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Abstract

This paper investigates the effects of negation in discourse comprehension. The paper is based on the finding by Mac-Donald and Just (1989) that after reading sentences such as *Elizabeth bakes some bread but no cookies* subjects are faster to respond to the probe *bread* than to the probe *cookies*. The question arises whether this differential availability of the relevant concepts is due to negation, or whether it reflects the fact that a bread is present in the described situation, whereas cookies are not. In order to decide between these alternatives two experiments were conducted. In Experiment 1 negated entities that are absent from the described situation were compared with non-negated entities that are present, whereas in Experiment 2 negated entities that are present in the situation were compared with non-negated entities that are absent. The results of the two experiments indicate that both factors, namely 'negation' and 'absence from situation', affect the availability of concepts during discourse processing.

Introduction

One of the prominent functions of verbal communication is to inform readers / listeners about situations, events, or more generally, states of affairs that the reader / listener did not attend to or experience himself. For this, not only information about what is the case is useful, but also information about what is not the case. Information about what is not the case is usually conveyed by explicit or implicit negation (cf. (1) and (2)).

(1) *The demonstrator did not eat for a week.*

(2) *The demonstrator refused to eat for a week.*

Whereas negation is a topic of much research in linguistics and philosophy (for a review, see Horn, 1989), experimental studies investigating the processing of negatives are relatively rare. There is a number of experimental studies concerned with negation within research on deductive reasoning, focussing on the specific difficulties that people have with drawing inferences from negative premises (for a review, see Wason & Johnson-Laird, 1972). In addition, psycholinguistic studies conducted in the seventies investigated the impact of negation on sentence verification (for a review, see Carpenter & Just, 1975). However, the hypotheses and models proposed within this research context were directed at a rather late stage of processing, namely the computation of truth values. As

MacDonald and Just (1989) rightly pointed out, before investigating the processes of computing truth values, more should be known about the representation of the meaning of such sentences.

MacDonald and Just presented their subjects with sentences such as

(3) *Almost every weekend, Elizabeth bakes some bread but no cookies for the children.*

and immediately afterwards tested the availability of the relevant concepts (bread vs. cookies) by means of a probe-recognition task or a naming task. Latencies were longer for nouns that had been negated in the sentence. The authors conclude that a negative particle decreases the activation level of the respective concept. Although not explicitly stated, the discourse-level representation which the authors seem to have in mind is of a propositional format similar to the Kintsch & van Dijk model (Kintsch & van Dijk, 1978). With propositional formats negation is extrinsically represented, i.e. by a specific operator. This operator could be considered to act as a kind of hitch making the access to those parts of the proposition that are in the scope of the negation difficult. Such an assumption is reasonable since it is well known that entities introduced within a negated phrase are usually not available for pronominal reference (see DRT, Kamp & Reyle, 1993, p.99ff). Assuming that retrieval in probe recognition tasks and naming tasks is basically similar to anaphor resolution, the observed latency difference is in line with propositional theories.

However, within discourse-comprehension research, there is an alternative to propositional theories, namely the theory of mental models (Johnson-Laird, 1983), which can account for the data as well. The mental model theory posits that during discourse comprehension, readers / listeners do not only construct text-based propositional representations but also non-linguistic representations of the state of affairs that the text is about. These non-linguistic representations, called mental models, are characterized as being structurally analogous to the states of affairs they represent. In fact numerous psycholinguistic studies focussing on the representation of spatial relations have provided clear evidence for this hypothesis (e.g., Glenberg, Meyer & Lindem, 1987; Kelter, Kaup & Habel, in press; Morrow, Bower & Greenspan, 1990; Rinck &

Bower, 1994). If during text comprehension a mental model is constructed that is analogous to the state of affairs it represents, the model should only contain tokens corresponding to entities that are part of the situation described, moreover, the model should only represent properties and relations that are true for these entities. Thus, for example, the mental model built for the sentence

(4) *The old man did not wear a hat.*

should not contain a token corresponding to a hat, since there is no hat in the situation described. Assuming a mental model is tapped in word-recognition and word-naming tasks, the result of MacDonald and Just can easily be explained - sentence (3) describes a situation in which there is bread but not a single cookie.

Although the two theoretical approaches in this particular case lead to the same conclusions as to the relative availability of the negated and non-negated concepts, this is not always the case. Take for instance text (5).

(5) *Elizabeth tidies out her drawers. She burns the old letters but not the photographs. Afterwards she cleans up.*

If the availability of *letters* and *photographs* is tested after the last sentence different predictions emerge. The propositional account outlined above predicts that *photographs* are less available than *letters*, because according to this account the position of the negative particle is crucial, and it is *photographs* which is in the scope of the negation. In contrast, the mental model theory predicts *letters* to be less available than *photographs*, because according to this account the situation described is crucial and the letters are no longer present in the situation after the last sentence of the text.

Along these lines of reasoning two experiments were conducted. The goal of Experiment 1 was simply to examine whether the effect of negation observed by MacDonald and Just (1989) for the processing of isolated sentences would also emerge with reading longer texts, which can be considered to come closer to natural reading conditions. This seems especially important for investigating the processing of negatives, since the contexts for plausible negatives are very restrictive: the use of negation is adequate only if differences with respect to expectations shall be communicated (Givon, 1978; Wason, 1972; for a review see Horn, 1989, chap. 1). In Experiment 1 subjects were presented with coherent narrative texts including sentences such as (3), and the availability of negated and non-negated concepts was assessed by means of a probe recognition task. Since it is conceivable that it takes some time to update a mental model, the availability of the concepts was not only tested shortly after the negation but also after two sentences elaborating the situation. Experiment 2 was designed to clarify whether the effect is indeed a negation effect or, alternatively, should better be characterized as a "content-effect", i.e. as being due to one entity being present in the situation while the other one is absent. Subjects were presented with texts including sections such as

(5). The availability of the negated and non-negated concepts was again assessed by means of a probe-recognition task.

Experiment 1

Method

Subjects. Thirty-two Hamburg University students took part in the experiment. They were paid for their participation.

Material. The material consisted of 51 passages, each describing an event. 16 passages were used as experimental items and 35 as filler items. Three passages each belonged together thematically and formed a coherent narrative text.

The experimental passages were constructed according to the following schema (see example in Table): After a short introductory section, describing the protagonist's goals or motives, the critical sentence followed, always containing a phrase like .... *s/he VERB-ed a NOUN₁ but not a NOUN₂*. The verb denoted an action that brings an object into existence (e.g., to bake; to knit; to build). The two nouns named objects A and B that could each be conceived as the outcome of the action equally well. For half of the subjects NOUN₁ named object A and NOUN₂ named object B, for the other subjects the assignment was reversed. The subsequent sentence described the completion of the action without reference to one of the objects. Two further embellishing sentences followed with the second one involving an implicit nominal anaphor referring to the newly created object. This implicit anaphor was such that the subjects could not determine the intended referent if they had not understood the critical sentence beforehand. All experimental passages were constructed in such a way that the negation in the critical sentence was pragmatically acceptable (*Because he doesn't always want to build what his brother suggests, ..*).

Filler passages varied in length and served to obscure the construction principle.

Test words used in the probe-recognition task in experimental trials were the nouns (NOUN₁, NOUN₂) of the critical phrases. For 10 filler trials, test words were nouns (object names) which had been mentioned in the passage, whereas for the remaining 25 filler trials the test words had not been mentioned before.

Design and Procedure. Subjects were tested individually. Each subject was presented with all 51 (experimental and filler) passages. In 50% of the experimental trials the probe was presented immediately after the completion sentence ("early probe"), in the other 50% the probe word was presented after the final sentence of the passage ("late probe"). For each of these two conditions the probe was the name of the negated concept in half of the trials and the name of the non-negated concept in the other half. In the filler trials the probe was always presented after the final sentence of the passage. Texts and probe words were displayed on a video monitor (15") with palatino-font 14 pt and 28 pt, respectively. Text presentation was sentence by sentence, self-paced by the subject pressing the "space"-key. Pressing the key after reading

Table 1: Sample Passage from Experiment 1

title	— John's ninth birthday —
passage 1 (exp)	
setting	John is turning nine years old today. He has already got a lot of nice presents. He is totally thrilled by the Lego bricks, which he got from his uncle. The only problem is, however, that he is never able to decide what to build next. His older brother has already suggested many different things.
negation	Because he doesn't always want to build what his brother suggests, John is now building a castle, but not a church.
completion	Soon all his bricks will be used up.
early probe	CHURCH / CASTLE
filler 1	It's great, all these things you can do with Lego bricks.
filler 2	John's brother is totally impressed by the construction that he sees when he enters the room.
late probe	CHURCH / CASTLE
passage 2 (fill)	....
passage 3 (exp)	....

either the completion sentence or the final sentence (depending on whether it was the "early probe" or the "late probe" condition) elicited the presentation of the probe word. Subjects were to decide whether or not the word had been mentioned in the text by pressing the appropriate key. They were asked to respond as quickly and accurately as possible. Subjects were encouraged to read the material carefully for comprehension. The experimental session lasted approximately 60 minutes.

Results

Mean latencies of correct responses and percentages of errors in the probe recognition task are displayed in Table . Latencies and errors showed parallel trends across conditions which rules out a speed-accuracy tradeoff.

In what follows, F_1 refers to tests against an error term that was based on subject variability and F_2 refers to tests against an error term that was based on item variability.

Table 2: Mean latencies (in ms) of correct responses and percentages of errors in Experiment 1.

	Probed concept			
	non-negated		negated	
Probe position	RT	% error	RT	% error
early	1319	5	1707	11
late	1570	12	1800	21

Errors. Error rates were higher for probe words naming the negated concept than for probe words naming the non-negated concept, $F_1(1,31) = 9.8, p < .01; F_2(1,15) = 8.44, p < .05$. 'Probe position' proved significant as well. Participants made more errors with probe words appearing late (after the anaphor sentence) than with probe words appearing early (after the completion sentence), $F_1(1,31) = 7.7, p < .01; F_2(1,15) = 5.60, p < .05$. The interaction of the two factors was not significant, $F_1, F_2 < 1$.

Latencies. Response times to probes that named the negated concepts were slower than to those naming the non-negated concepts, $F_1(1,31) = 18.48, p < .01; F_2(1,15) = 31.88, p < .01$. Participants responded slower to probes appearing late than to probe words appearing early, $F_1(1,31) = 6.57, p < .05; F_2(1,15) = 3.55, p < .08$. The two factors did not interact, $F_1(1,31) = 2.10, p > .15; F_2 < 1$.

Discussion

The results replicate the effect observed by MacDonald and Just (1989) for isolated sentences. Negated concepts were less available than non-negated concepts. It could be argued that the non-negated concept was always mentioned before the negated concept, and therefore the effect is possibly a sort of primacy-effect. However, in the study by MacDonald and Just (1989) order of mentioning was controlled and was found to be of no relevance. Moreover, for our results it would be difficult to defend the primacy-effect interpretation, considering that mentioning of concepts and the probe-recognition task were seperated by one sentence (early probe position) or even three sentences (late probe position).

Experiment 2 was designed to determine whether the differential availabilty between the negated and non-negated concepts found in Experiment 1 is to be attributed to inhibition due to the negative particle (propositional theories) or to the particular situation described, i.e. the non-negated entity being present whereas the negated entity is being absent.

Experiment 2

To distinguish between the different interpretations for the results of Experiment 1 (and for the results obtained by MacDonald and Just), subjects in this experiment were presented with passages containing sections such as (5), i. e. with passages that describe a situation in which the entity named by the negated noun is present whereas the entity named by the non-negated noun is absent. If the position of the negative particle is the crucial factor for the availability of the concepts, the negated concept should be less available than the non-negated concept after reading these passages. In contrast, if the specific situation described in the text is crucial (mental-model theory), the negated concept, which in this case is present in the described situation, should be more available than the non-negated concept, which in this case is absent.

From a mental-model-theory perspective, reading sections such as (5) should lead to an updating of the current mental model. A model in which letters and photographs are represented is transferred into a model in which photographs are represented but no letters. However, if neither the letters nor the photographs were mentioned before, the processes of updating might be different, i.e. might not involve a deletion of entities. It is unclear whether or not the intermediate mental model (the one corresponding to the situation before the burning, in which photographs as well as letters are represented) is constructed at all. In order to obtain more information about this factor, the critical concepts (photographs and letters) were mentioned in the setting section in half of the texts. For the other half of the texts the critical concepts were not mentioned earlier than in the negation sentence.

Method

Subjects. Thirty-two Hamburg University students took part in the experiment. They were paid for their participation.

Material. The material was similar to that used in Experiment 1, except that the critical phrases of the experimental passages contained sentences of the form .... *s/he VERB-ed the NOUN$_1$ but not the NOUN$_2$*, with the verb naming an action that causes an object to vanish (e.g., to burn, to eat up). In 8 of the 16 experimental passages the critical objects (objects named by NOUN$_1$ and NOUN$_2$) were already mentioned in the setting section, whereas for the other 8 experimental passages the objects were first mentioned in the negation sentence (see example in Table). For all experimental passages the completion sentence was the final sentence of the passage.

Design and Procedure. Each subject was presented with all 16 experimental passages and additionally with 35 filler passages. For each subject the negated concept was the probe in 8 experimental passages and the non-negated concept was the probe in the other 8 passages. In contrast to Experiment 1, the probe word was presented after the completion sentence in all trials. In all other respects the procedure was identical to Experiment 1.

Table 3: Sample Passage from Experiment 2

title	— Cleaning up the attic —
passage 1 (exp)	
setting	Today is Peter's day off from work. Peter has decided to clean up the attic. For years, old furniture has been piling up in there. In order to create some space in the attic, Peter decides to chop up some of the furniture and burn it in the garden.
critical	Peter burns the old bed, but not the big cupboard.
completion	After coming back from the garden, Peter goes to the attic and looks around happily.
probe	BED / CUPBOARD
passage 2 (fill)	....
passage 3 (exp)	....

Results

Mean latencies of correct responses and percentages of errors in the probe recognition task are displayed in Table . Latencies and errors showed parallel trends across conditions which rules out a speed-accuracy tradeoff.

Errors. Error rates were insignificantly lower for probes naming concepts introduced prior to the negation sentence than for probes naming concepts not introduced prior to the negation-sentence, $F_1(1, 31) = 3.06, p = .09$; $F_2(1, 14) = 2.70, p > .10$. Subjects made more errors with probes naming the negated concepts than with probes naming the non-negated concepts. This effect, however, was only marginal, $F_1(1, 31) = 4, 14, p > .05$; $F_2(1, 14) = 1.69, p > .20$. The two factors did not interact, $F_1, F_2 < 1$.

Latencies. The response times to probes naming the negated concepts were slightly slower than to those naming the non-negated concepts. This effect, however, was not significant $F_1(1, 31) = 2.74, p > .10$; $F_2 < 1$. The response times to probes naming concepts introduced prior to the negation sentence were nonsignificantly faster than to probes not introduced prior to the negation sentence, $F_1(1, 31) = 2.23$, $p > .10$; $F_2 < 1$. The interaction between the two factors was not significant, $F_1, F_2 < 1$.

Table 4: Mean latencies (in ms) of correct responses and percentages of errors in Experiment 2.

	Probed concept			
	non-negated		negated	
concepts	RT	% error	RT	% error
men. before	1317	1	1367	2
not men. before	1366	2	1414	6

Figure 1: Mean latencies (in ms) of correct responses in Experiment 1 and Experiment 2

Since the general aim of this experiment was to decide between the propositional interpretation and the mental-model interpretation, with the two crucial factors being varied orthogonally only across experiments, the data from this experiment were compared with the data from Experiment 1 within a single analysis with the two factors 'negation' and 'absense from situation'. In this analysis, in order to get comparable data, only the response times for early probes were used from Experiment 1 and only those for probes not mentioned prior to the negation sentence from Experiment 2. The mean latencies are displayed in Figure There is a main effect of negation, $F_1(1, 124) = 7.04, p < .01$; $F_2(1, 44) = 5.03$, $p < .05$, as well as a main effect of 'absence from situation', $F_1(1, 124) = 4.17, p < .05$; $F_2(1, 44) = 4.07, p < .05$, i.e. subjects respond significantly slower to negated probes than to non-negated probes and subjects respond significantly slower to probes that correspond to entities not present in the described situation than to those corresponding to entities present in the situation. The effect of 'negation' is numerically stronger for the probes corresponding to entities absent from the described situation than for those present in the situation. However, this interaction is not significant, $F_1(1, 124) = 2.23, p > .10$; $F_2(1, 44) = 2.49, p > .12$.

Discussion

Experiment 2 was conducted in order to be able to decide between the two different interpretations for the effect observed by MacDonald and Just (1989) which was replicated in Experiment 1 . However, the results of this experiment do not really allow for a decision.

If the position of the negation marker is the crucial factor for the availability of the concepts, non-negated concepts should in general be more available than negated concepts, independent of whether or not the corresponding entities are present in the described situation. Contrary to this prediction, the factor 'negation' did not have a reliable impact on the latencies in Experiment 2.
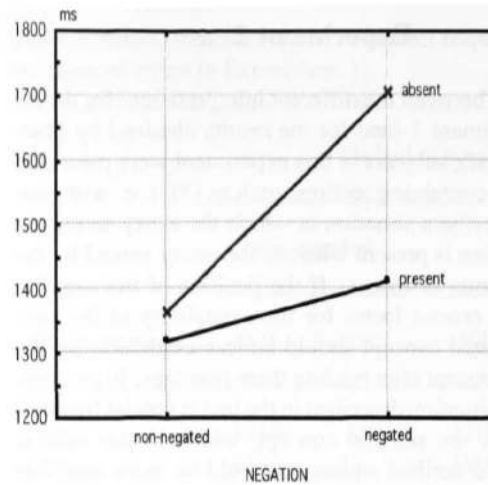
If, on the other hand, the crucial factor for the availability of concepts is whether or not the corresponding entities are present in the described situation, entities present in the situation should in general be more available than entities not present in the situation, independent of the linguistic form of the description. The effect of negation should have been reversed in Experiment 2, because negated concepts here corresponded to entities present in the situation and therefore should have been more available than non-negated concepts.

To summarize, it seems as if both factors play a crucial role for the availability of concepts during text comprehension, i.e. availability of a concept is a function of whether or not the concept is negated and of whether or not the corresponding entity is present in the described situation. The specific differences in availability presented in figure 1 nicely match this view.

General Discussion

The goal of this study was to obtain more information about how negatives are processed during text comprehension. The focus was on the kind of representation constructed during the processing of negative sentences. More specifically, the study adressed the question, whether the finding that *bread* is more available than *cookies* after reading sentences such (3), is better characterized as an effect of negation in propositional representations or, alternatively, as an effect of the content of representations at an extra-linguistic level, i.e. the representational level of mental models. For theories of propositional format, the relevant factor for differential availability of *cookies* and *bread* after reading (3) is the position of the negation marker - *cookies* is in the scope of negation and therefore less available than *bread*. For the mental model theory this effect is not due to the linguistic form of the sentence, but is based on the content of the mental model available after reading (3) - bread is represented, but no cookies. The results

of the two experiments indicate that neither the pure propositional interpretation nor the pure mental model interpretation can account for the differential availability of the relevant concepts. Both factors (position of negation and content of mental model) seem to be relevant for the availability of the concepts.

However, some qualifications are in order.

1) The specific method used in the two experiments for measuring the availability of concepts, namely the probe-recognition task is not unproblematic in the context of negation. As MacDonald and Just (1989) have pointed out, this task introduces a potential confusion for the subjects, sometimes requiring them to make a positive response to a probe word that had been mentioned within a negated phrase. It could be argued that the differential availability between the negated concepts and the non-negated concepts does not reflect a negation effect due to inhibition but rather an interference effect due to the specific task. However, in order to eliminate the possibility of response confusions, MacDonald and Just used a different task to measure availability in their second experiment, namely the probe-naming task, which requires subjects merely to name the probe word aloud. The negation effect was not relevantly influenced by this variation. Furthermore interference alone cannot account for the different results obtained in Experiment 1 and Experiment 2 of the present paper. If the differences in response latencies were due to interference alone, comparable effects should have been obtained in the two experiments.

2) The critical sentences used in Experiment 1 and Experiment 2 did not only differ with respect to whether or not the negated concepts are present in the described situation. In Experiment 1 the target concepts were mentioned within indefinite noun phrases (.... *s/he VERB-ed a NOUN₁ but not a NOUN₂*) whereas in Experiment 2 they were mentioned within definite noun phrases (*s/he VERB-ed the NOUN₁ but not the NOUN₂*). Although not relevant to an account of the results by propositional theories of the van Dijk / Kintsch type, this difference may play an important role in linguistically more sophisticated theories such as the Discourse Representation Theory (DRT) by Kamp (1981). DRT posits that entities introduced via a negated verb phrase are represented in a special substructure which is not accessible for reference resolution. This can account for the results of Experiment 1. However, a definite noun phrase does not introduce an entity, but refers to an entity. According to DRT this entity - even if not mentioned before   gets represented as if it had been introduced in a non-negated phrase, i.e. in the accessible structure. Thus, DRT is consistent with the finding of Experiment 2 , that after reading passages such as (5), *photographs* is equally available as *letters*.

To summarize, in Experiment 1 and Experiment 2 the impact of two factors on the availability of concepts mentioned in texts was investigated, namely negation and 'absence from the situation described'   Both factors were found to affect the availability of concepts. However DRT can also account

for the differential results by treating definite and indefinite noun phrases differently. Further investigations have to clarify whether in addition to negation definitness or presence in the situation is crucial.

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