guesses when both disjuncts were true.

The analysis of children's open-ended feedback raises two important issues. First, as I mentioned before, it runs counter to what the 3AFC judgment task suggests with respect to exclusivity implicatures (i.e. trials with disjunction when both disjuncts are true). The forced-choice judgment task suggests that children find such cases unproblematic while analysis of their spontaneous feedback shows that they provided more corrections to the puppet. Second, a common explanation for why children fail at deriving implicatures is that they cannot access the stronger alternative to the disjunction *or*, namely *and* (Barner et al., 2011). However, in the context of the guessing game, some children explicitly mentioned the word *and* as what the puppet should have said instead of *or*. Interestingly, these children continued to reward the puppet and considered the guess "right". This raises the possibility that children's forced-choice truth value judgments, whether with two or three alternatives, do not fully reflect their pragmatic knowledge. In study 3, I decided to make children's open-ended feedback the main dependent variable of study and directly compare this to a 2AFC truth judgment in the same task. This design allowed me to directly compare children's open-ended and forced choice responses.

3.4 Study 3: Children's 2AFC judgments and open-ended feedback

This study used the same paradigm as study 2 but focused on children's open-ended feedback and aimed at replicating the findings in study 2. The main hypothesis was that four-year-olds provide corrective feedback to the puppet if both disjuncts are true, but they do not consider this infelicity to be grave enough to render the guess "wrong". The main hypothesis along with relevant analyses and predictions were preregistered in an "As Predicted" format[5]. The study used a 2AFC judgment task to compare with the open-ended feedback results. The prediction was that children will provide corrective feedback to the puppet when both disjuncts were true, yet consider the guess "right" and not reflect this infelicity in truth value judgments. This is what the study found.

3.4.1 Methods

[5]The As Predicted pdf document is accessible at `https://aspredicted.org/x9ez2.pdf`.

Table 3.6: Summary of Study 1, 2, and 3 Methods

Study	N	Age	Mode	Response Options
Study 1 - Part 1	57	Adults	Online (Mturk)	Wrong, Right
Study 1 - Part 2	52	Adults	Online (Mturk)	Wrong, Kinda Right, Right
Study 2	42	3;1-5;2 (M = 4;3)	Study Room	Circle (Wrong), Little Star (Little Right), Big Star (Right)
Study 3	50	3;6-5;9 (M = 4;7)	Study Room	Yes (Right)/No (Wrong) - Open-ended Feedback

Materials and Design

Study 3 was similar to Study 2 but differed in how children provided their judgments. Based on the findings in Study 2, I focused on verbal judgments and feedback, instead of rewards. I used two different ways of measuring children's judgments. First, I encouraged children to provide verbal feedback to the puppet. They were asked to say "yes" when the puppet was right, and "no" when he was not. They were also encouraged to help the puppet say it better when he was not right. After children were done with this initial open-ended feedback, for each trial we asked them a forced choice yes/no judgment question: "Was Jazzy (the puppet) right?". This question elicited a "yes" or "no" response for each trial independent of their earlier open-ended response. These two measures allowed me to compare open-ended and forced choice judgments.

Participants and Procedure

I recruited 50 English speaking children from the Bing Nursery School at Stanford University. Children were between 3;6 and 5;9 years old (Mean = 4;7). The setup and procedure were similar to Study 2, except there were no rewards on the table. As before, participants sat through three phases: introduction, instruction, and test. The introduction phase made sure children knew the names of the animals on the cards. In the instruction phase, they received four training trials, as shown in table 3.7.

As in Study 2, the experimenter put the sleeping mask over the puppet's eyes and explained that Jazzy (the puppet) was going to guess what animal was on the cards. He then picked the first card and asked the puppet: "*What do you think is on this card?*" The puppet replied with "*There is a dog*". The experimenter showed the cat-card to the child and said: when Jazzy is *not right*, tell him "No". He then asked the child to say "no" to the puppet. The second trial followed the same pattern except that the puppet guessed *right* and the experimenter invited the child to say "yes" to the puppet. There were two more instruction trials trials before the test phase began. This contained 16 randomized trials, half of which contained guesses with the words "and" and "or".[ˆ4]

[ˆ4]You can find the randomization code as well as the details of the methods on the online repository for this dissertation.

Table 3.7: Instruction Trials for Study 3.

Card	Guess	Response
CAT	there is a dog!	No!
ELEPHANT	there is an elephant!	Yes!
DOG-ELEPHANT	there is a cat!	No!
DOG	there is a dog!	Yes!

3.4.2 Results

Here I first look at the results of the 2AFC judgement task for each trial type and compare them to those of the adults' in Study 1. Then I will analyze children's open-ended responses and compare them to the forced choice responses obtained in the same trials.

For the 2AFC judgments I excluded 26 trials (out of total 800) where children either did not provide a Yes/No response or provided both (i.e. "Yes and No"). The exclusions were almost equally distributed among different types of guesses and cards. In my analysis of children's open-ended feedback, I excluded 8 trials (out of total 800) where children either did not provide any feedback or their feedback could not be categorized into the existing categories.

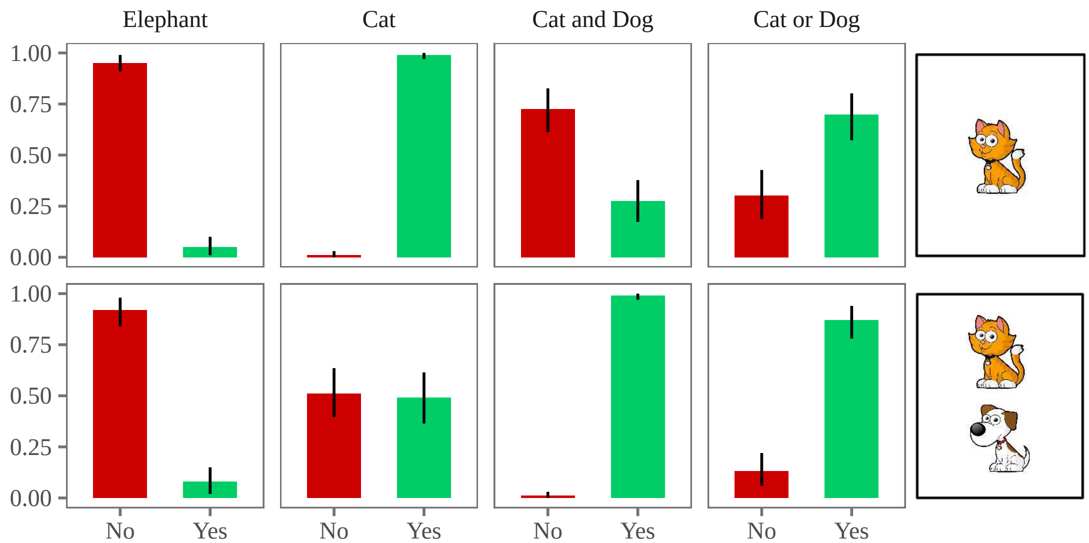

Figure 3.13: Children's binary truth value judgments.

Two-Alternative Forced Choice Judgments

Figure 3.13 shows children's 2AFC judgments. In the leftmost column, when the animal guessed (e.g. elephant) was not on the card, children considered the guess "wrong". When the animal guessed (e.g. cat) was the only animal on the card, children considered the guess "right". However, if the animal guessed (e.g. cat) was only one of the animals on the card, children were equally split between "wrong" and "right" judgments. On the other hand, almost all adults considered such guesses "right" in their 2AFC judgments (Figure 3.4). In such trial types, children seem to interpret the guess "there is a cat" as "there is **only** a cat", while adults do not. This difference between children and adults is unexpected for a theory of meaning acquisition that assumes children are overall more logical/literal interpreters than adults (Noveck, 2001).

In the trials with *and* and *or*, we see that children's judgments were similar to those of adults'. Figure 3.14 compares adults' and children's 2AFC judgments. In trials with conjunction, when only one of the animals was on the card, most children considered the guess "wrong". This is similar to adults' judgments, and different in extent: adults were more consistent and unanimously rejected such guesses. A mixed effects logistic regression with the fixed effect of age category (adult vs. child) and random effect of subject found no significant difference between adults' and children's responses in such trials (see Table 3.8, Conjunction - One Animal).

Table 3.8: Mixed effects logistic models for disjunction trials in 2AFC judgments of adults and children, using `glmer` in R's {LME4} package. Formula: $Response \sim AgeCategory + (1|Subject)$.

Trial Data	Coefficient	Standard Error	Z-Value	P-value
Conjunction - One Animal	-2.05	2.86	-0.72	0.47
Disjunction - One Animal	1.34	1.79	0.75	0.45

In conjunctive guesses where both animals were on the card, both children and adults were unanimous in considering the guess "right". In disjunctive trials when only one of the animals was on the card, most children considered the guess "right". This is again similar to adults but differs from them in extent: adults more consistently and unanimously judged such guesses as "right". Yet again, a mixed effects logistic regression with the fixed effect of age (adult vs. child) and random effect of subject found no significant difference between adults' and children's responses in such trials (see Table 3.8, Disjunction - One Animal). Adults and children showed almost identical patterns of judgments in trials where there was two animals on the card and the guess used the connective "or". Children and adults did not differ in their rate of rejecting disjunctive guesses when both disjuncts were true. Finally, there is a small but significant preference in children's judgments of disjunctive statements for both disjuncts to be true. Comparing the disjunctive trials with one animal and two animals on the card, a mixed-effects logistic model with the fixed effect of disjunction type and the random effect of subjects found that children had a slight preference for both animals to be on the card (b= 1.85, se= 0.56, z= 3.32, $p < 0.001$). There was a similar small trend in children's three-alternative judgments in study 2. While this was quite small compared to the other effects observed in these studies, it nevertheless indicated a minor difference between children's and adults' judgments. I will return to this in more detail in section 3.5.1 of the General Discussion.

Open-ended Feedback

Figure 3.15 shows the distribution of children's feedback to the puppet in Study 3. (See table 3.5 for the definitions and examples of feedback categories. There were no "None" responses in this study since the experimenter explicitly asked children to provide feedback to the puppet. The distribution of the responses in the other three categories (Judgment, Description, and Correction) revealed a

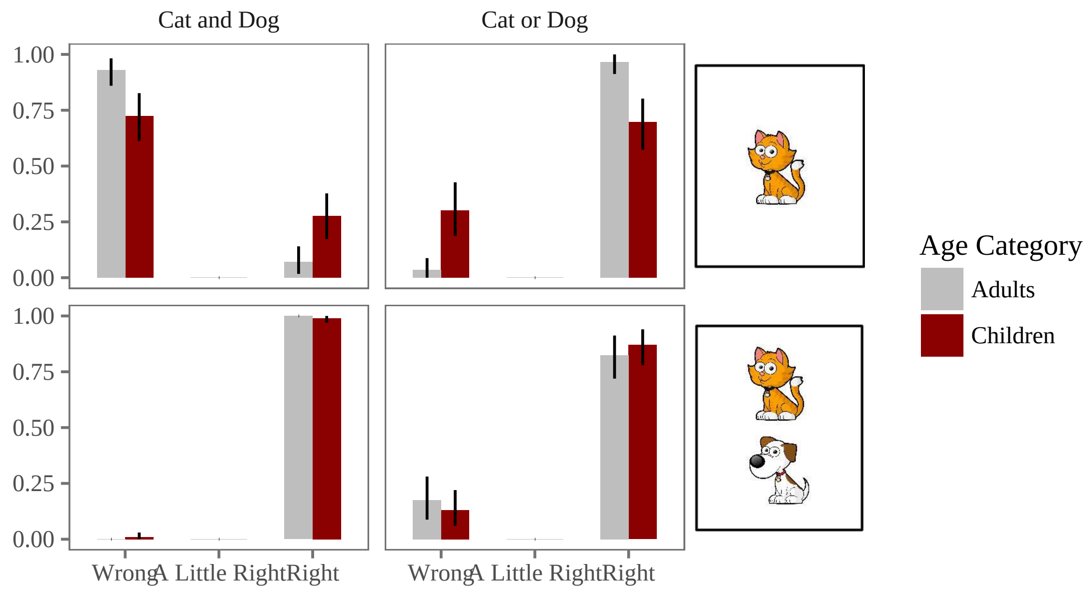

Figure 3.14: The comparison of the 2AFC judgment task for conjunction and disjunction trials in adults (study 1) and children (study 3).

successful replication of Study 2.

Children's feedback showed four main patterns. First when the puppet guessed an animal not on the card (e.g. elephant), there is a split pattern between negative judgments like "no!" and simple descriptions of what was on the card, e.g. "cat!". Children provided no corrections on such trials. Second, almost all children responded with positive judgments like "yes" when the puppet's guess accurately matched what was on the card. This was the case in trials where there was only one animal on the card (e.g. cat) and the puppet mentioned it, and trials where there were two animals and the puppet mentioned both with a conjunction (e.g. cat and dog). Third, children provided the highest number of corrective feedback in trials where the guess was either false or infelicitous. These included three trial types: (a) the ones where there were two animals on the card but the puppet only guessed one (e.g. cat); (b) the ones where the puppet guessed two animals with conjunction (e.g. cat and dog) but only one of them was on the card; and (c) the ones where there were two animals and the puppet guessed both but used a disjunction (e.g. cat or dog). The fourth general pattern was unique to disjunctive trials with only one animal on the card. In such cases, almost all children simply named the animal on the card (e.g. "Cat!"). Figure 3.16 breaks down children's open-ended feedback based on whether children said "yes", "no", or said something else. Responses

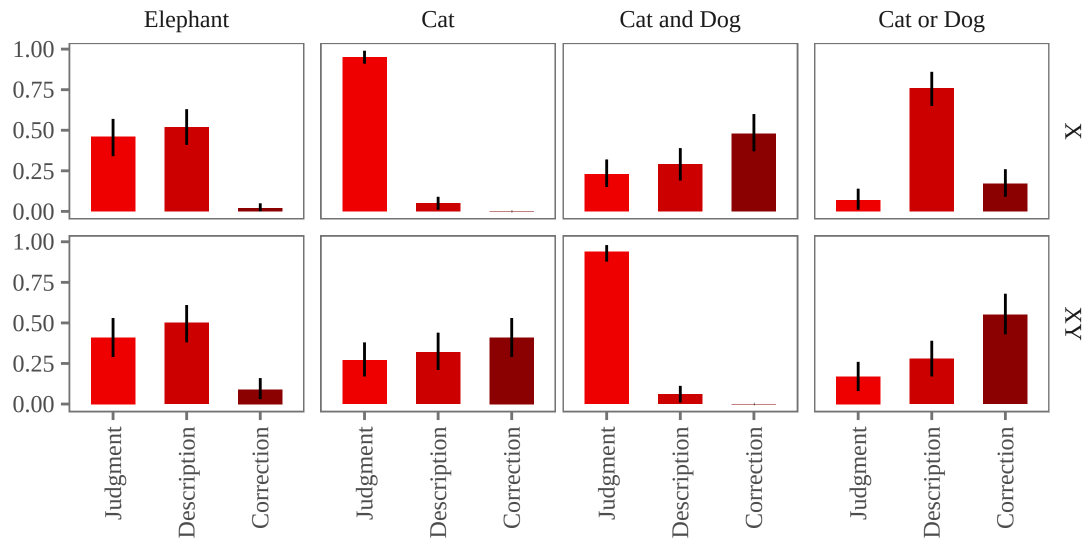

Figure 3.15: Children's Open-ended Feedback. Error bars represent 95% confidence intervals.

that were not yes/no judgments are grouped in a middle category shown with a dash. The goal here is to compare children's open-ended judgments with their forced choice judgments shown in figure 3.13. Children's open-ended judgments and their forced choice judgments in study 3 show similar patterns for all types of guesses except for disjunctive ones. In trials that the puppet guessed using "or", the vast majority of children refused to provide a yes/no judgment when they were not forced to. Instead, they described the animal on the card or provided corrections to the puppet's infelicitous disjunctive guess.

One way to interpret these results is that disjunctive guesses (with at least one disjunct true) are considered neither right nor wrong by almost all children. When children were forced to provide wrong-right responses in the experimental context, some may conformed to the adult patterns of judgment and some did not. However, it is possible that such deviations from adult judgments do not reflect differences in the comprehension of disjunction, but rather differences in how children map their adult-like comprehension onto the notions of "right" and "wrong" in a forced choice judgment task. Figure 3.17 is similar to figure 3.16 but it uses color-fill to show what children said in addition to yes or no. The gray color represents the trials where children only said yes/no and nothing else. The yellow-fill represents descriptions where children mentioned the animal on the card (i.e. "cat!"). The blue fill represents children's corrective feedback that used the exclusive focus particles *just* or

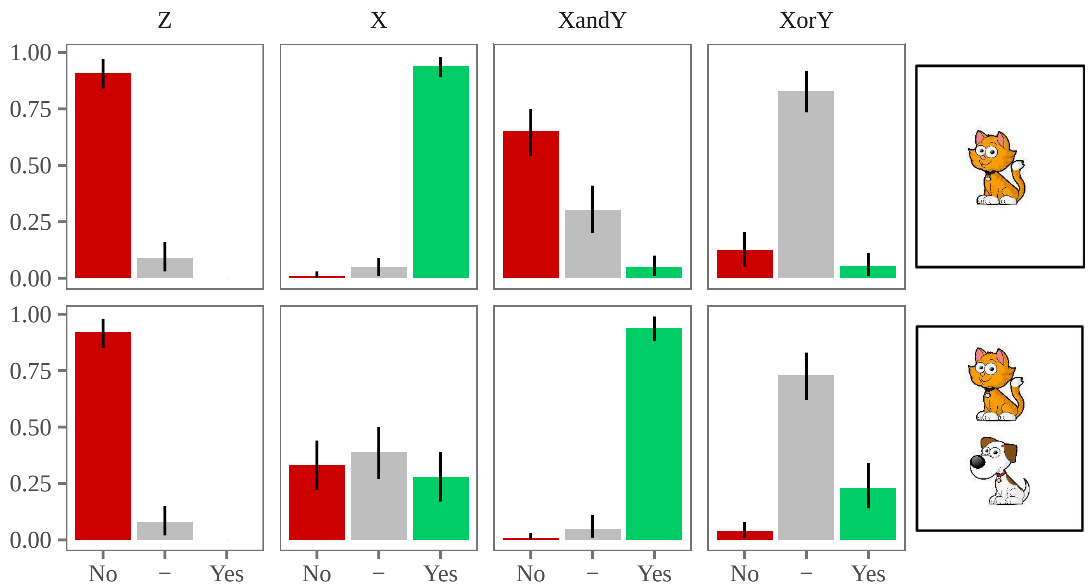

Figure 3.16: Children's open-ended feedback to the puppet's guesses.

only (i.e. "just a cat!"). Such a corrective feedback suggests that the guess included an animal that did not belong and should have been excluded. Finally the red fill represents the inclusive corrective feedback that emphasized the word *and* or said *both* (i.e. "both", "cat AND dog"). Such corrective feedback indicated that two animals should be included.

As shown in the leftmost column, when the puppet mentioned an animal that was not on the card (e.g. elephant), children responded with a simple "no" or "no" followed by what **was** on the card (e.g. no! elephant!). When there was only one animal on the card and the puppet mentioned the animal (e.g. cat), children responded with a simple "yes". However, when the card had two animals (e.g. cat and dog) and the puppet only mentioned one of them (e.g. cat), children were likely to provide inclusive feedback. They said *both* or emphasized *and*, as in "cat **AND** dog". However, in such trials children were equally split between saying yes, no, or neither.

In the trials with conjunctive and disjunctive guesses, when there was only one animal on the card (e.g. cat) and the puppet used a conjunction (e.g. cat and dog), children were likely to say a simple "no" or say "no", followed by "only/just" (e.g. no, just a cat). Some children did not say "no" but did respond with "only/just". When the card had two animals on it and the puppet mentioned both using *and*, children responded with a simple "yes". In trials with disjunctive guesses like "cat or dog", children avoided yes/no responses. Instead, when the card had only one animal, children

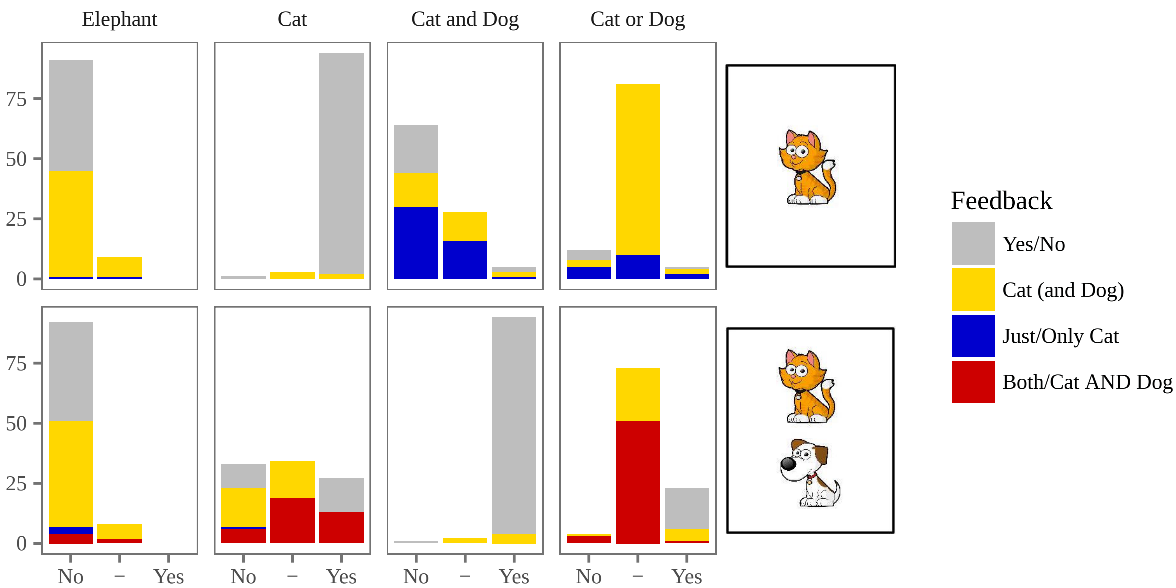

Figure 3.17: Children's open-ended feedback. The x-axis shows whether children said yes or no and the color fill shows what children said other than yes/no.

mentioned that animal. When the card had both animals, children said *both* or emphasized the word *and*, as in "cat **AND** dog". Figure 3.18 shows the same feedback data in Figure 3.17 but uses the x-axis to also show the proportion of feedback categories other than yes/no judgments. My goal here was to display the trial types with corrective feedback (blue and red). These trial types include: (1) conjunction when only one conjunct is true, (2) disjunction when both disjuncts are true, (3) simple guesses (e.g. "there is a cat") when two animals were on the card. These trial types involved guesses that are either false or infelicitous.

Furthermore, the type of corrective feedback children provided matched the type of mistakes made in the guesses. With conjunctive guesses like "cat and dog" when there was only one animal on the card (e.g. cat), children provided exclusive corrections (e.g. just/only a cat), suggesting that the other animal (e.g. dog) should have been excluded. With disjunctive guesses like "cat or dog" and simple guesses like "cat" when there were two animals on the card, children provided inclusive feedback, indicating that another animal should have been included. This is particularly notable in the case of disjunction since both animals were mentioned, but children still emphasized that the connective *and* should have been used, or that *both* mentioned animals were on the card.

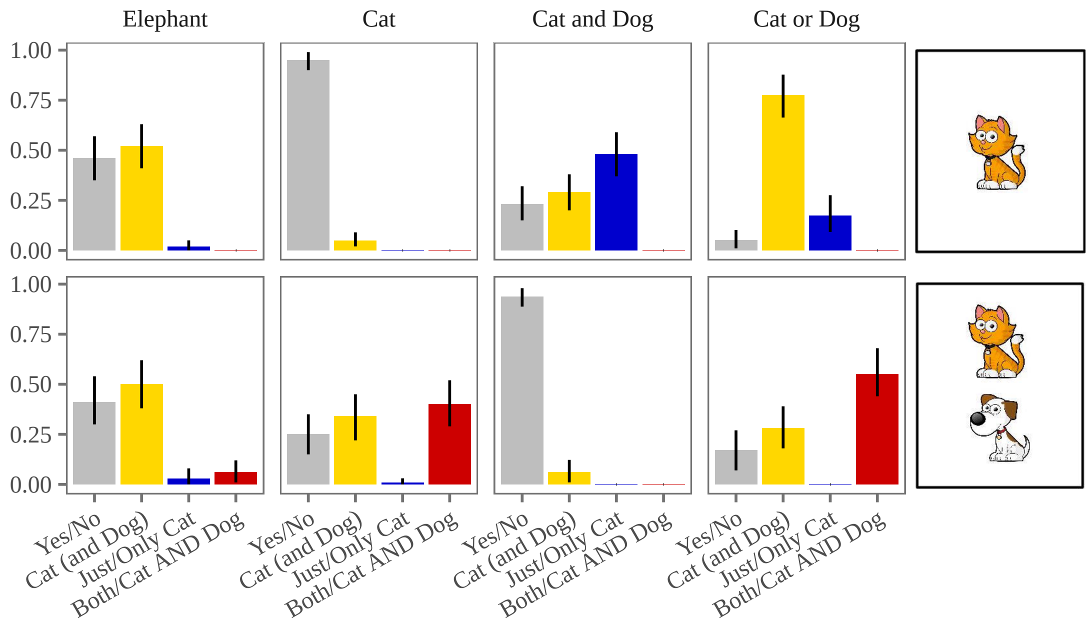

Figure 3.18: Children's feedback categories in disjunction trials.

3.4.3 Discussion

Study 3 measured children's comprehension of logical connectives by asking them to judge a puppet's guess in two ways: with open-ended feedback and with a two-alternative forced choice task. First, I asked children to say "yes" to the puppet if he was right and "no" if he was wrong. However, children could provide any form of feedback they wanted. Second, I followed children's open-ended feedback with a two-alternative forced choice question: "Was the puppet right?" This way, I could measure children's comprehension in two different ways in the same trial. Ideally, both measures should show similar results. However, the findings were similar for conjunctive guesses, but not disjunctive ones. Children avoided binary right/wrong feedback with disjunction and preferred to provide more nuanced feedback when they could.

The 2AFC responses followed the predicted pattern: conjunctive guesses with only one conjunct true were considered wrong while those with both conjuncts true were judged to be right. Disjunctive guesses were judged right whether one or both disjuncts was true. There was no significant difference in the 2AFC task between the responses of children and those of adults in Study 1.

Children's open-ended feedback in Study 3 replicated that in Study 2. They provided more corrective feedback in false and infelicitous trials than in true and felicitous ones. The corrective feedback was tailored to the puppet's mistake. If the puppet used a conjunction when there was only one animal on the card, children pointed out that the other animal should have been excluded using the exclusive adverbials *just* and *only*. If the puppet used a disjunction when both animals were on the card, children stressed *and* or *both*, implying that both animals should be included.

While the 2AFC results suggested that children take no issue with disjunctive guesses when both disjuncts are true, the analysis of their corrective feedback showed that they provide appropriate corrections in such cases and emphasize that the connective *and* would have been a better guess. Taking both measures together, I conclude that even though children are aware of the problem with such guesses, they do not consider them *wrong*. These results are similar to what I reported for adults in Study 1.

3.5 General Discussion

I reported three studies on adults and four-year-olds' comprehension of the logical connectives *and* and *or*. The first study used two- and three-alternative forced choice judgment tasks with adults. In the 2AFC task, adult interpretations closely matched the semantic accounts of *and* and *or* as conjunction and inclusive disjunction. The judgments did not register robust signs of pragmatic infelicities. However, the 3AFC judgment task, showed signs of pragmatic infelicities, especially in disjunctive guesses with true disjuncts. When both disjuncts were true, participants were more likely to choose "kinda right" rather than "right".

The second study used a 3AFC judgment task with four-year-old children. It also included an exploratory analysis of children's open-ended verbal feedback to the puppet in the experimental setting. Children's interpretations were similar to those of adults in the 3AFC task and only differed for pragmatically infelicitous disjunctions. When both disjuncts were true, adults tended to judge disjunctive guesses as "kinda right". This was evidence for the pragmatic infelicity of such guesses. While, children judged such disjunctive statement as "right", the analysis of their open-ended feedback showed that they took issue with such statements as well, and provided appropriate corrective feedback.

In the third study, I focused on eliciting open-ended verbal feedback from children and followed it with a 2AFC task. In the 2AFC task, children's responses reflected the semantics of connectives as conjunction and inclusive disjunction. There was no significant difference between children and adults in the two-alternative judgments. Since the 2AFC task appeared to be a good indicator of semantic knowledge, it seemed reasonable to conclude that adults and four-year-olds displayed similar semantic knowledge of the connectives. Analysis of the children's open-ended feedback replicated the findings in study 2. Children provided more corrective feedback in false and pragmatically infelicitous trials with logical connectives than in felicitous trials. The comparison of the 2AFC task and children's open-ended responses shows that children are sensitive to the infelicity of disjunctions with true disjuncts, even though they consider them to be "right" guesses.

Overall, I did not find major differences between adults' and four-year-old children's interpretations of logical connectives *and* and *or* in the context of the guessing game. However, there were two minor differences. First, I found that in both 2AFC and 3AFC judgment tasks, children showed a small preference for disjunctions with both disjuncts true rather than only one. Adults on the other hand showed the opposite pattern: they preferred disjuncts with only one disjunct true. Second, in both 2AFC and 3AFC judgment tasks, children rated disjunctions with both disjuncts true higher than adults. That is, they considered utterances like "there is a cat or a dog" when both animals were on the card "right" more often than adults. Here I discuss these two differences and their potential causes in more detail.

3.5.1 Preference for True Disjuncts

First for some children, there was a small preference for both disjuncts being true, compared to only one. This effect is similar in kind but not magnitude, to an effect that Singh et al. (2016) and L. Tieu et al. (2016) reported. In my study this effect is quite small while Singh et al. (2016) and L. Tieu et al. (2016) seem to have found bigger effects. Based on this, Singh et al. (2016) proposed that many children at this age-range have a pragmatically driven conjunctive interpretation of disjunction. In short, due to a non-adult like alternative set to the connective *or*, children strengthen a disjunctive statement pragmatically and derive a conjunction. The studies reported here provide no support for this proposal. In both 2AFC and 3AFC judgments, children clearly differentiated between disjunctive and conjunctive guesses. Furthermore, analysis of children's open-ended feedback showed distinctly different response patterns for conjunction and disjunction. More importantly, the open-ended feedback to disjunctive guesses showed the opposite pattern to that predicted by the conjunctive hypothesis. Children took issue with disjunctions that had both disjuncts true and provided more corrective feedback in such cases. Therefore, Singh et al. (2016) and L. Tieu et al. (2016) findings appear to be a product of forced choice tasks rather than a real reflection of children's comprehension of connectives.

However, even assuming that this small preference for true disjuncts is not due to the measurement method, it can be accounted for by several other hypotheses that have not been successfully ruled out yet. First, the conjunctive interpretation may not be due to a faulty pragmatic computation, but rather a default conjunctive interpretation when the connective is not properly heard/understood or is unknown. To check this hypothesis, it may be possible to test children's comprehension of novel or noisy connectives. A novel coordination like *cat dax dog* with *dax* as a nonce connective may be interpreted as a conjunction. Such results would suggest that in studies with high cognitive demand, children may default to a conjunctive interpretation if they miss the relevant connective. Second, the conjunctive preference may be due to some children's preference for the linguistic labels to match the animals on the card (or more generally linguistic description and state of the world). This hypothesis is consistent with the results in the other trial type that had mismatch in the number of animals and the guess while the guess was technically true: simple guesses (e.g. there is a cat) when two animal (e.g. cat and dog) were present on the card. Children were equally split between "wrong" and "right" in their judgments while adults considered such guesses as "right". In light of these alternative explanations, I are hesitant to attribute this small preference to a pragmatically driven conjunctive interpretation of disjunction.

3.5.2 Lack of Infelcity with True Disjuncts

The second difference between adults and children emerged in the 3AFC judgment task: in disjunctive trials (e.g. "cat or dog") with two animals (e.g. cat and dog), adults were more likely to choose "kinda right" than children were. Children mostly chose "right". This response pattern is often taken to mean that children found no infelicity with such disjunctions or that they did not "derive an exclusivity implicature". This lack of infelicity/implicature is consistent with the generalization that children are more likely than adults to interpret scalar terms literally, and that children do not compute implicatures or judge infelicity to the same **rate** that adults do (Pouscoulous & Noveck, 2009, Katsos (2014)). But why is that?

There have been three major proposals to account for children's low rate of implicatures: 1.

processing (Reinhart, 2004, Pouscoulous, Noveck, Politzer, & Bastide (2007)) 2. non-adult-like lexical entry (Barner et al. (2011), Horowitz, Schneider, & Frank (2017)) and 3. pragmatic tolerance (Katsos & Bishop, 2011). Here I show that none of these accounts provide a satisfactory explanation of the results in this study.

1. Processing First, the processing accounts locate the problem in children's processing capacities such as working memory. They suggest that pragmatic computations are cognitively taxing and children lack the appropriate processing resources to carry them out appropriately. A prediction of processing accounts (at least in their current format) is that children will show reduced implicature computations for all types of implicatures - scalar or ad-hoc. This prediction was not borne out in my experimental results. In Study 3, children were much more likely than adults to call a simple guess (e.g. "cat") "wrong" in the 2AFC task if there were two animals on the card (e.g. "cat and dog"). Processing accounts do not predict that children would derive more implicatures than adults but this is what I found for the traditional interpretation of the judgment task.

2. Non-adult Like Lexicon Several proposals blame the structure of the child's lexicon for the alleged failure in deriving implicatures/infelicity. The assumption is that the child's lexical entry for scalar items must include three elements for successful derivation: 1. the semantics of the weak term (e.g. *some*, *or*) 2. the semantics of the strong term (e.g. *all*,*and*); and possibly 3. a scale that recognizes the stronger term as an alternative to the weaker one (e.g. <*some*, *all*>, <*or*, *and*>). Each of these elements have been pinpointed as the source of the problem in previous studies (Horowitz et al., 2017, Katsos & Bishop (2011), Barner et al. (2011)). However none of them seem to apply to the results reported here.

If children in this study lack the semantics of the connective *or*, I can expect them to either perform at chance or default to a conjunctive interpretation. Neither prediction is borne out in study 2 and 3. Furthermore, children's free-form linguistic feedback suggests good understanding of disjunction. So this explanation seems unlikely. The problem cannot be that children do not know the meaning of *and* either. Children's performances in both study 2 and 3 for conjunction trials show that they understand its meaning very well. Finally, while it is possible that children lacked the appropriate lexical scale and could not access the stronger alternative, this explanation cannot be the whole story. Several children in both study 2 and 3 stressed the word *and* suggesting that the puppet should have used the stronger term instead. However, they judged the puppet's guess as "right". If children could not access the stronger term, they could not mention it in their feedback either.

3. Pragmatic Tolerance Katsos & Bishop (2011) suggested that children tend to tolerate pragmatic infelicities more than adults. They showed that when children are provided with a 2AFC judgment task, they tolerate the infelicity of *some* when *all* applies but when they are presented with a 3AFC task they choose the middle option and report this infelicity. As in a processing account, the pragmatic tolerance account predicts that scalar and ad-hoc implicatures will be similarly affected. However, I did not find results similar to those of Katsos & Bishop (2011). When children were presented with a 3AFC task, they chose the highest reward (and not the middle option) for uses of *or* when *and* applied. Second, and more importantly, I found different patterns for ad-hoc and scalar implicatures as mentioned before. This is not predicted by the tolerance account unless children are assumed to be more tolerant towards violations of scalar implicatures than they are towards ad-hoc ones. While tolerance may not be the source of the problem here, I believe that a number of discussions including those of Katsos & Bishop (2011) and later Katsos (2014) point to an important factor: the role of measurement in estimates of children's pragmatic capacity.

Several observations in the current studies here provide support for the hypothesis that methodological issues, and more specifically issues of measurement contribute to the differences found between adults and children in pragmatic capacity. First, Study 1 showed that even for adults, the estimates of adult infelicity rates may differ based on the number of alternatives in the forced choice task. A 2AFC task tends to underestimate adults' rate of response to pragmatic infelicity. Second, children's open-ended linguistic feedback in the experimental context better reflected their sensitivity to pragmatic nuances than the forced-choice judgment tasks. Third, children showed a higher rate of infelicity judgments for cases of ad-hoc implicatures (simple guesses with two animals on the card) than adults did. While a difference in sensitivity to ad-hoc vs. scalar implicatures has been reported and argued for before (Horowitz et al., 2017; Stiller, Goodman, & Frank, 2015), a higher sensitivity than adults is not predicted by any of the current accounts.

In order to better understand the differences between adults and children's pragmatic capacities, it is necessary to have a good understanding of how measurements affect estimates of adults and children's performance in the experimental tasks. Children may be no more capable of making exhaustive inferences than adults and not less capable of making scalar inferences either. They may simply have a different construal of the wrong-right scale and of what the forced-choice task is about. The concepts “right” and “wrong” are as much subject to developmental change and differences between adults and children as are scalar items in general. It is reasonable to assume that children’s understanding of what constitutes as “right” or “wrong” does not conform to that of adults. However, it remains to be established what these differences are and how they affect the estimates of children’s pragmatic abilities. It is important to point out that such issues of measurement could be the culprit behind both children’s seemingly slight preference for true disjuncts explained earlier and for their lack of infelicity when both disjuncts are true.

A General Approach for Measuring Implicature/Infelicity Rate

Methodological issues are nothing new in studies of children’s semantic and pragmatic development. Developing the best measures of children’s linguistic capacities has always been a major concern for researchers in the field. My goal here is to propose some future steps that can address the methodological concerns in children’s pragmatic development.

As Pouscoulous & Noveck (2009) and Katsos (2014) have suggested, the central issue is **the rate** at which children and adults manifest pragmatic reasoning in the experimental setting. No one doubts children’s capacity to perform such computations. At issue is the extent to which children and adults compute implicatures. And the claim is that children perform such computations less often than adults; or that children do not perform such computations when adults normally would. In the previous section, I discussed factors that can cause this difference including processing demands, the structure of the lexicon, tolerance, as well as issues of measuring adults and children’s comprehension. As Katsos (2014) pointed out, it seems reasonable to assume that all these factors play some part here. What matters is the degree to which each contributes to the outcome. Figure 3.19 shows the factors that affect pragmatic computations as well as the observations of the rate of pragmatic computations in an experiment. First it is important to distinguish between factors that affect pragmatic computations and those that affect the observed rate in the experimental setting. As I showed in experiment 1, given the number of alternatives in the forced choice task (2AFC vs. 3AFC), I may get different estimates of adults’ infelicity judgments, yet it is unreasonable to assume that there is a difference in adults’ pragmatic capacities in these two tasks. A similar situation exists when I compare children’s forced choice measures of infelicity and their open-ended feedback. In disjunctive trials where both disjuncts are true, the forced choice tasks show no sign of infelicity

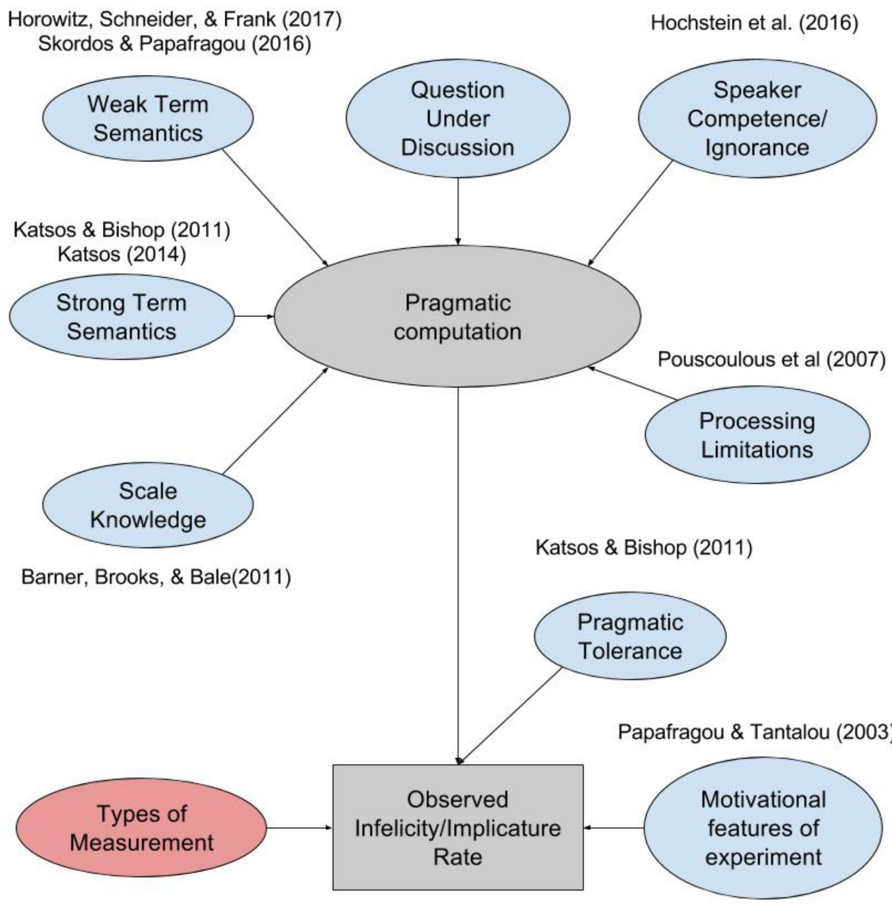

Figure 3.19: Factors that coul affect pragmatic computations and the estimates of these computations in the experimental settings.

while the open ended responses show that children are sensitive to the infelicity of disjunction when a conjunction would have been more appropriate.

3.6 Conclusion

To conclude, I showed that children and adults do not differ substantially in their **semantic** knowledge of the logical connectives. The results were highly consistent with the current accounts that posit the semantics of *and* as logical conjunction and *or* as logical (inclusive) disjunction. With respect to pragmatic knowledge, the three-alternative forced choice judgment task showed that adults are sensitive to the infelicity of disjunctive statements when both disjuncts are true. I showed that while the three-alternative judgment task failed to register such a sensitivity for children, my systematic analysis of children's verbal open-ended feedback showed that children are sensitive to pragmatic infelicities and can provide appropriate corrections to infelicitous utterances with logical connectives.

Chapter 4

Parents' and Children's Production of Disjunction

4.1 Introduction

This chapter presents two studies on parents and children's production of *and* and *or*. The first study investigates the frequency of *and* and *or* in parents and children's speech to answer two questions: 1. at what age do children start to produce *and* and *or*. 2. do children reach their parent's level of production for these words? and if they do at what age? The second study explores the frequency of different interpretations *and* and *or* have in child-directed speech. This study seeks to answer the following two questions: 1. What are the most frequent interpretations of *and* and *or* in child-directed speech? 2. What are reliable cues that can help children interpret and acquire the meanings of *and* and *or*?

4.2 Study 1: *and* and *or* in parents' and children's speech

This study investigates the production of *and* & *or* by children and their parents in an online collection of corpora. The goal is to understand the overall frequencies of these items and investigate the developmental trends in children's productions. After describing the study methods in section 4.2.1, I investigate some important properties of the corpora such as their word density for parents and

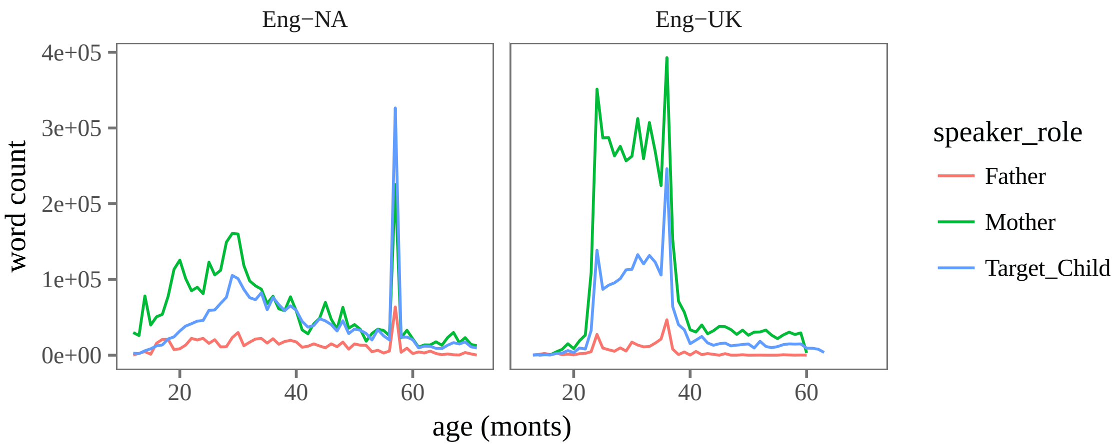

Figure 4.1: Word frequency in the North America and UK corpora of CHILDES.

children at different ages as well as the frequency of different utterance types in the speech of parents and children. I explain that function words are sensitive to the distribution of utterance types or more broadly speech acts or constructions with particular communicative functions. Therefore, it is important for developmental studies on the production of function words to investigate their frequencies within different utterance types, speech acts, or constructions with specific communicative functions. In section 4.2.3, I first look at the overall and monthly relative frequencies of *and* and *or* in the speech of parents and children. Then, I use utterance type as a proxy for speech acts and investigate the relative frequencies of these connectives within declaratives and questions. I summarize the main results and important conclusions of the study in section 4.2.4.

4.2.1 Methods

For samples of parents' and children's speech, this study used the online database childes-db R and its associated R programming package `childesr` (Sanchez et al., in prep). Childes-db is an online interface to the child language components of TalkBank, namely CHILDES (MacWhinney, 2000) and PhonBank. Two collections of corpora were selected: English-North America and English-UK. All word tokens were tagged for the following information: 1. The speaker role (mother, father, child), 2. the age of the child when the word was produced, 3. the type of the utterance the word appeared in (declarative, question, imperative, other), and 4. whether the word was "and", "or", or some "other" word.

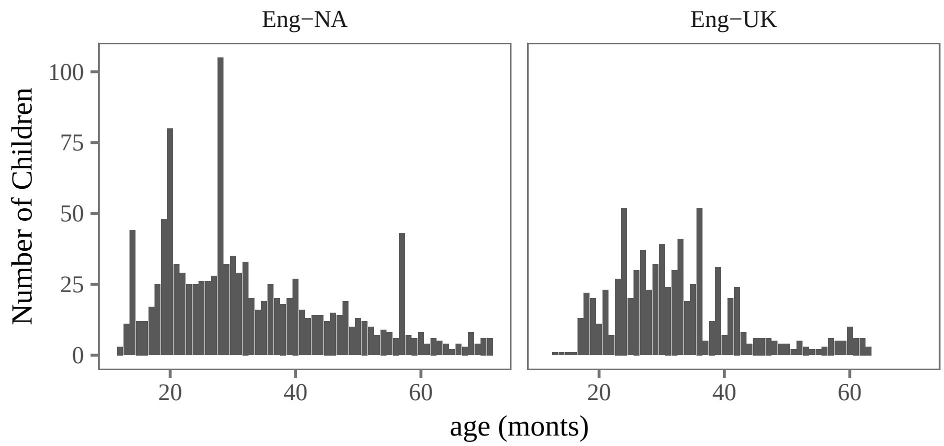

Figure 4.2: The number of children represented at different ages in the North America and UK corpora in CHILDES.

Exclusion Criteria

First, observations (tokens) that were coded as unintelligible were excluded (N = 290119). Second, observations that had missing information on children's age were excluded (N = 1042478). Third, observations outside the age range of 1 to 6 years were excluded (N = 686870). This exclusion was mainly because there was not much data outside this age range. Figure 4.3 shows the distribution of transcripts based on the age of the child at recording time. The mean age is shown with a red vertical line (Mean Age = 3.73, SD = 2.21). The collection contained the speech of 504 children and their parents after the exclusions.

Procedure

Each token was marked for the utterance type that the token appeared in. This study grouped utterance types into four main categories: "declarative", "question", "imperative", and "other". Utterance type categorization followed the convention used in the TalkBank manual. The utterance types are similar to sentence types (declarative, interrogative, imparative) with one exception: the category "question" consists of interrogatives as well as rising declaratives (i.e. declaratives with rising question intonation). In the transcripts, declaratives are marked with a period, questions with a question mark, and imperatives with an exclamation mark. It is important to note that The manual also provides terminators for special-type utterances. Among the special type utterances, this study included the following in the category "questions": trailing off of a question, question with exclamation, interruption of a question, and self-interrupted question. The category imperatives also included "emphatic imperatives". The rest of the special type utterances such as "interruptions" and "trailing off" were included in the category "other".

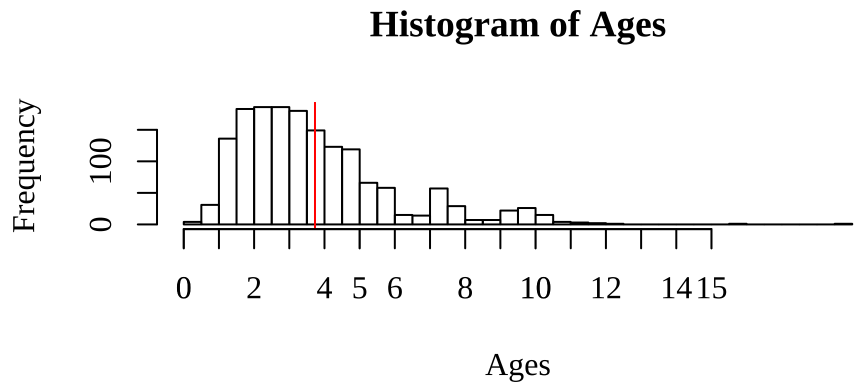

Figure 4.3: Distribution of children's ages at recording times. Mean age is shown using a red vertical line.

4.2.2 Properties of the CHILDES Corpora

In this section, I report some results on the distribution of words and utterances among the speakers in our collection of corpora. The collection contained 14159609 words. Table (4.1) shows the total number of *and*'s, *or*'s, and words in the speech of children, fathers, and mothers. The collection contains 8.8 times more words for mothers compared to fathers and 1.8 more words for mothers compared to children. Therefore, the collection is a better representative of the mother-child interactions than father-child interactions. Compared to *or*, the word *and* is 10.8 times more likely in the speech of mothers, 9.2 times more likely in the speech of fathers, and 30.3 times more likely in the speech of children. Overall, *and* is 13.35 times more liklely than *or* in this collection which is close to the rate reported by Morris (2008). He extracted 5,994 instances of *and* and 465 instances of *or* and found that overall, *and* was 12.89 times more frequent than *or* in child-parent interactions. Figure 4.4 shows the number of words spoken by parents and children at each month of the child's development. The words in the collection are not distributed uniformly and there is a high concentration of data between the ages of 20 and 40 months (around 2 to 3 years of age). There is also a high concentration around 60 months (5 years of age). The speech of fathers shows a relatively low word-count across all ages. Therefore, in our analyses we should be more cautious in drawing conclusions on the speech of fathers generally, and the speech of mothers and children after age 5. The

Table 4.1: Number of and's, or's, and the total number of words in the speech of children and their parents in English-North America and English-UK collections after exclusions.

Speaker Role	and	or	total
Father	15,488	1,683	967,075
Mother	153,781	14,288	8,511,478
Target_Child	78,443	2,590	4,681,056

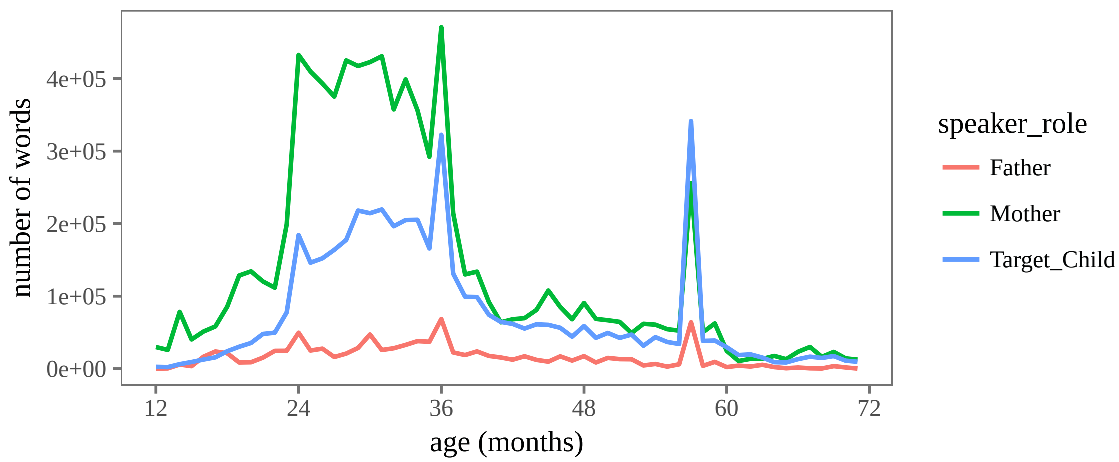

Figure 4.4: The number of words in the corpora for parents and children in each month of children's development.

distribution of function words is sensitive to the type of utterance or more broadly the type of speech act produced by speakers. For example, question particles may appear more frequently in questions than other types of utterance. Therefore, it is important to check the distribution of speech acts in corpora when studying different function words. Since it is hard to classify and quantify speech acts automatically, here I use utterance type as a proxy for speech acts. I investigate the distribution of declaratives, questions, and imperatives in our collection of corpora on child-parent interactions. Figure 4.5 shows the distribution of different utterance types in the speech of parents and children. Overall, most utterances are either declaratives or questions, and there are more declaratives than questions in our collection. While mothers and fathers show similar proportions of declaratives and questions in their speech, children produce a lower proportion of questions and higher proportion of declaratives than their parents. Figure 4.6 shows the developmental trend of declaratives and questions between the ages of one and six. Children start with only producing declaratives and add non-declarative utterances to their repertoire gradually until they get closer to the parents' rate

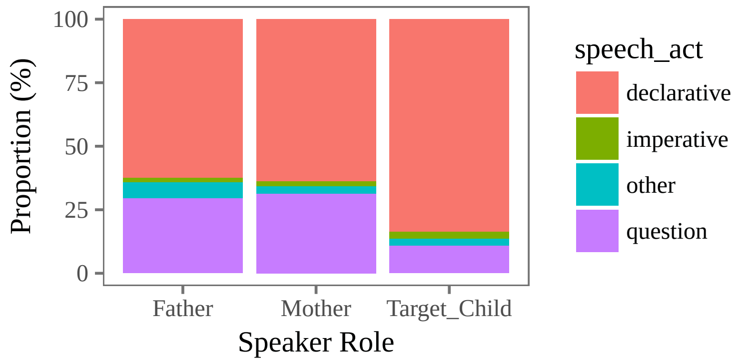

Figure 4.5: The proportion of declaratives and questions in children's and parents' utterances.

around the age six. They also start with very few questions and increase the number of questions they ask gradually. It is important to note that the rate of declarative and questions in children's speech does not reach the adult rate. These two figures show that parent-child interactions are asymmetric. Parents ask more questions and children produce more declaratives. This asymmetry also interacts with age: the speech of younger children has a higher proportion of declaratives than older children.

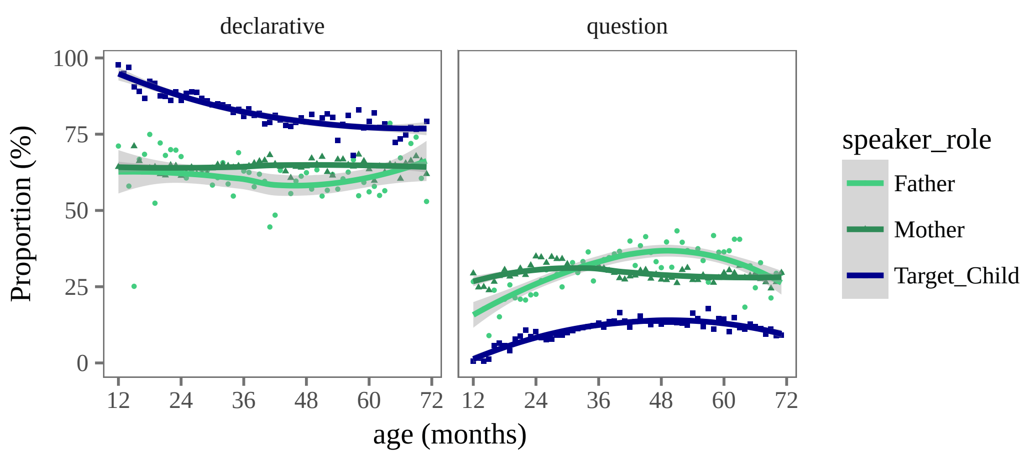

Figure 4.6: Proportion of declaratives to questions in child-parent interactions by age.

The frequency of function words such as *and* and *or* may be affected by such conversational asymmetries if they are more likely to appear in some utterance types than others. Figure 4.7 shows the proportion of *and*'s and *or*'s that appear in different utterance types in parents' and children's

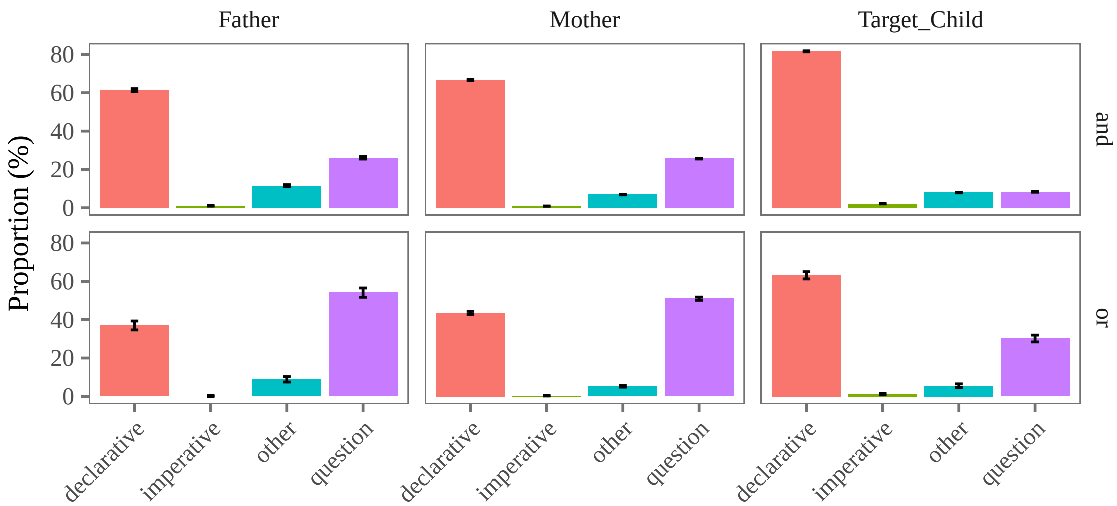

Figure 4.7: The proportion of and/or in different utterance types in the speech of parents and children.

speech. In parents' speech, *and* appears more often in declaratives (around 60% in declaratives and 20% in questions). On the other hand, *or* appears more often in questions than declaratives, although this difference is small in mothers. In children's speech, both *and* and *or* appear most often in declaratives. However, children have a higher proportion of *or* in questions than *and* in questions.

The differences in the distribution of utterance types can affect our interpretation of the corpus data on function words such as *and* and *or* in three ways. First, since the collection contains more declaratives than questions, it may reflect the frequency and diversity of function words like *and* that appear in declaratives better. Second, since children produce more declaratives and fewer questions than parents, we may underestimate children's knowledge of function words like *or* that are frequent in questions. Third, given that the percentage of questions in the speech of children increases as they get older, function words like *or* that are more likely to appear in questions may appear infrequent in the early stages and more frequent in the later stages of children's development. In other words, function words like *or* that are common in questions may show a seeming delay in production which is possibly due to the development of questions in children's speech. Therefore, in studying children's productions of function words, it is important to look at their relative frequencies in different utterance types as well as the overall trends. This is the approach we pursue in the next section.

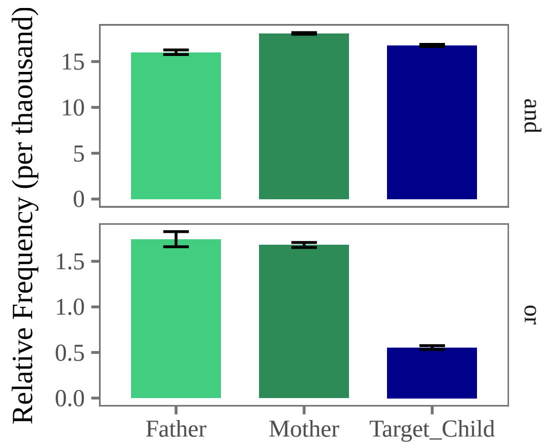

Figure 4.8: The relative frequency of and/or in the speech of fathers, mothers, and children. 95% binomial proportion confidence intervals calculated using Agresti-Coull 's approximate method.

4.2.3 Results

First, I consider the overall distribution of *and* and *or* in our corpora and then look closer at their distributions in different utterance types. Figure 4.8 shows the frequency of *and* and *or* relative to the total number of words produced by each speaker (i.e. fathers, mothers, and children). The y-axes show relative frequency per thousand words. It is also important to note that the y-axes show different ranges of values for *and* vs. *or*. This is due to the large difference between the relative frequencies of these connectives. Overall, *and* occurs around 15 times per thousand words but *or* only occurs 3 times per 2000 words in the speech of parents and around 1 time every 2000 words in the speech of children. Comparing the relative frequency of the connectives in parents' and children's speech, we can see that overall, children and parents produce similar rates of *and* in their interactions. However, children produce fewer *or*'s than their parents. Next we look at the relative frequencies of *and* and *or* in parents and children's speech during the course of children's development. Figure 4.9 shows the relative frequencies of *and* and *or* in parents' and children's speech between 12 and 72 months (1-6 years). Production of *and* in parents' speech seems to be relatively stable and somewhere between 10 to 20 *and*'s per thousand words over the course of children's development. For children, they start producing *and* between 12 and 24 months, and show a sharp increase in their production until they reach the parent level between 30 to 36 months of age. Children stay close to the parents' production level between 36 and 72 months, possibly surpassing them a bit at 60 months – although as stated in the previous section, we should be cautious about patterns after 60 months due to the small amount of data in this period. For *or*, parents produce between 1 to 2 *or*'s every thousand words and mothers show a slight increase in their productions between 12 to 36 months. Children start producing *or* between 18 to 30 months of age. They show a steady increase in their productions of *or* until they get close to 1 *or* per thousand words at 48 months (4 years) and stay at that level until 72 months (6 years).

Children's productions of *and* and *or* show two main differences. First, the onset of *or* productions is later than *and* productions. Children start producing *and* around 1 to 1.5 years old while *or* productions start around 6 months later. Second, children's *and* production shows a steep rise and reaches the parent level of production at three-years old. For *or*, however, the rise in children's production level does not reach the parent level even though it seems to reach a constant level between the ages of 4 and 6 years. Not reaching the parent level of *or* production does not necessarily mean that children's understanding of *or* has not fully developed yet. It can also be due to the nature of parent-child interactions. For example, since parents ask more questions than children and *or* appears frequently in questions, parents may have a higher frequency of *or*. There are two ways of controlling for this possibility. One is to research children's speech to peers. Unfortunately such a large database of children's speech to peers is not currently available for such an analysis. Alternatively, we can look at the relative frequencies and developmental trends within utterance types such as declaratives and questions to see if we spot different developmental trends. This is what I pursue next. Figure 4.10 shows the relative frequency of *and* and *or* in declaratives, questions, and imperatives. *and* has the highest relative frequency in declaratives while *or* has the highest relative frequency in questions. Figure 4.11 shows the developmental trends of the relative frequencies of *and* and *or* in questions and declaratives. Comparing *and* in declaratives and questions, we see that the onset of *and* productions are slightly delayed for questions but in both declaratives and questions, *and* productions reach the parent level around 36 months (3 years). For *or*, we see a similar delay in questions compared to declaratives. Children start producing *or* in declaratives at around 18 months but they start producing *or* in questions at 24 months. Production of *or* increases in both declaratives and questions until it seems to reach a constant rate in declaratives between 48 and 72 months. The relative frequency of *or* in questions continues to rise until 60 months. Comparing figures 4.9 and 4.11, we see that children are closer to the adult rate of production in declaratives

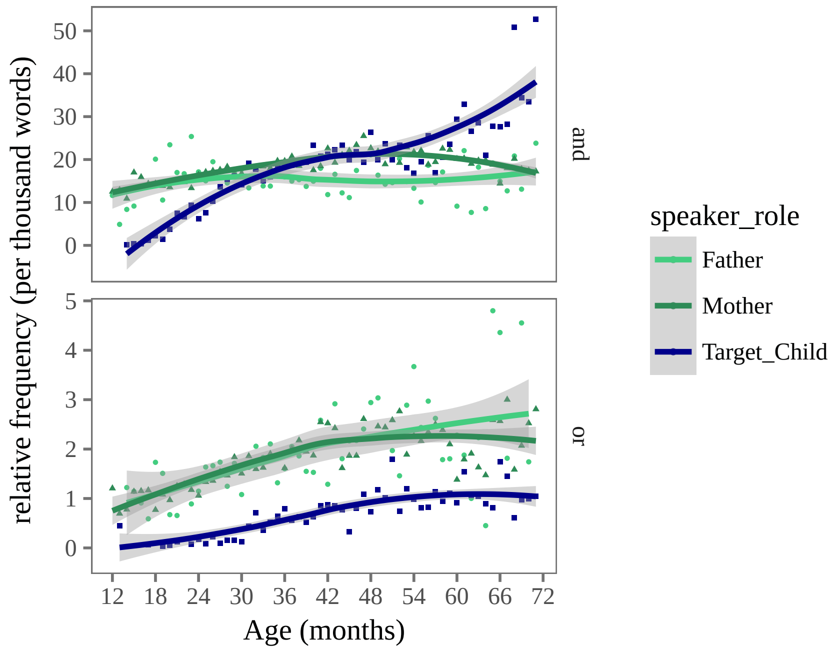

Figure 4.9: The monthly relative frequency of and/or in parents and children's speech between the 12 and 72 monts (1-6 years).

than questions. The large difference between parents and children's production of *or* in figure 4.9 may partly be due to the development of *or* in questions. Overall the results show that children have a substantial increase in their productions of *and* and *or* between 1.5 to 4 years of age. Therefore, it is reasonable to expect that early mappings for the meaning and usage of these words are developed in this age range.

4.2.4 Discussion

The goal of this study was to explore the frequency of *and* and *or* in parents and children's speech. The study found three differences. First, it found a difference between the overall frequency of *and* and *or* in both parents and children. *and* was about 10 times more frequent than *or* in the speech of parents and 30 times more liklely in the speech of children. Second, the study found a difference between parents' and children's productions of *or*. Relative to the total number of words spoken by parents and children between the ages of 1 and 6 years, both children and parents produce on average 15 *and*'s every 1000 words. Therefore, children match parents' rate of *and* production overall. This is not the case for *or* as parents produce 3 *or*'s every 2000 words and children only 1

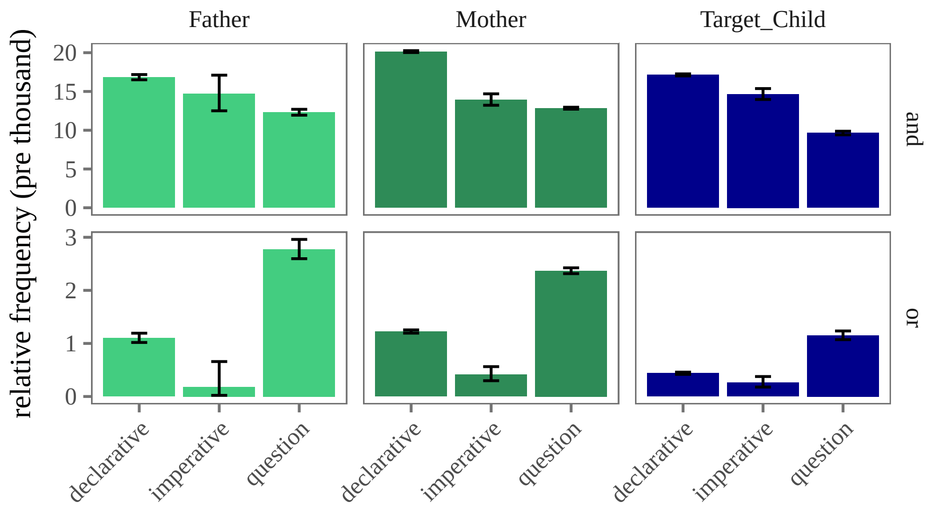

Figure 4.10: Relative frequency of and/or in declaratives, imperatives, and interrogatives for parents and children

every 2000 words. Third, the study found a developmental difference between *and* and *or* as well. The study found that the onset of production is earlier for *and* than *or*. Looking at the monthly relative frequencies of *and* and *or* in the speech of parents and children, the study also found that children reach the parents' level of production for *and* at age 3 while *or* does not reach the parents' level even at age 6.

What causes these production differences? The first difference – that *and* is far more frequent than *or* – is not surprising or limited to child-directed speech. *and* is useful in a large set of contexts from conjoining elements of a sentence to connecting discourse elements or even holding the floor and delaying a conversational turn. In comparison, *or* seems to have a more limited usage. The second and the third differences – namely that children produce fewer *or*'s than parents, and that they produce *and* and reach their parents rate earlier than *or* – can be due to three factors. First, production of *and* develops and reaches the parents' rate earlier possibly because it is much more frequent than *or* in children's input. Previous research suggests that within the same syntactic category, words with higher frequency in child-directed speech are acquired earlier (J. C. Goodman, Dale, & Li, 2008). The conjunction word *and* is at least 10 times more likely than *or* so earlier acquisition of *and* is consistent with the effect of frequency on age of acquisition. Second, research in concept attainment has suggested that the concept of conjunction is easier to conjure and possibly acquire than the concept of disjunction. In experiments that participants are asked to detect a

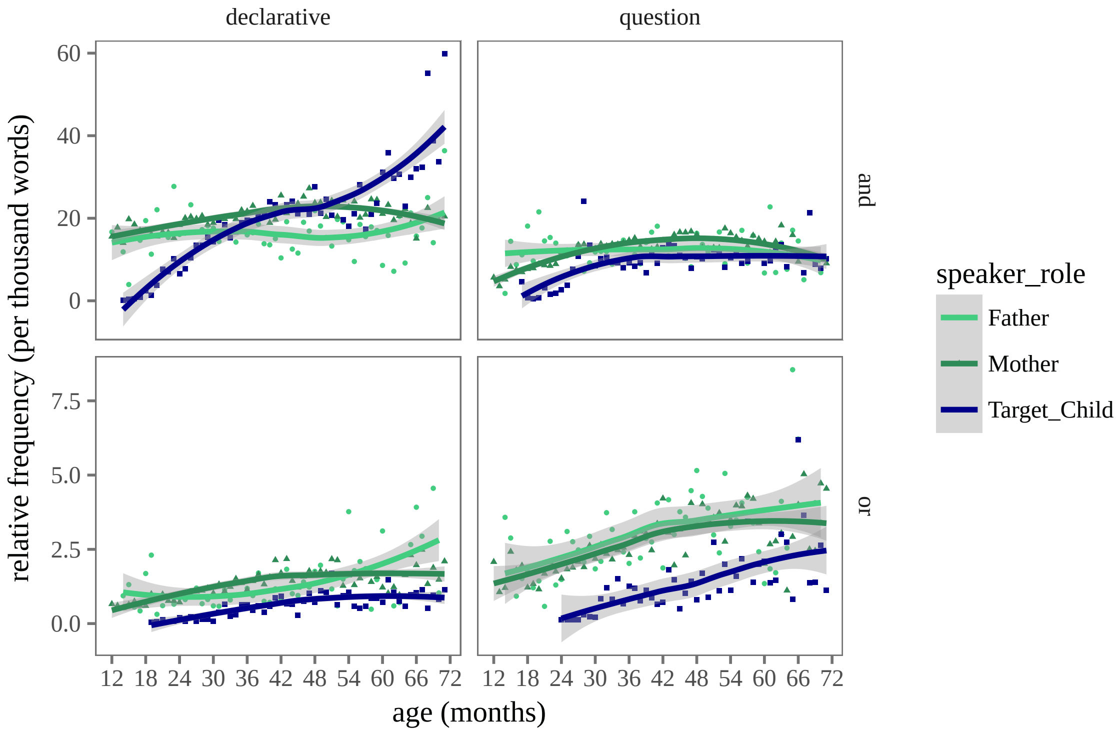

Figure 4.11: Relative frequency of and/or in the speech of parents and childern between the child age of one and six years.

pattern in the classification of cards, participants can detect a conjunctive classification pattern faster than a disjunctive one (Neisser & Weene (1962)). Therefore, it is possible that children learn the meaning of *and* faster and start to produce it earlier but they need more time to figure out the meaning and usage of *or*.

A third possibility is that the developmental difference between *and* and *or* is mainly due to the asymmetric nature of parent-child interactions and the utterance types that each role in this interaction requires. For example, this study found that parents ask more questions from children than children from parents. It also found that *or* is much more frequent in questions than *and* is. Therefore, parent-child interaction provides more opportunities for parents to use *or* than children. In the next study we will discuss several constructions and communicative functions that are also more appropriate for the role of parents. For example, *or* is often used to ask what someone else wants like "do you want apple juice or orange juice?" or for asking someone to clarify what they said such as "did you mean ball or bowl?". Both of these constructions are more likely to be produced by a parent than a child. *or* is also used to introduce examples or provide definitions such as "an animal is like a rabbits or a lion or a sheep". It is very unlikely that children would use such constructions to define terms for parents! Furthermore, such constructions also show their own developmental trends. For example, the study found that children start with almost entirely producing declaratives and increase their questions until at age 4 to 6, about 10% of their utterances are questions. Therefore, children's ability to produce *or* in a question is subject to the development of questions themselves. More generally, the developmental difference between *and* and *or* may also be due to a difference in the development of other factors that production of *and* and *or* rely on such as constructions. In future research, it is important to understand to what extend each of these potential causes – frequency, conceptual complexity, and the development of other factors such as utterance type or constructions with specific communicative functions – contribute to the developmental differences in the production of conjunction and disjunction.

4.3 Study 2: Interpretations of *and* and *or* in child-directed speech

Previous study reported on the frequencies of *and* and *or* in parents and children's speech production. To help us better understand children's linguistic input, this study offers a close examination of the interpretations that *and* and *or* have in child-directed speech. It helps us better understand the available input to children's learning mechanisms. A similar study was conducted by Morris (2008), who reported the most common interpretation of *and* is conjunction and *or* exclusive disjunction. In this exploratory study, annotators judged the interpretation of *and* and *or* and coded them for for several linguistic and conceptual cues. The study had two main goals. First, to replicate the finding of Morris (2008) and second, to identify any cues in children's input that might help them learn the interpretations, and ultimately the meaning, of *and* and *or*.

4.3.1 Methods

This study used the the Providence corpus (Demuth, Culbertson, & Alter, 2006) available via the PhonBank section of the TalkBank archive. The corpus was chosen because of its relatively dense data on child-directed speech as well as the availability of audio and video recordings that would allow annotators access to the context of the utterance. The corpus was collected between 2002 and 2005 in Providence, Rhode Island. Table 4.2 reports the name, age range, and the number of recording sessions for the participants in the study. All children were monolingual English speakers and were followed from around age 1 to 4 years. Based on Study 1, this is the age range when children develop their early understanding or mappings for the meanings of *and* and *or*. The corpus contains roughly biweekly hour-long recordings of spontaneous parent-child interactions, with most recordings being of mother-child interactions. The corpus consist of a total of 364 hours of speech.

Table 4.2: Information on the participants in the Providence Corpus. Ethan was diagnosed with Asperger's syndrome and therefore was excluded from this study.

Name	Age Range	Sessions
Alex	1;04.28-3;05.16	51
Ethan	0;11.04-2;11.01	50
Lily	1;01.02-4;00.02	80
Naima	0;11.27-3;10.10	88
Violet	1;02.00-3;11.24	51
William	1;04.12-3;04.18	44

Exclusion Criteria

I excluded data from Ethan since he was diagnosed with Asperger's Syndrome at age 5. I also excluded all examples found in conversations over the phone, adult-adult conversations, or utterances heard from TV or radio. Such cases did not count as child-directed speech. I excluded proper names and fixed forms such as "Bread and Circus" (name of a local place) or "trick-or-treat" from the set of examples to be annotated. The rationale here was that such forms could be learned and understood with no actual understanding of the connective meaning. I counted multiple instances of *or* and *and* within the same disjunction/conjunction as one instance. The reason is that, in a coordinated structure, the additional occurrences of a connective typically did not alter the annotation categories, most importantly the interpretation of the coordination. For example, there is almost no difference between "cat, dog, and elephant" versus "cat and dog and elephant" in interpretation. In short, I focussed on the coordinated construction as a unit rather than on every separate instance of *and*

and *or*. Instances of more than two connectives in a coordination were rare in the sample.

Procedure

All utterances containing *and* and *or* were extracted using the CLAN software and automatically tagged for the following: (1). the name of the child; (2). the transcript address; (3). the speaker of the utterance (father, mother, or child); (4). the child's birth date, and (5). the recording date. Since the focus of the study was mainly on disjunction, we annotated instances of *or* in all the child-directed speech from the earliest examples to the latest ones found. Given that the corpus contained more than 10 times the number of *and*s than *or*s, I randomly sampled 1000 examples of *and* to match 1000 examples of *or*. Here I report the results on 465 examples of *and* and 608 examples of *or*.

Annotation Categories

Every extracted instance of *and* and *or* was manually annotated for 7 categories: 1. Connective Interpretation 2. Intonation Type 3. Utterance Type 4. Syntactic Level 5. Conceptual Consistency 6. Communicative Function and 7. Answer Type. In what follows, I explain how each annotation category was defined in detail and provide some prototypical examples of the category.

Connective Interpretation This category is the dependent variable of the study. Annotators listened to coordinations such as "A or B" and "A and B", and decided the intended interpretation of the connective with respect to the truth of A and B. We used the sixteen binary connectives shown in Figure 4.12 as the space of possible connective interpretations. Annotators were asked to consider the two propositions raised by the coordinated construction, ignoring the connective and functional elements such as negation and modals. Consider the following sentences containing *or*: "Bob plays soccer or tennis" and "Bob doesn't play soccer or tennis". Both discuss the same two propositions: A. Bob playing soccer, and B. Bob playing tennis. However, the functional elements combining these two propositions result in different interpretations with respect to the truth of A and B. In "Bob plays soccer or tennis" which contains a disjunction, the interpretation is that Bob plays one or possibly both sports (inclusive disjunction IOR). In "Bob doesn't play soccer or tennis" which contains a negation and a disjunction, the interpretation is that Bob plays neither sports (NOR). For connective interpretations, the annotators first reconstructed the coordinated propositions without

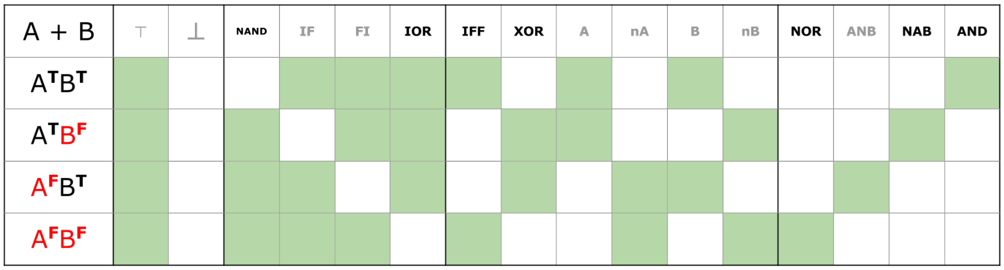

Figure 4.12: The truth table for the 16 binary logical connectives. The rows represent the set of situations where zero, one, or both propositions are true. The columns represent the 16 possible connectives and their truth conditions. Green cells represent true situations.

the connectives or negation and then decided which propositions were implied to be true/false.

This approach is partly informed by children's development of function and content words. Since children acquire content words earlier than functions words, we assumed that when learning logical connectives, they better understand the content of the propositions being coordinated rather than the functional elements involved in building the coordinated construction. For example, considering the sentences "Bob doesn't play soccer or tennis" without its function words as "Bob, play, soccer, tennis", one can still deduce that there are two relevant propositions: Bob playing soccer, and Bob playing tennis. However, the real challenge is to figure out what is being communicated with respect to the truth of these two propositions. If the learner can figure this out, then the meaning of the functional elements can be reverse engineered. For example, if the learner recognizes that "Bob plays soccer or tennis" communicates that one or both propositions are true (IOR), the learner can associate this interpretation to the unknown element *or*. Similarly, if the learner recognizes the interpretation of "Bob doesn't play soccer or tennis" as neither proposition is true (NOR), they can associate this interpretation to the combination of disjunction and the overt sentential negation. Table 4.3 reports the connective interpretations found in our annotations as well as some examples for each interpretation.

Table 4.3: Annotation classes for connective interpretation

Connective	Meaning	Examples
AND	Both propositions are true	*"I'm just gonna empty this and then I'll be out of the kitchen." – "I'll mix them together or I could mix it with carrot, too."*
IOR	One or both propositions are true	*"You should use a spoon or a fork." – "Ask a grownup for some juice or water or soy milk."*
XOR	Only one proposition is true	*"Is that a hyena? or a leopard?" – "We're gonna do things one way or the other."*
NOR	Neither proposition is true	*"I wouldn't say boo to one goose or three." – "She found she lacked talent for hiding in trees, for chirping like crickets, or humming like bees."*
IFF	Either both propositions are true or both are false	*"Put them [crayons] up here and you can get down. – Come over here and I'll show you."*
NAB	The first proposition is false, the second is true.	*"There's an Oatio here, or actually, there's a wheat here."*

Intonation Type For this category, annotators listened to the utterances and decided whether the intonation contour on the coordination is flat, rise, or rise-fall. Table @ref shows the definitions and examples for these intonation types. In order to judge the intonation of the sentence accurately, annotators were asked to construct all three intonation contours for the sentence and see which one is closer to the actual intonation of the utterance. For example, to judge the sentence "do you want orange juice↑ or apple juice↓?", they reconstructed the sentence with the prototypical flat, rising, and rise-fall intonations and checked to see which intonation is closer to the actual one. It is important to note that while these three intonation contours provide a good general classification, there is a substantial degree of variation as well as a good number of subtypes within each intonation type.

Table 4.4: Definitions of the intonation types and their examples.

Intonation Types	Definitions	Examples
Flat	Intonation does not show any substantial rise at the end of the sentence.	*"I don't hear any meows or bow-wow-wows."*
Rise	There is a substantial intonation rise on each disjunct or generally on both.	*"Do you want some seaweed? or some wheat germ?"*
Rise-Fall	There is a substantial rise on the non-final disjunct(s), and a fall on the final disjunct.	*"Is that big Q or little q?" – "(are) You patting them, petting them, or slapping them?"*

Utterance Type Annotators decided whether an utterance is a declarative, an interrogative, or an imperative. Table @ref (tab:utteranceTypes) provide the definitions and examples for each utterance type. Occasionally, we found examples with different utterance types for each coordinand. For example, the mother would say "put your backpack on and I'll be right back", where the first cooridnand is an imperative and the second a declarative. Such examples were coded for both utterance types with a dash in-between: imperative-declarative.

Table 4.5: Definitions of the utterance types and their examples.

Utterance Types	Definitions	Examples
Declarative	Typically a statement with a subject-verb-object word order and a flat intonation.	*"It looks a little bit like a drum stick or a mallet."*
Interrogative	Typically a question with either subject-auxiliary inversion or a rising terminal intonation.	*"Is that a dog or a cat?"*

Utterance Types	Definitions	Examples
Imperative	Typically a directive with an uninflected verb and no subject	*"Have a little more French toast or have some of your juice."*

Syntactic Level For this annotation category, annotators decided whether the coordination is at the clausal level or at the sub-clausal level. Clausal level was defined as sentences, clauses, verb phrases, and verbs. Coordination of other categories was coded as sub-clausal. This annotation category was introduced to check the hypothesis that the syntactic category of the coordinands may influence the interpretation of a coordination. The intuition was that a sentence such as "He drank tea or coffee" is less likely to be interpreted as exclusive than "He drank tea or he drink coffee." The clausal vs. sub-clausal distinction was inspired by the fact that in many languages, coordinators that connect sentences and verb phrases are different lexical items than those that connect nominal, adjectival, or prepositional phrases (see Haspelmath, 2007).

Table 4.6: Definitions of the syntactic levels and their examples.

Syntactic Level	Definitions	Examples
Clausal	The coordinands are sentences, clauses, verb phrases, or verbs.	*"Does he lose his tail sometimes and Pooh helps him and puts it back on?"*
Sub-clausal	The coordinands are nouns, adjectives, noun phrases, determiner phrases, or prepositional phrases.	*"Hollies can be bushes or trees."*

Conceptual Consistency Propositions that are connected by words such as *and* and *or* often stand in complex conceptual relations with each other. For conceptual consistency, annotators decided whether the propositions that make up the coordination can be true at the same time or not. If the two propositions could be true at the same time they were marked as consistent. If the two propositions could not be true at the same time and resulted in a contradiction, they were marked as inconsistent. Our annotators used the following diagnostic to decide the consistency of the disjuncts: Two disjuncts were marked as inconsistent if replacing the word *or* with *and* produced a contradiction. For example, changing "the ball is in my room *or* your room" to "the ball is in my room *and* your room" produces a contradiction because a ball cannot be in two rooms at the same time.

Table 4.7: Definitions of the intonation types and their examples.

Consistency	Definitions	Examples
Consistent	The coordinands can be true at the same time.	*"We could spell some things with a pen or draw some pictures."*
Inconsistent	The coordinands cannot be true at the same time.	*"Do you want warm or cold tomato sauce?"*

First, it is important to note here that this criterion is quite strict. In many cases, the possibility of both propositions being true is ruled out based on prior knowledge and expectations of the situation. For example, when asking people whether they would like tea or coffee, it is often assumed and expected that people choose one or the other. However, wanting to drink both tea and coffee is not conceptually inconsistent. It is just very unlikely. Our annotations of consistency are very conservative in that they still consider such unlikely cases as consistent.

Second, there are much more complex relations between coordinated propositions that we have not coded for. For example, coordinated propositions sometimes stand in a causal relation (e.g. the cup fell and broke) or sometimes in a temporal relation (e.g. she brushed her teeth and went to bed), among many more. It is quite feasible to assume that the rich conceptual structure of these propositions help children learn the meaning and use of connectives such as *and*, *or*, *if*, *therefore*, etc. It is possible to develop a more detailed investigation on the relation between propositions and how that affects the acquisition of connective meaning generally. However, in this study we mainly focus on conceptual consistency of the coordinated propositions and how that affects the acquisition of *and* and *or*.

It is also important to note that if the coordinands are inconsistent, this does not necessarily means that the connective interpreation must be exclusive. For example, in a sentence like "you could stay here or go out", the alternatives "staying here" and "going out" are inconsistent. Yet, the overall interpretation of the connective could be conjunctive: you could stay here AND you could go out. The statement communicates that both possibilities hold. This pattern of interaction between possibility modals like *can* and disjunction words like *or* are often discussed under the lable "free-choice inferences" in the semantics and pragmatics literature (Kamp, 1973; Von Wright, 1968). Another example is unconditionals such as "Ready or not, here I come!". The coordinands are contradictions: one is the negation of the other. However, the overall interpretation of the sentences is that in both cases, the speaker is going to come.

Communicative Functions This study constructed a set of categories that captured particular usages or communiative functions of the words *or* and *and*. These communicative functions were created using the first 100 annotation examples and then they were used for the classification of the rest of the examples. Table 4.8 shows the definitions and examples of the 10 communicative functions used in this study. The table contains some functions that are general and some that are specific to coordination. For example, directives are a general class while conditionals are more specific to coordinated constructions. It is also important to note that the list is not an unstructured one; we see some communicative functions as subtypes of others. For example, "identifications" and "unconditionals" are sybtypes of "descriptions" while "conditionals" are a subtype of directives. Furthuremore, "repairs" seem parallel to other categories in that any speech at can be repaired. We do not fully explore the details of these functions in this study but such details matter for a general theory of acquisition that makes use of the speaker's communicative intentions as early coarse-grained communicative cues for the acquisition of fine-grained meaning such as function words.

Table 4.8: Definitions of the communicative functions and their examples.

Answer Type	Definitions	Examples
Descriptions	describing what the world is like or asking about it. The primary goal is to inform the addressee about how things are.	"*It's not in the ditch or the drain pipe.*"
Identifications	Identifying the category membership or an attribute of an object. Speaker has uncertainty. A subtype of "Description".	"*Is that a ball or a balloon honey?*"
Definitions and Examples	Providing labels for a category or examples for it. Speaker has no uncertainty. Subtype of Description.	*"this is a cup or a mug." – "berries like blueberry or raspberry"*
Preferences	Asking what the addressee wants or would like or stating what the speaker wants or would like	*"do you wanna play pizza or read the book?"*
Options	Either asking or listing what one can or is allowed to do. Giving permission, asking for permission, or describing the possibilities. Often the modal "can" is either present or can be inserted.	*"you could have wheat or rice."*
Directives	Directing the addressee to act or not act in a particular way. Common patterns include "let's do ...", "Why don't you do ...", or prohibitions such as "Don't ...". The difference with "options" is that the speaker expects the directive to be carried out by the addressee. There is no such expectation for "options".	*"let's go back and play with your ball or we'll read your book."*

Answer Type	Definitions	Examples
Clarifications	Something is said or done as a communicative act but the speaker has uncertainty with respect to the form or the content.	*"you mean boba or bubble?"*
Repairs	Speaker correcting herself on something she said (self repair) or correcting the addressee (other repair). The second disjunct is what holds and is intended by the speaker. The speaker does not have uncertainty with respect to what actually holds.	*"There's an Oatio here, or actually, there's a wheat here."*
Conditionals	Explaining in the second coordinand, what would follow if the first coordinand is (or is not) followed. Subtype of Directive.	*"put that out of your mouth, or I'm gonna put it away." – "Come over here and I'll show you."*
Unconditionals	Denying the dependence of something on a set of conditions. Typical format: "whether X or Y, Z". Subtype of Descriptions.	*"Ready or not, here I come!"* (playing hide and seek)

Answer Type Whenever a parent's utterance was a polar question, the annotators coded the utterance for the type of response it received from the children. Table 4.9 shows the answer types in this study and their definitions and examples. Utterances that were not polar questions were simply coded as NA for this category. If children responded to polar questions with "yes" or "no", the category was YN and if they repeated with one of the coordinands the category was AB. If children said yes/no and followed it with one of the coordinands, the answer type was determined as YN (yes/no). For example, if a child was asked "Do you want orange juice or apple juice?" and the child responded with "yes, apple juice", our annotators coded the response as YN. The reason is that in almost all cases, if a simple yes/no response is felicitous, then it can also be optionally followed with mentioning a disjunct. However, if yes/no is not a felicitous response, then mentioning one of the alternatives is the only appropriate answer. For example, if someone asks "Do you want to stay here or go out?" a response such as "yes, go out" is infelicitous and a better response is to simply say "go out". Therefore, we count responses with both yes/no and mentioning an alternative as a yes/no response.

Table 4.9: Definitions of answer types and their examples.

Answer Type	Definitions	Examples
No Answer	The child provides no answer to the question.	Mother: *"Would you like to eat some applesauce or some carrots?"* Child: *"Guess what Max!"*
YN	The child responds with yes or no	Father: *"Can I finish eating one or two more bites of my cereal?"* Child: *"No."*
AB	The child responds with one of the disjuncts (alternatives)	Mother: *"Is she a baby elephant or is she a toddler elephant?"* Child: *"It's a baby. She has a tail."*

Inter-annotator Reliability

To train annotators and confirm their reliaiblity for disjunction examples, two annotators coded the same 240 instances of disjunction. The inter-annotator reliability was calculated over 8 iterations of 30 examples each. After each iteration, annotators met to discuss disagreements and resolve them. They also decided whether the category definitions or annotation criteria needed to be made more precise. Training was completed after three consecutive iterations showed substantial agreement between the annotators (Cohen's $\kappa > 0.7$) for all categories. Figure 4.13 shows the precentage agreement and the kappa values for each annotation category over the 8 iterations. Agreement in three catgories showed substantial improvement after better and more precise deifinitions and annotation criteria were developed: connective interpretation, intonation, and communicative function. First, connective interpretation showed major improvements after annotators developed more precise criteria for selecting the propositions under discussion and separately wrote down the two propositions connected by the connective word. For example, if the original utterance was "do you want

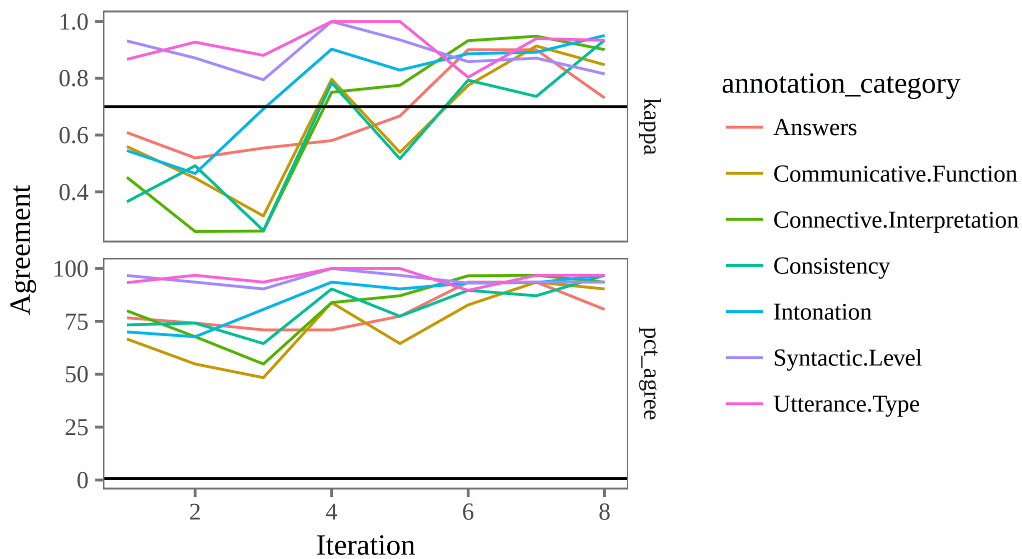

Figure 4.13: Inter-annotator agreement for disjunction examples.

milk or juice?", the annotators wrote "you want milk, you want juice" as the two propositions under discussion. This exercise clarified the exact propositions under discussion and sharpened annotator intuitions with respect to the connnective interpretation that is communicated by the utterance. Second, annotators improved agreement on intonation by reconstructing an utterance's intonation for all three intonation categories. For example, the annotator would examine the same sentence "do you want coffee or tea?" with a rise-fall, a rise, and a flat intonation. Then the annotator would listen to the actual utterance and see which one better resembles the actual utterance. This method helped annotators judge the intonation of an utterance more accurately. Finally, agreement on communicative functions improved as the definitions were made more and more precise. For example, the definition of "directives" in Table 4.8 explicitly mentions the difference between "directives" and "options". Clarifying the definitions of communicative functions helped improve annotator agreement.

Inter-annotator reliability for conjunction was calculated similar to disjunction examples. Two different annotators coded 300 utterances of *and*. Inter-annotator reliability was calculated over 10 iterations of 30 examples. Figure 4.14 shows the precentage agreement between the annotators as well as the kappa values for each iteration. Despite high percentage agreement between annotators, the kappa values did not pass the set threshold of 0.7 in three consecuitive iterations. This paradoxical result is mainly due to a property of kappa. An imbalance in the prevalence of annotation categories

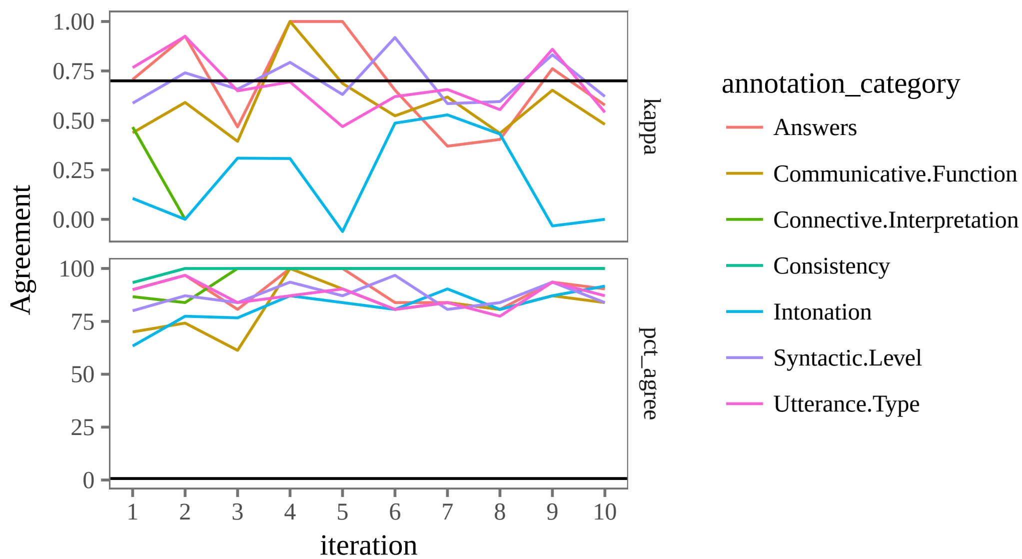

Figure 4.14: Inter-annotator agreement for disjunction examples.

can drastically lower the value of kappa. When one category is extremely common with high agreement while other categories are rare, kappa will be low (Cicchetti & Feinstein, 1990; Feinstein & Cicchetti, 1990). In almost all annotated categories for conjunction, there was one class that was extremely prevalent. In such cases, it is much more informative to look at the class specific agreement for the prevalent category than the overall agreement measured by Kappa (Cicchetti & Feinstein, 1990; Feinstein & Cicchetti, 1990). Table 4.10 lists the dominant classes as well as their prevalence, the values of class specific agreement index, and category agreement index (Kappa). Class specific agreement index is defined as $2n_{ii}/n_{i.} + n_{.i}$, where i represents the class's row/column number in the category's confusion matrix, n the number of annotations in a cell, and the dot ranges over all the row/column numbers (Fleiss, Levin, & Paik, 2013, p. 600; Ubersax, 2009). The class specific agreement indeces are very high for all the most prevalent classes showing that the annotators had very high agreement on these class, even though the general agreement index (Kappa) was often low. The most extreme case is the category "consistency" where almost all instances were annotated as "consistent" with perfect class specific agreement but low overall Kappa. In the case of utterance type and syntactic level where the distribution of instances across classes was more even, the general index of agreement Kappa is also high. In general, examples of conjunction showed little variablility across annotation categories and mostly fell into one class within each category. Annotators had very high agreement for these dominant classes.

Table 4.10: Most prevalent annotation class in each annotation category with the values of class agreement indeces and category agreement indeces (Kappa).

Annotation Category	Class	Prevalence	Class Agreement Index	Kappa
intonation	flat	0.86	0.89	0.24
interpretation	AND	0.96	0.98	0.39
answer	NA	0.84	0.94	0.67
utterance_type	declarative	0.76	0.94	0.70
communicative_function	description	0.77	0.90	0.59
syntactic_level	clausal	0.67	0.91	0.70
consistency	consistent	0.99	1.00	0.50

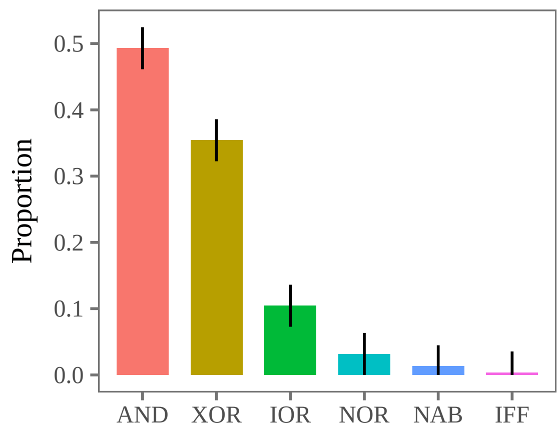

Figure 4.15: The proportion of different interpretations of the connectives and/or in child-directed speech

4.3.2 Results

First, I show the results for the study's dependent measure[1]. Figure (4.15) shows the distribution of the connective interpretations in the study. The most common interpretation was the conjunctive interpretation AND (0.49) followed by the exclusive XOR (0.35). Figure (4.16) shows the distribution of connective interpretations by the connective words *and* and *or*. For *and*, the most frequent interpretation (in fact almost the only interpretation), is conjunction AND. For *or*, the most frequent interpretation is exclusive disjunction XOR. These results replicate the findings of Morris (2008). Based on these results, Morris argued that given the high frequency of conjunction and exclusive disjunction in the input, children should map the meanings of *and* and *or* as conjunction and exclusive disjunction, at least initially, between the ages of 2 and 5. Children learn the inclusive interpretation

[1]All the confidence intervals shown in the plots for this section are simultaneous multinomial confidence intervals computed using the Sison & Glaz (1995)'s method

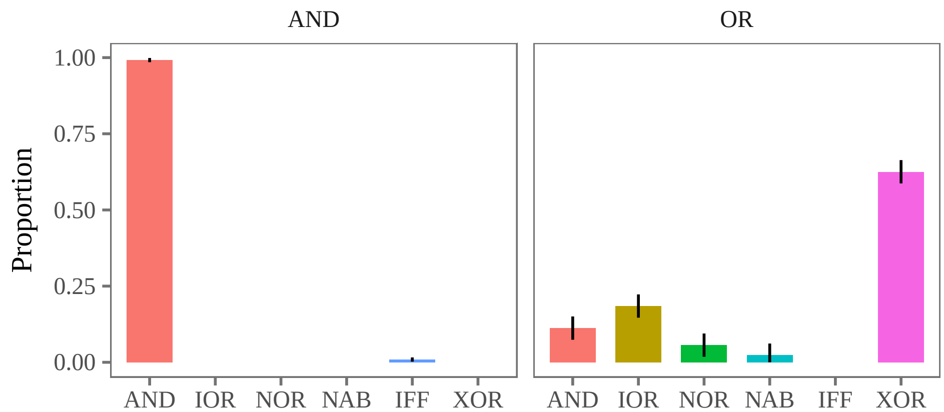

Figure 4.16: Interpretations of and/or in child-directed speech

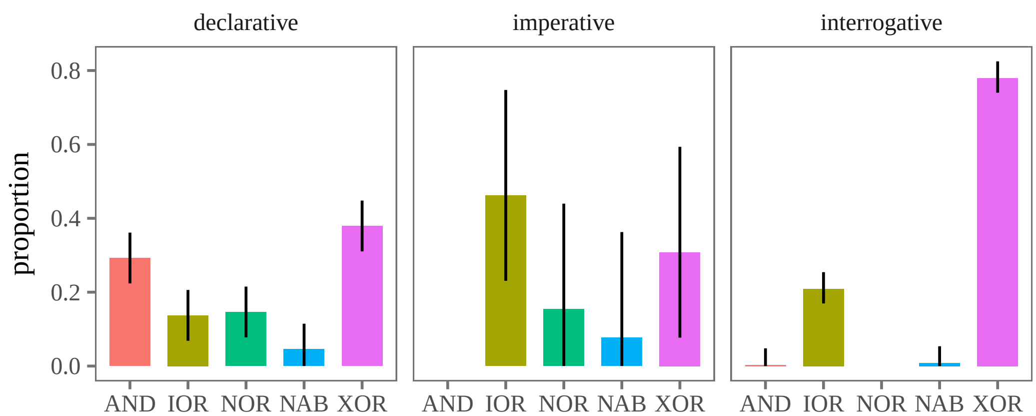

Figure 4.17: Connective interpretations in different sentence types.

of disjunction later as they encounter more inclusive (logical) uses of *or*. However, comprehension tasks show that children between 3 and 5 tend to interpret *or* as inclusive disjunction rather than exclusive disjunction in a variety of declarative sentences (Chierchia et al., 2001; Gualmini et al., 2000a, 2000b, among others; Notley et al., 2012). How can children learn the inclusive semantics of *or* if they rarely hear it? The remainder of this section explore the role of cues in child directed speech that could help children successfully interpret a disjunction as inclusive or exclusive. I will first look at the effect of utterance type on the interpretation of *or*. Figure 4.17 shows the distribution of connective interpretations in declarative, interrogative, and imperative sentences. Interrogatives are more likely to be interpreted as exclusive disjunction XOR, imperatives are more likely to be interpreted as inclusive or exclusive, and declaratives are most likely exclusive XOR or conjunctive AND. It is important to note here that the inclusive interpretations of imperatives are largely due

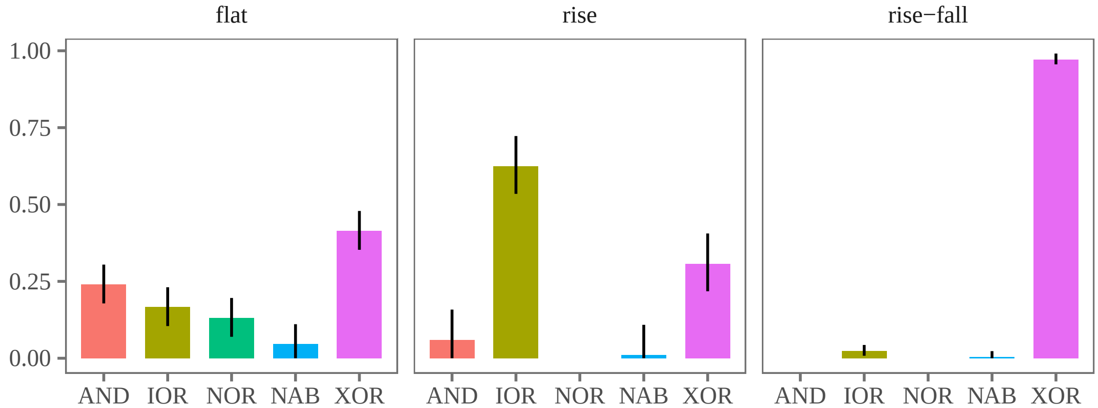

Figure 4.18: The distribution of connective interpretations in flat, rising, and rise-fall intonation contours.

to invitations to action such as "Have some food or drink!". Such invitational imperatives seem to convey inclusivity IOR systematically. They are often used to give addressee full permission with respect to both alternatives and it seems quite odd to use them to imply exclusivity ("have some food or drink but not both!"), and they do not seem to be conjunctive either ("have some food and have some drink"). They rather imply that the addressee is invited to have food, drink, or both. Figure (4.18) shows the proportions of different connective interpretations in the three intonation contours: flat, rise, and rise-fall. A disjunction with a rise-fall intonation is most likely interpreted as exclusive XOR. A disjunction is more likely to be interpreted as inclusive IOR if the intonation is rising. And a disjunction with a flat intonation may be interpreted as exclusive XOR, conjunctive AND, or inclusive IOR. These results are consistent with Pruitt & Roelofsen (2013)'s experimental findings that a rise-fall intonation contour on a disjunction results in an exclusive interpretation. Since rise-fall and rising intonation contours are almost always on interrogatives, Figures 4.17 and 4.18, suggest that the rise-fall and rising intonation types distinguish exclusive and inclusive interpretations of disjunction in interrogatives. Furthermore, given a flat intonation type, an imperative may be more likely to be inclusive. Figure 4.19 shows the proportions of connective interpretations in disjunctions with consistent vs. inconsistent disjuncts. When the disjuncts were consistent, the interpretation could be exclusive XOR, inclusive IOR, or conjunctive AND. When the disjuncts were inconsistent, however, a disjunction almost always received an exclusive XOR interpretation. These results suggest that the exclusive interpretation of a disjunction often stems from the inconsistent or contradictory nature of the disjuncts themselves and not necessarily the connective word *or*. It

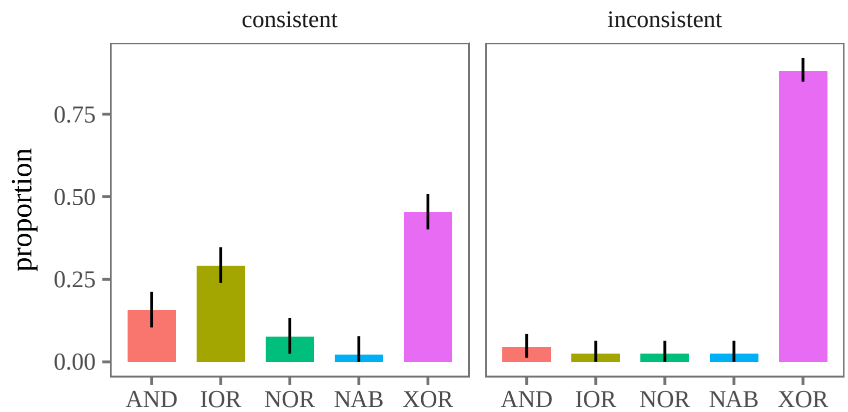

Figure 4.19: Connective interpretations in disjunctions with consistent and inconsistent disjuncts.

should be noted here that in all *and*-examples, the disjuncts were consistent. This is not surprising given that inconsistent meanings with *and* result in a contradiction. The only exception to this was one example where the mother was mentioning two words as antonyms: "short and tall". This example is quite different from the normal utterances given that it is meta-linguistic and list words rather than asserting the content of the words. In Figure 4.20, I break down connective interpretations by both intonation and consistency. The results show that disjunctions are interpreted as exclusive XOR when they carry either inconsistent disjuncts or a rise-fall intonation. If the disjunction has consistent disjuncts and carries a rising intonation, it is most likely interpreted as inclusive IOR. Disjunctions with consistent disjuncts and a flat intonation contour could have conjunctive AND, inclusive IOR, or exclusive XOR interpretations. Figure 4.21 shows connective interpretations by the syntactic level of the disjunction. As a reminder, we annotated disjunctions with clausal and verbal disjuncts as "clausal" and those with other syntactic categories as sub-clausal. The goal was to assess the role of syntax in the interpretation of disjunction. The results suggest a small effect of clausal level disjuncts. Disjunctions are more likely to be interpreted as exclusive when their disjuncts are clauses or verbs rather than nominals, adjectives, or prepositions (all sub-clausal units). For the last independent variable in our study, I take a look at how disjunction interpretations are affected by the communicative function of the utterance they appear in. Figure 4.22 shows the proportions of connective interpretations in the 10 different communicative functions of this study. The results show that certain functions increase the likelihood of some connective interpretations. An exclusive XOR interpretation of *or* is common in acts of clarification, identification, stating/asking

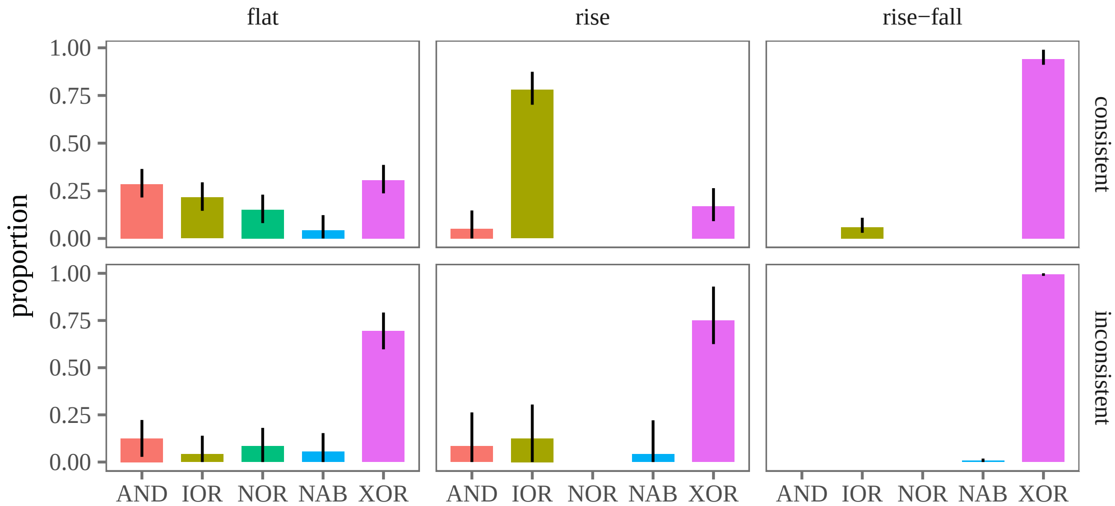

Figure 4.20: Interpretations of and/or in the three intonation contours flat, rising, and rise-fall.

preferences, stating/asking about a description, or making a conditional statements. These results are consistent with expectations on the communicative intentions of that these utterances carry. In clarifications, the speaker needs to know which of two alternatives the other party meant. Similarly in identifications, speaker needs to know which category does a referent belongs to. In preferences, parents seek to know which of two alternatives the child wants. Even though descriptions could be either inclusive or exclusive, in the current sample most descriptions were questions about the state of affairs and required the child to provide one of the alternatives as the answer. In conditionals such as "come here or you are grounded", the point of the threat is that only one disjunct can be

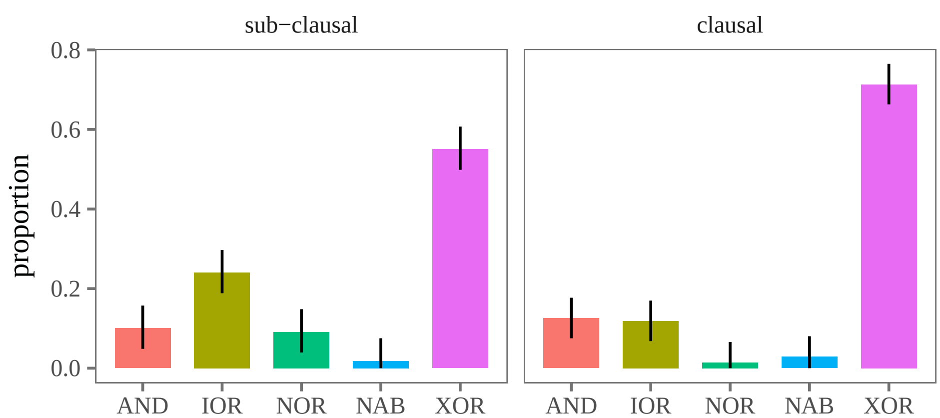

Figure 4.21: Connective interpretations in clausal and sub-clausal disjunctions.

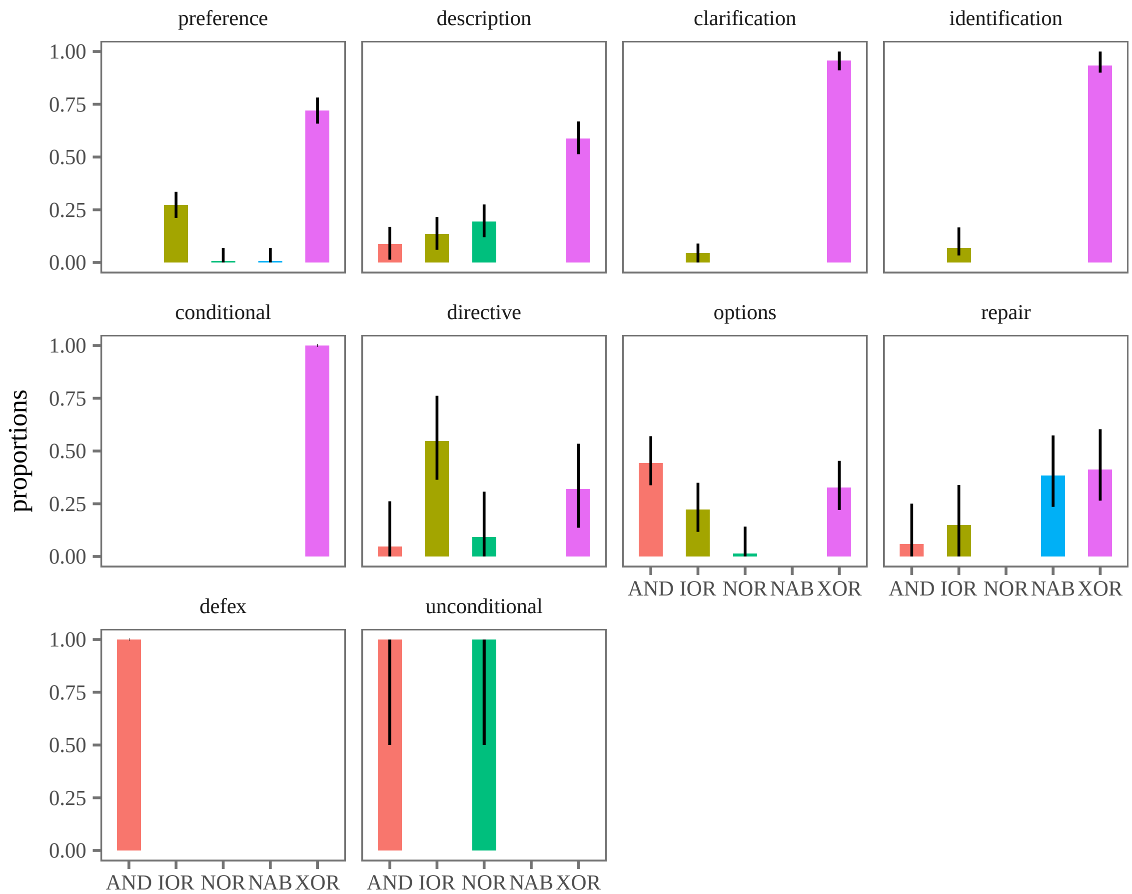

Figure 4.22: Connective interpretations in different communicative functions.

true: either "you come and you are not grounded" or "you don't come and you are grounded". This is similar to an exclusive interpretation of *or*.

Repairs often received an exclusive XOR or a second disjunct true NAB interpretation. This is expected given that in repairs the speaker intends to say that the first disjunct is incorrect or inaccurate. Unconditionals and definitions/examples always had a conjunctive AND interpretation. Again, this is to be expected. In such cases the speaker intends to communicate that all options apply. If the mother says that cats are animals like lions or tigers, she intends to say that both lions and tigers are cats and not one or the other. Interestingly, in some cases (not all), *or* is replaceable by and: cats are animals like lions and tigers. In unconditionals, the speaker communicates that in both alternatives, a certain proposition holds. For example, if the mother says "ready or not, here I come!", she communicates that "I come" is true in both "you are ready" and "you are not ready".

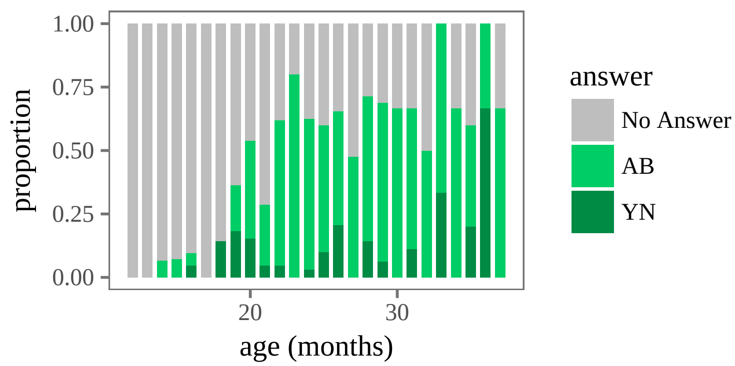

Figure 4.23: The proportions of children's answer types to polar questions containing the connectives and/or at different ages (in months).

Options were often interpreted either as conjunctive AND or inclusive IOR. The category options contained examples of free-choice inferences such as "you could drink orange juice or apple juice". This study found free-choice examples much more common than the current literature on the acquisition of disjunction suggests. Finally, directives received either an IOR or XOR interpretation. It is important to note here that the most common communcative function in the data were preferences and descriptions. Other communicative functions such as unconditionals or options were fairly rare. Despite their infrequent appearance, these constructions must be learned by children at some point, since almost all adults know how to interpret them. It is clear from the investigation here that any learning account for function word meaning/interpretation also needs to account for how such infrequent constructions are learned.

Finally, I take a look at how children responded to the questions containing *and* and *or*. As a reminder, we annotated every polar question such as "do you want cereal or toast?" for the type of answer children provided. An answer such as "yes/no" is annotated as YN and an answer with alternatives such as "cereal/toast" is annotated as "AB". Figure (4.23) shows the monthly proportions of these answer types between 1 and 3 years of age. Initially, children provide noy answer to polar questions, but by the age 3, the majority of such questions receive a yes/no (YN) or alternative (AB) answer. These two answer types are not necessarily appropriate for all types of polar questions that contain *and* and *or*. For example, a polar question with *and* such as "do you want cereal and juice?" typically receives an answer that contains "yes/no" rather than only one of the alternatives such as "cereal/juice". Alternative answers are typically provided to alternative questions with the rise-fall intonation. For example, a questions such as "do you want to stay here or

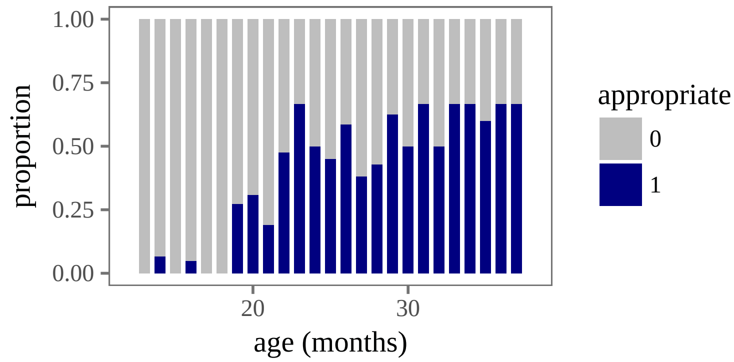

Figure 4.24: Proportion of children's appropriate resonses

go out?" receives an answer such as "stay here" and not "yes". However, a polar disjunctive question such as "any tea or coffee?" typically contains a "yes"/"no" rather than only one of the alternatives like "tea/coffee", even though both answers are possible. Based on such typical responses patterns, we can definite appropriate answers as alternative (AB) answers to alternative questions (with "or" and rise-fall intonation) and yes/no answers (YN) to the other questions. Of course this classification is too strict and misses some nuanced cases but it provides a rough estimate of appropriate answers offered to parents' questions. Figure (4.24) shows the monthly proportion of children's "appropriate" answers between the ages of 1 and 3. The results show that even with a strict measure, children show an increase in the proportion of their appropriate responses to questions containing *and* and *or* between 20 to 30 months of age (roughly 2 and 3 years of age). This increase in appropriate responses is consistent with the results in the previous section that suggested children's u understanding of *and* and *or* develops between 2 and 4 years of age.

4.3.3 Discussion

The goal of this study was to discover the potential cues in child-directed speech that could help children learn the interpretations of *and* and *or*. The study presented 1000 examples of *and* and *or* in child-directed speech, annotated for their truth-conditional interpretation, as well as five candidate cues to their interpretation: (1) Utterance Type; (2) Intonation Type; (3) Syntactic Level; (4) Conceptual Consistency; (5) Communicative Function. Like Morris (2008), this study found that the most common interpretations of *and* and *or* are conjunction AND and exclusive disjunction XOR. When the data were broken down by the connectives, *and* was almost always interpreted as a conjunction while *or* received three main interpretations: exclusive disjunction XOR, inclusive disjunction IOR, and conjunction AND.

While the most frequent interpretation of *or* was exclusive XOR overall followed by IOR, the distribution of disjunction interpretations shifted when they were broken down by the cues identified here. A disjunction was most likely exclusive if the alternatives were inconsistent (i.e. contradictory). A disjunction was most likely exclusive if it appeared in a question. Within questions, a disjunction was most likely exclusive if the intonation was rise-fall. If the intonation was rising, the question was interpreted as inclusive. The syntactic category of the disjuncts could also provide information for interpretation. If the disjuncts were clausal then it was more likely for the disjunction to be interpreted as exclusive, even though this effect was small. Finally, specific communicative functions required specific interpretations of the connective. *or* often received a conjunctive interpretation in the following contexts: defining terms and providing examples, enumerating options, and in unconditional constructions. These results suggest that in order to successfully learn to interpret a disjunction, children need to pay attention to a wide variety of formal and conceptual factors.

In order to have a rough measure of children's comprehension of disjunction, this study also investigated the types of answers they provided to polar questions with disjunction. Between the ages of 20 and 30 months (roughly 1;6 to 2;6 years), children start to answer *or* questions appropriately. They would respond to a yes/no question such as "do you want any apple juice or orange juice?" with a yes/no answer. They would also respond to an alternative question, as in"do you want to play inside or outside?", with one of the alternates, e.g. "inside". This finding is consistent with the first corpus study presented in this chapter, which reported that the age range between 1;6 and 4 is the age range in which children develop their understanding of *and* and *or*.

Due to the exploratory nature of this study, it is important to replicate and extend these results and conclusions in future studies. For example, future studies could use an automated procedure for the annotation of categories such as utterance type, syntactic level, and intonation. An automated procedure would also allow for the annotation of larger samples and so could result in more reliable estimates for the role of various factors in learning the meanings of function words. For categories such as communicative function and connective interpretation, future studies could use a larger number of independent annotators to increase the speed and number of annotations. However, several results reported in this study are independently supported by previous research. Morris (2008) found similar results with respect to the overall interpretation of disjunction in child-directed speech: *and* is most often interpreted as conjunction and *or* as exclusive disjunction. In an experimental study, Pruitt & Roelofsen (2013) have shown that a rise-fall intonation results in an exclusive interpretation. Geurts (2006) has argued that a portion of exclusivity inferences are simply due to the fact that the alternatives are mutually exclusive and inconsistent.

Finally, the list of cues investigated here is in no way exhaustive. There are at least two additional, possibly important factors/cues that I set aside due to the difficulties that their annotation would have introduced. First, an exclusive interpretation is sometimes the result of a presupposition that only one alternative can hold or would matter for the purposes of the conversation. For example, in the context of a class activity where students pair up, a statement such as "Lisa worked with Ann or John" is interpreted as exclusive simply because the context already presupposes that only one disjunct can be true. Second, some exclusivity inferences are due to the speaker's choice of connective, namely using *or* rather than *and*. Grice (1989) famously argued that in some cases, we interpret a disjunction like *A or B* as A or B, but not both because we reason that if the speaker intended to communicate that both alternatives hold, s/he would have said *A and B*. This study did not annotate for such cases. However, the study's results suggest that such cases of exclusive interpretations are less frequent in child-directed speech that the ones already annotated for. Investigating how often such cases of pragmatic exclusion appear in child-directed speech can help us better understand the role of input in children's acquisition of scalar implicatures.

4.4 Conclusion

This chapter presented two studies on the frequency and usage of *and* and *or*. The first study looked at the frequencies of these two words in a large collection of corpora for children between the ages of 1 and 6 years. It showed that children start producing *and* between 12 to 18 months of age and rapidly increase their productions until they reach the adult rate at 30 months. The production of *or* starts a little later, between 18-30 months, and rapidly reaches a steady rate at 48 months. This rate is below the adult rate for *or* in child directed speech. The results suggest we can expect an early understanding of disjunction between the ages of 18 and 30 months.

The second study looked at the interpretations of *and* and *or* in a sample of child directed speech, as well as the cues that accompany these instances. The study confirmed preivous finding that exclusive disjunciton is the most common interpretation of *or* in child directed speech. However, the also found that exclusive interpretations are reliably cued by intonation and the consistency of the disjuncts. In the absence of these cues, a disjunction is most likely inclusive or conjunctive. In the next chapter, I provide a computational model that uses the cues discussed here to learn the interpretation of utterances containing *and* and *or*.

Chapter 5

Cue-based Acquisition of Disjunction

5.1 Introduction

In Chapter 1, I reviewed the complexities involved in interpreting a disjunction word such as *or* in English. I showed that a disjunction can be interpreted as inclusive, exclusive, and even conjunctive. In adition to these truth-conditional interpretations, a disjunction is sometimes associated with speaker ignorance/indifference as well. Given the wide range of interpretations that *or* can have, how can children learn to interpret it correctly? In Chapter 2, I presented the results of Morris (2008) that suggested children rarely hear the word *or*; and when they do, they largely hear the exclusive interpretation (75-80% of the time). The annotation study of Chapter 4 replicated Morris (2008)'s finding. In Chapter 2, I also reported the results of recent comprehension studies that show children between the ages of three and five can interpret *or* as inclusive disjunction (Crain, 2012). Chapter 3 confirmed that children between three and five can interpret *or* as inclusive in simple existential sentences. The finding of the comprehension studies and the corpus studies taken together present a learning puzzle: how can children learn to interpret *or* as inclusive if they mostly hear exclusive examples? This chapter provides a solution by developing a cue-based account for children's acquisition of connectives. More generally, the account proposed in this chapter is helpful for learning words with multiple interpretations when one interpretation dominates the learner's input.

Learning from multiple cues is a common approach in language acquisition (See Monaghan & Christiansen, 2014 for an overview). In the domain of function word semantics, Wynn (1992) proposed a cue-based account for the acquisition of number words. In the next section, I briefly review their proposal and report their findings. The annotation study in Chapter 4 used a methodology similar to that of Wynn (1992) and reported several cues that may help children's acquisition of the connectives *and/or*. In this section, I use the data in my annotation study to present a cue-based account of connective acquisition. This account provides a straightforward solution to the learning puzzle of disjunction. I support this claim using three modeling experiments. The models incorporate the proposed cues to learn decision trees that predict the interpretation of a disjunciton/conjunction with an accuracy of above 80%. I end the chapter with a discussion of the assumptions and limitations of the proposed account.

5.2 The Cue-based Account for Number Words

Research on children's acquisition of numeral words (e.g. *one*, *two*, *three*, etc.) has suggested that children initially know that number words more than "one" refer to precise numerosities but they do not know exactly which number refers to which word (Wynn, 1992). P. Bloom & Wynn (1997) searched for linguistic cues that could help children associate numerals with quantity and numerosity. They considered two classes of cues: syntactic and semantic. Syntactic cues to word meaning were first discussed by R. Brown (1957). He wrote: "If a part of speech has reliable semantic implications, it could call attention to the kind of attribute likely to belong to the meaning of the word ... the part of speech memebership of the new word could operate as a filter selecting for attention probably relevant features of the nonlinguistic world." He tested preschoolers with nonce constructions "to sib", "a sib", and "any sib" showing that children can use the modifying function words to decide witheher the nonce word *sib* should refer to an action, an object, or a substance.

Semantic cues, on the other hand, are provided by the meaning of the known words in the sentence. Consider the sentence "there were several gloobs." The use of *gloob* in the plural noun phrase "several gloobs" makes it possible to infer that "gloob" is not an action or a spatial relationship but rather an entity that can have multiple instances. Using only the syntactic cues, there still remains a wide range of referential uncertainty since a gloob may be anything from an egg to an alien creature. Now consider the sentence “I ate several gloobs for breakfast.” What a gloob may be is now restricted to edible entities, probably those that are suitable for breakfast. The meanings of the verb *eat* and the adverbial phrase “for breakfast” help us further narrow down the possible meanings for *gloob*.

It is not always easy to tell whether a cue is syntactic or semantic. Here I avoid this issue by using the term “compositional cues” to refer to both syntactic and semantic cues that aid the interpretation of an unknown word. Using the term “compositional” also brings into attention the fact that syntactic and semantic cues are interrelated and do not act in an independent or unstructured way. Consider the sentence “After eating breakfast, I saw several gloobs.” Even though the words *eat* and *breakfast* are present in the sentence, they do not restrict the possible meanings for *gloob* as they did before. In other words, it is not the mere presence of these words in the sentence that act as cues but rather the way they combine with the unknown word to convey the main communicative message of the utterance.

P. Bloom & Wynn (1997) proposed that children learn number word meanings by attending to the compositional cues that accompany number words such as the words’ ordering relative to other words, other funciton words they co-occur with, and the count-mass status of the nouns they modify. They specifically discussed four cues. Two cues could help children notice that number words pattern like quantifiers. First, similar to quantifiers, number words precede adjectives and do not follow them. Second, they participate in the “. . . of the Xs” construction: “one of the gloobs”, “some of the gloobs”, “most of the gloobs”, etc. The third cue is the co-occurrence of number words with count nouns. This cue can inform learners that their meaning is restricted to the quantification of individuals. Finally, unlike other adjectives, numerals cannot be modified further using an adverb such as *very* or *too* (“very big animals” vs. “*very two animals”). According to P. Bloom & Wynn (1997), this cue can help a learner understand that number words pick an absolute property of a set rather than a continuous one.

Using the data available in the CHILDES corpora, P. Bloom & Wynn (1997) investigated the presence of cues to number word meaning in chlild directed speech for three children between the ages of one and three. They found that these children and their parents only use number words with count nouns; they do not use number words with modifiers and only use them before adjectives, not after. Finally, they found that these children and their parents use only number words and quantifiers in the partitive construction and not adjectives. The results of their corpus study shows that the compositional cues they proposed for number word acquisition are available in children's linguistic input. In the next section, I discuss some compositional cues that can help a learner limit the hypothesis space to connective meanings for coordinators such as *and*, *or*, *but*, *so*, etc.

5.3 Cues to coordinator meanings

Three important compositional cues can help learners in restricting their hypotheses to coordinator meanings. First, as pointed out by Haspelmath (2007), coordination has very specific compositional properties. Coordinators combine two or more units of the same type and return a larger unit of the same type. The larger unit has the same semantic relation with the surrounding words as the smaller units would have had without coordination. These properties separate coordinators from other function words such as articles, quantifiers, numerals, prepositions, and auxiliaries which are not used to connect sentences or any two similar units for that matter. In fact, the special syntactic properties of coordinators have compelled syntactic theories to consider specific rules for coordination.

The literature on syntactic bootstrapping suggests that children can use syntactic properties of the input to limit their word meaning hypotheses to the relevant domain (R. Brown, 1957; see Fisher, Gertner, Scott, & Yuan, 2010 for a review; Gleitman, 1990). In our 1073 annotations of conjunction and disjunction, we found that 56% of the times *and/or* connected sentences or clauses. This pattern is unexpected for any other class of function words and it is possible that the syntactic distriution of coordinators cue the learners to the space of sentential connective meanings.

Second, in our annotation study we found that *and* never occurs with inconsistent coordinands (e.g. "clean and dirty") while *or* commonly does (e.g. "clean or dirty"). The inconsistency of the coordinands can cue the learner to not consider conjunction as a meaning for the coordinator given that a conjunctive meaning would too often lead to a contradiction at the utterance level. On the other hand, choosing disjunction as the meaning avoids this problem. Third, the large scale study of Chapter 4 found that *or* is more likely to occur in questions than statements while *and* is more likely in statements. Since questions often contain more uncertainty while statements are more informative, it is possible that these environments bias the learner towards selecting hypotheses that match this general communicative function. Disjunction is less informative than conjunction and it

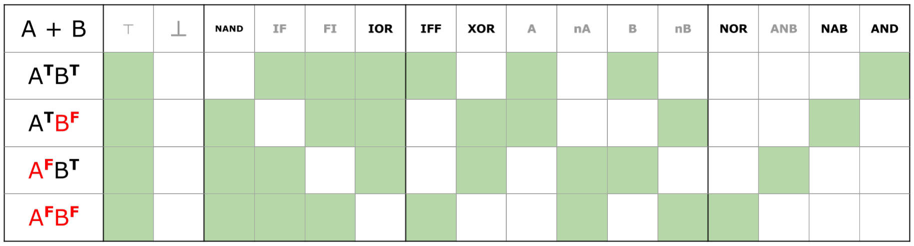

Figure 5.1: The truth table for the 16 binary logical connectives. The rows represent the set of situations where zero, one, or both propositions are true. The columns represent the 16 possible connectives and their truth conditions. Green cells represent true situations.

is possible that the frequent appearance of *or* in questions cues learners to both its meaning as a disjunction as well as the ignorance inference commonly associated with it.

Finally, it is reasonable to assume that not all binary connective meanings shown in Figure 5.1 are as likely for mapping. For example, coordinators that communicate tautologies or contradictions seem to be not good candidates for informative communication. Similarly, if A coordinated with B simply asserts the truth of A and says nothing about B, it is unclear why it would be needed if the language already has the means of simply asserting A. It is possible that pragmatic principles already bias the hypothesis space to favor candidates that are communicatively more efficient. Even though these findings are suggestive, they need to be backed up by further observational and experimental evidence to show that children do actually use these cues in learning connective meanings. In the next section, I turn to the more specific issue of learning the correct interpretation of *and*/*or* from the input data. Similar to the case of number words, previous research has provided insight into how children comprehend a disjunction and what they hear from their parents. The main question is how children learn what they comprehend from what they hear. I turn to this issue in the next section.

5.4 Learning to interpret *and*/*or*: A cue-based account

Previous comprehension studies as well as the one reported in Chapter 3 have shown that children as early as age three can interpret a disjunction as inclusive. However, Morris (2008)'s study of

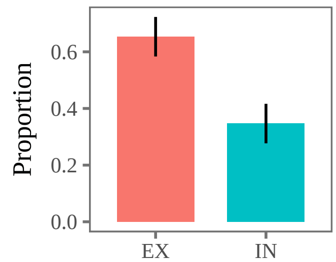

Figure 5.2: Proportion of exclusive and inclusive interpretations of disjunction in child-directed speech. Error bars represent bootstrapped 95% confidence intervals.

child-directed speech showed that exclusive interpretations are much more common than other interpretations of disjunction in children's input. In Figure 5.2, I show the results of Chapter 4's annoation study by grouping the disjunction interpretations into exclusive (EX) and inclusive (IN), i.e. non-exclusive categories. These results replicate Morris (2008)'s finding and reinforce a puzzle raised by Crain (2012): How can children learn the inclusive interpretation of disjunction when the majority of the examples they hear are exclusive? To answer this question, I draw insight from the Gricean approach to semantics and pragmatics discussed in Chapter 1. Research in Gricean semantics and pragmatics has shown that the word *or* is not the only factor relevant to the interpretation of a disjunction. It is not only the presence of the word *or* that makes us interpret a disjunction as inclusive, exclusive, or conjunctive, but rather the presence of *or* along with several interpretive factors such as intonation (Pruitt & Roelofsen, 2013), the meaning of the disjuncts (Geurts, 2006), and the conversational principles governing communication (Grice, 1989). Therefore, the interpretation and acquisition of the word *or* cannot be separated from all the factors that accompany it and shape its final interpretation.

In the literature on word learning and semantic acquisition, form-meaning mapping is construed as mapping an isolated form such as *gavagai* to an isolated concept such as "rabbit". While this approach may be feasible for content words, it will not work for function words such as *or*. First, the word *or* cannot be mapped isolated from its formal context. As Pruitt & Roelofsen (2013) showed, the intonation that accompanies a disjunction affects its interpretation. Therefore, a learner needs to pay attention to the word *or* as well as the intonation contour that accompanies the disjunction. Second, the word *or* cannot be mapped to its meaning isolated from the semantics of the disjuncts that accompany it. As Geurts (2006) argued, the exclusive interpretation is often enforced simply because the options are incompatible. For example, "to be or not to be" is exclusive simply because one cannot both be and not be. In addition, conversational factors play an important role in the interpretation of *or* as Grice (1989) argued. In sum, the interpretation and acquisition of function words such as *or* require the learner to consider the linguistic and nonlinguistic context of the word and map the meanings accordingly.

Previous accounts have adopted a model in which a function word such as *or* is mapped to its most likely interpretation: $or \rightarrow \oplus$. This model is often used in cross-situational accounts of content words. Here I argue that the direct mapping of *or* to its interpretation without consideration of its linguistic context is the primary cause of *or*'s learning puzzle. Instead, I propose that the word *or* is mapped to an interpretation in a context-dependent manner, along with the interpretive cues that accompany it such as intonation and disjunct semantics:

[connective: *or*, Intonation: rise-fall, Disjuncts: inconsistent] $\rightarrow \oplus$

[connective: *or*, Intonation: rising, Disjuncts: consistent] $\rightarrow \vee$

Figure 5.3 shows that the rate of exclusive interpretations change systematically when we break the data in Figure 5.2 down by intonation and consistency. Given a rise-fall intonation contour, a disjunction is almost always interpreted as exclusive. Similarly, if the propositions are inconsistent, the disjunction is most likely interpreted as exclusive. When either of these two features are absent, a disjunction is more likely to receive an inclusive interpretation.

In this account, it is not a single word that gets mapped to an interpretation but rather a cluster of features. This method has two advantages. First, it deals with the context dependency of disjunction interpretation. The learner knows that *or* with some intonation has to be interpreted differently from one with another. Second, it allows the learner to pull apart the contribution of *or* from the interpretive cues that often accompany it. In fact, analysis of all mapping clusters in which *or* participates and generalization over them can help the learner extract the semantics of *or* the way it is intended by Gricean semanticists. For those skeptical of such an underlying semantics for *or*, there is no need for further analysis of the mapping clusters and the meaning of *or* as a single lexical item is distributed among the many mappings in which it participates. In the next section, I implement this idea using decision tree learning.

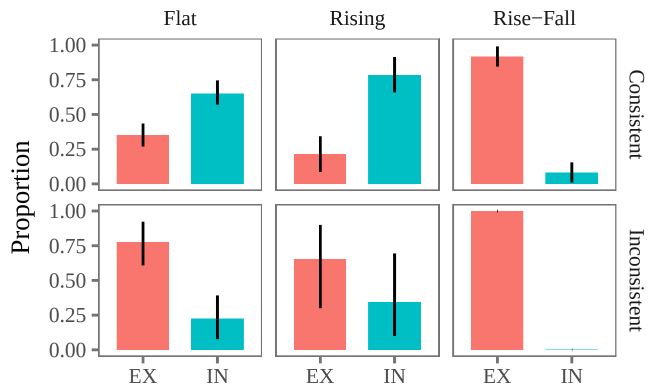

Figure 5.3: Exclusive and inclusive interpretations broken down by intonation (flat, rise, rise-fall) and consistency. Error bars represent bootstrapped 95% confidence intervals.

5.5 Modeling Using Decision Tree Learning

A decision tree is a classification model structured as a hierarchical tree with nodes, branches, and leaves (Breiman, 2017). The tree starts with an initial node, called the root, and branches into more nodes until it reaches the leaves. Each node represents the test on a feature, each branch represents an outcome of the test, and each leaf represents a classification label. Using a decision tree, observations can be classsifed or labeled based on a set of features. For example, we can make a decision tree to predict whether a food item is a fruit or not based on its color (green or not) and shape (round or not). An example decision tree is the following: at the root, the model can ask whether the item is green or not. If yes, the model creates a leaf and labels the item as "not fruit". If no, the model creates another node and asks if the item is round. If yes, the item is classified as a "fruit" and if not it is classifed as "not fruit".

Decision trees have several advantages for modeling cue-based accounts of semantic acquisition. First, decision trees use a set of features to predict the classification of obsevations. This is analogous to using cues to predict the correct interpretation of a word or an utterance. Second, unlike many other machine learning techniques, decision trees result in models that are interpretable. Third, the order of decisions or features used for classification is determined based on information gain. Features that appear higher (earlier) in the tree are more infomrative and helpful for classification. Therefore, decision trees can help us understand which cues are probably more helpful for the acquisition and interpreation of a word.

Decision tree learning is the construction of a decision tree from labled training data. In this section, I apply decision tree learning to our annotated data by constructing random forests (Breiman, 2001; Ho, 1995). In random classification forests multiple decision trees are constructed on subsets of the data and the decisions are made by taking the majority vote. Next section discusses the methods used in constructing the random forests for interpreting connectives *or/and*.

5.5.1 Methods

The random forest models were constructed using the Sci-kit Learn (Pedregosa et al., 2011). The annotated data had a feature array and a connective interpretation label for each connective use. Connective interpreations included exclusive (XOR), inclusive (IOR), conjunctive (AND). The features or cues used included all other annotation categories: intonation, consistency, syntactic level, utterance type, and communicative function. All models were trained with stratified 10-Fold cross-validation to reduce overfitting. Stratified cross-validation maintains the distribution of the initial data in the random sampling to build cross validated models. Maintaining the data distribution ensures a more realistic learning environment for the forests. First a grid search was run on the hyperparamter space to establish the number of trees in each forest and the maximum tree depth allowable. The default number of trees for the forests was set to 20, with a max depth of eight and a minimum impurity decrease (i.e. gini decrease) of 0. Decision trees were fit with high, medium, and low minimum gini decrease values. High gini decrease values tested trees that did not use any features for branching. Such trees represent the traditional approach to mapping that directly maps words to their most likely interpretation. Medium minimum gini decrease values allowed for very conservative branching. Such trees represent a cue-based account in which only one or two most informative features are used for interpreation. Finally low minimum gini decrease values allow for less conservative and more elaborate trees with more features. Such trees represent an account that allows for multiple cues to be used for interpretation.

5.5.2 Results

I first present the results of the random forests trained to classify exclusive and inclusive interpretations of disjunction. Figure 5.4 shows the decision tree with high minimum gini decrease. As expected, a learner that does not use any cues would interpret *or* as exclusive. Figure 5.5 shows the most accurate decision tree with medium minimum gini decrease. The tree has learned to use intonation and consistency to classify disjunctions as exclusive or inclusive. As expected, if the intonation is rise-fall or the disjuncts are inconsistent, the interpretation is exclusive. Otherwise, if the intonation is not rise-fall and the disjuncts are consistent, then the disjunction is classified as inclusive. Figure 5.6 presents the most accurate decision tree with low minimum gini decrease. In addition to using intonation and consistency like the previous tree, the tree has learned to use communicative functions further identify exclusive interpretations. Conditionals (e.g. be careful or you'll get hurt) and descriptions are found more likely to be exclusive. Figure 5.7 shows a cross-validated learning curve of the forest with low minimum gini decrease on increasingly large training sets. The forest surpasses mean accuracy of 80% after training on about 20 data points.

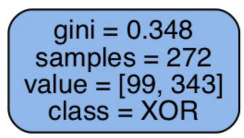

Figure 5.4: Tree grown with minimum impurity decrease of 0.1. The tree always classifies examples of disjunction as exclusive.

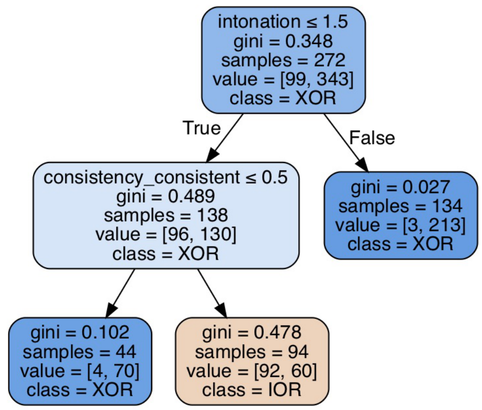

Figure 5.5: Tree grown with minimum impurity decrease of 0.05. The tree classifies examples of disjunction with rise-fall intonation as exclusive (intonation > 1.5). If the intonation is not rise-fal but the disjuncts are inconsistent (consistency < 0.5), then the disjunction is still classified as exclusive. However, if neither of these two holds, the disjunction is classified as inclusive.

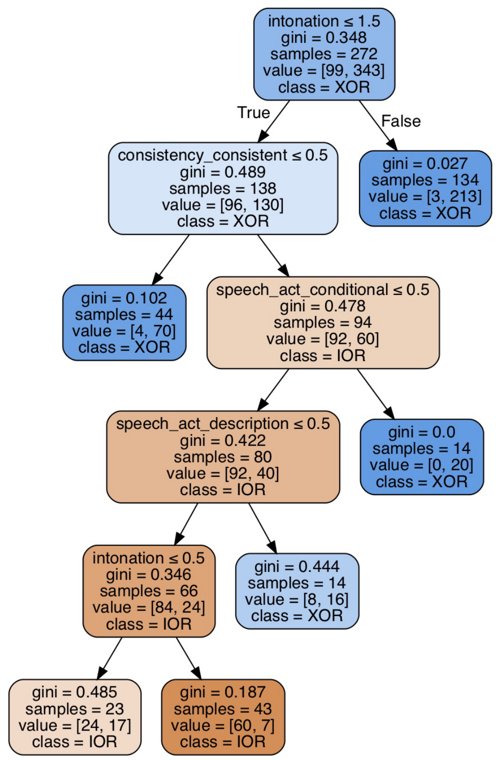

Figure 5.6: Tree grown with minimum impurity decrease of 0.01. The tree classifies examples of disjunction with rise-fall intonation as exclusive (intonation $>$ 1.5). If the intonation is not rise-fal but the disjuncts are inconsistent (consistency $<$ 0.5), then the disjunction is still classified as exclusive. Even if the disjuncts are conditional but the communicative function is conditional (speech_act_conditional $>$ 0.5), the classification is again exclusive. A similar decision is made for the communicative function of description and the rest of the disjunctions that do not satisfy any of these conditions are classified as inclusive.

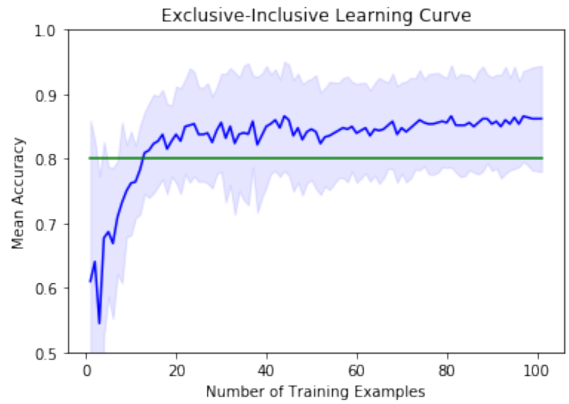

Figure 5.7: Cross-validated learning curve of the forest with binary exclusive-inclusive classification and with low minimum gini decrease.

Next I use decision tree learning for learning conjunction as well as disjunction and distinguish between inclusive, exclusive, and conjunctive interpretations. Figure 5.8 shows the example tree with high minimum gini decrease, which only uses the presence of the words *or*/*and* as the cue to interpret conjunction and disjunction. As expected, the tree interprets a coordination with *and* as a conjunction and one with *or* as exclusive disjunction. Figure 5.9 shows the highest scoring decision tree with medium minimum gini decrease. In addition to the presence of *and*/*or*, the tree uses intonation, consistency, and communicative function to distinguish exclusive and inclusive uses of disjunction. A disjunction that is not rise-fall, inconsistent, and conditional is classified as inclusive. Figure 5.10 presents the highest scroing decision tree with low minimum gini decrease. This tree is almost identical to the tree in Figure 5.9, except that descriptions are also classified as exclusive. Figure 5.11 shows a cross-validated learning curve of the forest with low minimum gini decrease on increasingly large training sets. The forest surpasses mean accuracy of 80% after training on about 40 data points.

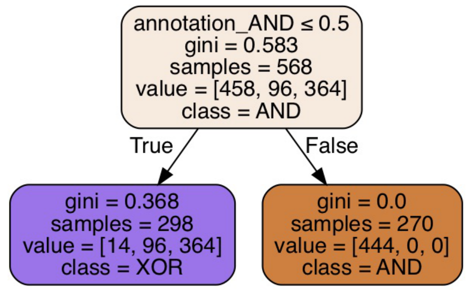

Figure 5.8: Tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.05. The tree uses the words and/or and classifies them as conjunction and exclusive disjunction.

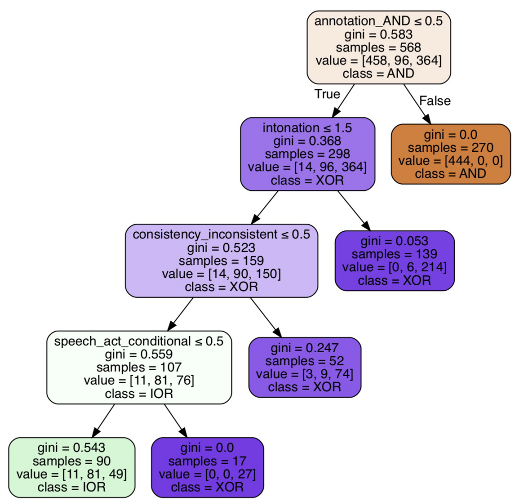

Figure 5.9: Tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.015. In addtion to the words and/or, the tree uses intonation, consistency, and the communicative function of conditionals to detect exclusive uses of disjunction.

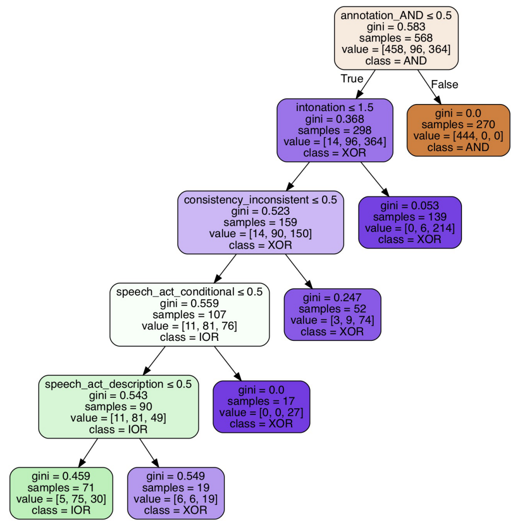

Figure 5.10: Tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.005. After using the words and/or, intonatio, and consistency, the tree uses communicative functions of conditional and descreiptions to detect exclusive disjunctions.

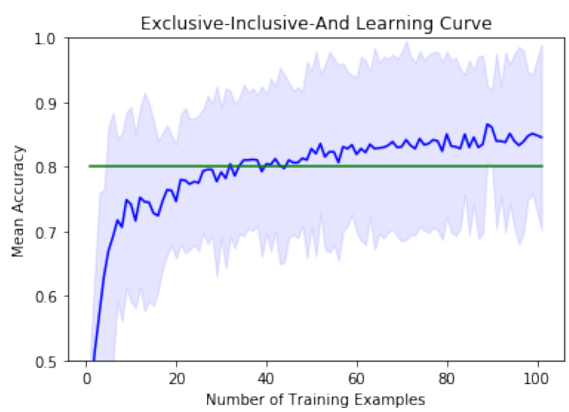

Figure 5.11: Cross-validated learning curve of the forest with binary exclusive-inclusive classification and with low minimum gini decrease.

5.6 Discussion

In this chapter, I discussed two accounts for the acquisition of function words. The first account is similar to cross-situational content word acquisition, in that words are isolated and directly mapped to their most likely meanings. The second account is what I call cue-based context-dependent mapping in which words are mapped to meanings conditional on a set of present cues in the context. I showed that the first account's direct mapping of forms to meanings runs into a learning problem for the disjunction word *or*. Under this account, the input statistics supports an exclusive interpretation for *or* while in comprehension studies we find children interpreting *or* as inclusive. I showed that the cue-based account resolves this problem by allowing *or* to be mapped to its interpretation according to the contextual cues that disambiguate it. The results of my decision tree learning experiments on the annotated data from child-directed speech suggested that such an approach can successfully learn the exclusive and inclusive interpretations of a disjunction. More broadly, the cue-based context-dependent mapping account proposed in this chapter is useful for the acquisition of ambiguious words and interpretations that are consistent but relatively infrequent in child-directed speech.

Conclusion

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