Expressing ignorance or indifference
Modal implicatures in Bi-directional OT

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Abstract. The article presents a formal analysis in the framework of bi-directional optimality theory of the free choice, ignorance and indifference implicatures conveyed by the use of indefinite expressions or disjunctions. Ignorance is expressed by standard means of epistemic logic. To express indifference we use Groenendijk and Stokhof's question meanings. To derive implicature, Grice's conversational maxims, and an additional principle expressing preferences for minimal models, are formulated as violable constraints used to select optimal candidates out of a set of alternative sentence-context pairs. The implicatures of an utterance of ϕ are then defined as the sentences which are entailed by any optimal context for ϕ (but not by ϕ itself). Entailment is defined in a version of update semantics where contextual updates are derived by competition among contexts. Free choice and other modal implicatures of disjunctions and indefinites will follow, but also scalar implicatures and exhaustification.

Key words: free choice indefinites, disjunction, implicatures, bi-directional optimality theory.

1 Modal implications of indefinites and disjunction

The article proposes a formal analysis of the ignorance, indifference and free choice effects conveyed by the use of disjunctions or indefinite pronouns. As an illustration consider the German prefixed indefiniteness marker *irgend* in examples (1) from Haspelmath, (2) from Kratzer and Shimoyama (2002) and (3) from Kratzer (2005):[1]

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[1] For ignorance effects see also, for example, the *to*-series in Russian (Haspelmath, 1997), for indifference and free choice readings the Italian *uno qualsiasi* (Chierchia, 2004).

(1) a. *Irgend jemand* hat angerufen. (# – Wer war es?)
'Someone (I don't know/care who) has called. (# – Who was it?)'
b. Jemand hat angerufen. (– Wer war es?)
'Someone has called. (– Who was it?)'

(2) Mary musste *irgendeinen* Mann heiraten.
'Mary had to marry irgend-one man'.
a. There is some man Mary had to marry, the speaker doesn't know or care who it was. (ignorance or indifference)
b. Mary had to marry a man, any man was a permitted marriage option for her. (free choice)

(3) *Irgendein* Kind kann sprechen.
'Irgend-one child can talk'.
a. Some particular child is able/allowed to talk - the speaker doesn't know or care about which one. (ignorance or indifference)
b. Some child or other is permitted to talk - any child is a permitted option. (free choice)

In (1), by using *irgend*, the speaker conveys that she doesn't know or care about who called. So it is odd for the hearer to ask who it was. Examples (2) and (3) are ambiguous between a specific reading (2-3a), conveying an ignorance or indifference meaning, and a non-specific reading (2-3b), conveying a free choice effect.

Disjunction gives rise to similar effects as shown in the following examples:

(4) a. Ron is a movie star or a politician. (ignorance or indifference)
b. Have you ever kissed a Russian or an American? (indifference)

(5) Ron must go to Tbilisi or Batumi.
a. The speaker doesn't know which of the two. (ignorance)
b. Ron may go to Tbilisi and may go to Batumi. (free choice)

(6) Ron may go to Tbilisi or Batumi.
a. The speaker doesn't know which of the two. (ignorance)
b. Ron may go to Tbilisi and may go to Batumi. (free choice)

Following Kratzer and Shimoyama (2002), Schulz (2004) and Alonso-Ovalle (2005), I assume that ignorance, indifference and free choice effects are not part of the meaning of the *irgend*-indefinites or disjunction, rather they have the status of an implicature. An indication that this is indeed so comes from the fact that these effects disappear in the scope of downward entailing contexts (cf. Gazdar 1979):

(7) a. Ron isn't a movie star or a politician.
b. Niemand musste *irgend jemand* einladen.
'Noone had to invite anyone'

If modal effects were part of the meaning of the sentence, (7a) could be true in a situation where Ron is a movie star or a politician and the speaker knows or cares about which of the two. And (7b) 'could be true in a situation where people had to invite a particular person, hence weren't given any options. This is clearly not so.' [Kratzer and Shimoyama (2002), p.14]

Ignorance implicatures have received a lot of attention in the literature (e.g. Gazdar 1979, Sauerland 2004). Free choice effects have also been largely discussed (e.g. Kratzer and Shimoyama 2002 and Schulz 2004). None of these approaches, however, is completely satisfactory. The problematic case is the one illustrated in (3b) and (6b), involving the free choice interpretation of an indefinite or a disjunction in the scope of a possibility operator. While free choice inferences of necessity statements (examples (2b) and (5b)) can be easily explained, free choice inference of possibility statements always require *ad hoc* solutions (cf. Fox 2006 for a recent overview). One of the goals of this article is to explain the behavior of indefinites or disjunction under possibility by standard Gricean pragmatics without *ad hoc* moves. On my proposal, Gricean reasonings will be recasted in the formal framework of bidirectional optimality theory. The advantage of such formalization is that it gives us a perspicuous account, for each implicature, of the principles and the complexity of the reasoning required for its derivation. Grice's conversational maxims, and an additional principle expressing preferences for minimal models (cf. Schulz and van Rooij 2004, 2006), are formulated as violable constraints used to select optimal candidates out of a set of alternative sentence-context pairs. The implicatures of an utterance of ϕ are then defined as the sentences which are entailed by any optimal context for ϕ (but not by ϕ itself). Scalar implicatures and exhaustivity inferences (cf. Spector, 2003) will follow, but also the modal implicatures of indefinites and disjunctions including the somehow non standard indifference implicatures.

The rest of the article is structured as follows. The next section reviews a number of previous analyses and motivates the present account. Section 3 presents a BiOT analysis of implicatures. Section 4 shows how ignorance, indifference and free choice implicatures follow from such an analysis, but also scalar implicatures and exhaustification. Section 5 draws conclusions and describes some further lines of research.

2 Modal implications as conversational implicatures

Conversational implicatures are inferences which arise from interplay of basic semantic content and general principles of social interaction. The key ideas about implicatures have been proposed by Grice who identified four of such principles.

(8) QUANTITY (i) Make your contribution as informative as is required for the current purposes of the exchange; (ii) Do not make your contribution more informative than is required.
QUALITY Make your contribution one that is true.
MANNER Be brief and orderly.
RELATION Be relevant.

In what follows we will see whether modal implications of indefinites and disjunctions, in particular when they occur under a possibility operator, can be derived from the assumption that speakers satisfy these maxims.

In the present analysis, ignorance and indifference implications follow from the following intuitive reasoning where the first QUANTITY submaxim plays a crucial role. For ease of exposition we restrict ourselves to the case of disjunction (existential sentences can be seen as generalized disjunctions).

(9) a. The speaker S said 'A or B', rather than the more informative 'A'. Why?
  b. Suppose 'A' were relevant to the current purposes of the exchange, and S had the information that A. Then S should have said so. [QUANTITY]
  c. Therefore,
    (i) Either 'A' is irrelevant; (indifference)
    (ii) Or S has no evidence that 'A' holds. (ignorance)
  d. Parallel reasoning for 'B'.

Indifference readings of 'A or B' arise in situations where it doesn't matter which of the two disjuncts hold. In case it matters, ignorance readings arise. The speaker knows that 'A or B' is true but has no evidence that 'A' holds or 'B' holds. Therefore, both options are epistemically possible.

Free choice effects of necessity statements follow by the same reasoning under the assumption that the speaker is maximally informed about the specific modality involved (cf. Zimmermann 2001).

(10) a. S said '□(A or B)', rather than the more informative '□A'. Why?
  b. Suppose '□A' were relevant to the current purposes of the exchange, and S had the information that □A. Then S should have said so.
  c. Therefore,
    (i) Either '□A' is irrelevant; (indifference)
    (ii) Or S has no evidence that '□A' holds. (ignorance)
  d. Parallel reasoning for '□B'.

If both '□A' and '□B' are relevant, we can conclude that the speaker does not know □A and does not know □B. Under the assumption that the speaker is *maximally informed* we can conclude that '$\Box A$' and '$\Box B$' are both false. This fact, in combination with the original sentence, implies the free choice implication '$\Diamond A$ and $\Diamond B$'.

In what follows, I will formalize these Gricean reasonings in the framework of bi-directional optimality theory. The main motivation for assuming such a framework concerns the free choice implications of possibility statements as in the following example.

(11) John may go to Tbilisi or Batumi. ⇒ John may go to Tbilisi and John may go to Batumi.

We would like to derive from $\Diamond(A \vee B)$ the conjunction $\Diamond A \wedge \Diamond B$. It is easy to see, however, that if we apply the reasoning illustrated above, assuming as alternatives to $\Diamond(A \vee B)$ the natural candidates $\Diamond A$ and $\Diamond B$, we do not obtain the desired free choice effects.

(12) a. $\Diamond(A \vee B)$ (sentence)
b. $\Diamond A$, $\Diamond B$ (alternatives)
c. # $\neg\Diamond A$, $\neg\Diamond B$ (quantity implicature)

A different, but less natural choice of alternatives would give us better results. Schulz (2004) and Aloni & van Rooij (2004), for example, assume the following compositionally defined set of syntactic alternatives for a given sentence:

(13) a. $\text{Alt}(A \vee B) = \{A, B\}$ closed under Boolean operators
b. $\text{Alt}(\Box\phi) = \{\Box\psi \mid \psi \in \text{Alt}(\phi)\}$
c. $\text{Alt}(\Diamond\phi) = \{\Box\psi \mid \psi \in \text{Alt}(\phi)\}$

The behavior of disjunction under possibility is then captured as follows, where, roughly, quantity implicatures are obtained by negating the alternatives of the sentence.

(14) a. $\Diamond(A \vee B)$ (sentence)
b. $\Box A$, $\Box B$, $\Box\neg A$, $\Box\neg B$ (alternatives)
c. $\Diamond\neg A$, $\Diamond\neg B$, $\Diamond A$, $\Diamond B$ (quantity implicature)

Note, however, that this analysis requires for $\Diamond$ an *ad hoc* move (necessity statements as alternatives, rather than possibility ones), which is hard to justify.

Another interesting option are the 'exhaustive' alternatives that Kratzer and Shimoyama (2002) seem to assume (see Chierchia, 2004 for an explicit proposal). Let us first have a look at the intuitive reasoning behind Kratzer and Shimoyama's account (henceforth K&S). Speaker said $\Diamond(A \vee B)$, rather than $\Diamond A$. Why? The reason cannot be that speaker had no evidence for $\Diamond A$ (this is exactly what we want to derive, that speaker *had* evidence for $\Diamond A$). As alternative reason, K&S propose what they call the *avoidance of a false exhaustivity inference*. If speaker had said $\Diamond A$, by exhaustivity inference I would have concluded $\neg\Diamond B$. If speaker had said $\Diamond B$, by exhaustivity inference I would have concluded $\neg\Diamond A$. Since speaker did not use the shorter alternative forms, I can conclude that speaker did hold both A and B as possible.

Chierchia (2004) in his formalization of K&S reasoning assumes as alternative for modal disjunctions the following 'exhaustive' sentences:

(15) a. $\text{Alt}(\Box(A \vee B)) = \{\Box A \wedge \neg\Box B, \Box B \wedge \neg\Box A\}$
b. $\text{Alt}(\Diamond(A \vee B)) = \{\Diamond A \wedge \neg\Diamond B, \Diamond B \wedge \neg\Diamond A\}$

As the following shows this choice of alternatives gives us the right results for the possibility case, where again implicatures are obtained by negating stronger alternatives:

(16) a. $\Diamond(A \vee B)$ (sentence)
b. $\Diamond A \wedge \neg\Diamond B,\ \Diamond B \wedge \neg\Diamond A$ (alternatives)
c. $\Diamond A \rightarrow \Diamond B,\ \Diamond B \rightarrow \Diamond A$ (implicatures)
d. $\Diamond A$ and $\Diamond B$ (follows from a and c)

But first of all, these 'exhaustive' alternatives cannot be defined compositionally, so it remains somehow unexplained, where they originate. Secondly, this proposal does not generalize to the case of plain disjunction. If $\text{Alt}(A \vee B) = \{A \wedge \neg B, B \wedge \neg A\}$, then $A \vee B$ would implicate $A \wedge B$.[2] Furthermore, once we assume stronger 'exhaustive' alternatives which are then negated for Gricean reasons, it is hard to explain why 'exaclty 3' (3 and not 4 or 5,...) should not count as alternative to '3', or exclusive 'or' should not count as alternative to inclusive 'or'. The question that arises for this proposal is why exhaustive alternatives should play a role in the free choice case, but not in the scalar one.

My analysis of free choice implicature incorporates many important insights from Schulz (2004) and Aloni and van Rooij (2004). On the other hand, it can also be seen as a formalization of K&S anti-exhaustivity reasoning. It differs from K&S and Chierchia's accounts, however, in many essential aspects. For example, K&S and Chierchia's derivations only work for those examples where the indefinite or disjunction occurs under a modal. To account for free choice or ignorance implicatures of episodic sentences, like $A \vee B$, they need to assume the presence of a covert modal operator. My account, like Schulz (2004) and Aloni and van Rooij (2004), solves this problem by being explicit about the epistemic nature of the implicatures involved. Implicatures will have a modal nature (usually of the form 'speaker believes/doesn't believe...'), the original sentences do not need to.

The most important aspect of my proposal, however, is that contrary to all previous analyses of free choice implicatures, no notion of an alternative for a given sentence needs to be defined. Rather, as usual in optimality theory, each sentence will be taken to compete with every other sentence in the language. The set of *relevant* alternatives for a particular sentence will be automatically 'selected' by the constraints. In particular, for $\Diamond(A \vee B)$, the natural alternative forms $\Diamond A$ and $\Diamond B$ will play an essential role, and not the 'exhaustive' forms $\Diamond A \wedge \neg\Diamond B$ and $\Diamond B \wedge \neg\Diamond A$. The latter alternatives will be ruled out by my manner constraint that will also be responsible for ruling out 'exactly n' as alternative for 'n'. The reason why the alternatives $\Diamond A$ and $\Diamond B$ will be good enough to derive free choice reading is that, in my formalization, they automatically obtain an exhaustive interpretation. Exhaustive interpretations are indeed selected by the minimal model principle, unless they are ruled out (blocked) by the existence of a better alternative form. This is precisely what happens for $\Diamond(A \vee B)$. It doesn't

[2] Chierchia would partially disagree with this criticism. According to him, 'exhaustive' alternatives do also play a role in existential episodic sentences and are used to account for universal readings of free choice items in subtrigged constructions like *John kissed any women with a red cup.* His analysis, however, presupposes an essential difference between implicatures of existential sentences and disjunctions, the latter indeed never receives such universal interpretation. In my analysis instead implicatures of disjunction and existential sentences will be explained by the same mechanism. As for the universal meaning of subtrigged sentences, somewhere else (see Aloni, 2006) I have proposed an alternative account that also uses exhaustification, but not at the sentential level, to create sets of mutually exclusive propositions, but at the DP level to create maximal sets of individuals.

obtain an exhaustive interpretation (e.g. only A is possible) because such content could have been expressed by another form (e.g. $\Diamond A$) in a more perspicuous way. Here is the intuitive reasoning involved in the case of disjunction under possibility, according to my solution:

(17) a. Speaker said $\Diamond(A \vee B)$
b. Could it be that A is not possible? No, otherwise the speaker would have used $\Diamond B$;
c. Could it be that B is not possible? No, otherwise the speaker would have used $\Diamond A$.
d. Therefore, we can conclude that A is possible and that B is possible.

This kind of reasoning involving competition and blocking between different forms for different contents, has been perspicuously formalized in the framework of bi-directional optimality theory (henceforth BiOT).

3 Conversational implicature in BiOT

In optimality theory (Prince and Smolensky, 1993/2004), ranked constraints are used to select a set of optimal candidates from a larger set of candidates. In the present analysis, the constraints are the Gricean maxims (appropriately formulated) and the minimal model principle. The competing candidates will be form-content pairs, but interpreted in a way that departs from previous work on OT semantics (Hendriks and de Hoop, 2001, Blutner, 2000): the form component will be identified with a sentence or better its logical form (determining its semantic interpretation); whereas the content part will be a context (determining the pragmatic interpretation of the sentence). Intuitively, if a sentence-context pair (ϕ, C) is optimal, a speaker in C can use ϕ with a minimal violation of the constraints.

Optimal pairs are defined by Blutner and Jäger's notion of weak optimality (see Blutner, 2000):

(18) A candidate $\langle$FORM, CONTENT$\rangle$ is *weakly optimal* iff there are no other better *weakly optimal* pairs $\langle$FORM$'$, CONTENT$\rangle$ or $\langle$FORM, CONTENT$'\rangle$.

As standard in OT, a candidate α is at least as good as α' iff α's constraint violations are no more severe than α''s, where single violations of a higher ranked constraint override in severity multiple violations of lower ranked constraints. In the following subsections I give a precise definition of the competing candidates and of the adopted constraints.

3.1 Sentences and contexts

Let W be a set of worlds and V a valuation function which assigns in each world a truth value to each propositional letter. Then a context C is a pair $\langle Q, s\rangle$ where Q is an issue (an equivalence relation over W) and s is a state (a subset of W). States represent what the speaker believes. Issues represent what the speaker cares about (cf. Groenendijk, 1999). For example, a speaker in $\langle W, W^2 \rangle$ knows and cares about nothing, a speaker in $\langle W, \{(w,v) \in W^2 \mid w = v\} \rangle$ knows nothing and cares about everything, and finally a speaker in $\langle \{w\}, W^2 \rangle$ knows everything and cares about nothing. Intuitively, if two worlds are related by Q, then their differences are irrelevant to the speaker. So indifference wrt p can be represented by an equivalence relation connecting p-worlds with not p-worlds.

We will say that a context $\langle Q, s \rangle$ entails $\heartsuit?\phi$ to be read as 'I care whether ϕ' iff Q entails $?\phi$ according to the standard Groenendijk and Stokhof's notion of entailment between questions (see Groenendijk and Stokhof, 1984); and, as standard in update semantics, a context $\langle Q, s \rangle$ entails $\Diamond/\Box\phi$, to be read epistemically, iff s is consistent with/entails ϕ (see Veltman, 1996). Here are more detailed definitions of these notions in terms of an update semantics. The language under consideration is that of modal propositional logic with the addition of the sentential operator '$\heartsuit?$'.

Definition 1. [Updates]

- $C[p] = C'$ iff $s_{C'} = \{w \in s_C \mid V(p)(w) = 1\}$ & $Q_{C'} = Q_C$
- $C[\neg\phi] = C'$ iff $s_{C'} = s_C \setminus s_{C[\phi]}$ & $Q_{C'} = Q_C$
- $C[\phi \wedge \psi] = C[\phi][\psi]$
- $C[\Box\phi] = \begin{cases} C & \text{if } C[\phi] = C \\ \langle \emptyset, Q_C \rangle & \text{otherwise} \end{cases}$
- $C[\heartsuit?\phi] = \begin{cases} C & \text{if } C[?\phi] = C \\ \langle \emptyset, Q_C \rangle & \text{otherwise} \end{cases}$

where $C[?\phi] = C'$ iff $s_{C'} = s_C$ & $Q_{C'} = \{(w,v) \in Q_C \mid \langle \{w\}, Q_C \rangle[\phi] = \langle \{w\}, Q_C \rangle$ iff $\langle \{v\}, Q_C \rangle[\phi] = \langle \{w\}, Q_C \rangle\}$

Disjunction, implication and possibility are defined as standard in terms of conjunctions, negation and necessity. Entailment is defined as follows.

Definition 2. [Entailment] $C \models \phi$ iff $C[\phi] = C$

All clauses in definition 1 are standard in update semantics, except that for $\heartsuit?\phi$. Sentence $\heartsuit?\phi$ is, like $\Box\phi$, a test returning either the original context (if updating with $?\phi$ does not bring anything new) or the absurd state (otherwise). An update with $?\phi$ can only modify the issue parameter. In most cases the output issue is the intersection between the input issue and the partition assigned to $?\phi$ by Groenendijk and Stokhof's standard theory of questions. So, for example, $[?\phi] = [?\neg\phi]$, and, therefore, $\heartsuit?\phi$ iff $\heartsuit?\neg\phi$. The only difference with the standard partition theory concerns the epistemic cases $?\Box/\Diamond\phi$. On the present account, $[?\phi] = [?\Box/\Diamond\phi]$. Therefore, we obtain that whenever $\heartsuit?\phi$ holds $\heartsuit?\Box/\Diamond\phi$ holds as well. Finally note that $\heartsuit?$ can be iterated, but its iteration yields a tautology. $\heartsuit?\heartsuit?\phi$ is true in any context. The intuition is that disregarding whether you care or not whether ϕ, you always care whether you care whether ϕ.

3.2 Ranked Constraints

Gricean Constraints On the present account, Grice's maxims are formulated as properties of sentence-context pairs $\langle \phi, C \rangle$, and are ordered, according to their relative degree of violability:

(19) Quality, Relation > Manner > Quantity

Quantity formalizes only the first submaxim of Grice's original principle. The second submaxim is covered by Relation.

Definition 3. [Gricean Constraints]

Quality: $C \models \Box\phi$
Relation: $C \models \heartsuit?\phi$
Manner: Avoid sentential operators (negations and modals).
Quantity: If $\phi \models \psi$ and $\psi \not\models \phi$, then $\phi \prec \psi$.

For a candidate $\langle \phi, C \rangle$, Quality holds iff the context C entails the sentence ϕ; Relation holds iff C entails $?\phi$.

Manner penalizes negative or modal candidates. This formalization of Grice's maxim is somehow stipulative. The empirical motivation is to block unwelcome alternatives like (i) $A \wedge \neg B$ for A, (ii) $(A \vee B) \wedge \neg(A \wedge B)$ for $(A \vee B)$, and (iii) $\Diamond A \wedge \Diamond B$ for $\Diamond(A \vee B)$, without blocking, for example, $\neg(A \vee B)$ for $\neg A$ or $\neg B$.

Quantity expresses a preference for stronger sentences, where strength is defined in terms of entailment. It assigns gradient violations (cf. the Nuclear Harmony Constraint of Prince and Smolensky 1993/2004, section 2.2.): $\alpha \prec \beta$ means that α incurs a lesser violation than β.[3]

The minimal model principle At the level of information processing, language comprehension can be thought as construction of an internal model for a piece of discourse. These models contain representations of the individuals mentioned in the discourse, their properties and relations. Two standard assumptions in AI are that (i) world knowledge plays a role in the constructions of these models, and (ii) these models are **minimal** in the following sense: they are constructed by making only those sentences true which have to be true (cf. closed-world reasoning largely used in planning, and McCarthy's predicate circumscription).

The idea that I am trying to formalize here is that implicatures are entailments of internal representations of possible speaker's states i.e. sets of these internal models. The minimality assumption (ii) will be used to explain the classical scalar implicatures and exhaustivity inferences (see Schulz and van Rooij 2004, 2006 for similar accounts)

(20) Ron is a movie star or a politician. $\Rightarrow$ not both (scalar implicature)

[3] This formulation has been suggested to me by an anonymous reviewer who is gratefully acknowledged.

(21) Q: Who signed the petition? A: Ann ⇒ nobody else (exhaustification)

Assumption (i) that world knowledge plays a role in the constructions of these internal states could be used as a starting point to explain the so called I-implicatures (or R-implicatures in Horn, 1984).

(22) a. John had a drink. ⇒ John had an alcoholic drink. (I-implicatures)
b. John has a secretary. ⇒ John has a female secretary.
c. John was able to solve the problem. ⇒ John solved the problem.

If language comprehension is obtained via construction of internal representations, it seems natural to assume that in processing these sentences people would more easily come up with models where a stereotypical interpretation obtains rather than a non-stereotypical one.

To formalize the minimality constraint, I will define an ordering $\leq_Q$ between worlds with respect to an issue Q (cf. Schulz and van Rooij 2006):

Definition 4. [Minimal worlds] $v \leq_Q v'$ iff $\forall p$ s.t. $Q \models ?p: \ v \models p \ \Rightarrow \ v' \models p$

Minimal worlds are worlds which satisfy the least number of relevant atomic sentences. As an illustration, let us assume A and B as the unique two atoms under consideration. We are considering then only four worlds: $w_\emptyset, w_A, w_B, w_{AB}$, where each world is indexed with the atomic propositions holding in it. Suppose A and B are both relevant wrt Q. Then $\leq_Q$ would determine the following ordering:

$$w_\emptyset \leq_Q w_A,\ w_B \leq_Q w_{AB}$$

In terms of $\leq_Q$ I define now an ordering between states and contexts (note that here my definitions are different from those in Schulz and van Rooij 2006).

Definition 5.

1. $s \leq_Q s'$ iff $\forall v \in s : \exists v' \in s' : v \leq_Q v'$
2. $C \leq C'$ iff $Q_C = Q_{C'}$ & $s_C \leq_{Q_C} s_{C'}$
3. $C < C'$ iff $C \leq C'$ & $C' \not\leq C$

States are ordered wrt the relevant atoms they hold as possible. Again, assuming that A and B are the unique atoms under discussion and that they are both relevant with respect to Q, then $\leq_Q$ orders the possible states as follows, where $\{w_\emptyset\}$ is the minimal state, and any set containing w_{AB} is maximal.

$$\begin{array}{llll} \{w_\emptyset\} < & \{w_A\} & < \{w_A, w_B\} & < \{w_{AB}\} \\ & \{w_\emptyset, w_A\} & \{w_\emptyset, w_A, w_B\} & \{w_\emptyset, w_{AB}\} \\ & \{w_B\} & & \ldots \\ & \{w_\emptyset, w_B\} & & \end{array}$$

Contexts with the same issue are ordered wrt the minimality of their states. Contexts with different issues are incomparable.

The minimal model principle expresses a preference for minimal contexts. Like quantity, it assigns gradient violations. If $C < C'$, then C incurs a lesser violation than C'.

Definition 6. [Minimal model principle] If $C < C'$, then $C \prec C'$.

For reasons that will become clear, the minimal model principle is taken as the lowest constraint:

(23) QUALITY, RELATION > MANNER > QUANTITY > MINIMAL MODELS

To sum up, we have presented five constraints formalized as properties of sentence-context pairs. The Gricean constraints can be thought as speaker's constraints, in particular manner and quantity that determine an ordering between possible forms. The minimal model principle, instead, which compares alternative states is typically a hearer constraint. Interestingly the latter is taken to be the lowest principle. These constraints select for each sentence ϕ a set of optimal contexts. The implicatures of ϕ can then be defined as what must hold in all these optimal contexts.

Implicatures Let $opt(\phi)$ be the set of contexts C such that (ϕ, C) is optimal. The implicatures of ϕ are defined as follows.

Definition 7. [Implicatures] ϕ implicates ψ, $\phi \approx\!\!\!\!| \ \psi$ iff $\forall C : C \in opt(\phi)$: $C \models \psi$ & $\phi \not\models \psi$

To my knowledge, the idea of defining implicatures in terms of entailment of contexts has been introduced by Schulz (2004), and then has been used in a number of papers by Schulz and van Rooij. It is reminiscent of treatments of presuppositions. For example, in the standard satisfaction theory, the presupposition of ϕ is defined as what is entailed in any context in which ϕ can be felicitously uttered. On the present account, however, the two issues of deriving implicatures from context and of determining the felicitous contexts for an utterance are treated as independent. The defended OT analysis only accounts for the former.

4 Applications

4.1 Exhaustivity inferences

The first result we will present concerns the exhaustification of positive answers. Let A and B be different atomic sentences. Then we predict that A implicates not B, if B is relevant.

(24) $A \approx\!\!\!\!| \ \heartsuit ?B \rightarrow \neg B$

This result captures the obvious fact that exhaustivity implicatures depend on the question under discussion which determines what are the relevant alternatives. Consider the answer 'Anna signed the petition' as a reply to the following two questions. Only in the first case the answer receives an exhaustive interpretation.

(25) Q: Who signed the petition? A: Anna ⇒ not Bill

Q′: Did Ann sign the petition? A: Yes $\not\approx$ not Bill

To illustrate how (24) obtains, let us assume again that A and B are the unique atoms under consideration, and so $w_\emptyset, w_A, w_B, w_{AB}$ the unique worlds. By $[w, w', ...]$, I will denote the state consisting of the worlds w, w',....

If B is relevant, then $[w_A]$ is the only optimal state for A. Any other stronger form true in $[w_A]$, notably $A \wedge \neg B$, is ruled out by manner. Any other state satisfying A is ruled out either by MMP, which requires states to be minimal (e.g. $[w_A, w_{AB}]$); or by quantity, if there is a stronger optimal sentence holding in the state (e.g. $A \wedge B$ in $[w_{AB}]$).[4]

Consider now the case in which B is irrelevant. In this case any state entailing A is optimal for the sentence: state $[w_A]$, but also states $[w_A, w_{AB}]$, and $[w_{AB}]$. State $[w_A, w_{AB}]$ is optimal because being B irrelevant it does not play a role in ordering the states for MMP. State $[w_{AB}]$ because it cannot be ruled out by the irrelevant $(A \wedge B)$. Therefore, in this case, no conclusion can be drawn about the truth value of B.

The previous discussion is illustrated by the following tableau. By $\mathbf{Q}_{(?\phi)?\psi}$ I denote the partition expressed by (the conjunction of $?\phi$ and) $?\psi$. As usual in OT, '⇒' indicates an optimal candidate, '!*' a crucial constraint violation.

		QUAL, REL	MAN	QUAN	MMP
	A - $\langle \mathbf{Q}_{?B}, [w_A] \rangle$	!*		*	
	A - $\langle \mathbf{Q}_{?A}, [w_B] \rangle$	!*		*	
⇒	A - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$			*	*
	$(A \wedge \neg B)$ - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$		!*		*
	A - $\langle \mathbf{Q}_{?A?B}, [w_A, w_{AB}] \rangle$			*	!***
	A - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$			!*	***
⇒	$(A \wedge B)$ - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$				***
⇒	A - $\langle \mathbf{Q}_{?A}, [w_A] \rangle$			*	*
⇒	A - $(\mathbf{Q}_{?A}, [w_A, w_{AB}] \rangle$			*	*
⇒	A - $\langle \mathbf{Q}_{?A}, [w_{AB}] \rangle$			*	*
	$(A \wedge B)$ - $\langle \mathbf{Q}_{?A}, [w_{AB}] \rangle$	!*			*

We turn now to the case of a negative sentence $\neg A$. Let us just consider the case in which both A and B are relevant. Interestingly, no exhaustive implicature arise in this case.

(26) $\neg A \not\approx_{?A?B} \Diamond B \wedge \Diamond \neg B$

Assuming that both A and B are relevant, the only optimal state for $\neg A$ is $[w_\emptyset, w_B]$. The alternative states $[w_B]$ and $[w_\emptyset]$ are blocked by the optimal forms B and $\neg(A \vee B)$ respectively. The former form is preferred by manner, the latter by quantity.

[4] Sentence $A \wedge B$ does not violate manner, because it does not involve negation. Note, however, that this is not essential for the final result. If $A \wedge B$ had violated manner, $[w_{AB}]$ would have been ruled out for A by MMP, rather than by quantity.

		QUAL, REL	MAN	QUAN	MMP
⇒	$\neg A$ - $\langle \mathbf{Q}_{?A?B}, [w_B, w_\emptyset] \rangle$		*	*	*
	$\neg A$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset] \rangle$		*	!*	
⇒	$\neg(A \vee B)$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset] \rangle$		*		
	$\neg A$ - $\langle \mathbf{Q}_{?A?B}, [w_B] \rangle$		!*	*	*
⇒	B - $\langle \mathbf{Q}_{?A?B}, [w_B] \rangle$			*	*

These predictions seem to be sustained by the facts. Compare the following two answers to question Q.

(27) Q. Who signed the petition?
A. Maria ⇒ nobody else signed the petition
B. Not John ⇒ I don't know about anybody else

The first positive answer receives an exhaustive interpretation, no relevant alternative individuals signed the petition. The negative answer does not have this implicature, as predicted by the present account. A proper analysis of the effect of negation on exhaustification requires, however, further empirical investigation.

Let us now consider the epistemic modal cases. Again we will consider only the interesting case in which both A and B are relevant. We start with $\Box A$.

(28) $\Box A \approx_{?A?B} \neg\Box B$

Assuming that both A and B are relevant, the unique optimal state for $\Box A$ is $[w_A, w_{AB}]$. The alternative relevant states $[w_A]$ and $[w_{AB}]$ are blocked by the non modal (and therefore preferred by manner) optimal forms A and $A \wedge B$ respectively. Thus, $\Box A$ implicates that $\neg\Box B$, but not that$\neg B$. This fact captures the intuition that adding 'I know' in an answer blocks an exhaustive interpretation.

(29) Q. Who signed the petition?
C. I know that Maria signed ⇒ I don't know about anybody else

Let us now turn to the case of possibility. Assuming that both A and B are relevant, the unique optimal state for $\Diamond A$ is $[w_A, w_\emptyset]$. Indeed, the alternative state $[w_A]$ is blocked by the optimal form A, and any other state either does not satify the sentence (e.g. $[w_\emptyset]$) or contains w_B, and therefore will be ruled out by the MMP, if not by quantity. The optimal state $[w_A, w_\emptyset]$ entails that A is not necessary, and that B is not possible.

(30) $\Diamond A \approx_{?A?B} \neg\Box A, \neg\Diamond B$

Note that $[w_A, w_\emptyset]$ is also optimal for $\neg B$. The two forms are incomparable by quantity, and violate manner in the same way. In this system they are predicted, correctly, to have the same implicatures.

The following tableau summarizes these results:

	QUAL, REL	MAN	QUAN	MMP
$\Rightarrow$ A - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$			*	*
$\Box A$ - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$		!*		*
$\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$		!*	*	*
$\Rightarrow$ $(A \wedge B)$ - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$				***
$\Box A$ - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$		!*		***
$\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$		!*	*	***
$\Rightarrow$ $\Box A$ - $\langle \mathbf{Q}_{?A?B}, [w_A, w_{AB}] \rangle$		*		***
$\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_A, w_{AB}] \rangle$		*	!*	***
$\Rightarrow$ $\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A] \rangle$		*	*	*
$\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A, w_B] \rangle$		*	*	!**

To summarize our predictions on exhaustification: if both A and B are relevant, A implicates $\neg B$, $\Box A$ implicates $\neg \Box B$, and $\Diamond A$ implicates $\neg \Diamond B$. The latter result will play a crucial role in my explanation of the emergence of free choice inferences for $\Diamond(A \vee B)$, as we will see in the next subsection.

4.2 Modal and scalar implicatures of disjunction

The BiOT analysis presented in the previous section makes the following predictions.

(31) a. $\phi_1 \vee \phi_2 \mid\!\approx \neg \Box \phi_i \vee \neg \heartsuit ?\phi_i$ $\qquad \forall i \in \{1, 2\}$
b. $\Box(\phi_1 \vee \phi_2) \mid\!\approx \neg \Box \phi_i \vee \neg \heartsuit ?\phi_i$
c. $\Diamond(\phi_1 \vee \phi_2) \mid\!\approx \neg \Box \phi_i \vee \neg \heartsuit ?\phi_i$

A speaker using a (modal) disjunction implicates that for each disjunct ϕ_i either she doesn't know whether it is true or she doesn't care whether it is true.

Ignorance and free choice implicatures are obtained if we restrict competition to contexts in which the speaker cares about both disjuncts. In these cases, uses of (modal) disjunctions implicate that both disjuncts are epistemically possible.

(32) a. $\phi_1 \vee \phi_2 \mid\!\approx_{?\phi_1, ?\phi_2} \Diamond \phi_1 \wedge \Diamond \phi_2$
b. $\Box(\phi_1 \vee \phi_2) \mid\!\approx_{?\Box\phi_1, ?\Box\phi_2} \Diamond \phi_1 \wedge \Diamond \phi_2$
c. $\Diamond(\phi_1 \vee \phi_2) \mid\!\approx_{?\Diamond\phi_1, ?\Diamond\phi_2} \Diamond \phi_1 \wedge \Diamond \phi_2$

Results (31b)-(32b) and (31c)-(32c) can be extended to non- epistemic modals $\Box'/\Diamond'$ under certain conditions that have been discussed by Zimmermann 2001, namely if we restrict competition to contexts in which the following principles hold: $\neg \Box \Box' \phi \rightarrow \neg \Box' \phi$ and $\neg \Box \Diamond' \phi \rightarrow \neg \Diamond' \phi$. Since existential statements can be seen as generalized disjunctions all these results extend to the case of indefinite expressions. In what follows we have a closer look at these results. We start with the ignorance and indifference implicatures of plain disjunctions.

Plain disjunction Any context C resulting optimal for $A \vee B$ according to the discussed ranked constraints, entails for each disjunct that either it is not believed to be true by the speaker or it is irrelevant (see (31a)).

We have three types of optimal contexts for $A \vee B$. In the first type, both disjuncts are relevant, Q_C entails $?A$ and $?B$. The optimal state for the disjunction in this case is $[w_A, w_B]$. The stronger form $(A \vee B) \wedge \neg(A \wedge B)$ is ruled out by manner. The more informative states $[w_A]$, $[w_B]$ and $[w_{AB}]$ are blocked by quantity. The other states $[w_A, w_{AB}]$, $[w_B, w_{AB}]$ and $[w_A, w_B, w_{AB}]$ are ruled out by MMP. The optimal context entails that both disjuncts are epistemically possible.

(33) $A \vee B \approx\!\!|_{?A?B} \Diamond A \wedge \Diamond B$ (ignorance)

But also that they are mutually exclusive.

(34) $A \vee B \approx\!\!|_{?A?B} \neg(A \wedge B)$ (scalar implicature)

The ignorance implicature follows by quantity, the scalar implicature by MMP, as illustrated in the following tableau.

		QUAL, REL	MAN	QUAN	MMP
⇒	$A \vee B$ - $\langle \mathbf{Q}_{?A?B}, [w_A, w_B] \rangle$			**	**
	$(A \vee B) \wedge \neg(A \wedge B)$ - $\langle \mathbf{Q}_{?A?B}, [w_A, w_B] \rangle$		!*		**
	$A \vee B$ - $\langle \mathbf{Q}_{?A?B}, [w_A, w_{AB}] \rangle$			**	!***
	$A \vee B$ - $\langle \mathbf{Q}_{?A?B}, [w_A, w_B, w_{AB}] \rangle$			**	!***
	$A \vee B$ - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$			!**	*
⇒	A - $\langle \mathbf{Q}_{?A?B}, [w_A] \rangle$			*	*
	$A \vee B$ - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$			!**	***
⇒	$(A \wedge B)$ - $\langle \mathbf{Q}_{?A?B}, [w_{AB}] \rangle$				***

The second type of optimal context for $A \vee B$ is one in which none of the disjuncts are relevant, but the disjunction is, Q_C entails $?(A \vee B)$, but it does not entail $?A$ or $?B$. These contexts model the indifference reading, where it matters whether the disjunction is true, but the differences between the disjuncts are irrelevant.

(35) $A \vee B \approx\!\!|_{?(A \vee B)} \neg\heartsuit ?A \wedge \neg\heartsuit ?B \wedge \heartsuit ?(A \vee B)$ (indifference)

Note that in these contexts no conclusion can be drawn about the speaker's epistemic attitude towards the two disjuncts, beyond the fact that at least one of the two must be true. So no ignorance implicature arises in these cases. This is because QUANTITY does not play any role here. Since none of the stronger alternatives to the sentence are relevant in these contexts, stronger interpretation cannot be blocked. Scalar implicatures are blocked as well, because since the atoms A and B are irrelevant, all worlds are equally minimal in these contexts. This seems to be correct because like exhaustivity implicatures also scalar implicatures depend on the issue under discussion. Interestingly, as shown by (36), they do not arise on an indifference reading of disjunction.

(36) Q: Have you ever kissed a Russian or an American? A: Yes. $\not\Rightarrow$ not both

The following tableau illustrates these results. Note that none of the contexts in this tableau can compete with the contexts in the previous tableau with respect to MMP. This is because the two types of contexts have different issues thus they cannot be ordered by $\leq$. This means that the first candidate in the previous tableau is not ruled out by the following optimal contexts contrary to what is suggested by the number of *s in the MMP column.

	QUAL REL	MAN	QUAN	MMP
$\Rightarrow$ $A \vee B$ - $\langle \mathbf{Q}_{?(A\vee B)}, [w_A, w_B] \rangle$			**	
$\Rightarrow$ $A \vee B$ - $\langle \mathbf{Q}_{?(A\vee B)}, [w_A, w_{AB}] \rangle$			**	
$\Rightarrow$ $A \vee B$ - $\langle \mathbf{Q}_{?(A\vee B)}, [w_A, w_B, w_{AB}] \rangle$			**	
$\Rightarrow$ $A \vee B$ - $\langle \mathbf{Q}_{?(A\vee B)}, [w_A] \rangle$ A - $\langle \mathbf{Q}_{?(A\vee B)}, [w_A] \rangle$	 !*		** *	
$\Rightarrow$ $A \vee B$ - $\langle \mathbf{Q}_{?(A\vee B)}, [w_{AB}] \rangle$ $(A \wedge B)$ - $\langle \mathbf{Q}_{?(A\vee B)}, [w_{AB}] \rangle$	 !*		**	

There is also a third option, in which only one of the disjuncts is relevant beside the disjunction itself, for example, if Q_C entails $?(A \vee B)$ and $?A$, but it does not entail $?B$. In this case, the optimal state is $[w_B]$. Since B is not relevant, this interpretation cannot be blocked by quantity and it is minimal by MMP.

	QUAL REL	MAN	QUAN	MMP
$\Rightarrow$ $A \vee B$ - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_B] \rangle$ B - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_B] \rangle$	 !*		** *	
$A \vee B$ - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_A] \rangle$ $\Rightarrow$ A - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_A] \rangle$			!** *	* *
$A \vee B$ - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_{AB}] \rangle$			**	!*
$A \vee B$ - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_A, w_B] \rangle$			**	!*
$A \vee B$ - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_A, w_{AB}] \rangle$			**	!*
$A \vee B$ - $\langle \mathbf{Q}_{?A?(A\vee B)}, [w_A, w_B, w_{AB}] \rangle$			**	!*

Intuitions are not very sharp in this case. However, in support of this result consider a situation like the following. Suppose you are expecting Ann's call ($C \models \heartsuit?A$). Instead Bill calls ($C \models B$), about whom you don't care ($C \not\models \heartsuit?B$). We correctly predict then that in this situation you can say (37) signaling that you don't care of that particular person who called, namely Bill, that he called.

(37) Irgend jemand hat angerufen. ‘Irgend-one has called’

Epistemic Modals If both A and B are relevant, our analysis predicts the following implicatures for disjunction in the scope of an epistemic modal.

(38) a. $\Box(A \vee B) \approx\!\!|_{?\Box A, ?\Box B} \Diamond A \wedge \Diamond B$
b. $\Diamond(A \vee B) \approx\!\!|_{?\Diamond A, ?\Diamond B} \Diamond A \wedge \Diamond B$

Let us start with illustrating the case of necessity. If both A and B are relevant, then $[w_A, w_B, w_{AB}]$ is the unique optimal state for $\Box(A \vee B)$, which then implicates $\Diamond A$ and $\Diamond B$ (and $\neg\Box(A \wedge B)$).[5] Any other subset of this state is blocked either by an optimal non-modal form preferred by manner (e.g. $[w_A, w_B]$ by $(A \vee B)$), or by an optimal stronger modal form preferred by quantity (e.g. $[w_A, w_{AB}]$ by $\Box A$).

Let us now turn to the more interesting case of disjunction under possibility. If both A and B are relevant, then $[w_\emptyset, w_A, w_B]$ is the unique optimal state for $\Diamond(A \vee B)$, which then implicates $\Diamond A$ and $\Diamond B$ (but also the scalar implicatures $\neg\Diamond(A \wedge B)$, and $\neg\Box(A \vee B)$). The form-context pair $\Diamond(A \vee B)$-$\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A, w_B]\rangle$ is optimal because no better alternative optimal form is available for such context ($\Diamond A \wedge \Diamond B$ that would be preferred by quantity is ruled out by manner) and no better optimal context is available for such form. All states not including $w_\emptyset$ would be blocked by optimal non-modal alternative forms (by manner), or in the case of $[w_A, w_B, w_{AB}]$ by the stronger $\Box(A \vee B)$ (by quantity). As for the states including $w_\emptyset$ consider the following tableau.

	QUAL REL	MAN	QUAN	MMP
a. $\Diamond(A \vee B)$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A]\rangle$		*	!*	*
⇒ $\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A]\rangle$		*		*
b. $\Diamond(A \vee B)$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_B]\rangle$		*	!*	*
⇒ $\Diamond B$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_B]\rangle$		*		*
⇒ c. $\Diamond(A \vee B)$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A, w_B]\rangle$		*	*	**
$\Diamond A$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A, w_B]\rangle$		*		!**
$\Diamond B$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A, w_B]\rangle$		*		!**
d. $\Diamond(A \vee B)$ - $\langle \mathbf{Q}_{?A?B}, [w_\emptyset, w_A, w_B, w_{AB}]\rangle$		*	*	!***

Here the contexts in (a) and (b) are blocked for $\Diamond(A \vee B)$ by the existence of alternative sentences which would be more appropriate choice for a speaker there, namely $\Diamond A$ and $\Diamond B$ respectively. Candidate (d) is ruled out by MMP. For $\Diamond(A \vee B)$ remains then as unique weakly optimal context the one in (c) which entails indeed the free choice implication $\Diamond A \wedge \Diamond B$.

The reasoning behind this implicature can be summarized as follows. Speaker said $\Diamond(A \vee B)$. Disregarding (d), three different interpretations are compatible with such a form.

(39) a. The speaker believes: Possible A and not possible B.
b. The speaker believes: Possible B and not possible A.
c. The speaker believes: Possible A and possible B.

The third candidate wins, because the first two contents are blocked by the better alternative forms $\Diamond A$ and $\Diamond B$ respectively, which by the MMP automatically receive such exhaustive interpretations. Intuitively, we can reason as follows: if speaker had known that B was not possible, she would have said $\Diamond A$. If she had

[5] Note that also $\Diamond(A \wedge B)$ is among the predicted implicatures of the sentence. I don't know whether this is correct. It could be repaired by assuming that modal and non-modal sentence never compete with each other, but then we would predict that $\Box(A \vee B)$ implicates $\neg(A \wedge B)$, rather than $\neg\Box(A \wedge B)$. And that $\Box A$ implicates $\neg B$, rather than $\neg\Box B$.

known that A was not possible, she would have used $\diamond B$. She didn't use these stronger forms. Therefore we can conclude that both A and B are possible.

Consider now the case in which the modal is not interpreted epistemically. A further possible interpretation arises for these cases:

e. The speaker doesn't know whether A is possible or B is possible.

This interpretation represents ignorance readings that can be paraphrased as 'You may do A or B, I don't remember which'. It is easy to see, however, that if we assume that the speaker is competent about what is possible or necessary, i.e. we restrict our competition to contexts satisfying the two following principles (I use $\Box'/\diamond'$ for non-epistemic modals): $\neg\Box\Box'\phi \rightarrow \neg\Box'\phi$ and $\neg\Box\diamond'\phi \rightarrow \neg\diamond'\phi$, then the free choice interpretation (c) is optimal also for non-epistemic interpretation of the possibility operator.

To summarize, of the possible interpretations for $\diamond(A \vee B)$, the 'exhaustive' interpretations (a) and (b) are blocked by the stronger forms $\diamond A$ and $\diamond B$. Candidate (e) represents the ignorance reading of the sentence and it is available only for non-epistemic interpretation of $\diamond$. Candidate (c), representing the free choice interpretation, wins under the assumption that the speaker is competent about what is possible (this is always the case for epistemic $\diamond$, and usually obtains when the sentence is used performatively).

5 Conclusion

I have presented a formal analysis of implicatures in the framework of Bidirectional OT, and have applied it to explain modal implicatures of disjunctions and indefinite expressions, but also scalar implicatures and exhaustification. A large number of further questions arise. The most urgent concerns implicatures of complex sentences. Another interesting question is whether free choice implicatures of non-epistemic modals could be derived as indifference implicatures rather than as I suggest in the previous section. A further open question concerns the exact relation between different kinds of indefinite pronouns (see Haspelmath, 1997). On the present account all indefinite expressions implicate speaker's ignorance or indifference. How do we account then for the difference between *irgend*-indefinites and plain indefinites. The implicatures of the latter have clearly a conversational nature. The implicatures of the former, instead, seem to have a double nature. On the one hand, they are derivable by the Gricean maxims like standard *conversational* implicatures. On the other, like *conventional* implicatures (e.g. those of *therefore* or *but*), they are hard to cancel, and somehow seem to be part of the lexical meaning of the pronoun. A proper investigation of this and other questions will have to be left to another occasion.

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