Rapid Acquisition of Disjunction from Prosody and Consistency

Masoud Jasbi
masoudj@stanford.edu
Department of Linguistics
Stanford University

Akshay Jaggi
ajaggi@stanford.edu
Department of Linguistics
Stanford University

Michael C. Frank
mcfrank@stanford.edu
Department of Psychology
Stanford University

Abstract

Ambiguity poses a challenge to children learning the meaning of words. For example, a disjunction such as `A or B` can be interpreted as inclusive (A or B, or both) or exclusive (A or B, not both). Linguistic studies suggest that the core meaning of *or* is inclusive and despite the dominance of exclusive interpretations, children successfully and quickly learn the meaning of *or* as inclusive. This raises a larning puzzle: how can children quickly learn what they rarely hear? We argue that children can use the regularities of *or* in child-directed speech to learn the interpretation of a disjunction from a few examples.

Keywords: language acquisition; word learning; logical words; and; or; nativism; constructivism.

Introduction

The social media company LADbible reported the following in a tweet: "James Bond producer says next 007 could be black **or** a woman". A twitter user named Robert responded sarcastically with: "if only women could be black!" What in the producer's speech gave the impression that the next 007 could not be both black **and** a woman? The word *or*. A disjunction like "A or B" is associated with two interpretations: **inclusive**, and **exclusive**. "A or B" is inclusive when it is interpreted as "A or B **or both**". This is probably what LADbible meant when reporting the James Bond producer. However, "A or B" can also be exclusive: "A or B, but **not both**". Robert's response shows that he had an exclusive interpration of *or*. What factors determine the interpretation of *or* and how do children learn its meaning given this ambiguity?

A large body of research in linguistics and philosophy in the past 50 years has created a common consensus on the meaning of *or* (see Aloni (2016)). Data on the interpretation of disjunction across different sentences, contexts, and even languages show that the core meaning of disjunction words such as *or* is **inclusive**. This is similar to the definition of disjunction in formal logics. The **exclusive** interpretation of *or* is the result of enhancing its inclusive semantics via other (extra-semantic) factors such as intonation (Pruitt & Roelofsen, 2013), inconsistency of the options (Geurts, 2006), and pragmatic reasoning over the speaker's choice of *or* instead of *and* (Grice, 1975). Therefore, interpreting a disjunciton is a complex process that needs to take into account the meaning of *or* as well as different structural and contextual factors that accompany it. How do we, as children, learn such a complex interpretive system?

There are two accounts of children's acquisition of disjunciton: a **constructivist** account, and 2. a **nativist** account. Under the constructivist account, children learn the meaning of *or* by paying attention to how parents use it in different contexts. They form usage-rules and expand their usage repertoire as they grow up. The prediction is that children's production of *or* is slow and gradual, mirroring what they hear from parents. Morris (2008) found that *and* is about 13 times more frequent than *or* in parents' speech to children. As predicted by the constructivist account, Morris (2008) reported that children also learn to produce *and* much more quickly than *or*. They reach the adult rate of *and* at age 3 while for *or* there is a gradual increase in production, possibly reaching the adult level at ages 5 or 6. The faster acquisition of *and* is consistent with the constructivist theory that emphasizes the role of usage frequency in children's linguistic development. Morris (2008) also reported that the majority of *or* examples children hear are exclusive. He argued that consistent with the constructivist account, the majority of *or*'s children produce are also exclusive. Therefore, the inclusive semantics of *or* is developed after the exclusive interpretation.

However, several comprehension studies of *or* in different linguistic contexts show that children as young as three-years old interpret *or* as inclusive disjunction (Crain, 2012). This is surprising given Morris (2008)'s finding that the majority of *or* examples children hear are exclusive. How do children learn the interpretation of disjunction as inclusive if they rarely hear it? We call this the **learning puzzle of disjunction**. Crain (2012) suggests that instead of learning from the parents' usage of *or*, children rely on the innate knowledge that the the disjunciton operator in their native language must have an inclusive meaning. This nativist account predicts that *or* is learned relatively quickly and accurately by children.

Here we present an alternative answer that provides a synthesis between the nativist and constructivist accounts. We show that children can use regularities in parents' usage of *or* to learn the interpretation of disjunction from a handful of examples. In study 1, we use a large scale corpus study of parents and children's speech to show that both *and* and *or* appear relatively quickly in children's speech and reach the adult rate by the age 4. This finding is consistent with the comprehension studies that show children have an adult-like understanding of these words by the age four. In study 2, we replicate Morris (2008)'s finding that the majority of *or* examples in child-directed speech have an exclusive interpretation. However, we also show that these exclusive interpretations correlate systematically with two factors external to *or*: intonation and consistency of the options. Exclusive interpretations are either inconsistent in nature (e.g. clean or dirty) or carry a distinct rise-fall intonation. We show that setting aside these cases, the interpretation of a disjunction is inclusive.

We argue that if children track the interpretive cues that accompany a disjunction, they can tease apart the role of the word *or* from factors that accompany and enhance it to shape the exclusive interpretation. This way children can discover that exclusivity corrleates with rise-fall intonation and inconsistent options, while *or* itself does not exclude the option of both disjuncts being true. We implement this novel account in a decision-tree that correctly learns to predict the interpretation of a disjunction with 80% accuracy after only a few examples. Our results show that the richness and systematicity of children's linguistic input allows rapid acquisition of disjunction with no need for an innate assumptions specific to the meaning of disjunction. We discuss the important implications of this work for the theories of word learning in the last section.

Study 1: Corpus Study

First, we conducted an exploratory and large scale investigation of *and* and *or* productions in parents and children. The goal of the study was to find out when children start producing these words and when they reach the adult rate of production. We conclude that children start producing *and* around 1.5 or 2 years of age, and *or* between the ages of 2 and 3. They reach the adult rate of production for *and* around 3 and for *or* around 4 or possibly earlier.

Methods

We accessed the Child Language Data Exchange System (CHILDES, MacWhinney (2000)) via the online platform childes-db and its associated R package childesr (Sanchez et al., in prep). We extracted all instances of *and* and *or* from the English corpora (ENG-NA and ENG-UK). We limited our analysis to the data between one and six years because there is scarce data outside this age range. We computated the relative frequency of connective production by dividing the total number of *and*/*or* in the speech of fathers, mothers, and children at a particular age by the total number of words spoken at that age. We present the relative frequency as parts per thousand.

Results

In figure 1, we show the relative frequencies of *and* and *or* in the speech of parents and children between one and six years. It is important to note that the y-axes for *and* vs. *or* show different ranges. This is due to the big difference in the relative frequencies of *and* and *or*. In the speech of parents, *and* is produced around 20 times per thousand words while *or* is only produced around 2 times per thousand words. This confirms previous findings that *or* is much less frequent in child directed speech than a similar funciton word such as *and*.

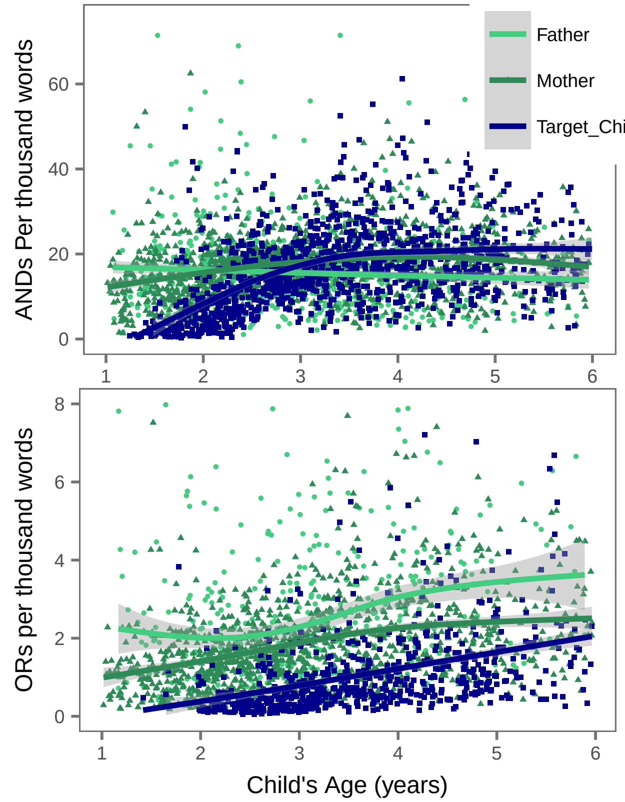

Figure 1: The relative frequency of AND (top) and OR (bottom) per thousand words in the speech of fathers, mothers, and children between the ages of 1 and 6.

And and *or* seem to show different developmental rajectories in the speech of children. For *and*, there is a rapid increase in its production between the ages of 1.5 and 3 before it reaches the adult rate around the age 3 and stay at that level until the age 6. For *or*, on the other hand, we see a slow incrase from the age 2 until the age 6 when it reaches the adult rate. This difference in the development of *and* & *or* production was attributed to the frequency of these items in child-directed speech. Since *and* is much more frequent than *or*, it is learned much faster than *or*. Morris (2008) argued that such patterns support the item-based and usage-based acquisition of logical words.

However, the analysis above does not control for other factors that can affect the production of words by children. An important factor to control for is the development of speech acts. While content words such as *dog* or *chair* may appear freely in different types of speech acts, function words are highly constrained by the type of speech acts they can appear in. For example, it is reasoable to assume that question words such as *how* and *why* are much more likey to occur in questions than statements (declaratives). If parent-child interaction is such that parents ask more questions than children, it is not surprising to find higher rates of *how* and *why* production in parents than children. Therefore, it is important to control for the speech act a function word appears in.

Figure 2 shows the relative frequencies of *and* and *or* in questions vs. declaratives, in the speech of parents and children between one and six years. Here, the relative frequency is computed by dividing the total number of *and*/*or* in a question/declarative in the speech of fathers, mothers, and children at a particular age, by the total number of words in a question/declarative spoken at that age. As before, we present the relative frequency as parts per thousand.

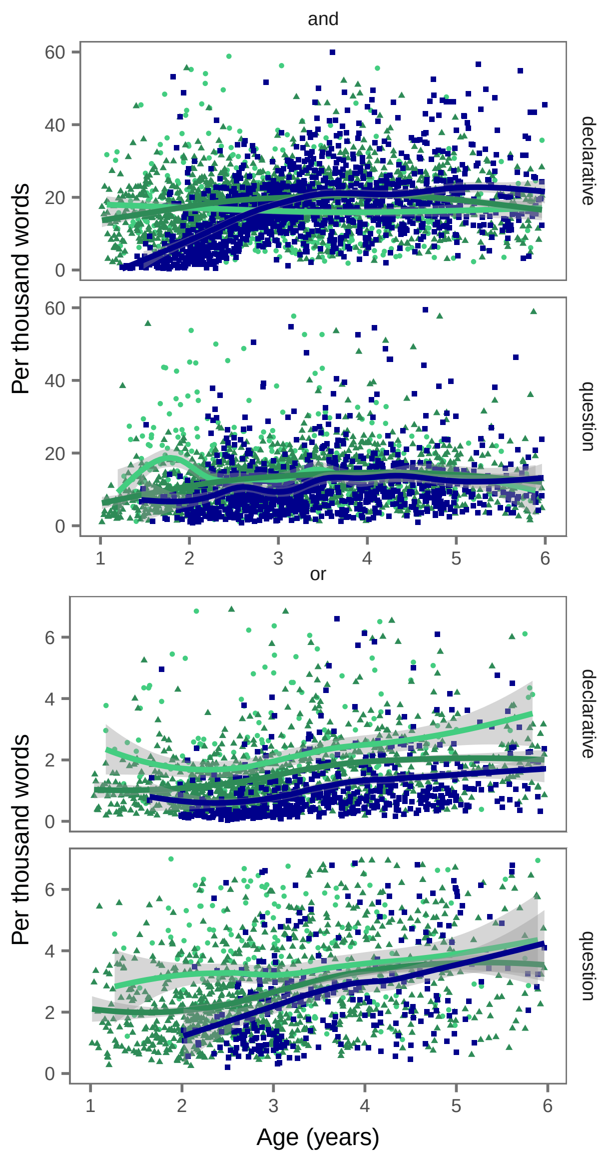

Figure 2: The relative frequency of AND (top) and OR (bottom) per thousand words in delcaratives and questions in the speech of fathers, mothers, and children between the ages of 1 and 6,

The results show similar developmental trajectories for the production of *and* and *or* in children. For both words, there is a relatively rapid incease in their frequency between the ages of 2 and 4 before reaching the parent rate at the age of 4 and staying at that rate until the age of 6. This pattern of production is consistent with the nativist observations that the acquisition of *and* and *or* is rapid and that children have an adult-like comprehension of these two connectives at the age 4.

Summary

And is a lot more frequent than or in child directed speech.

In the first six years, it appears that children reach the adult production rate for and but not or.

This is at least partly because or is more frequent in questions and children produce fewer questions than parents.

The developmental trajectory of connective production is best described as a quick increase in production between the ages of 2 and 4 and staying around the parents' rate between the ages 4 and 6. This is compatible with the comprehension studies which suggest children understand *and* and *or* by the age four.

Study 2: Annotation Study

Use standard APA citation format. Citations within the text should include the author's last name and year. If the authors' names are included in the sentence, place only the year in parentheses, as in (**???**), but otherwise place the entire reference in parentheses with the authors and year separated by a comma (**???**). List multiple references alphabetically and separate them by semicolons (**???**, **???**). Use the et. al. construction only after listing all the authors to a publication in an earlier reference and for citations with four or more authors.

For more information on citations in R Markdown, see **here.**

Footnotes

Indicate footnotes with a number[1] in the text. Place the footnotes in 9 point type at the bottom of the page on which they appear. Precede the footnote with a horizontal rule.[2]

Figures

All artwork must be very dark for purposes of reproduction and should not be hand drawn. Number figures sequentially, placing the figure number and caption, in 10 point, after the figure with one line space above the caption and one line space below it. If necessary, leave extra white space at the bottom of the page to avoid splitting the figure and figure caption. You may float figures to the top or bottom of a column, or set wide figures across both columns.

Two-column images

You can read local images using png package for example and plot it like a regular plot using grid.raster from the grid package. With this method you have full control of the size of your image. **Note: Image must be in .png file format for the readPNG function to work.**

You might want to display a wide figure across both columns. To do this, you change the `fig.env` chunk option

[1] Sample of the first footnote.

[2] Sample of the second footnote.

to `figure*`. To align the image in the center of the page, set `fig.align` option to `center`. To format the width of your caption text, you set the `num.cols.cap` option to `2`.

One-column images

Single column is the default option, but if you want set it explicitly, set `fig.env` to `figure`. Notice that the `num.cols` option for the caption width is set to `1`.

Figure 4: One column image.

R Plots

You can use R chunks directly to plot graphs. And you can use latex floats in the fig.pos chunk option to have more control over the location of your plot on the page. For more information on latex placement specifiers see **here**

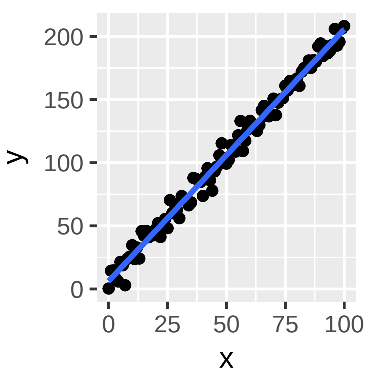

Figure 5: R plot

Tables

Number tables consecutively; place the table number and title (in 10 point) above the table with one line space above the caption and one line space below it, as in Table 1. You may float tables to the top or bottom of a column, set wide tables across both columns.

You can use the xtable function in the xtable package.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.00	0.10	-0.0	0.97
x	1.94	0.09	21.6	0.00

Table 1: This table prints across one column.

Conclusion

List what you showed and argued for.

Talk about important implications for theories of word learning.

Possibly talk about the original tweet and how that falls still outside what your algorithm learns.

Acknowledgements

Place acknowledgments (including funding information) in a section at the end of the paper.

References

Aloni, M. (2016). Disjunction. In E. N. Zalta (Ed.), *The stanford encyclopedia of philosophy*. Stanford University. Retrieved from `https://plato.stanford.edu/archives/win2016/entries/disjunction/`

Crain, S. (2012). *The emergence of meaning*. Cambridge University Press.

Geurts, B. (2006). Exclusive disjunction without implicatures. *Ms., University of Nijmegen*.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. Morgan (Eds.), *Syntax and semantics* (Vol. 3: Speech Acts, pp. 43–58). Academic Press.

MacWhinney, B. (2000). *The childes project: The database* (Vol. 2). Psychology Press.

Morris, B. J. (2008). Logically speaking: Evidence for item-based acquisition of the connectives and & or. *Journal of Cognition and Development*, *9*(1), 67–88.

Pruitt, K., & Roelofsen, F. (2013). The interpretation of prosody in disjunctive questions. *Linguistic Inquiry*, *44*(4), 632–650.

Sanchez, A., Meylan, S., Braginsky, M., MacDonald, K., Yurovsky, D., & Frank, M. C. (in prep). Childes-db: A flexible and reproducible interface to the child language data exchange system (childes).

Figure 3: This image spans both columns. And the caption text is limited to 0.8 of the width of the document.