A Problem with the Semantics of Negative Raising Predicates

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1 Aspects of negation

This paper[1] concentrates on some aspects of the problematic behavior, from a logical point of view, of natural language negation, a topic that 'lies at the heart of the intersection of syntax, semantics, and communicative intent' [Hor78, 214].

Natural language negation shows much more variation than negation in most logical systems. Take for example English, which has quite a number of negative expressions in addition to standard *not*. The following sentences illustrate this:

(1) a. John does **n't** sleep
b. John **never** sleeps
c. John **seldom** sleeps
d. John **rarely** sleeps
e. **Not everybody** sleeps
f. **Nobody** sleeps
g. **Few people** sleep
h. **At most three people** sleep

Intuitively, all expressions involve some sort of negation: they all state that something is not, or not completely, the case. Moreover, all expressions are able to license so-called negative polarity items, words and expressions that are 'unhappy' without a negation:[2]

(2) a. John does**n't** read *any* books (*John reads *any* books)
b. John **never** reads *any* books (*John always reads *any* books)
c. John **seldom** reads *any* books (*John often reads *any* books)

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[2]The asterisks '*' denote ungrammaticality.

d. John **rarely** reads *any* books (*John often reads *any* books)
e. **Not everybody** reads *any* books (*Everybody reads *any* books)
f. **Nobody** reads *any* books (*Somebody reads *any* books)
g. **Few people** read *any* books (*Many people read *any* books)
h. **At most three people** read *any* books (*At least three people read *any* books)

Following Zwarts ([Zwa81], [Zwa86]), it is possible to characterize negative expressions of natural language with the help of DeMorgan's laws (cf. also [vdW94, 36ff.]). For expository purposes, they are repeated below:

(3) **DeMorgan's laws**
a. $\neg(X \cap Y) = \neg X \cup \neg Y$
b. $\neg(X \cup Y) = \neg X \cap \neg Y$

Suppose these laws are generalized for arbitrary operators f. Then the result is the following:

(4) **Generalized DeMorgan's laws**
a. $f(X \cap Y) = f(X) \cup f(Y)$
b. $f(X \cup Y) = f(X) \cap f(Y)$

The next step is to split apart the identity relation into two subset relations:

(5) **Generalized DeMorgan's laws, split**
a. $f(X \cap Y) \subseteq f(X) \cup f(Y)$
b. $f(X) \cup f(Y) \subseteq f(X \cap Y)$
c. $f(X \cup Y) \subseteq f(X) \cap f(Y)$
d. $f(X) \cap f(Y) \subseteq f(X \cup Y)$

For certain negative(-like) operators, some of these relations hold, whereas it is not the case that all of them hold. Operators that only obey (5b) and (5c) are known as monotone decreasing or antitone [Dun93].[3] Natural language expressions that typically possess these two properties without obeying the other two relations are *few people*, *at most three men* and *seldom*. This is illustrated below with the noun phrase *few people*:

(6) a. Few people dance and sing $\not\rightarrow$ few people dance or few people sing (cf. 5a)
b. Few people dance or few people sing $\rightarrow$ few people dance and sing (cf. 5b)
c. Few people dance or sing $\rightarrow$ few people dance and few people sing (cf. 5c)
d. Few people dance and few people sing $\not\rightarrow$ few people dance or sing (cf. 5d)

Negative expressions for which relation (5d) holds as well are known as anti-additive [Hoe83].[4] The noun phrases *nobody* and *nothing* and the adverb *never* are prime examples of this class of expressions. Their anti-additive character will be illustrated with the noun phrase *nobody*:

[3] One also finds terms such as 'downward entailing', 'downward monotonic', 'scale reversing' and 'polarity reversing' [Fau75, Lad79, Zwa81, BC81].

[4] One also finds the term 'ideal' [Zwa81].

(7) a. Nobody dances and sings $\not\rightarrow$ nobody dances or nobody sings (cf. 5a)
b. Nobody dances or nobody sings $\rightarrow$ nobody dances and sings (cf. 5b)
c. Nobody dances or sings $\rightarrow$ nobody dances and nobody sings (cf. 5c)
d. Nobody dances and nobody sings $\rightarrow$ nobody dances or sings (cf. 5d)

On the other hand, negative expressions for which, in addition to (5b, 5c), (5a) holds as well, are known as antimultiplicative. Typical natural language representatives of this class are negated universals such as *not always* and *not everybody*. The property is illustrated with the noun phrase *not everybody*:

(8) a. Not everybody sings and dances $\rightarrow$ not everybody sings or not everybody dances (cf. 5a)
b. Not everybody sings or not everybody dances $\rightarrow$ not everybody sings and dances (cf. 5b)
c. Not everybody sings or dances $\rightarrow$ not everybody sings and not everybody dances (cf. 5c)
d. Not everybody sings and not everybody dances $\not\rightarrow$ not everybody sings or dances (cf. 5d)

Finally, the expressions for which all four relations hold are called antimorphic. Antimorphic natural language operators are of course *not*, but also Dutch *allerminst* 'not at all' and *geenszins* 'no way', and negated unique descriptions such as *not Judas* and *not the Queen of England*. The essence of antimorphy may be illustrated with sentence negation:

(9) a. John doesn't dance and sing $\rightarrow$ John doesn't dance or John doesn't sing (cf. 5a)
b. John doesn't dance or sing $\rightarrow$ John doesn't dance and sing (cf. 5b)
c. John doesn't dance or sing $\rightarrow$ John doesn't dance and John doesn't sing (cf. 5c)
d. John doesn't dance and John doesn't sing $\rightarrow$ John doesn't dance or sing (cf. 5d)

Let me give an overview of the various negative expressions in the form of a table:

(10) **Four types of negative expressions**

<table>
<tr><td colspan="2">monotone decreasing
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
few, seldom, hardly</td></tr>
<tr><td>antimultiplicative
$f(X \cap Y) \subseteq f(X) \cup f(Y)$ (5a)
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
not every, not always</td><td>anti-additive
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
$f(X) \cap f(Y) \subseteq f(X \cup Y)$ (5d)
nobody, never, nothing</td></tr>
<tr><td colspan="2">antimorphic
$f(X \cap Y) \subseteq f(X) \cup f(Y)$ (5a)
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
$f(X) \cap f(Y) \subseteq f(X \cup Y)$ (5d)
not, not the teacher, not Judas
allerminst, geenszins</td></tr>
</table>

The characterization of negative natural language expressions in terms of downward monotonicity is interesting in and by itself, but it turns out to be relevant in understanding the complex distribution of negative polarity items as well. Not all negative polarity items have the same distribution: some need stronger negations than others. In my dissertation [vdW94], I reach, among other things, the following conclusions (shifting to Dutch data now) (cf. also [Zwa93]):

(11) **The distribution of Negative Polarity Items**

a. Many negative polarity items are happy with downward entailing expressions: e.g. *hoeven* ('need'), *ooit* ('ever') and *kunnen uitstaan* ('can stand').
b. Many other negative polarity items need anti-additive expressions in order to yield grammatical sentences, e.g. *ook maar* ('at all') and *met een vinger aanraken* ('touch with a finger').
c. Some negative polarity items need to be in the scope of antimultiplicative expressions in order to be happy, e.g. *rozegeur en maneschijn* (lit. 'rose scent and moonshine': 'sunshine and roses').
d. Some negative polarity items are only fine in the scope of antimorphic operators, e.g. the idiomatic *pluis* (lit. 'fluff') and *voor de poes* (lit. 'for the cat': 'to be trifled with').
e. Sometimes, but not always, a negative polarity item is happy with a negative expression of a stronger type.

Let me illustrate these generalizations with some example sentences.[5]

[5]Not all speakers have exactly the same judgements, but that is irrelevant. Relevant is that there exist various types of negative polarity items that have the type of distribution exhibited in these examples.

(12) downward entailing *weinig mensen*

a. **Weinig mensen** *hoeven* tegenwoordig de galg te vrezen
Few people need nowadays the gallows to fear
'Few people have to fear the gallows these days'

b. ***Weinig mensen** hebben *ook maar* een idee van logica
Few people have at all an idea of logic

c. *Het leven is voor **weinig mensen** *rozegeur en maneschijn*
The life is for few people sunshine and roses

d. ***Weinig mensen** zijn *voor de poes*
Few people are to be trifled with

(13) anti-additive *niemand*

a. **Niemand** *hoeft* tegenwoordig de galg te vrezen
Nobody need nowadays the gallows to fear
'Nobody needs to fear the gallows these days'

b. **Niemand** heeft *ook maar* een idee van logica
Nobody has at all an idea of logic
'Nobody has any idea of logic'

c. *Het leven is voor **niemand** *rozegeur en maneschijn*
The life is for nobody sunshine and roses

d. ***Niemand** is voor de poes
Nobody is for the cat

(14) antimultiplicative *niet altijd*

a. Mensen *hoeven* tegenwoordig **niet altijd** de galg te vrezen
People need nowadays not always the gallows to fear
'People don't have to always fear the gallows these days'

b. *Mensen hebben **niet altijd** *ook maar* een idee van logica
People have not always at all an idea of logic

c. Het leven is **niet altijd** *rozegeur en maneschijn*
The life is not always sunshine and roses
'Life is not always sunshine and roses'

d. *AIO's zijn **niet altijd** *voor de poes*
Graduate students are not always for the cat

(15) antimorphic *niet*

a. Je *hoeft* **niet** bang te zijn voor de galg
You need not afraid to be for the gallows
'You need not fear the gallows'

b. *Mensen hebben **niet** *ook maar* een idee van logica
People have not at all an idea of logic

c. *Het leven is **niet** *rozegeur en maneschijn*
The life is not sunshine and roses

d. AIO's zijn **niet** *voor de poes*
Graduate students are not for the cat
'Graduate students are not to be trifled with'

Let me again summarize these findings in the form of a table:

(16) **Four classes of Negative Polarity Items**

<table>
<tr><td colspan="2">monotone decreasing
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
OK: hoeven, kunnen uitstaan
bad: ook maar, rozegeur en maneschijn, voor de poes</td></tr>
<tr><td>antimultiplicative
$f(X \cap Y) \subseteq f(X) \cup f(Y)$ (5a)
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
OK: hoeven, roz. en manes.
bad: ook maar, voor de poes</td><td>anti-additive
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
$f(X) \cap f(Y) \subseteq f(X \cup Y)$ (5d)
OK: hoeven, ook maar
bad: roz. en manes., voor de poes</td></tr>
<tr><td colspan="2">antimorphic
$f(X \cap Y) \subseteq f(X) \cup f(Y)$ (5a)
$f(X) \cup f(Y) \subseteq f(X \cap Y)$ (5b)
$f(X \cup Y) \subseteq f(X) \cap f(Y)$ (5c)
$f(X) \cap f(Y) \subseteq f(X \cup Y)$ (5d)
OK: hoeven, voor de poes
bad: ook maar, roz. en manes.</td></tr>
</table>

2 Function composition and the monotonicity calculus

The negative expressions such as the ones discussed earlier may be viewed as functions, just as all other natural language expressions [KF85]. Of course, such functions may, under the right conditions, be composed. The rules governing the composition of upward and downward functions might be called a *Monotonicity Calculus* [Kas93, SV91]. For ease of reference, the main rules are gathered in (17), in which $\circ$ means ‘composed with’ and $=$ means ‘results in’:

(17) **A simple monotonicity calculus**

a. upward $\circ$ upward $=$ upward
b. upward $\circ$ downward $=$ downward
c. downward $\circ$ upward $=$ downward
d. downward $\circ$ downward $=$ upward

In order to see how this works, consider a categorial derivation such as the following [Kas93, 135] (cf. also [Zwa86]):

(18)

```
John didn't see any of the paintings
---- ------ --- --------------------
S/VP VP/VP VP/NP    NP
upw  downw  upw
   -----------
     VP/NP
     downw
--------------
   S/NP
   downw
```

The downward monotonic nature of the negation is passed on through repeated composition with upward monotonic expressions [Kas93, 135]. In the end, the complex function corresponding to *John didn't see* (S/NP) is downward monotonic and this enables it to take the negative polarity item *any of the paintings* as its argument.

It will be clear, however, that this monotonicity calculus is too crude a tool for the analysis of natural language [Kas93, 136]. For instance, it does not distinguish between an antimorphic function such as *not*, an anti-additive function such as *nobody*, an antimultiplicative function such as *not everybody*, and a downward monotonic expression such as *few people*. I will return to a more refined monotonicity calculus shortly.

3 Negative raising predicates

Certain verbs are transparant for negation. With a term that reminds of the illustrious past of transformational grammar, these verbs are known as negative raising predicates.[1] A real life illustration of the behavior of such a verb is given in (19):

(19) a. I believe that Santa Clause does**n't** exist
b. I do**n't** believe that Santa Clause exists

At least under one reading, sentence (19b) is (more or less, cf. [Hor89]) equivalent to sentence (19a).

Given our earlier discussion of negative polarity items, on the one hand, and function composition, on the other, it will hardly come as a surprise that a negation plus a negative raising verb is able to license negative polarity items, e.g., English 'punctual' *until*:[2]

(20) a. I believe that John did**n't** will arrive *until* tomorrow
b. I **don't** believe that John will arrive *until* tomorrow

The same story holds for other languages (viz., Dutch) and other negative expressions as well. I give one example, which involves the NPI *ook maar* 'at all'.

[1] Cf. [Hor78, Hor89].

[2] English *any* is rather promiscuous and may, in certain cases, be licensed by a distant negation without an intervening negative raising predicate [Hor78].

(21) a. Ik geloof dat **niemand** *ook maar* een idee van logica heeft
I believe that nobody at all an-idea of logic has
I believe that nobody has any idea of logic
b. **Niemand** gelooft dat ik *ook maar* een idee van logica heb
Nobody believes that I at-all an idea of logic have
Nobody believes that I have any idea of logic

Negative Raising is lexically governed: the class of possible NR predicates is restricted to certain semantic domains, but it is unpredictable *a priori* whether or not an element of this domain possesses the property or not [Hor78].

NR predicates form the most important exception to the rule that the licensing of (strict) negative polarity items (NPIs) is clause-bound.[3] As we already saw, an embedded NPI may be licensed by a downward entailing operator [Lad79] in the matrix clause via such a negative raising predicate. With other types of verbs, the result of this configuration is ungrammatical:

(22) a. **No Belgian** believes that the Dutch will *lift a finger* to help him
b. John does**n't** believe that Peter will arrive *until* tomorrow
c. ***No Belgian** knows that the Dutch will *lift a finger* to help him
d. *John does**n't** realize that Peter will arrive *until* tomorrow

Assume that negative raising essentially is a semantic phenomenon.[4] Without directly solving what the semantic properties of negative raising exactly are, Iwill, in the remaining sections, show that the interaction of negative raising and polarity licensing may shed some light on this problem.

4 A problem with Negative Raising Predicates

Given the assumptions about function composition discussed in section 2, we indeed expect negative operators in the main clause to be able to license negative polarity items in the subordinate clause. This expectation was born out by the facts in section 3. The facts, however, are more complex than they may seem at first sight. As I already pointed out in my dissertation [vdW94], we get unexpected results in the case of (Dutch) strong NPIs such as *voor de poes*. If such a strong negative polarity item, in need an antimorphic licenser, occurs in a subordinate clause, such an antimorphic operator is not able to license the embedded strong NPI from the matrix clause. Consider the following examples:

(23) a. Zij is **niet** *voor de poes*
She is not for the cat
'She is not to be trifled with'

[3]The only other exception I know of involves bound pronouns; cf. [vdW85, vdW95b].

[4]This semantic approach thus makes a Negative Raising transformation or an abstract negative operator [Pro94] unnecessary.

b. *Ik geloof **niet** dat zij *voor de poes* is
I believe not that she for the cat is
'I don't believe she is to be trifled with'[1]

On the other hand, Negative Polarity Items of medium strength, i.e. NPIs that need an anti-additive licenser (such as Dutch *ook maar*), may be licensed by a matrix negation via Negative Raising predicates:

(24) a. **Niemand** heeft *ook maar* iets gezien
Nobody has at-all anything seen
'Nobody has seen anything at all'
b. Ik geloof **niet** dat iemand *ook maar* iets gezien heeft
I believe not that somebody at-all anything seen has
'I don't believe that anybody saw anything at all'

With a verb that is not a negative raising predicate, the sentence is ungrammatical:[2]

(25) *Ik weet **niet** dat iemand *ook maar* iets gezien heeft
I know not that somebody at-all anything seen has

The picture becomes even more complicated if we take into account the fact that weak negations (downward entailing operators) that cannot license NPIs of medium strength in the same clause appear to be able to do so from a higher clause:

(26) a. ***Weinig mensen** hebben *ook maar* iets gezien
Few people have at-all anything seen
'Few people have seen anything at all'
b. **Weinig mensen** herinneren zich *ook maar* iets gezien te hebben
Few people remember themselves at-all anything seen to have
'Few people remember to have seen anything at all'

With a verb that doesn't show Negative Raising, the sentence is ungrammatical again:

(27) ***Weinig mensen** vermoeden *ook maar* iets gezien te hebben
Few people guess at-all anything seen to have

These data suggest that the composition of antimorphic operators with negative raising predicates does not result in an antimorphic operator, which is what one would expect if negative raising predicates would be homomorphisms. This seems to imply that NR predicates are not homomorphisms after all. The apparent strengthening of weak negations in (26) is moreover completely unexpected.

The following is a complete paradigm of the relevant cases:

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[1]A reviewer suggested an alternative, and, if correct, much simpler explanation of the facts in these examples: *voor de poes* appears to occur with *niet* only, so why not assume that *niet voor de poes* is an idiom (cf. [Kri94] for a parallel suggestion). The suggestion, however, is untenable in the light of the fact that *voor de poes* occurs with other antimorphic operators as well, such as *geenszins* 'no way' and *allerminst* 'not at all'. For example a sentence such as *Zij is geenszins voor de poes* ('She is no-way for the cat', i.e., 'She is absolutely not to be trifled with') is fine.

[2]Some verbs that do not show negative raising, such as Dutch *beweren* 'claim' allow for this type of long distance licensing as well. cf. [Hor78].

(28) a. U beweert dat Jan niet gelooft dat er ook maar iets gebeurd is
You claim that John doesn't believe that anything has happened at all
b. U beweert dat Jan nauwelijks gelooft dat er ook maar iets gebeurd is
You claim that John hardly believes that anything has happened at all
c. U beweert dat niemand gelooft dat er ook maar iets gebeurd is
You claim that nobody believes that anything has happened at all
d. *U beweert dat niet iedereen gelooft dat er ook maar iets gebeurd is
You claim that not everybody believes that anything has happened at all

These examples leave no other conclusion than that composition of downward entailing, anti-additive and antimorphic operators with negative raising predicates yields an anti-additive operator, but composition of an antimultiplicative operator and a neg raising predicate does not result in an anti-additive one. The fact that all sentences become grammatical if the NPI *ook maar* is replaced by the weaker *hoeven* suggests that all compositions of a negative operator with a negative raising predicate are monotone decreasing:

(29) a. U beweert dat Jan niet gelooft dat we huiswerk hoeven te maken
You claim that John doesn't believe that we homework need to make
b. U beweert dat Jan nauwelijks gelooft dat we huiswerk hoeven te maken
You claim that John hardly believes that we homework need to make
c. U beweert dat niemand gelooft dat we huiswerk hoeven te maken
You claim that nobody believes that we homework need to make
d. U beweert dat niet iedereen gelooft dat we huiswerk hoeven te maken
You claim that not everybody believes that we homework need to make
hoeven te maken

That is to say, the distribution of negative polarity items in subordinate clauses dependent on negated negative raising predicates suggest the following:

(30) **Composition results**
a. composition of a monotone decreasing operator and a negative raising predicate yields an anti-additive operator.
b. composition of an anti-additive operator and a negative raising predicate yields an anti-additive operator.
c. composition of an antimorphic operator and a negative raising predicate yields an anti-additive operator.
d. composition of an antimultiplicative operator and a negative raising predicate yields a monotone decreasing operator.

I will now investigate whether these results are corroborated by the validity of inference patterns. Consider the composition of a downward monotonic noun phrase (*few people*) and a negative raising predicate (*think*):

(31) a. Few people think that John dances and sings $\not\rightarrow$ few people think that John dances or few people think that John sings (cf. 5a)
b. Few people think that John dances or few people think that John sings $\rightarrow$ few people think that John dances and sings (cf. 5b)

c. Few people think that John dances or sings $\rightarrow$ few people think that John dances and few people think that John sings (cf. 5c)
d. Few people think that John dances and few people think that John sings $\rightarrow$ few people think that John dances or sings (cf. 5d)

As far as one can have any judgements about the validity of entailment relations between such complicated expressions, they seem to be in harmony with the earlier results. The crucial one is (31d): its validity makes the complex and composed expression *few people think that* an anti-additive one.

How about changing the downward monotonic expression for an anti-additive one such as *nobody*? Again, the data seem to confirm our expectations:

(32) a. Nobody thinks that John dances and sings $\not\rightarrow$ nobody thinks that John dances or nobody thinks that John sings (cf. 5a)
b. Nobody thinks that John dances or nobody thinks that John sings $\rightarrow$ nobody thinks that John dances and sings (cf. 5b)
c. Nobody thinks that John dances or sings $\rightarrow$ nobody thinks that John dances and nobody thinks that John sings (cf. 5c)
d. Nobody thinks that John dances and nobody thinks that John sings $\rightarrow$ nobody thinks that John dances or sings (cf. 5d)

Composition of an antimorphic operator and a negative raising predicate should yield an anti-additive operator as well.

(33) a. I don't think that John dances and sings $\not\rightarrow$ I don't think that John dances or I don't think that John sings (cf. 5a)
b. I don't think that John dances or I don't think that John sings $\rightarrow$ I don't think that John dances and sings (cf. 5b)
c. I don't think that John dances or sings $\rightarrow$ I don't think that John dances and I don't think that John sings (cf. 5c)
d. I don't think that John dances and I don't think that John sings $\rightarrow$ I don't think that John dances or sings (cf. 5d)

Here, the crucial line is (33a). The simple (simplistic) monotonicity calculus of (17) predicts validity of this inference, the polarity data predict falsehood but cf. below). I have the impression that the polarity data are on the right track.

Finally, the composition of an antimultiplicative operator and a negative raising predicate gives comparable results:

(34) a. Not everybody thinks that John dances and sings $\not\rightarrow$ not everybody thinks that John dances or not everybody thinks that John sings (cf. 5a)
b. Not everybody thinks that John dances or not everybody thinks that John sings $\rightarrow$ not everybody thinks that John dances and sings (cf. 5b)
c. Not everybody thinks that John dances or sings $\rightarrow$ not everybody thinks that John dances and not everybody thinks that John sings (cf. 5c)
d. Not everybody thinks that John dances and not everybody thinks that John sings $\not\rightarrow$ not everybody thinks that John dances or sings (cf. 5d)

Again, the implication data seem to corroborate our expectations based on polarity items. The difficulty of the judgements concerning such complicated implications, however, calls for cautiousness and more research – but that goes beyond the scope of this short paper (cf., however, [vdW95a]).

5 Towards a semantics for negative raising predicates?

Given that the simple monotonicity calculus of (17) in section 2 is incompatible with the results of the last section, let's take a look at a more refined monotonicity calculus. Such an Extended Monotonicity Calculus or EMC can be found in [Zwa92].[1] Here are some of the main results (Zwarts's Theorem 15):

(35) **Extended Monotonicity Calculus**
Let B, B^* and B^{**} be three Boolean algebras and let $f : B \to B^*$ and $g : B^* \to B^{**}$. Then:

a. If f is additive and g is additive, then $g \circ f$ is additive.
b. If f is additive and g is anti-additive, then $g \circ f$ is anti-additive.
c. If f is anti-additive and g is multiplicative, then $g \circ f$ is anti-additive.
d. If f is anti-additive and g is antimultiplicative, then $g \circ f$ is additive.
e. If f is multiplicative and g is multiplicative, then $g \circ f$ is multiplicative.
f. If f is multiplicative and g is antimultiplicative, then $g \circ f$ is antimultiplicative.
g. If f is antimultiplicative and g is additive, then $g \circ f$ is antimultiplicative.
h. If f is antimultiplicative and g is anti-additive, then $g \circ f$ is multiplicative.

The combination of (30b) and (35b) suggests that negative raising predicates should be additive, and (30d) and (35f) together hardly leave any other conclusion than that negative raising predicates are not multiplicative. The aforementioned properties are, of course, the positive duals of anti-additivity and antimultiplicativity, respectively. Here are the relevant definitions [vdW94, 30]:

(36) a. A function f is *additive* iff $f(X \cup Y) = f(X) \cup f(Y)$
b. A function f is *multiplicative* iff $f(X \cap Y) = f(X) \cap f(Y)$

If these findings are anywhere near right, this suggests that the first of the following implications should be valid (as it follows the additivity pattern), whereas the second one should not be valid (as it follows the multiplicativity pattern):

(37) a. John thinks that it will rain or freeze tomorrow $\not\to$ John thinks that it will rain tomorrow or John thinks that it will freeze tomorrow
b. John thinks that it will rain and freeze tomorrow $\to$ John thinks that it will rain tomorrow and John thinks that it will freeze tomorrow

[1] Cf. also [SZ90, p. 542-43] and [Kas93].

This, however, seems to be incorrect: if John believes that a disjunction will be the case, he will not necessarily believe that any of the disjuncts will be the case by itself. If, however, he believes that a conjunction of two propositions will be the case, he will also believe that any of the two propositions will be the case.[2]

Now it appears that an inconsistency has been derived: the polarity data, combined with the Extended Monotonicity Calculus, suggest that negative raising predicates be additive but not multiplicative, whereas the inference patterns that are valid for negative raising predicates lead to the conclusion that they are multiplicative but not additive.

One might try to solve this inconsistency in various ways: by reference to the semantics of belief predicates [GS90], or by claiming that negative raising is a phenomenon that is not semantic, but rather pragmatic in nature [Hor78, Hor89], or even by refuting the Extended Monotonicity Calculus or by suggesting that the polarity data are too subtle and too untrustworthy all by themselves. All these possibilities call for additional research and are therefore beyond the scope of this paper.

However, our problems in finding independent evidence for our claim that negative raising predicates are additive, which was based on the behavior of polarity items, do not imply that no such evidence be found, nor that negative polarity behavior is an unreliable guide in the semantic field. To convince oneself of the contrary of the latter, one should take a look at [SVvdWZ94].

6 Conclusion

In this small exercise in applied logic, I have tried to shed some light on the semantics of negative raising predicates. Guided by the distribution of negative polarity items of various strengths, we arrived at the conclusion that negative raising predicates possess the logical property of *additivity*. This result turned out to be not unproblematic, but the solution of the problems involved calls for additional research outside the scope of this paper.

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