Processing of sentences with predicate negation: The role of opposite predicates

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Abstract. In this paper we discuss the *two-step simulation hypothesis of negation processing* proposed by Kaup et al. [3,4] with regard to negating two sorts of predicates: those with clear opposites ("long" vs "short", "closed" vs "open") and those without clear opposites ("red", "triangle"). The hypothesis by Kaup et alia predicts that negation is integrated into sentence meaning on the later stage of sentence processing, which involves that a comprehender of the sentence simulates the corresponding actual state of affairs. We suggest that, given the hypothesis is true, in the case of those predicates for which one can find in the language clear opposites, such a simulation is facilitated via identifying the negative of a given predicate with its opposite. In the case of predicates such as "red", that lack of a clear opposite should make processing of the negative sentence more effortful.

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1 Predicate negation: negative and opposite predicates

Negation in logic is an operator reversing truth- or semantic-values. In natural language negation turns an affirmative sentence into its denial. An affirmative sentence with one unary predicate such as, e.g. "He is happy" can be negated by placing a sentential negation operator, thus a negation operator that takes the whole sentence into its scope, in front of the sentence: "*It is not the case* that he is happy", or, which is more common in natural languages, by placing a negation operator inside a sentence: "He is *not* happy". It has been observed [7] that this last sentence may, however, be still considered as ambiguous with negation interpreted in two ways: as a wide-scope predicate negation, so the positive predicate "happy" is negated about a subject (then it is an operator on a verb rather than on a predicate), or as a narrow-scope predicate negation, where the negative predicate "not-happy" is affirmed about a subject. Although on a surface level these readings appear to be logically equivalent, this ambiguity seems to play a role in processing of NL sentences. In particular, if the wide- and narrow-scope predicate negations do not share the same logical properties, "He is not not-happy" might not be equivalent to "He is happy", which would be the case if both negations were interpreted as a classical boolean negation. Needless to say, at least from a pragmatical perspective these sentences differ:

"He is not not happy" seems to communicate clearly something more than "He is happy".

Furthermore, in the literature [7] predicate negation ("not happy") is distinguished from predicate *term* negation ("*un*happy"). Let us observe that a sentence "He is not happy" does not, quite obviously, mean the same as "He is *un*happy". While one does not have to be either "happy" or "unhappy", with "happy" and "not happy", the division seems more dichotomic. Thus "happy" and "unhappy" create a pair of so-called *opposites*, so predicates expressing opposite or contrary properties, whilst "happy" and "not happy" are *negatives*, and express, at least from a logical perspective, contradictory values. Let us just note, that an opposite predicate to a given predicate P does not have to be created from P with the use of any form of a predicate term negation – in many cases it is just another predicate, that does not have any morphological component in a form of a term negation, expressing an opposite, or a "polar" property ("long" and "short"). Obviously, apart from cases of contradictory predicates ("open/closed"), opposites are not semantically equivalent to negatives. While an opposite to a given predicate P usually entails this predicate's negative: what is short cannot be long, no similar dependence holds in the other direction: not everything that is not long must be short, a not-pretty person does not have to be ugly, etc. Let us also observe that in natural language the contradiction between a predicate P and its negative *not-P* is still not so obvious. It seems questionable whether in NL we can say that any object O is either happy or not-happy. There are two reasons for this scepticism. First is vagueness of NL predicates, which is a source of a gap of a "grey or neutral area" between those objects which can be clearly classified as P (e.g. "happy") and those which are clearly in the complement set, that is those that are *not-P* ("not happy"). Second reason is that an object may be categorized in the manner that precludes possible applications of some predicates. Though it is obvious that no spoon can be happy, it is not easy to decide if the expression "This spoon is not happy" is a meaningful sentence of English.

Finally let us make the important observation: While all adjectives in natural language have negatives, thus can be negated ("long" and "not long", "happy" and "not happy"), not for all of them we can find clear opposites. For instance "short" is opposite to "long", "big" is opposite to "'small", but it is difficult to determine which color term is opposite to "red". Predicates referring to colors or shapes ("triangle") seem to lack clear opposites, or alternatively we could also say that they have multiple opposites, that is all the alterative properties (e.g. in the case of "red" all the "non-red" colors) are their opposites. Further on we will see how the difference between predicates with respect to whether or not they have clear opposites might affect processing of negative sentences with those predicates.

2 Processing negative sentences: the two-step simulation hypothesis

From the psycholinguistic perspective, the interesting question concerns how negative sentences are processed by the brain. Kaup, Ludtke et al. [3,4] propose a *two-step simulation hypothesis of negation processing*. According to this hypothesis comprehension of negative sentence such as "This door is not open" involves first a representation of a negated state of affairs (open door) followed on a later stage of processing by a representation of an actual state of affairs (closed door).

Kaup et al. [3] investigated comprehension of sentences, affirmative and negative, using contradictory predicates, such as "The door was open" vs "The door was not open" and "The door was closed" vs "The door was not closed". Sentences were followed by pictures which either depicted negated or actual state of affairs. Pictures were shown either after 750 ms or after 1500 ms delay, thus subjects were divided into two groups. They were asked to name the depicted object.

For the short time interval subjects' reaction was faster in the case of affirmative sentences followed by pictures matching the actual state of affairs, while for negative sentences there was no difference in subjects reaction time. For the long time interval the result was opposite. There was no difference in subjects's reaction to affirmative sentences, while for negative sentences subjects reacted faster in the case of pictures matching the actual state of affairs. The authors interpret this result concluding that while comprehending a sentence such as "This door is not open", after a given time interval, subjects change from a representation of a negated state of affairs ("open door") to a representation of an actual state of affairs ("closed door").

Further ERP recoding experiments [4], employing sentence-picture verification paradigm with negative and positive sentences followed by matching and mismatching pictures ("there is a ghost in front of the tower"/ "there is no ghost in front of the tower"), supported the earlier behavioral data. Although the authors observed that negation is recorded early in the comprehension process (enhanced negativity starting 250 msec after an onset of a negated noun in the ERP), further investigations suggested that negation is fully integrated into sentence meaning only at the later point of the comprehension process: the main effect of negation in addition to the priming effect was observed in the N400 window only for the long delay condition (1500 msec), while for the short delay the priming effect was independent of whether the sentence contained a negation.

3 Representing negated predicates: the role of opposites

Following the conclusions of the study by Kaup et alia we discuss in the present paper the predictions of their hypothesis with respect to non-contradictory predicates of two sorts: those with and those without clear opposites. The "open/closed"

opposition as discussed in the paper by [3] is an example of a dichotomic division. In this case the opposites can be easily identified with negatives: what is not open is certainly closed – at least assuming some common-sense approximation. However, for other non-contradictory predicates, and especially for those predicates which as "red" lack clear single opposites, the question how their negatives are represented is more complicated. The two-step simulation hypothesis of negation processing predicts that integration of negation into sentence meaning on the later stage of sentence processing involves that a comprehender of the sentence simulates the corresponding actual state of affairs. However, it is not clear whether such a simulation is at all possible in the case of negation of e.g. color terms. In principle one can represent an object which is "not red", but since it is hard to have a concept of an object as deprived of color, one would need to face the problem of choosing between various equivalent alternative options, namely all the non-red colors: blue, yellow, green, etc. This might be the source of a higher processing effort in the case of sentences that use such predicates. In worst case, a comprehender of such a sentence, e.g. "This balloon is not red", might not have any representation of what should be the actual state of affairs, since a representation of "not red" lacks a visual component.

With non-contradictory predicates that have clear opposites, e.g. "long" and "short", we are somehow half way. Although "not-long" is not equivalent to "short", we have a vague representation of "not-long" which, in spite of an obvious semantical gap, does not seem to differ that much from our representation of "short". It is possible that even if the negative of a given predicate cannot be semantically identified with the opposite of this predicate (as "not long" and "short" cannot be), this kind of simplification might be done during sentence processing or even, more consciously, during reasoning process. People hence may tend to identify in the case of some adjectives (e.g. "long", "heavy") their negatives with their opposites. Thus, "not long" might be identified, at least in some contexts, with "short", and "not short" with "long", even if this duality does not exhaust all the mean possibilities. This phenomenon would be then an effect of a cognitive "need" for a positive representation of an actual state of affairs. Consequently, there is a disparity between predicates having opposites (e.g. "long") and those which lack opposites ("red"). While it is quite easy to represent an object which is not long, since we can just use the concept "short" to substitute the abstract construct "not long", we do not have any natural concept or representation of "not red".

Let us make perhaps a more philosophical remark: It seems that we represent objects rather as *having properties* than as not having them, because negating a property about an object does not provide any definite (even partial) description of this object. Hence, a representation of an object that is *non-P* is incomplete or defective. To avoid this problem a subject may construct a mental representation of a negative property *non-P* with the use of a property contradictory (if available) or opposite to P. If, however, P lacks a clear opposite, then such a representation is problematic.

4 Double negation elimination in reasoning

Furthermore, we would like to extend our analysis to processing of inference in which one has to go through the double negation elimination, especially on the meta-linguistic level. Suppose that a reasoning subject has to make an inference from the premise that *it is not the case that an object O is not P*, where *P* is an unary predicate. Logically speaking she should infer that *O is P*. However, if processing of the negative sentence involves in each case a simulation of the actual state of affairs, then negating a sentence "O is not P" means simulating first *not-P*, and only subsequently negating this state of affairs. We suspect that such a process should be suppressed in the case of those predicates that lack clear opposites, since the simulation of *non-P* is disturbed. The way of avoiding this problem would be to operate on a purely syntactic level by observing that two negations can be eliminated. The question for the experimental investigations is what are the real strategies of processing this kind of inferences.

In fact we have observed isolated cases of reasoning "error", that could be explained by presuming the processing difference of negated predicates of the two sorts: with and without clear opposites. The below-described observation was made during the experiment concerning acceptance of scalar implicatures "not all" for such quantifiers as "most" and "some" [8], and serves here as an illustration of a base intuition for further experimental investigation of this phenomenon. We observed that a subject who accepts in general scalar implicature and understands "most" as entailing "not all", refuses implicature in a specific case, based on a specific character of the predicate.

Task A1: *You know that:*
Most zarkotki do not have long ears
Can you say on the basis of the above sentence that some zarkotki have long ears?
Subject[1]: *Yes, sure. If you say "most", then it is not all.*

Task A2: *You know that:*
Most mermogliny are not pink.
Can you say (...) that some mermogliny are pink?
Subject: *No*
Experimenter: *But just a while ago, you said "yes" for an identical question?!*
Subject: *(referring to a previous task) With ears you can have either long or not long. But there are more colors than just pink. In this case we have many possibilities.*

We can clearly see that the subject accepts implicature in the case of predicate "long", but refuses in the case of "pink", referring to the character of the property, which, for a subject, is not of a "dichotomic" kind: While she says

[1] female, 28, university background in tourism studies, profession: consulting

that objects are either long or not long, in the case of colors she mentions "many possibilities".

To analyze how the reasoning process in the above-described case may look, let us focus more detailed on the considered pragmatical inference: "Most A are not B" $\rightarrow$ "Some A are B". According to the standard theory of scalar implicature [2,5,6], the use of a weaker lexical item from a given category (here: quantifiers) implicates that a sentences with a stronger item of the same category is false, since, according to the Gricean *Maxim of Quantity* [1], a speaker would be required to make a stronger, more informative utterance if a true one were available. Hence, in our case, the negative sentence $Most(A, not\, B)$[2] gives rise to the implicature that a sentence with the informationally stronger quantifier "no" is false, that is that: $\neg No(A, B)$, which is equivalent to $Some(A, B)$. Alternatively, if the negation in $Most(A, not\, B)$ is by default interpreted as a narrow-scope predicate negation, and thus *not B* forms a predicate *non-B*, then one can *directly* implicate $Some(A, not\, notB)$, which should be reduced to $Some(A, B)$ by the law that is known in syllogistic as *obversion principle*.

Suppose now that, as the discussed hypothesis predicts, the semantic integration of negation involves that a subject simulates the actual state of affairs that corresponds to *non-B* and only then she is able to further negate this predicate about an object. However, if there are many alternative properties that can be denoted by *non-B*, this process may be hindered. A predicate "non-pink" is true about those objects that are either blue, *or* green, *or* yellow, *or* red, etc. Such a long disjunction which creates a complement to "pink" might be too difficult to grasp in a representation and thus might be substituted by some restriction of this set, e.g. by "blue or green". Then a complement to a so-defined "non-pink" is not only "pink" but may be also e.g. "violet" or "red", etc. Another explanation for the poor performance in this case might be that applying *De Morgan* rules seems difficult for people, i.e. $\neg(p \vee q)$ is often understood as $\neg p \vee \neg q$ (instead of $\neg p \wedge \neg q$). If such a mistake occurs, then "not non-pink" might be interpreted as "either not blue, *or* not orange *or* not red, etc."

5 Conclusion

In our short case study we discussed the consequences of the two-step simulation hypothesis by Kaup et al. [3,4] with respect to negating two sorts of predicates: those with and those without clear opposites. We predict, that given the hypothesis is true, the processing of negative sentences should be more effortful in the case of predicates without clear opposites. Finally we want to emphasize that the present analysis is a preliminary preparation for further experimental work that should prove the plausibility of the presented hypotheses.

[2] We use a notation $Q(A, B)$ to represent a sentence "Q A are B", were Q is a NL quantifier.

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