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Lifting conditionals to inquisitive semantics*

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Abstract This paper describes how any theory which assigns propositions to conditional sentences can be lifted to the setting of inquisitive semantics, where antecedents and consequents may be associated with multiple propositions. We show that the lifted account improves on the original account in two ways: first, it leads to a better analysis of disjunctive antecedents, which are treated as introducing multiple assumptions; second, it extends the original account to cover two further classes of conditional constructions, namely, unconditionals and conditional questions.

Keywords: conditionals, inquisitive semantics, disjunctive antecedents, unconditionals, conditional questions

1 Introduction

1.1 Inquisitive semantics

Traditionally, the meaning of a sentence is taken to lie in its truth conditions. In the standard intensional semantics framework (Montague 1973; Gallin 1975), the truth conditions of a sentence are encoded by a set of possible worlds—called a *proposition*—namely, the set of those possible worlds in which the sentence is true.

A more information-oriented perspective on meaning is taken in the framework of *inquisitive semantics* (Ciardelli, Groenendijk & Roelofsen 2013). In inquisitive semantics, the meaning of a sentence is given not by its truth conditions relative to a state of affairs, but in terms of support conditions relative to a state of information. This approach allows us to associate sentences not with a single proposition, but with a set of propositions—those propositions that contain just enough information to support the sentence. These propositions are called the *alternatives* for the sentence.

Many clauses are still associated with a unique proposition; for instance, the clause *Alice sings* is still associated with a unique proposition, consisting of those worlds in which Alice sings. However, some clauses are *inquisitive*, that is, they are

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associated not with a single proposition, but with multiple propositions. The disjunctive clause *Alice sings or dances*, for instance, is associated with two propositions, one consisting of those worlds in which Alice sings, and the other consisting of those worlds where Alice dances. Similarly, the interrogative clause *whether Alice sings* is associated with two propositions, one consisting of those worlds in which Alice sings, and the other consisting of those worlds in which she doesn't.

On the one hand, inquisitive semantics provides a framework in which declarative and interrogative clauses can be given a uniform analysis; on the other hand, by refining the notion of meaning, it also allows for a more fine-grained analysis of the semantics of some operators, such as disjunction. These features have been fruitfully exploited in recent work, both in linguistics (a.o., AnderBois 2012, 2014; Coppock & Brochhagen 2013; Szabolcsi 2015; Roelofsen & Farkas 2015; Theiler, Roelofsen & Aloni 2016), and in logic (a.o., Ciardelli & Roelofsen 2015b; Ciardelli 2016).

1.2 Conditionals

Conditional sentences, both of the indicative type (*if they play Bach, Alice will go*) and of the subjunctive type (*if they had played Bach, Alice would have gone*), are one of the most thoroughly investigated topics in natural language semantics.

Within the standard intensional semantics framework, a multitude of approaches to conditionals has been developed. In many—though not all—of these approaches, a conditional sentence is taken to express a proposition. Without any pretense of exhaustiveness, let me mention a few accounts of this kind: the material account, familiar from classical logic; strict accounts (e.g., Warmbrōd 1981; Gillies 2009); the selection function account (Stalnaker 1968); the variably strict account (Lewis 1973); the restrictor account (Lewis 1975; Kratzer 1986); premise semantics (Kratzer 1981); and causal accounts (Schulz 2011; Kaufmann 2013).[1] All these accounts work under the assumption that the antecedent and the consequent of a conditional express a proposition, and describe how these propositions are used to determine the proposition expressed by the conditional. Thus, these accounts define an operation $\Rightarrow$ which maps two propositions p and q to a conditional proposition $p \Rightarrow q$.

1 This leaves out so-called suppositional accounts (e.g. Adams 1975), dynamic accounts (e.g., Veltman 2005; Starr 2014; Willer 2015) and expressivist accounts (e.g., Yalcin 2007). In these accounts, a conditional sentence is not construed as expressing a proposition; for this reason, the lifting recipe described in this paper is not applicable to them. While the account of Willer (2015) already incorporates ideas from inquisitive semantics, the more general issue of how to integrate these approaches with inquisitive semantics must be left for future work.

1.3 Aim and structure of the paper

Our goal in this paper is to show how any account in which conditionals are taken to express propositions can be lifted to operate in the context of inquisitive semantics, where both the antecedent and the consequent, as well as the conditional as a whole, may be associated with multiple propositions. We will see that whatever account we start with, the lifted account improves on it in three ways. First, disjunctive antecedents, such as the one in (1a), generally receive a more satisfactory treatment in the lifted account. Second, the lifted account allows us to analyze not only standard *if*-conditionals, but also so-called *unconditionals*, such as (1b), which have been argued to belong to the class of conditional sentences (see Zaefferer 1991; Rawlins 2008). Third, the lifted account allows us to analyze in a uniform way not only conditional statements, but also conditional questions, such as (1c).

(1) a. If they play Bach or Handel, Alice will go.
b. Whether or not they play Bach, Alice will go.
c. If they play Bach, will Alice go?

The paper is organized as follows. In Section 2, we give some background about the three empirical domains we just mentioned: disjunctive antecedents, unconditionals, and conditional questions; we discuss previous accounts which are closely related to the ideas explored in this paper, and explain how our proposal generalizes and unifies these accounts. In Section 3, we describe our lifting recipe in the context of a system of propositional inquisitive logic equipped with a conditional operator. In Section 4 we discuss the predictions that our account makes for various classes of conditional sentences. Section 5 discusses the relation between regular conditionals and unconditionals, providing an account of the semantic and pragmatic differences between the two. Section 6 sums up and makes some concluding remarks.

2 Background

2.1 Disjunctive antecedents

Consider the following conditionals. One seems justified in inferring (2b) from (2a), but not in inferring (2c) from (2b).

(2) a. If Alice or Bea invites Charlie, he will go.
b. If Alice invites Charlie, he will go.
c. If Alice invites Charlie and then cancels, he will go.

The inference from (2a) to (2b) is an instance of the principle called *simplification of disjunctive antecedents* (SDA), while the inference from (2b) to (2c) is an instance of the principle called *strengthening of the antecedent* (SA). Using the standard notations $\wedge, \vee$ for conjunction and disjunction, and writing $>$ for the conditional construction, these principles can be written as follows.

$$\frac{A \vee B > C}{A > C}\ (\text{SDA}) \qquad\qquad \frac{A > C}{A \wedge B > C}\ (\text{SA})$$

There is a strong intuition (see, e.g., Nute 1975; Ellis, Jackson & Pargetter 1977; Alonso-Ovalle 2009; Fine 2012; Willer 2015) that SDA is indeed a valid inference pattern: whenever a conclusion follows from a disjunctive antecedent, the same conclusion should follow from each disjunct individually. On the other hand, the inference pattern SA seems generally *in*valid, as witnessed by our example.[2]

These intuitions pose a well-known problem for classical theories of conditionals: as noted by Fine (1975) and further demonstrated by Ellis et al. (1977), the principles SDA and SA are inter-derivable based on a classical treatment of the connectives. Hence, working within the context of classical logic, it seems impossible to obtain a theory of counterfactuals which, as would seem desirable, validates SDA but not SA.

In recent years, this problem has motivated approaches which advocate a more fine-grained account of disjunction. A prominent account of this kind is due to Alonso-Ovalle (2009) (for related accounts, see also van Rooij 2006; Fine 2012). The starting point of Alonso-Ovalle's proposal is a non-standard account of disjunction: rather than mapping two propositions p and q to their union $p \cup q$, disjunction is taken to collect these propositions into a set, delivering $\{p, q\}$. Thus, disjunctive clauses are viewed as denoting not a single proposition, but a set of propositions. Exploiting this feature, disjunctive antecedents can be treated as introducing not a single disjunctive assumption, but rather two distinct assumptions, one for each disjunct. For the conditional to be true, the consequent must follow on each assumption. In this way, we obtain an account of conditionals that validates SDA, without validating SA.

As we will see, the our lifting preserves the fundamental idea of Alonso-Ovalle's account, namely, that disjunctive antecedent introduce multiple distinct assumption.

2 Apparent counterexamples to SDA have been pointed out in the literature. However, these examples all have a special form, with the consequent coinciding with one of the disjuncts in the antecedent. The most famous example is from McKay & Van Inwagen (1977): *If Spain had fought with the axis or the allies in WWII, she would have fought with the axis.* On the standard theory of counterfactuals (Lewis 1973), the apparent truth of this sentence would be explained by saying that worlds where Spain fought with the axis are more similar to the actual world than worlds where Spain fought with the allies. If so, however, we would expect that the following counterfactual is also true: *If Spain had fought with the axis or the allies in WWII, Hitler would have been pleased.* As Nute (1980) notes, this seems wrong: in this case, we interpret this conditional as claiming that Hitler would have been pleased if Spain fought with the allies, in accordance with SDA. This problem, together with the fact that alleged counterexamples all have a special form, suggests that these counterexamples involve some kind of anomaly. In Footnote 10, we will see that these cases can be accommodated in our account under the assumption that an additional operator is inserted to repair this anomaly.

However, this idea is implemented slightly differently in our proposal than in Alonso-Ovalle's. In our approach, disjunction is not treated as a special connective; rather, all connectives are taken to operate on inquisitive meanings, rather than on truth conditions. This allows us to retain a logically well-behaved theory of propositional connectives (Roelofsen 2013), avoiding some thorny issues that arise in the theory underlying Alonso-Ovalle's account (see Ciardelli & Roelofsen 2015a).

Moreover, our proposal generalizes Alonso-Ovalle's idea in two different ways. First, Alonso-Ovalle's account is based on a specific account of conditionals, namely, the minimal change semantics of Lewis (1973). By contrast, our inquisitive lifting can be applied to an arbitrary account of conditionals, so long as this accounts associates conditional sentences with propositions. This seems especially important in view of recent challenges for minimal change semantics: in particular, Champollion, Ciardelli & Zhang (2016) provide empirical evidence which is incompatible with minimal change semantics, regardless of the issue of disjunctive antecedents, and regardless of what is taken to count as a minimal change. Importantly, our lifting allows us to disentangle the problem dealing with conditional antecedents from the problem of determining the right procedure for making counterfactual assumptions.

Second, we will derive our account of disjunctive antecedents as a special case of a more general account of the interaction between conditionals and inquisitive constructions—an interaction which occurs not just in conditionals with disjunctive antecedents, but in other conditional sentences as well.

2.2 Unconditionals

Another class of sentences where the interaction between conditionals and inquisitiveness is manifested are *unconditionals*. These are sentences such as the following.

(3) a. Whether they play Bach or not, Alice will go.
b. Whether they play Bach or Handel, Alice will go.
c. Whatever music they play, Alice will go.

Unconditionals are tightly related to ordinary conditionals. For instance, it seems that (3a) can be rendered as "Alice will go if they play Bach, and also if they don't". The relation existing between unconditionals and conditionals is brought out most clearly in the account of Rawlins (2008), which treats unconditionals as a particular conditional construction. Syntactically, what is special about unconditionals is that their "antecedent" is an interrogative clause. Following standard theories of questions (in particular, Hamblin 1973), Rawlins assumes that the semantic value of an interrogative is not a proposition, but a set of propositions. Each of these propositions is then treated as providing a different restrictor for a (possibly silent) modal present in the main clause of the unconditional. The unconditional is true in case the main clause is true under each of these restrictors.

While they are concerned with different empirical domains, Rawlins's account and Alonso-Ovalle's share the same core idea, namely, that conditional antecedents can sometimes contribute multiple assumptions. As we will see, the lifting proposed in this paper allows us to deal with disjunctive antecedents and interrogative antecedents in a uniform way. This is based on the fact that, in the inquisitive setting, there is a semantic affinity between disjunctive clauses and interrogative clauses: both are inquisitive expressions, which are associated with multiple propositions. Thus, unconditionals and conditionals with disjunctive antecedents can be viewed as two cases of conditionals with inquisitive antecedents, and they can be analyzed in terms of a general pattern of interaction between conditionals and inquisitiveness.

Furthermore, our account allows us to generalize the main idea underlying Rawlins's account, disentangling it from the specific account of conditionals it builds on, and making it compatible with a broad range of accounts.

2.3 Conditional questions

A third class of conditional sentences in which the interaction between conditionals and inquisitiveness is manifested are conditional questions, such as the following.

(4) a. If they play Bach, will Alice go?
b. If Alice goes, will they play Bach or Handel?
c. If they had played Bach, would Alice have gone?
d. If Alice had gone, would they have played Bach or Handel?

In spite of the huge literature on conditionals, conditional questions have not received much attention. Existing accounts (Velissaratou 2000; Isaacs & Rawlins 2008; Groenendijk 2009) only deal with indicative conditional questions like (4a) and (4b), and not with counterfactual questions (4c) and (4d).[3] By contrast, our lifting can be combined with an account of counterfactuals to obtain an analysis of (4c) and (4d). Moreover, our approach does not commit us to a specific theory of conditionals, but makes it possible to analyze conditional questions on the basis of one's favorite theory, provided this theory associates conditional sentences with propositions. In other words, we provide an account of conditional questions which is modular with respect to the underlying theory of conditionals.

3 A strategy to deal with counterfactual conditional questions in dynamic semantics is outlined in Isaacs & Rawlins (2008), but not pursued in detail.

3 Lifting conditionals

In this section we show how a theory which assigns propositions to conditional statements can be lifted to the setting of inquisitive semantics—where the antecedent and the consequent of a conditional may be inquisitive. To spell out the proposal more perspicuously, we will implement our account in a formal system of propositional inquisitive logic enriched with a conditional operator. We start in Section 3.1 by introducing the language of this logic and the models used to interpret it; in Section 3.2 we give the semantics of the system, including the semantics of the conditional operator in our inquisitive setting; finally, in Section 3.3 we describe how conditional sentences of English are supposed to be translated to our formal language.

3.1 Language and models

The language of our logic consists of sentences that are built up from a set $\mathscr{P}$ of atomic sentences by means of conjunction ($\wedge$), disjunction ($\vee$), negation ($\neg$), and a conditional operator ($>$). Thus, sentences are defined recursively as follows:

$$\varphi \ ::= \ p \mid \bot \mid \varphi \wedge \varphi \mid \varphi \vee \varphi \mid \neg\varphi \mid \varphi > \varphi$$

A model for our language is a structure $M = \langle W, V, \Rightarrow \rangle$ consisting of three items:

i. A set W, the elements of which are referred to as *possible worlds*. Subsets $s \subseteq W$ are called *propositions* or *information states*.[4,5]

ii. A valuation function $V : W \times \mathscr{P} \to \{0,1\}$ which specifies, for any world w and atomic sentence p, whether p is true at w ($V(w,p) = 1$) or false ($V(w,p) = 0$).

iii. A binary operation $\Rightarrow$, which maps two propositions a and b to a proposition $a \Rightarrow b$. This operation encodes the account of conditionals that we generalize.

As we mentioned in the introduction, many existing accounts of conditionals provide an operation $\Rightarrow$ of the kind needed for our lifting. In each of these accounts, this operation is defined in terms of some more fundamental piece of structure. For instance, the account of Lewis (1973) assumes a notion of relative similarity between

4 Even though propositions and information states are both modeled as sets of possible worlds, we think of them in a different way: we view a proposition as encoding a single piece of information, and an information state as encoding a body of information.

5 The use of sets of worlds to represent information is rooted in the work of Hintikka (1962) and Stalnaker (1978), and quite common in logic and formal semantics. The fundamental idea is that a piece, or body, of information may be modeled as the set of worlds compatible with this information.

worlds, i.e., a map which assigns to each world w a partial order $\leq_w$ of the set W, satisfying some conditions. In terms of this notion, the map $\Rightarrow$ is defined as follows:[6]

$$a \Rightarrow b \;:=\; \{w \in W \mid \text{ any } \leq_w \text{-minimal element in } a \text{ is also in } b\}$$

Similarly, e.g., the premise semantics of Kratzer (1981) defines $\Rightarrow$ in terms of premise sets, while the causal account of Kaufmann (2013) defines it in terms of a causal graph and causal laws. However, our lifting recipe only needs access to the operation $\Rightarrow$ itself, not to the specific structure in terms of which it was defined. This allows us to abstract away from the details of a specific theory of conditionals.

3.2 Semantics

As usual in inquisitive semantics, sentences are interpreted in terms of a relation of support relative to an information state. Formally, an information state is modeled as a set of possible worlds, namely, those worlds that are compatible with the information available in the state. The support clauses for atomic sentences and for the connectives $\wedge, \vee, \neg$ are the following ones (see Ciardelli & Roelofsen 2011):[7]

- $s \models p \iff V(w,p) = 1$ for all $w \in s$
- $s \models \varphi \wedge \psi \iff s \models \varphi$ and $s \models \psi$
- $s \models \varphi \vee \psi \iff s \models \varphi$ or $s \models \psi$
- $s \models \neg\varphi \iff s \cap t = \emptyset$ for all $t \models \varphi$

In words, an atomic sentence p is supported in s iff the information available in s implies that p is true. A conjunction is supported iff both conjuncts are supported. A disjunction is supported iff either disjunct is supported. Finally, a negation $\neg\varphi$ is supported in s iff s is not compatible with any information state that supports φ.

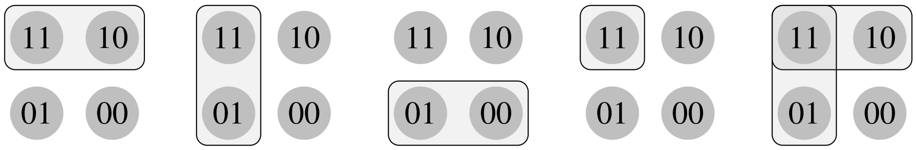
We say that a sentence φ is *true* at a world w, notation $w \models \varphi$, in case φ is supported at the singleton state $\{w\}$. It is then easy to verify that the truth-conditional behavior of all the propositional connectives is in accordance with classical logic. The set of worlds at which φ is true is called the *truth-set* of φ, and denoted $|\varphi|$.

An *alternative* for φ is defined as a maximal information state supporting φ; thus, the alternatives for φ are those information states that contain just as much information as needed to support φ. The set of alternatives for φ is denoted $\mathsf{alt}(\varphi)$.

$$\mathsf{alt}(\varphi) = \{s \subseteq W \mid s \models \varphi \text{ and there is no } t \supset s \text{ such that } t \models \varphi\}$$

6 Lewis's general definition is slightly more complicated, to be applicable to cases in which there are no closest worlds in a given proposition. Here, we only give the simpler clause as an illustration.

7 These clauses are obtained by transferring to the inquisitive setting the classical analysis of connectives as algebraic operators in the space of meanings. For discussion of this point, see Roelofsen (2013).



(a) p (b) q (c) $\neg p$ (d) $p \wedge q$ (e) $p \vee q$

Figure 1 The alternatives for some sentences. 11 stands for a world where p and q are both true, 10 for a world where p is true and q is false, and so on.

In our system, we have the following connection between the truth-set of a sentence and its alternatives: φ is true at a world w iff w belongs to some alternative for φ.

Fact 1. $|\varphi| = \{ w \in W \,|\, w \in s \text{ for some } s \in \mathsf{alt}(\varphi) \}$

We say that a sentence φ is *inquisitive* if it has two or more alternatives, and *non-inquisitive* if it has only one. It follows from Fact 1 that, in case φ is non-inquisitive, its unique alternative must be precisely the truth-set $|\varphi|$.

Fact 2. *If φ is non-inquisitive,* $\mathsf{alt}(\varphi) = \{|\varphi|\}$

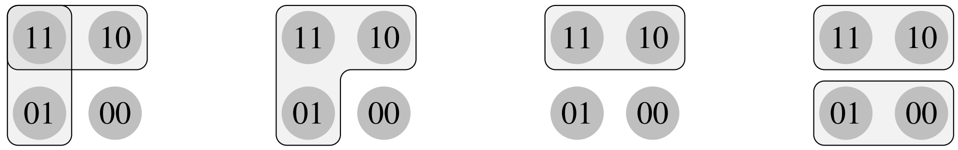
Thus, if φ is non-inquisitive, then just like in standard truth-conditional semantics, φ is associated with a unique proposition, consisting of those worlds where φ is true.

Many sentences of our language are indeed non-inquisitive: in particular, any $\vee$-free sentence is non-inquisitive. Therefore, sentences like $p, q, \neg p$, and $p \wedge q$ receive essentially the same treatment in our system as in classical intensional semantics. This is illustrated by the figures 1(a)–1(d). By contrast, sentences involving $\vee$ are typically inquisitive. For instance, Figure 2(a) shows that, in a model where p and q are logically independent (that is, no necessary relations hold between them), the disjunction $p \vee q$ has two distinct alternatives, namely, the sets $|p|$ and $|q|$.

Having all these notions in place, we are now ready to complete the definition of our semantics by giving the support clause that governs the conditional operator. This clause is the core of the proposal, since it is this clause that tells us how to use the operation $\Rightarrow$ to interpret conditionals in the inquisitive setting, where both antecedent and consequent may be inquisitive. The clause is the following:

- $s \models \varphi > \psi \iff \forall a \in \mathsf{alt}(\varphi)\ \exists b \in \mathsf{alt}(\psi)$ such that $s \subseteq a \Rightarrow b$

The intuition is that in order to support $\varphi > \psi$, a state needs to contain information that implies, for every alternative for the antecedent, that if that alternative were to



(a) $p \vee q$ (b) $!(p \vee q)$ (c) p (d) $?p$

Figure 2 An illustration of the effects of the projections operators '!' and '?'.

obtain, then some corresponding alternative for the consequent would obtain.

We will see this clause in action on a number of examples in Section 4. However, before coming to this illustration, we will describe how various conditional sentences in English are supposed to be translated to our propositional logic. In this way, in Section 4 we will be able to link the mathematical workings of our lifting operation to specific empirical predictions about the meaning of English conditional sentences.

3.3 Translating natural language sentences

In translating natural language sentences to our logic, we will make use of two derived operators, denoted by '!' and '?'. These operators are defined as follows:

$$!\varphi := \neg\neg\varphi \qquad\qquad ?\varphi := \varphi \vee \neg\varphi$$

The operator '!' makes a sentence non-inquisitive, collapsing the alternatives for the sentence into one. The operator '?' has the effect of adding to the alternatives for the formula a new alternative, consisting of those worlds where the formula is false. This is illustrated in Figure 2.

Now, English sentences will be formalized according to the following rules:[8]

i. the conditional and the unconditional construction translate to $>$;

ii. conjunctions, disjunctions, and negations translate to $\wedge, \vee$, and $\neg$;

iii. the translation of a declarative main clause is headed by the operator '!';

iv. the polar interrogative construction is rendered by the sequence '?!'.

8 Of course, this is only a rough sketch of a proper inquisitive Montague grammar, which cannot be described in detail here. Work in this direction is currently in progress. The architecture of the system and a sketch of a fragment are given in Ciardelli, Roelofsen & Theiler (2016).

Below, we display the translations of a number of conditional English sentences, where p translates the clause *they play Bach*, q translates *they play Handel*, and r translates *Alice goes*. In the following, we assume that p, q, and r are independent from one another in our model, that is, we assume that no necessary relations hold between them. For convenience, we drop the operator '!' from our translations whenever it is semantically vacuous: thus, for instance, (4a) should be translated as $p > !r$ according to our rules, but we simplify the translation to $p > r$.[9]

(5)
a. If they play Bach, Alice will go. $p > r$
b. If they play Bach or Handel, Alice will go. $p \vee q > r$
c. Whether they play Bach or not, Alice will go. $?p > r$
d. Whether they play Bach or Handel, Alice will go. $p \vee q > r$
e. If they play Bach, will Alice go? $p > ?r$
f. If Alice goes, will they play Bach or Handel? $r > p \vee q$

4 Predictions

Let us now use sentences (5a)–(5f) to illustrate the predictions that our lifted account of conditionals makes. First, consider a plain conditional statement like (5a). Given that $\mathsf{alt}(p) = \{|p|\}$ and $\mathsf{alt}(r) = \{|r|\}$, we have:

$$\begin{aligned} s \models p > r \quad &\iff \quad \forall a \in \{|p|\}\ \exists b \in \{|r|\} \text{ such that } s \subseteq a \Rightarrow b \\ &\iff \quad s \subseteq |p| \Rightarrow |r| \end{aligned}$$

This means that the unique maximal supporting state for (5a), the unique alternative, is precisely the proposition $|p| \Rightarrow |r|$. In symbols, we have $\mathsf{alt}(p > r) = \{|p| \Rightarrow |r|\}$. Thus, (5a) is non-inquisitive; it is associated with a unique proposition, which is precisely the proposition that our base account delivers when it is applied to the propositions associated with the antecedent and with the consequent. This illustrates a more general fact: as long as our antecedent and consequent are non-inquisitive, our lifted account completely coincides with the given base account. It is only on inquisitive clauses that our inquisitive lifting makes a real difference.

As a first case of interaction between conditionals and inquisitiveness, consider (5b), translated as $p \vee q > r$. Now, the consequent is non-inquisitive, but the antecedent is inquisitive: $\mathsf{alt}(p \vee q) = \{|p|, |q|\}$, and $\mathsf{alt}(r) = \{|r|\}$. Our clause gives:

$$\begin{aligned} s \models p \vee q > r \quad &\iff \quad \forall a \in \{|p|, |q|\}\ \exists b \in \{|r|\} \text{ such that } s \subseteq a \Rightarrow b \\ &\iff \quad s \subseteq |p| \Rightarrow |r| \text{ and } s \subseteq |q| \Rightarrow |r| \\ &\iff \quad s \subseteq (|p| \Rightarrow |r|) \cap (|q| \Rightarrow |r|) \end{aligned}$$

9 The translation given here will be refined in Section 5 to take into account the presuppositions connected with unconditional sentences.

Again, the conditional as a whole has a single alternative, namely, the proposition $(|p| \Rightarrow |r|) \cap (|q| \Rightarrow |r|)$. However, this alternative is not, in general, the same proposition $|p \vee q| \Rightarrow |r|$ that would be delivered by applying the base account to the disjunctive antecedent as a whole. Rather, the base account is applied twice, once for each alternative for the antecedent, and the resulting propositions are then intersected. Thus, the main idea of Alonso-Ovalle (2009) is preserved in our account: disjunctive antecedents are interpreted as providing multiple assumptions. In fact, it is easy to see that (5b) is predicted to be equivalent with the conjunction in (6), and that, therefore, simplifying the antecedent in (5b) is indeed a valid inference.[10]

(6) Alice will go if they play Bach, and she will go if they play Handel.
$(p > r) \wedge (q > r)$

On the other hand, if our base account does not validate the principle SA of antecedent strengthening, our lifted account will not validate it either. In this way, we can tease apart SDA and SA, and avoid the problem faced by purely truth-conditional theories.

Now consider the unconditional in (5c), translated as $?p > r$. Once more, the antecedent is inquisitive, while the consequent is not: $\mathsf{alt}(?p) = \{|p|, |\neg p|\}$, $\mathsf{alt}(r) = \{|r|\}$. Our support clause gives a result which is similar to the previous one:

$$\begin{aligned} s \models\, ?p > r \quad &\iff \quad \forall a \in \{|p|, |\neg p|\}\ \exists b \in \{|r|\} \text{ such that } s \subseteq a \Rightarrow b \\ &\iff \quad s \subseteq |p| \Rightarrow |r| \text{ and } s \subseteq |\neg p| \Rightarrow |r| \\ &\iff \quad s \subseteq (|p| \Rightarrow |r|) \cap (|\neg p| \Rightarrow |r|) \end{aligned}$$

Thus, (5c) has a unique alternative, i.e., the proposition $(|p| \Rightarrow |r|) \cap (|\neg p| \Rightarrow |r|)$. Quite intuitively, (5c) is analyzed as being true in case the conclusion that Alice will go follows both under the assumption that they will play Bach, and under the assumption that they won't. Indeed, it is easy to see that (5c) is equivalent with (7):

(7) Alice will go if they play Bach, and she will go if they don't.
$(p > r) \wedge (\neg p > r)$

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10 The counterexamples to SDA mentioned in Footnote 2 could be explained by stipulating that it is sometimes possible to insert a projection operator '!' in the antecedent. Thus, the counterfactual (i) *If Spain had fought with either the axis or the allies, it would have fought with the axis* would be translated as $!(p \vee q) > p$, and analyzed as a basic conditional with non-inquisitive antecedent. However, the possibility to insert '!' should be restricted to account for the apparent lack of ambiguity of ordinary conditionals like (5b). One possibility is to notice that, under very minimal assumptions, the form $p \vee q > p$ is equivalent to $q > p$. Assuming a general ban against structural redundancy, of the kind proposed, e.g., by Katzir & Singh (2013), this would make the logical form $p \vee q > p$ unavailable for a conditional such as (i), justifying the addition of an extra '!' as a repair strategy. This explanation would account for why SDA only seems to fail in sentences where the consequent coincides with one of the disjuncts in the antecedent, or is contextually equivalent to it.

Thus, our semantics provides a uniform account of disjunctive antecedents and interrogative antecedents as introducing multiple assumptions, and it provides an explanation for this commonality based on a feature shared by disjunctive and interrogative clauses: inquisitiveness. However, while our account reflects the fundamental similarity between disjunctive and interrogative antecedents, it does not yet reflect the subtle difference between them. In particular, note that (5d) is given exactly the same translation as (5b). Capturing the semantic difference between (5b) and (5d), and explaining their different pragmatics, is the topic of the next section.

Finally, let us turn to the third class of conditionals involving inquisitiveness, namely, conditional questions. Consider (5e). Now, the antecedent is not inquisitive, while the consequent is: $\mathsf{alt}(p) = \{|p|\}$, $\mathsf{alt}(?r) = \{|r|, |\neg r|\}$. Our clause gives:

$$\begin{aligned} s \models p > ?r \quad &\iff \quad \forall a \in \{|p|\}\ \exists b \in \{|r|, |\neg r|\} \text{ such that } s \subseteq a \Rightarrow b \\ &\iff \quad s \subseteq |p| \Rightarrow |r| \text{ or } s \subseteq |p| \Rightarrow |\neg r| \end{aligned}$$

In this case, our conditional is inquisitive: $\mathsf{alt}(p > ?r) = \{|p| \Rightarrow |r|, |p| \Rightarrow |\neg r|\}$. Since $|p| \Rightarrow |r| = |p > r|$ and $|p| \Rightarrow |\neg r| = |p > \neg r|$, we can also write the result as $\mathsf{alt}(p > ?r) = \{|p > r|, |p > \neg r|\}$. This captures the fact that, in order to resolve (5e), it is necessary and sufficient to establish either one of the following conditionals:

(8) a. If they play Bach, Alice will go. $p > r$
b. If they play Bach, Alice won't go. $p > \neg r$

Similarly, the question (5f), translated as $r > p \vee q$, is predicted to have two distinct alternatives, $|r > p|$ and $|r > q|$, which correspond to the two conditional statements *If Alice goes, they will play Bach* and *If Alice goes, they will play Handel*.

Thus, our lifted account can deal in a uniform way with conditional statements and conditional questions. This is not restricted to *indicative* conditional questions: if the account that is being lifted is an account of counterfactuals, our clause also allows us to interpret counterfactual questions. Also, notice that we do not wrongly predict (5f) to be equivalent with *If Alice goes, they will play Bach or Handel*; this is because, according to our translation rule (iii), the latter is rendered as $r > !(p \vee q)$.

To sum up, then, we have seen that our lifted account coincides with the original account on the analysis of plain conditionals that involve no inquisitiveness. At the same time, it provides a more satisfactory analysis of disjunctive antecedents, which are analyzed as introducing multiple assumptions, thereby validating SDA. Moreover, the lifted account extends the base account in two directions, dealing not only with conditional statements, but also with *un*conditional statements on the one hand, and with conditional *questions* on the other.

5 Conditionals and unconditionals

5.1 Unconditionals and their presuppositions

Consider again the sentences (5b) and (5d), repeated as (9a) and (9b). In the previous section, these two sentences were translated by the same formula, namely, $p \vee q > r$.

(9) a. If they play Bach or Handel, Alice will go.
b. Whether they play Bach or Handel, Alice will go.

In a sense, this is correct, since (9a) and (9b) seem to have the same truth conditions: both are true in case Alice will go if they play Bach, and also if they play Handel. Yet, intuitively there is also a difference between these sentences, which is not reflected by our translation. In this section, we refine our account to capture this difference.

The idea that we will pursue, which was defended already by Zaefferer (1991), is that the difference between (9a) and (9b) lies in what these sentences presuppose: the unconditional in (9b) presupposes that they will play either Bach or Handel, whereas the conditional in (9a) lacks this presupposition. A merit of our analysis is that this difference between *if*-conditionals and unconditionals does not have to be stipulated, but can be derived from two independent observations about the presupposition of interrogatives, and the way presuppositions project from conditional antecedents.

i. Interrogative clauses presuppose that one of their alternatives is true. (see, e.g., Belnap 1966)

ii. Conditionals inherit the presuppositions of their antecedent. (see, e.g., Karttunen 1973, 1974)

Since, like Rawlins (2008), we view unconditionals as conditional sentences with an interrogative clause as their antecedent, it follows from (i) and (ii) that unconditionals always presuppose that one of the alternatives for their antecedent is true.

5.2 Formalizing presuppositions

Let us now sketch how our formal system can be extended with presuppositions so that the difference between (9a) and (9b) is formally captured. First, we enrich our syntax with an operator $(\cdot)_{\langle \cdot \rangle}$ that allows us to mark a sentence as presupposing another: intuitively, a formula $\varphi_{\langle \psi \rangle}$ has the same semantics as φ, but it presupposes ψ. Second, we expand our support definition with a clause for the new operator.

- $s \models \varphi_{\langle \psi \rangle} \iff s \models \varphi$

Next, to each formula we recursively associate a set of presuppositions. The precise way of doing this is immaterial to what we will say below, as long as $\varphi_{\langle\psi\rangle}$ presupposes ψ, and conditionals inherit the presuppositions of their antecedents. For concreteness, we give here some specific clauses, inspired by Karttunen (1974); we use the notation $\varphi \to \psi$ as an abbreviation for the material conditional $\neg(\varphi \wedge \neg\psi)$.[11]

- $\pi(p) = \pi(\bot) = \emptyset$
- $\pi(\neg\varphi) = \pi(\varphi)$
- $\pi(\varphi_{\langle\psi\rangle}) = \pi(\varphi) \cup \pi(\psi) \cup \{\psi\}$
- $\pi(\varphi \wedge \psi) = \pi(\varphi) \cup \{\varphi \to \chi \mid \chi \in \pi(\psi)\}$
- $\pi(\varphi \vee \psi) = \pi(\varphi) \cup \{\neg\varphi \to \chi \mid \chi \in \pi(\psi)\}$
- $\pi(\varphi > \psi) = \pi(\varphi) \cup \{\varphi > \chi \mid \chi \in \pi(\psi)\}$

We will say that an information state s *properly supports* a sentence φ in case $s \models \varphi$, and $s \models \chi$ for all $\chi \in \pi(\varphi)$. Finally, we edit our translation rules to make sure that interrogative clauses are always associated with a presupposition that one of their alternatives holds. Recall that if φ is an inquisitive sentence of our language, then $!\varphi$ is a non-inquisitive sentence which has as its unique alternative the proposition that some alternative for φ is true. Hence, if the issue raised by an interrogative is expressed by φ, then the corresponding presupposition is captured by the formula $!\varphi$. Thus, we supplement our translation rules (i)–(iv) above with the following rule, ensuring that interrogatives are associated with an exhaustiveness presupposition:

v. interrogative clauses are always translated to formulas of the form $\varphi_{\langle !\varphi\rangle}$.

This rule is illustrated in the translation of the following two interrogative clauses.

(10) a. Whether they play Bach or not $\quad (p \vee \neg p)_{\langle !(p\vee\neg p)\rangle}$
b. Whether they play Bach or Handel $\quad (p \vee q)_{\langle !(p\vee q)\rangle}$

Now consider again (9a) and (9b), repeated below as (11a) and (11b). Given our refinement, these sentences are no longer assigned the same translation. We have:

(11) a. If they play Bach or Handel, Alice will go. $\quad p \vee q > r$
b. Whether they play Bach or Handel, Alice will go. $\quad (p \vee q)_{!(p\vee q)} > r$

11 A better choice here is to take $\to$ to be the inquisitive implication operator (Ciardelli & Roelofsen 2011), which generalizes material implication to questions in a more principled and meaningful way. Since we will not deal with sentences that presuppose questions, we will not worry about this.

It is easy to see that our sentences are still equivalent in their support conditions, and thus, they are also equivalent in terms of truth conditions. However, they are assigned different presuppositions: $\pi(p \vee q > r) = \emptyset$, while $\pi((p \vee q)_{!(p \vee q)} > r) = \{!(p \vee q)\}$. Notice that the presupposition $!(p \vee q)$ is precisely the translation of (12):

(12) They will play either Bach or Handel.

Thus, our revised account reflects both the similarity and the difference between the *if*-conditional (11a) and the unconditional (11b): the two are true in the same circumstances, but (11b), unlike (11a), presupposes that one of the alternatives for the antecedent obtains. This converges with the conclusion of Zaefferer (1991):

> Although intuitively the difference between conditionals and unconditionals seems to be striking [. . .], it lies only in the acceptability conditions of its utterance, not in [. . .] truth-conditions [. . .]

5.3 Division of labor between *if*-conditionals and unconditionals

Zaefferer also notes that there is a certain division of labor between an unconditional and the corresponding regular conditional, i.e., a regular conditional having the same alternatives for the antecedent. Depending on whether or not these alternatives cover the context set of the conversation, one or the other of these forms should be used.

> So the rule is: if the antecedent of a c[onditional] proposition exhausts the [. . .] background at the current state of the discourse, then it is an unconditional, if not it is a regular conditional. In each case it should be encoded accordingly, if the language allows for distinct encoding. (Zaefferer 1991: p. 233)

We can read this passage as postulating the following pragmatic rule for choosing whether to use an regular conditional form or a competing unconditional form.

Zaefferer's rule: if the alternatives for the antecedent cover the context set of the dscourse, use the unconditional form; otherwise, use the regular conditional form.

The existence of such a rule is supported by examples such as (13) and (14). In the case of (13), the alternatives for the antecedent cover the context set, and the regular conditional form sounds odd. In the case of (14), taken from Zaefferer (1991), the first sentence in the discourse indicates that the alternatives for the antecedent of the second sentence do not cover the context set, and the unconditional form is odd.

(13) a. Whether the baby is a boy or a girl, they will be a happy family.
b. ??If the baby is a boy or a girl, they will be a happy family.

(14) a. If you take the plane to Antwerp, the trip will take 3 hours; if you take the car or go by train, it will take ten hours.
b. ??If you take the plane to Antwerp, the trip will take 3 hours; whether you take the car or go by train, it will take ten hours.

In this section, we show that this specific rule can be explained based on general pragmatic principles in terms of the semantic difference existing between *if*-conditionals and unconditionals. For the sake of concreteness, we will consider the choice between two particular sentences, (9a) and (9b), repeated below as (15a) and (15b).

(15) a. If they play Bach or Handel, Alice will go.
b. Whether they play Bach or Handel, Alice will go.

We need to explain the following requirements for a speaker S in a context c.[12]

i. if it is not established in c that they will play either Bach or Handel, S is required to choose (9a) over (9b);

ii. if it is established in c that they will play either Bach or Handel, S is required to choose (9b) over (9a).

Requirement (i) can be explained in terms of a general ban against uttering sentences whose presuppositions are not supported by the discourse context. In our setting, this can be formulated as follows.

Satisfy presupposition (after Karttunen 1974)
Only utter a sentence φ in a context c provided $c \models \chi$ for all $\chi \in \pi(\varphi)$.[13]

Now, the unconditional (15b) is associated with a presupposition that they will play either Bach or Handel. If this is not established in the context c, then c does not support all the presuppositions of (15b). Therefore, an utterance of (15b) would violate *satisfy presupposition*. This makes (15b) infelicitous in the given context, which explains why the speaker is required to use (15a) instead.

Requirement (ii) can be explained based on a general principle that requires speakers to choose sentences that presuppose more over contextually equivalent

12 For simplicity, here we will identify the context c with the corresponding *context set*, i.e., the set of worlds compatible with the common ground of the exchange. Thus, here c is an information state. We say that something is established in c if it is true at every world in c.

13 As Karttunen himself remarked, this principle is too strong: speakers can felicitously utter sentences that have presuppositions which are not supported by the context at the time of utterance, provided these presuppositions can be accommodated easily and uncontroversially by the interlocutors upon hearing the sentence (see Karttunen 1974; von Fintel 2008). Strictly, Zaefferer's rule would also have to be modified to take accommodation into account: a speaker may felicitously use an unconditional whose antecedent alternatives do not cover the context set, if the fact that one of these alternatives is true can easily be accommodated. For simplicity, here we set aside the issue of accommodation.

sentences that presuppose less. Let us say that φ and ψ are equivalent in a context c, notation $\varphi \equiv_c \psi$, in case they are supported by the same subsets of c: $\varphi \equiv_c \psi \iff \forall s \subseteq c : (s \models \varphi \iff s \models \psi)$. Then, this principle can be formulated as follows.

Maximize presupposition (after Heim 1991; Sauerland 2008)
Suppose two sentences φ and ψ are in competition with each other. If $\varphi \equiv_c \psi$, $\pi(\varphi) \subset \pi(\psi)$, and $c \models \chi$ for all $\chi \in \pi(\psi)$, then in context c, choose ψ over φ.

Assuming that the forms in (15a) and (15b) are competitors, we reason as follows. These sentences are supported by the same states, so they are equivalent in any context. Moreover, we have π(15a) $= \emptyset$ and π(15b) $= \{!(p \vee q)\}$, so π(15a) $\subset$ π(15b). If it is established in c that they will play either Bach or Handel, then c supports all the presuppositions of (15b). Thus, the conditions to apply *maximize presupposition* are met, and the speaker is required to choose (15b) over (15a).

Thus, based on our account of the semantic difference between unconditionals and regular conditionals, Zaefferer's rule follows from general pragmatic principles.

Interestingly, this rule can in turn be used to explain the oddness of conditionals like (16a) in terms of competition with the corresponding unconditionals.

(16) a. #If they play Bach or they don't, Alice will go. $(p \vee \neg p) > r$
b. Whether they play Bach or not, Alice will go. $(p \vee \neg p)_{\langle !(p \vee \neg p)\rangle} > r$

The only presupposition of (16b), $!(p \vee \neg p)$, is a tautology—i.e., it is supported by any information state whatsoever. Thus, in any context, *maximize presupposition* requires a speaker to select (16b) over (16a). As a consequence, (16a) is not felicitous in any context. This, we suggest, is responsible for the oddness of this sentence.[14]

6 Conclusion

By moving from a purely truth-conditional semantics to inquisitive semantics, we obtain a more general view on conditional constructions which on the one hand solves the long-standing problem of disjunctive antecedents, and on the other hand encompasses not only conditional statements, but also unconditionals and conditional questions. All these constructions have something in common: they involve multiple alternatives. We have suggested that conditionals interact with alternatives according to a $\forall\exists$ pattern, where $\forall$ ranges over the alternatives for the antecedent, and $\exists$ over the alternatives for the consequent. Interestingly, we saw that several important features of the semantics of conditional expressions depend only on this pattern, and can be analyzed quite independently of a specific theory of the process of making assumptions and assessing their consequences.

14 Violations of *maximize presupposition* are known for resulting in odd sentences, such as #*Alice broke some nose of hers* or #*Alice missed a train, and then she missed a train* (see Sauerland 2008).

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