Conceptual and prosodic cues in child-directed speech can help children learn the meaning of disjunction

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Abstract

Current theories of word learning focus on cues and mechanisms that help children's acquisition of open-class words such as nouns and verbs. Little is understood about the role of input in children's acquisition of closed-class words such as articles and connectives. This paper investigates the cues in child-directed speech that can help the interpretation and acquisition of the connective *or*. Study 1 uses a large corpus of parent-child interactions to show that despite low occurance of *or* in child-directed speech, children quickly reach the adult level of production for this word by age 4. Study 2 uses annotations on a subset of parent-child interactions to show that disjunctions in child-directed speech are accompanied by reliable cues to the correct interpretation (exclusive vs. inclusive). We present a computational model that learns from a handful of annotated examples to correctly predict the interpretation of a disjuntion. These studies suggest that reliable cues in child-directed speech can assist rapid acquisition of functional categories such as disjunction words.

Keywords: language acquisition; word learning; logical words; conjunction, disjunction.

Introduction

When we think of words, we often think of nouns like *cat*, adjectives like *red*, or verbs like *run*. These classes of words - called **content words** - have thousands of members and constantly add new ones like *Google*, *crunk*, or *chillax*. Their meanings often refer to concrete and tangible entities or events in the world. This is not the case for **function words** like *and*, *or*, *of*, and *the*. Functional classes have few members and rarely accept new ones. Their meanings are highly abstract and provide the glue that holds content words together to form complete thoughts. These properties make function words challenging for theories of word learning.

Word learning is often construed as the process of isolating a word form, selecting a meaning from a set of candidate meanings, and mapping the word form to the selected meaning (Clark, 1995). While there has been a lot of research on cues and constraints that assist children in selecting the right meaning for content words, very little is known about the cues that help children's learning of functional meaning. This study makes the initial steps in discovering such cues by investigating the disjunction word *or* in parents' and children's speech.

The word *or* has long been a lab rat in linguistics and language acquisition. This interest in *or* is mainly due to its close connection to logical disjunciton. In formal logics, there are two types of disjunction: inclusive and exclusive. An **inclusive disjunction** such as "A $\vee$ B" is true when either A, B, or both are true. An **exclusive disjunction** such as "A $\oplus$ B" is true only when A or B is true but not both. The linguistic connective *or* can receive an inclusive interpretation like "A $\vee$ B" or an exclusive one like "A $\oplus$ B". For example, a waitor may ask if you would like something to eat or drink, not excluding the possibility that you would like both. However, the waitor may later ask if you would like to see the dessert menu or have the cheque, suggesting that you should chose one or the other.

A large body of research in formal semantics and pragmatics seeks to specify the meaning of *or* and factors that determine its interpreation as inclusive and exclusive. Grice (1975) argued that the core meaning of *or* is inclusive disjunction. The exclusive interpretation is the result of modifying this inclusive meaning by factors external to *or* itself. He suggested that upon hearing "A or B", we may exclude the possibility of both A and B being true simply because we reason that the speaker could have used the connective *and* instead of *or*. Therefore, the exclusive interpretation is the result of this pragmatic reasoning on the speaker's choice of *or* instead of *and* and not part of the meaning of *or* itself. Geurts (2006) argued that in many cases, exclusive interpretations stem from the inconsistent meaning of the options. For example, "to be or not to be" is exclusive simply because one cannot both be and not be! In an experimental study, Pruitt & Roelofsen (2013) showed that in questions, exclusive interpretations are the result of a rise-fall intonation. In short, while the meaning of *or* itself is inclusive, the situation where both options are true may be excluded by pragmatic reasoning, inconsistent options, or a rise-fall intonation.

Research in formal semantics and pragmatics raises a developmental question: how do children learn the meaning of *or* given the ambiguity it can give rise to? To answer this, Morris (2008) investigated instances of *and* and *or* in parents'

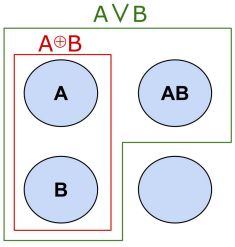

Figure 1: Inclusive disjunction (A$\vee$B) is true in situations where A, B, or both AB are true. Exclusive disjunction (A$\oplus$B) is true in situations where only A or only B is true.

and children's speech. He found that *and* occurs about 3 times every 100 utterances in the speech of parents while *or* occurs only once or twice every 400 utterances. More importantly, children reach the adult level of production for *and* relatively quickly and around the age 3 but their productions of *or* do not reach the adult level in the first five years. He also found that the majority of *or* examples children hear (75-80%) and produce (%90) have an exclusive interpretation. Based on these findings, he concluded that children's acquisition of *or* is slow and they understand its meaning as exclusive before they add the inclusive meaning to their repertoire.

However, experimental studies find that children between the ages 3 to 5 interpret *or* as inclusive disjunction (Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Crain, 2012; Jasbi & Frank, 2016). This is surprising given Morris (2008)'s finding that the majority of *or* examples children hear and produce are exclusive. How do children learn the inclusive meaning of *or* if they rarely hear it? Crain (2012) suggested that children rely on an innate universal principle that disjunction words must not be mapped onto exclusive meanings. In other words, in hearing a connective form, children consider inclusive disjunction (A $\vee$ B) as a viable meaning and not exclusive disjunction (A $\oplus$ B).

Here we present two studies that suggest children can rapidly learn the interpretation of disjunction from the conceptual and prosodic cues that accompany it in child-directed speech. In study 1, we use a large corpus of parent-child interactions to show that both *and* and *or* appear relatively quickly in children's speech and reach the adult rate of production by the age 4. In study 2, we conduct an annotation study to check the interpretation of disjunction as well as conceptual and prosodic cues that accompany it in child-dircted speech. 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 conceptual and prosodic cues. Exclusive interpretations are either conceptually inconsistent or carry a distinct rise-fall intonation. We show that setting aside these cases, the interpretation of a disjunction is most likely inclusive. We build a learning model that uses intonation and conceptual consistency to predict the interpretation of a disjunction with 80% accuracy after training on only 20 examples. These results suggest that children can rely on cues present in child-directed speech to tease apart the exclusive vs. inclusive interpretation of disjunction and map the meaning of *or* accordingly. We discuss the implications of these studies for the theories of word learning in the general discussion.

Study 1: Corpus Study

First, we conducted an exploratory 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.

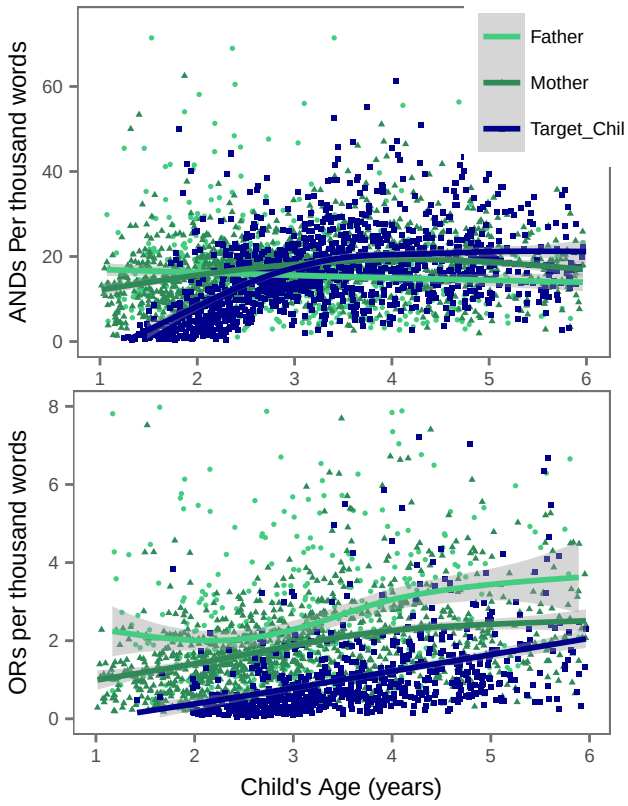

Figure 2: The relative frequency of AND (top) and OR (bottom) per thousand words in the speech of fathers, mothers, and children between the ages of 1 and 6.

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 limited data outside this age range. We computed 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. 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

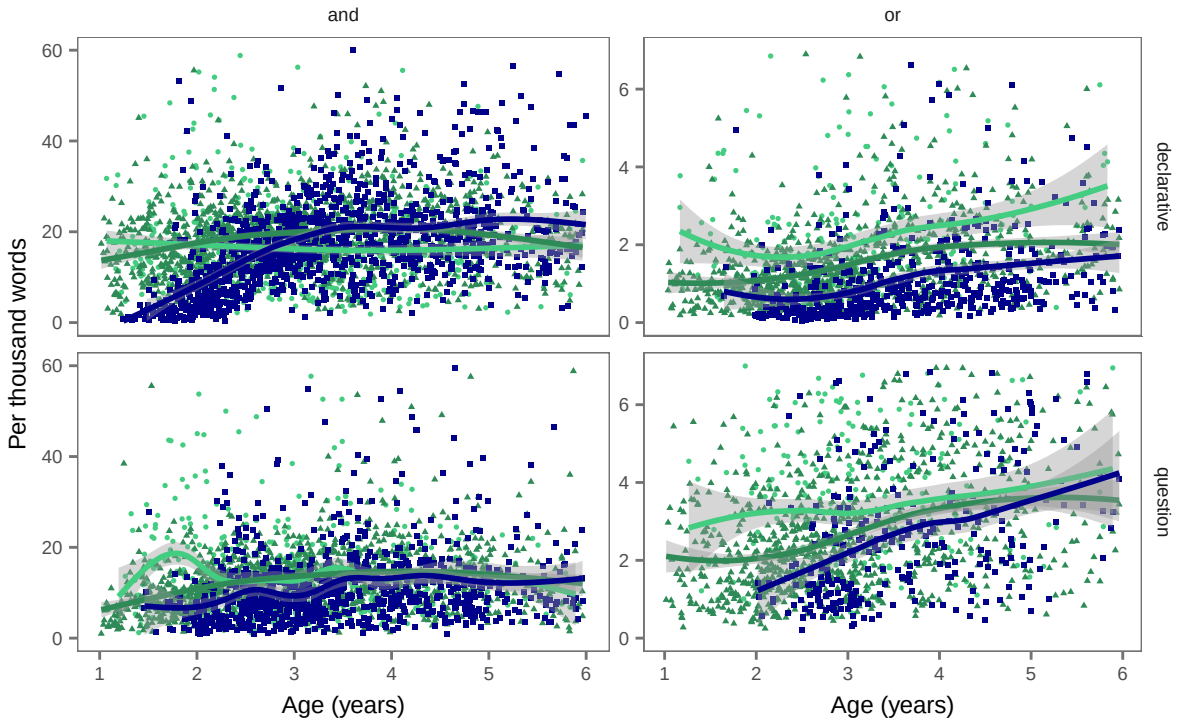

Figure 3: The relative frequency of AND (left) and OR (right) per thousand words in declaratives and questions in the speech of fathers, mothers, and children between the ages of 1 and 6.

function word such as *and*.

And and *or* seem to show different developmental trajectories 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 increase from the age 2 until at least age 6, as it approaches the adult rate. This difference in the development of *and* & *or* production is similar to the developmental trends reported by Morris (2008).

However, the analysis above does not control for other factors that can affect the production of words by children and adults. An important factor to control for is 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 reasonable 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. The results show that for both *and* & *or* children's production rates are not much different from those of adults in declaratives and questions. For both words, we often see a relatively rapid incease in children's productions between the ages of 2 and 4 before reaching a relative plateau between the ages of 4 and 6 either at or close to the parents' rate.

Study 2: Annotation Study

Study 1 showed that even though *or* is not very frequent in child-directed speech, children learn and produce it relatively quickly and reach the adult rate of production around the age 4. In study 2, we conducted an annotation study of *or* productions in child-directed speech. The goal of this study was to discover features of child-directed speech that may support rapid acuisition of *or*'s meaning from infrequent data. We conclude that conceptual and intonational cues that accompany a disjunction in child-directed speech allow for rapid acquisition of its interpretation.

Methods

We accessed the Providence corpus (Demuth, Culbertson, & Alter, 2006) via the phonbank section of the TalkBank system. We extracted all instances of *or* along with the two utterances before and after to provide context using the CLAN software. We annotated the examples for three major categories: 1. Interpretation 2. Intonation and 3. Conceptual con-

sistency. Table 1 shows these categories along with their subcategories and an example for each subcategory. The first category - disjunction interpretation - was our dependent measure. Annotators listened to a disjunction like "A or B" and decided whether the speaker intended to imply "not both A and B" (exlcusive) or "possibly both A and B" (inclusive). For the second category - intontation - annotators listened to the sentence containing disjunction and decided whether the intonation contour on the disjunction is rise-fall, rise, or flat. Table 1 includes examples that are prototypically read aloud with the intonation contour they are subcategorized as.

Finally, for conceptual consistency, annotators decided wether the propositions that make up the disjunction are inconsistent. For example, a disjunctive statement such as "The ball is in my room or your room" denotes two propositions: 1. The ball is in my room 2. The ball is in your room. Regardless of the connective used for these propositions, the propositions themselves refer to inconsistent states of affairs: they cannot be both true at the same time. In such cases, the inclusive meaning is simply not available due to the nature of the propositions themselves and not the interpretation of the connective. 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 "The ball is in my room and your room" is contradictory. The ball cannot be in two positions at the same time. It is important to note here that this is a particularly strict diagnostic. 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 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 consider such unlikely cases as consistent.

Category	Subcategory	Examples
Interpretation	Exclusive	Wanna stay or go?
	Inclusive	Anything to eat or drink?
Intonation	Flat	I'll get tea or coffee.
	Rise	Anything to eat or drink?
	Rise-Fall	Wanna stay or go?
Consistency	Consistent	I'll get tea or coffee.
	Inconsistent	Wanna stay or go?

Table 1: Annotation categories and examples.

Finally, to test inter-rater reliability, the two raters annotated the same 240 utterances. The interrater reliability was calculated over 8 iterations of 30 examples each. Training only completed after 3 consecutive iterations had substantial agreement between the raters (Cohen's $\kappa > 0.7$) for all categories.

Results

First, similar to Morris (2008), we found that the majority of *or* examples in CDS receive an exclusive interpretation ($\sim$%65). Figure 3 shows this difference in distribution. However, the rate of exclusive interpretations change systematically when we break the data down by prosody and consistency (Figure 4). 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 excluisive. When either of these two features are absent, a disjunction is more likely to receive an inclusive interpretation.

A mixed-effects binomial logistic regression using the pakcage {lme4} (Bates, Maechler, Bolker, Walker, & others, 2014) in R with the fixed effects of intonation and consistency, as well as the random effects for children found both intonation and consistency significant in interpreting disjunctions. Disjunctions were more likely to be interpreted as exclusive if they received a rise-fall intonation (β=-3.79, z=1.66, $p < 0.001$) or if they were inconsistent (β=-2.2, z=2.08, $p < 0.001$). Disjunctions were more likely to be interpreted as inclusive if they were consistent and received a rising (β=0.58, z=0.24, $p < 0.001$) or flat intonation (β=0.38, z=0.27, $p < 0.001$).

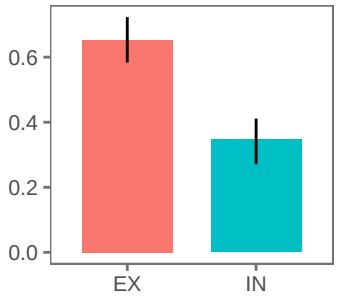

Figure 4: Proportion of exclusive and inclusive interpretations of disjunction in child-directed speech. Error bars represent bootstrapped 95% confidence intervals

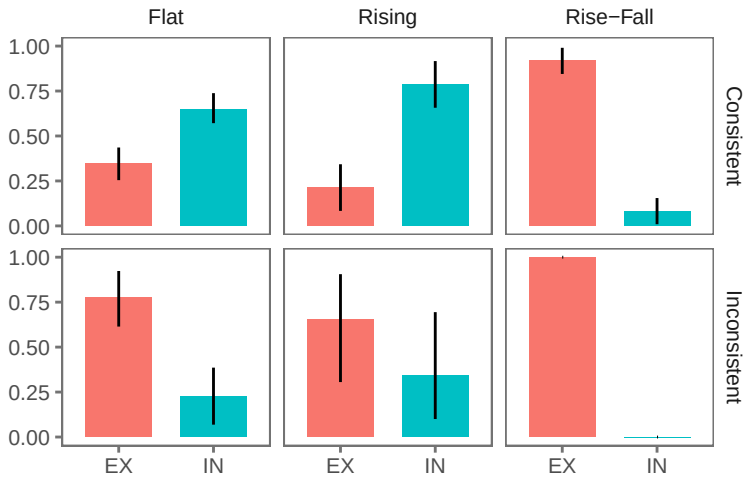

Figure 5: Distribution of exclusive and inclusive interpretations broken down by intonation (flat, rise, rise-fall) and consistency. Error bars represent bootstrapped 95% confidence intervals

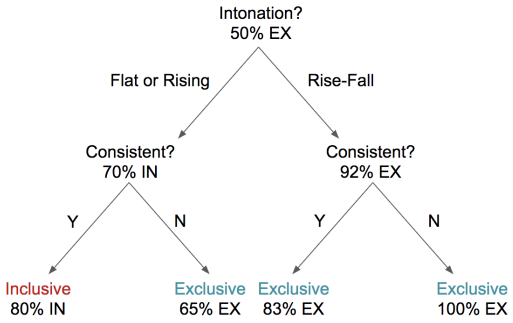

Figure 6: Optimal decision tree training on 200 datapoints. Intonation $>$ 1.5 are rise-fall while intonation $<$ 1.5 are flat or rising. Consistency $>$ 0.5 are consistent while consistency $<$ 0.5 are inconsistent. When *or* has neither rise-fall nor inconsistent disjuncts, it is marked inclusive. Otherwise, exclusive.

Next, using Sci-kit Learn's Decision Tree Module (Pedregosa et al., 2011), we built a predictive model to train on annotated *or* utterances and predict the exclusivity of unseen *or* utterances (annotated for intonation and consistency). Averaged over 100 trials and training on 200 examples, the average accuracy of a binary tree was 83%. More remarkably, the tree achieved an average of 80% accuracy after training on only 20 examples. The success of such a simple tree indicates that children could use a simple model to rapidly learn the exclusive interpretation of *or* from little data.

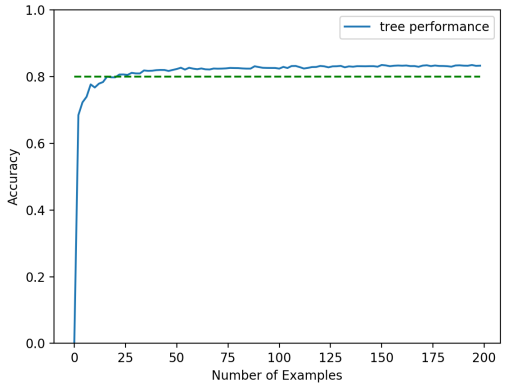

Figure 7: Decision Tree Accuracy as a function of number of examples seen

Summary

In study 2, we confirm Morris (2008)'s finding that exclusive interpretations of *or* are far more common than inclusive interpretations. However, we also show that the majority of these exclusive interpretations coincide with systematic indicators. Disjunctions that are accompanied by rise-fall intonation or inconsistent disjuncts are far more likely to be exclusive. Disjunctions that do no bear these features are more likely to be inclusive. Accounting for these external factors, a simple decision tree can rapidly learn to predict the exclusive interpretation of the disjunction.

Discussion

Studies presented in this paper resolve two puzzles in children's acquisition of disjunction. First, comprehension and production studies provided different accounts for the acquisition of the connectives *and* and *or*. Comprehension studies suggested that children learn the meaning of both *and* and *or* quickly and show an adult-like understanding of them by

the age 4. However, production studies suggested that *and* reaches the adult rate of production quickly and by the age 3 while *or* does not reach the adult level even at age 5. Study 1 showed that when we control for the speech acts that these connectives are most used for, we observe that both *and* and *or* reach the adult rate of production relatively quickly and by the age 4. This way, both comprehension and production studies paint a unified picture in which children's acquisition of *and* and *or* happens relatively quickly and between the ages of 2 and 4.

The second puzzle that this paper addressed was the (apparent) discrepency between what children hear from parents and the knowledge they manifest in comprehension studies. Previous studies showed that the majority of *or* examples children hear receive an exclusive interpretation, yet in comprehension tasks they interpret *or* as inclusive disjunction. Study 2 showed that even though the majority of *or* examples are exclusive, this exclusivity is due to prosodic and conceptual cues that accompany a disjunction and not *or* itself. We showed that when we break down the interpretations of disjunction in child-directed speech by prosody and concpetual consistency, the vast majority of exclusive interpretations are either inconsistent conceptually or accompanied by a distinctive rise-fall intonation. Otherwise, a disjunction that does not bear these cues is more likely to be interpreted as inclusive.

These findings suggest that if children track the interpretive cues that accompany the interpretation of a disjunction, they can tease apart the semantic contribution of *or* from the cues that accompany it. This way children can discover that exclusivity corrleates with rise-fall intonation and inconsistent options, while *or* itself does not exclude both disjuncts being true. We implemented this account in a decision-tree that learned to predict the interpretation of a disjunction with 80% accuracy after only 20 examples. These results suggest that the richness and systematicity of children's linguistic input may allow for rapid interpretation and acquisition of disjunction and obviate the need for an innate universal prinicple that bans mapping the meaning of a connective to exclusive disjunction. Based on the results presented in this paper, *or* in isolation may not be assigned an exclusive meaning simply because such a mapping is not supported by the language children hear.

More broadly, the account presented in this paper informs the theories of form-meaning mapping in general and more specifically theories of function word acquisition. As explained before, form-meaning mapping in child language acquisition is often construed as the task of associating a novel and isolated form such as *gavagai* to a delimited concept such as rabbit and storing it in memory. However, the case of disjunction paints a more complicated picture. For disjunction, it is not enough to isolate the word *or* for mapping and the learner needs to also consider the prosodic contour that accompanies *or*. Furthermore, when mapping the form *or* to its meaning, it is not enough to simply consider the overall interpretation and the learner should take into account the conceptual properties of the accompanying words and phrases. In other words, mapping the form *or* to its meaning involves considering both formal and conceptual context of the mapping.

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