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Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed?

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Abstract

We investigated whether comprehenders of isolated negative sentences with contradictory predicates (e.g., *The door was not open*) have available a representation of the actual state of affairs (closed door) from a certain point in the comprehension process on. In a self-paced-reading paradigm, participants were presented with affirmative and negative sentences in which a target entity and a contradictory predicate were being mentioned. After reading the sentence, participants were presented with a picture of the target entity that either matched or mismatched the entity's properties in the described world, and their task was to name out loud as quickly as possible the name of the depicted entity. When the delay between sentence and picture was 750 ms, a match effect with respect to the actual state of affairs occurred for the affirmative versions of the sentences but not for the negative versions of the sentences. When the delay was 1500 ms, a match effect with respect to the actual state of affairs occurred for the negative but not for the affirmative versions. The results are interpreted in the context of the experiential-simulations view of comprehension.
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1. Introduction

Consider a sentence such as *The door is not open*. This sentence implicitly refers to two states of affairs: The state of affairs that is being negated (the door is open), and the state of affairs that is actually the case (the door is not open). Most people would agree that in order to understand the sentence, one first has to understand what it is that is being negated. In other words, understanding a negated sentence requires representing the negated state of affairs (cf. Fauconnier, 1985). This

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assumption can be motivated when the pragmatics of negation is taken into account. Negative sentences are usually used to communicate deviations from expectancies (Givon, 1978; Horn, 1989; Wason, 1965; see also Glenberg et al., 1999, but see Giora, 2006). Thus, negative sentences not only convey information regarding the actual state of affairs but also information regarding expectancies. When processing a negative sentence, the comprehender can therefore be expected to represent these expectancies, or in other words, the negated state of affairs. However, it is clear that representing the negated state of affairs does not suffice to capture the meaning of the sentence. In addition to representing the negated state of affairs, one needs to represent the fact that this state of affairs does not hold for the world under consideration. Therefore, most authors assume that the representation of the negated state of affairs is mentally rejected (cf., Russell, 1948:139). Finally, once the respective representation has been rejected, the comprehender may turn to the implications of the sentence with respect to the actual state of affairs and modify his or her representation accordingly (cf. Langacker, 1991). For our example sentence this would imply that the comprehender first represents an open door, then mentally rejects this representation, and finally possibly represents a closed door. The different theories of negation mainly differ with respect to the mechanisms by which the mental rejection of the negated state of affairs is achieved, and as a result also slightly with respect to the role that the representation of the actual state of affairs is assumed to play in the processing of negation. As these differences play only a minor role for the empirical study that we will be reporting in this manuscript, we will postpone a discussion of the different theories until section 4.

In line with the assumptions concerning the processing steps associated with negative sentences, the psychological negation literature has provided evidence not only for the availability of representations of the negated state of affairs but on occasion also for the availability of a representation of the actual state of affairs. We will now briefly review both kinds of evidence. Studies from various areas of psychology have illustrated that inserting a negation marker into linguistic material (e.g., *The boy is hungry -> The boy is not hungry*) often does not result in qualitatively different results than the corresponding linguistic material without negation (e.g., *The boy is hungry*). These results can be interpreted as suggesting that comprehenders at the time of testing had available a representation of the negated state of affairs in the negative conditions (e.g., a representation of a hungry boy for *The boy is not hungry*). For instance, in a semantic priming study by Giora et al. (2004), associates of a concept (e.g., *piercing* for *sharp*) were primed independent of whether the concept was affirmed or negated in the stimulus sentence (e.g., *The instrument was sharp* versus *The instrument was not sharp*). Similarly, in an evaluative priming study by Deutsch (2002), concepts with negative valence (e.g., *disease*) were primed by noun phrases containing concepts with negative valence, and concepts with positive valence (e.g., *luck*) were primed by noun phrases containing concepts with positive valence, independent of whether the noun phrases were affirmative or negative (e.g., *a war* versus *no war* or *a party* versus *no party*). These results are in line with the view that representations of the negated state of affairs were present in the comprehender's mind at the time of testing. Strong evidence for this view is also provided by a recent study of ours, in which we presented participants with sentences such as *There was no eagle in the sky/nest* and subsequently asked them to decide whether a depicted object had been mentioned in the sentence (see Kaup et al., submitted for publication; see Zwaan et al., 2002 for the introduction of this paradigm). In experimental trials the correct response was always 'yes', but the shape of the depicted entity either matched the shape of the target entity in the negated state of affairs (eagle with its wings outstretched for . . . *in the sky*; eagle with its wings drawn in for . . . *in the nest*) or not (eagle with its wings drawn in for . . . *in the sky*; eagle with its wings outstretched for . . . *in the nest*).

Table 1
Materials used in studies employing sentence-picture verification tasks

Condition	Sentence	Picture	Negated state of affairs	Actual state of affairs
True affirmative	The star is above the plus.	*		*
		+		+
False affirmative	The plus is above the star.	*		+
		+		*
True negative	The plus is not above the star.	*	+	*
		+	*	+
False negative	The star is not above the plus.	*	*	+
		+	+	*

Responses in the picture-recognition task were significantly shorter when there was a match with respect to the negated state of affairs than when there was a mismatch. This suggests that participants had available a representation of the negated state of affairs when being probed with the picture. Finally, the well known results obtained in sentence-picture verification studies may be taken as indirect evidence for the claim that negated states of affairs are present in comprehenders' representations of negative sentences. Whereas true affirmative sentences are easier to verify than false affirmative sentences, the opposite holds for negative sentences—here, falsity is usually easier than truth (for an overview see Carpenter and Just, 1975; Clark, 1974). The reason may be that with false negative sentences the picture matches the state of affairs that is being negated whereas for true negative sentences the picture mismatches this state of affairs (see Table 1 for illustration, as well as Kaup et al., in press, for a more detailed discussion).

The above paragraphs review the evidence for a representation of the negated state of affairs. There is also evidence that certain aspects of the actual state of affairs are available after the processing of negative sentences under certain conditions. For instance, in studies investigating the impact of negation on the accessibility of text information, negated concepts were less available than non-negated concepts after processing of the sentences, only when the negated concepts were absent from the described situation and the non-negated concepts were present (as in *Mary bakes bread but no cookies*; cf. MacDonald and Just, 1989) but not when the negated concepts were present and the non-negated concepts were absent (as in *Elisabeth burns the letters but not the photographs*; Kaup, 1997, 2001). Similarly, 1500 ms after reading sentences mentioning a particular color word, accessibility of the color word was low when the corresponding color was absent from the described situation, independent of whether or not the color word had been mentioned within the scope of an explicit negation (Kaup and Zwaan, 2003). Both results suggest that accessibility in these cases was based on a representation of the actual state of affairs in which only those entities are being represented that are present in the described state of affairs.

Additional evidence is provided by the fact that the above mentioned sentence-picture verification studies in some cases produced *not* a negation-by-truth-value interaction but a main effect of truth value (for an overview see Carpenter and Just, 1975; Clark, 1974). By the same reasoning as above, this result could be taken as indication that in these cases, the pictures were compared with representations of the actual state of affairs (see Table 1 for illustration, as well as Kaup et al., in press). Also, in a recent study by Mayo et al. (2003) participants were presented with affirmative or negative character descriptions (e.g., *John is (not) a tidy person*) and afterwards were asked to judge whether a particular behavior (e.g., *John's clothes are folded*

neatly in his closet versus *John forgets were he left his car keys*) was congruent or incongruent with the personality of the character. Probes congruent with the actual personality of the character were judged faster than incongruent probes not only for affirmative but also for negative character descriptions. This indicates that the negative character descriptions activated properties of the actual state of affairs.[1]

A closer look at the conditions under which the two kinds of effects were observed in the above discussed studies reveals that the effects indicative of a representation of the negated state of affairs were typically observed right after the processing of the negative sentences, whereas the effects indicative of the actual state of affairs were typically observed later in the comprehension process (see Kaup et al., in press, for a detailed discussion). This may suggest that comprehending a negative sentence is a two-step process in which comprehenders first create a representation of the negated state of affairs and then shift attention towards the actual state of affairs at a later point in the comprehension process.

In line with this view, we recently found evidence that temporal characteristics of the experimental task indeed affect the availability pattern observed after the processing of negative sentences (Kaup et al., 2005). Participants were presented with sentences such as *The elephant is (not) above/below the giraffe* and subsequently saw a picture with two objects, one above the other. The task was to decide as quickly as possible whether both depicted objects had been mentioned in the sentence or not. In experimental trials, the correct response was always 'yes', but the picture either matched the spatial arrangement described in the sentence or not. For instance, for *The elephant is above the giraffe*, a picture of an elephant above a giraffe matches the state of affairs described in the sentence whereas a picture of a giraffe above an elephant mismatches this state of affairs. For *The elephant is not above the giraffe*, a picture of a giraffe above an elephant matches the actual state of affairs, whereas a picture of an elephant above a giraffe mismatches this state of affairs. In the latter case, the picture matches the negated state of affairs. When the picture was presented without delay, an interaction emerged: For affirmative sentences, responses were faster when the picture matched the described state of affairs than when the picture mismatched this state of affairs. For negative sentences, responses were faster when the picture matched the negated state of affairs than when the picture matched the actual state of affairs. This strongly suggests that participants had available a representation of the negated state of affairs when being probed with the picture in the negative versions. A different response-time pattern emerged when the picture was presented with a delay of 1500 ms. Under this condition, a main effect of match (with respect to the actual state of affairs) occurred, suggesting that participants now had available a representation of the actual state of affairs in the affirmative and the negative conditions. The difference in the two delay conditions manifested itself in a significant three-way interaction of delay, polarity, and match. However, planned comparisons revealed that although numerically the response times in the long-delay negative-match condition were shorter than the ones in the respective negative-mismatch condition, this difference was not significant. Different hypotheses come to mind: First, the null effect in the negative-long-delay conditions may reflect that some participants in some conditions were still focusing on the negated state of affairs whereas other participants in other conditions already had available a representation of the actual state of affairs. Under this interpretation the long delay was simply not long enough to produce pure match effects with respect to the actual state of affairs in the negative conditions of the experiment. Alternatively, the null effect could also

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[1] It should be noted however that this result only held for bipolar adjectives, for which there exists a highly accessible opposite term (e.g., *tidy–messy*). For unipolar adjectives (e.g., *responsible*) the results were ambiguous.

reflect that comprehenders in the negative-long-delay condition had available two representations, a representation of the negated state of affairs and a representation of the actual state of affairs, with both representations being in the focus of attention (cf. Ferreira, 2003, for evidence that dis-preferred readings of garden-path sentences are available even after the local ambiguity has been resolved). Under this interpretation, the null effect results because the picture in both conditions matches one of the two available representations and mismatches the other. Third, in principle, the null effect may of course also reflect that comprehenders in the negative-long-delay condition had available neither a representation of the negated state of affairs nor a representation of the actual state of affairs, for instance as a result of having applied a rejection mechanism to the previously created representation of the negated state of affairs.

The goal of the present study was to obtain more information with regard to the hypothesis that comprehenders eventually shift their focus of attention away from the negated state of affairs onto the actual state of affairs when processing negative sentences (Hypothesis 1 from above). To this end, we presented participants with affirmative and negative sentences with contradictory predicates (e.g., *The door is (is not) open/closed.*). Subsequently a picture appeared, and participants were to name out loud as quickly as possible the name of the depicted entity. In experimental trials, the picture always depicted the entity mentioned in the sentence, but either matched or mismatched the entitie's properties in the actual state of affairs. For instance, for *The door was open* a picture of an open door matches the actual state of affairs, whereas a picture of a closed door mismatches this state of affairs. Conversely, for *The door was not open* a picture of a closed door matches the actual state of affairs, whereas a picture of an open door mismatches this state of affairs. Thus, on a given trial, the picture could either depict the actual state of affairs of the preceding negative or affirmative sentence, or the picture could depict the respective alternate state of affairs (which corresponds to the negated state of affairs for negative sentences, as in Fig. 1).

Sentences with contradictory predicates have at least two advantages for investigating the issue at hand. First, negative sentences with contradictory predicates allow a definite conclusion with respect to the actual state of affairs. When told that the door was not open the comprehender can infer that the door must have been closed. The same does not hold for the sentences employed in the previous study. Strictly speaking, *The elephant is not above the giraffe* does not allow to infer that the elephant was below the giraffe (it could have been next to the giraffe, for instance). Second, and more important, in contrast to the sentences employed in the previous study (e.g., *The elephant is (not) above/below the giraffe*) the present sentences do not refer to two but to only one object. Hence, creating the meaning representations should be easier, and accordingly, effects reflecting the availability of the actual state of affairs may occur at an earlier point in time in the comprehension process. This allows us to test the hypothesis that comprehenders eventually have available a representation of the actual state of affairs without having to prolong the delay between sentence and picture presentation even further. In order to receive information regarding the time course of
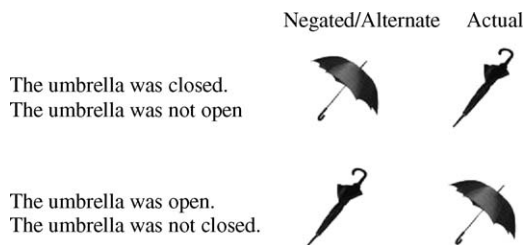

Fig. 1. Sample materials.

comprehension we employed an intermediate and a long-delay condition: Half of the participants received the picture with a delay of 750 ms whereas the other half received the picture with a delay of 1500 ms. The design therefore was a 2 (delay: intermediate versus long) $\times$ 2 (polarity: affirmative versus negative) $\times$ 2 (depicted state of affairs: 'actual' versus 'negated/alternate') design, with repeated measurement on all three factors in the by-items analysis and repeated measurement on the second and third factor in the by-participants analysis.[2]

If comprehenders of negative sentences indeed shift their attention away from the negated and onto the actual state of affairs from a certain point in the comprehension process on, then we would expect to find shorter response times in conditions where the picture matches the actual state of affairs than in conditions where the picture matches the 'negated' state of affairs. If on the other hand, participants simultaneously focus on both representations, or do not have available either of them (see Hypotheses 2 and 3 above) then we would not expect to find such a facilitation effect in the negative conditions of this experiment.

No clear cut predictions can be made with respect to the delay manipulation, as we do not know in advance at what time in the comprehension process (if at all) participants will shift attention towards the actual state of affairs with the present materials. Considering that the present sentences are relatively short and easy to comprehend, we would expect to find a clear facilitation effect with respect to the actual state of affairs in the negative long-delay condition. Possibly this facilitation will also be evident at the intermediate delay. If the facilitation effect turns out to be stronger for the long than for the intermediate delay condition, this would indicate that some participants in some conditions were still focusing on the negated state of affairs 750 ms after reading the negative sentences. In the *affirmative* conditions of the previous experiment, we found a facilitation effect with respect to the actual state of affairs at the short and the long delay condition. However, considering that the sentences employed in the present experiment are less complex, it also seems possible that the facilitation effect in the affirmative conditions will be confined to the intermediate delay condition in the present experiment: Results obtained in studies concerned with the processing of ironic statements suggest that comprehenders do not keep the created meaning representations active beyond a certain point in time in the comprehension process (Giora et al., 1998).

2. Method

2.1. Participants

One hundred and twelve students at the Berlin University of Technology participated in the experiment for course credit or financial reimbursement of 8 euros per hour. The first 56 students were assigned to the 750 ms group and the remaining 56 were assigned to the 1500 ms group.

2.2. Materials

Forty experimental sentences were constructed. All of these sentences were of the form <u>Die</u>/Der/Das X war/war nicht Y/Z (*The X was/was not Y/Z*), with Y and Z being contradictory

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[2] One may wonder why we didn't manipulate delay within participants. Pre-tests showed that a within manipulation of delay does not work well, if one does not want to explicitly instruct participants with respect to this manipulation. Without explicitly warning the participants about the different delays, they tend to be confused in the long-delay trials and think that the computer crashed when the picture does not come up as early as in the short-delay trials.

predicates with opposite meaning. Thus, each sentence was available in four different versions—two affirmative, two negative (e.g., *Die Tür war offen* [*The door was open*]/*Die Tür war zu* [*The door was closed*]/*Die Tür war nicht offen* [*The door was not open*]/*Die Tür war nicht zu* [*The door was not closed*]). Forty additional filler sentences were constructed. Twenty of these filler sentences were affirmative (*Die/Der/Das X war Y* [*The X was Y*]) and 20 were negative (*Die/Der/Das X war nicht Y* [*The X was not Y*]), with various sorts of predicates (e.g., *blond* [*blond*], *gross* [*tall*], *zerbrochen* [*broken*]). There were 120 black-and-white pictures. Eighty of these pictures were comprised of 40 pairs, with the two members of a pair depicting the same object in two different states (e.g., a door, either open or closed). The 40 different objects shown in these pictures corresponded to the objects named in the 40 experimental sentences, and the two states of each picture pair corresponded to the two predicates that were named in the different versions of each experimental sentence. The remaining 40 pictures showed objects not named in any of the sentences. All pictures were scaled such that the longer of the two sides was 314 pixels long.

For 24 of the filler sentences, comprehension questions were constructed. Twelve of these sentences were affirmative and 12 were negative, with six of the questions in each group requiring a 'yes' response and six a 'no' response. Eight of these were negative and eight affirmative, with four of the questions in each group requiring a 'yes' response and four a 'no' response.

2.3. Design and procedure

For each of the delay conditions we created eight lists that counterbalanced items and conditions. Each list included a different one of the eight possible versions (four sentences × two pictures) for each object. In half of the sentence versions, the picture depicted the 'actual' state of affairs of the preceding negative or affirmative sentence. In the other half of the sentence versions the picture depicted the 'alternate' or 'negated' state of affairs (see Fig. 1). Each participant saw one of these eight lists. Thus, we employed a 2 (delay: 750 ms versus 1500 ms) × 2 (sentence polarity: affirmative versus negative) × 2 (depicted state of affairs: actual versus negated/alternate) × 8 (list) design.

Each participant saw 20 affirmative and 20 negative experimental sentences, each of which was paired with a picture that depicted the entity mentioned in the grammatical subject position. In addition, each participant saw 20 affirmative and 20 negative filler sentences (e.g., *Die Treppe war steil* [*The staircase was steep*] and *Der Zug war nicht pünktlich* [*The train was not on time*], respectively), each of which was paired with a picture of an entity not mentioned in any of the sentences (e.g., picture of an apple and picture of a nut, respectively). The order in which these sentences were presented was random for each participant.

Participants were tested individually. They were seated at a table with a 17 in. Monitor, a table microphone and a CMU five button box (http://www.pstnet.com). At the beginning of the experimental session, the experimenter adjusted the microphone sensitivity to the individual participant. To this end, the participant was presented with a list of 10 words, one after the other, and was asked to name out loud each of the words in a clear voice and as quickly as possible. Upon registering a response, the computer program caused the current word to disappear and presented the next word in the list. The microphone sensitivity was adjusted up or down depending on whether the words disappeared without a clear response or stayed on the screen despite a clear response. After the adjustment phase, the participants were presented with written instructions regarding the experimental procedure, and then practiced the procedure in three practice trials. They were instructed to silently read each sentence at their own pace and then to

name out loud as quickly as possible the object in the picture that followed. Furthermore, they were informed that their naming latencies were being measured and that it was important for them to name out loud the depicted object as quickly and accurately as possible. They were told that the microphone would pick up on any disruptive sounds and that it was therefore important that they made as few unrelated sounds as possible. Throughout the experiment, the experimenter was in the room and recorded any microphone problems, smacking sounds or naming errors the participant made.

During each trial, participants first saw a sentence, left justified on the screen, which either did or did not mention the object they would later see. They pressed a key when they had understood the sentence, and then a fixation point appeared at the center of the screen for 750 ms or 1500 ms depending on the particular delay condition to which the participant was assigned. Subsequently the picture was presented. Participants then named out loud the object in the picture. Upon response registration, the picture disappeared. For trials with a comprehension question, the question was presented next. Participants indicated their answer by pressing the appropriate key on the button box. Participants were given feedback on their responses. The experiment took approximately 20 min to complete.

3. Results

Naming latencies of experimental trials were submitted to 2 (delay) × 2 (sentence polarity) × 2 (depicted state of affairs) × 8 (list) analyses of variance (ANOVAs) with repeated measurement on sentence polarity and depicted state of affairs in both the by-participant analysis and the by-items analysis, and delay as between participants but within items variable. Participants for whom the experimenter had recorded an exceptionally high number of technical and/or naming problems (smacking sounds, naming errors) were excluded from the analyses. More specifically, for both participant groups we excluded those participants for whom the number of problematic trials exceeded the mean number of problematic trials in this group by one standard deviation (750 ms: $N = 5$; 1500 ms: $N = 9$).[3] An additional five participants were excluded from the analyses because they had made eight or more errors with the overall 16 critical comprehension questions (750 ms: $N = 4$; 1500 ms: $N = 1$). The analyses were performed on valid responses only (i.e., on responses from trials without naming errors or microphone problems). Moreover, responses longer than 2000 ms or shorter than 200 ms were omitted. In determining outliers within the remaining naming latencies, we took not only differences among the participants into account, but also differences among the items, which seems particularly important with naming latencies because these typically depend heavily on properties of the particular word that is being uttered. We employed a two-step procedure: First, the valid experimental naming latencies of each subject were converted to z scores. Then naming latencies with a z score that deviated more than x standard deviations from the mean z score of the respective item in the respective condition were discarded, with x depending on the number of observations per condition, as suggested by Van Selst and Jolicoeur (1994). This eliminated less

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[3] This procedure was used because the criteria by which the experimenter classified a trial as problematic during the experiment were improved after running the 56 participants in the 750-ms-delay condition. As a consequence, the number of trials classified as problematic in the 1500-ms-delay condition was reduced relative to the 750-ms-delay condition. Thus, instead of using the same absolute criterion in both groups we decided to use the same relative criterion (which equals a threshold of 22/80 problematic trials in the 750-ms-delay condition and a threshold of 16/80 problematic trials in the 1500-ms-delay condition). However, it should be noted that the results do not depend on this decision—analyses based on the same absolute criterion in both groups (i.e., a threshold of 22/80) produced qualitatively similar results.

Table 2
Mean naming latencies/standard deviations (in ms) as a function of depicted state of affairs, sentence polarity and delay

Polarity	Depicted state of affairs				
	Actual (experimental), M/S.D.		Negated/alternate (experimental), M/S.D.		Unrelated (filler), M/S.D.
Delay: 750 ms					
Affirmative	619/126	<	642/146	<	752/105
Negative	643/143	=	648/130	<	791/104
Delay: 1500 ms					
Affirmative	624/98	=	626/100	<	739/81
Negative	611/102	<	634/103	<	773/101

Note: The mathematical symbols between the columns indicate the results of the planned comparisons between conditions. '=' indicates a null effect, '<' indicates a significant or marginally significant difference with $p < .065$.

than 3% of the data. The mean latencies and standard deviations are displayed in the first two columns of Table 2: In all conditions, response times were faster numerically when the picture matched the actual state of affairs than when the picture did not match this state of affairs. For affirmative sentences the respective difference was larger in the 750 ms conditions whereas for negative conditions, the difference was larger in the 1500 ms condition.

These numerical differences were reflected in the statistical analyses: There was a main effect of the depicted state of affairs with significantly faster response times in the conditions where the depicted state of affairs matched the actual state of affairs than in the conditions where it matched the negated or alternate state of affairs, $F1(1,77) = 5.9$, $p < .05$; $F2(1,32) = 4.71$, $p < .05$. Sentence polarity did not yield a significant main effect, $F1(1,77) = 1.8$, $p = .18$; $F2 < 1$, and more important, it did not interact with the effect of the depicted state of affairs, both $Fs < 1$. There was a main effect of delay, with shorter response times in the 1500 ms delay condition than in the 750 ms delay condition; however, this was only significant in the by-items analysis, $F1 < 1$; $F2(1,32) = 4.59$, $p < .05$. Furthermore, delay interacted with the polarity of the sentence, $F1(1,77) = 4.2$, $p < .05$; $F2(1,32) = 2.5$, $p < .12$, but not with the depicted state of affairs, $F1 < 1$; $F2 < 1$. Most important, there was a three-way interaction (marginally significant by subjects) of delay, sentence polarity, and depicted state of affairs, $F1(1,77) = 3.7$, $p = .057$; $F2(1,32) = 5.6$, $p < .05$.

Analyzing this interaction more closely revealed that with a 750 ms delay, the advantage of the actual state of affairs was due to the affirmative versions of the sentences whereas with a 1500 ms delay, it was due to the negative versions of the sentences. In other words, with a 750 ms delay, responses were faster when an affirmative sentence was followed by a picture that matched the actual state of affairs compared to a picture that mismatched this state of affairs, $F1(1,39) = 4.01$, $p = .052$; $F2(1,32) = 3.70$; $p = .064$, but no such difference obtained for the negative versions, both $Fs < 1$. In contrast, with a 1500 ms delay, responses were faster when a negative sentence was followed by a picture that matched the actual state of affairs compared to a picture that mismatched this state of affairs, $F1(1,38) = 5.3$, $p < .05$; $F2(1,32) = 4.2$, $p < .05$, but no such difference obtained for the affirmative versions, both $Fs < 1$.

In order to obtain more information on whether inhibition may have been involved in the processing of negative sentences, we compared the response times in the affirmative and negative experimental versions to the response times in the affirmative and negative filler versions (in which the depicted entity was not mentioned in the sentences). If response times elicited by the

picture depicting the negated state of affairs after a negative sentence are longer than response times in the negative filler conditions (baseline), then this would strongly suggest that comprehenders actively inhibited the representation of the negated state of affairs after processing the negative sentences. If the reverse is true, however, then this post hoc analysis will not be informative, as such an effect may reflect surface level priming given that the entity to be named was mentioned in the previous sentence in the experimental conditions but not in the filler conditions. The means of the response times in the filler conditions are displayed in the third column of Table 2 (column label: unrelated). Response times in the filler conditions were much longer than those in the experimental conditions in all versions, and these numerical differences were reflected in the statistical analyses. We performed separate 2 (delay) $\times$ 3 (version: actual versus alternate versus unrelated) $\times$ 8 list ANOVAs for the affirmative and the negative conditions, respectively. Both analyses yielded highly significant effects of version (affirmative sentences: $F1(2,76) = 110.0$, $p < .001$, $F2(1,97) = 22.7$, $p < .001$, negative sentences: $F1(2,76) = 140.7$, $p < .001$, $F2(1,97) = 28.4$, $p < .001$). For the negative sentences, there was a main effect of delay with shorter response times in the long-delay condition, but this effect was only significant in the by-items analysis ($F1(2,76) = 1.759$, $p = .19$; $F2(1,97) = 6.7$, $p < .05$). There was no main effect of delay for the affirmative sentences (all $Fs < 1$). There was no interaction of delay and version, in either of the analyses (affirmative sentences: $F1(2,76) = 1.2$, $p > .20$; $F2(1,97) = 1.1$, $p > .30$, negative sentences: all $Fs \leq 1$). Separate t-tests for the different contrasts revealed that response times in the picture naming task were significantly longer in the unrelated filler conditions than they were in the experimental conditions in all versions (short delay: aff_unrelated versus aff_actual: $t1(46) = -11.1$, $p < .001$; $t2(58) = -5.3$, $p < .001$; aff_unrelated versus aff_alternate: $t1(46) = -6.7$, $p < .001$; $t2(58) = -4.6$, $p < .001$; neg_unrelated versus neg_actual: $t1(46) = -10.3$, $p < .001$; $t2(58) = -5.2$, $p < .001$; neg_unrelated versus neg_negated: $t1(46) = -9.2$, $p < .001$; $t2(58) = -5.8$, $p < .001$; long delay: aff_unrelated versus aff_actual: $t1(45) = -9.7$, $p < .001$; $t2(58) = -4.9$, $p < .001$; aff_unrelated versus aff_alternate: $t1(45) = -9.7$, $p < .001$; $t2(58) = -5.0$, $p < .001$; neg_unrelated versus neg_actual: $t1(45) = -10.1$, $p < .001$; $t2(58) = -5.0$, $p < .001$; neg_unrelated versus neg_negated: $t1(45) = -14.4$, $p < .001$; $t2(58) = -7.2$, $p < .001$). Thus, these post hoc analyses do not provide evidence that the processing of negative sentences involves inhibitory mechanisms.

4. Discussion

The fact that response times in the negated-long-delay conditions were significantly shorter when the picture matched the actual state of affairs than when the picture matched the negated state of affairs supports the notion that comprehenders focused their attention on the actual state of affairs 1500 ms after processing the sentences. Had they focused on both states of affairs (negated and actual) or on neither (see Hypotheses 2 and 3 above) then no such response time difference should have emerged. The fact that the 750-ms-delay condition did not produce a corresponding match effect with respect to the actual state of affairs suggests that at this delay, some participants in some trials were still focusing on the negated state of affairs and other participants in other trials were already focusing on the actual state of affairs. In other words, when viewed in the context of the significant match effect in the long-delay condition, this null effect in the 750-ms-delay condition provides further support for the view that there is a certain 'tipping point' in the comprehension process at which comprehenders shift attention away from the negated state of affairs and onto the actual state of affairs. Had they immediately focused their

attention on the actual state of affairs (cf. Mayo et al., 2003) then we should have observed similar response time patterns in the two delay conditions.

Let us now turn to the results obtained in the affirmative conditions. As expected, responses to pictures in the 'actual' conditions were facilitated relative to responses in the 'alternate' conditions in the 750 ms delay condition. This is in line with the view that comprehenders of affirmative sentences represent the state of affairs described in the sentence. The fact that no such advantage effect obtained with affirmative sentences at 1500 ms is not surprising. Comprehenders will not keep their representations accessible indefinitely. Considering that affirmative sentences are easier to process than negative sentences, and that the sentences in this experiment were relatively short and easy to comprehend in general, it seems plausible that 1500 ms after self-paced reading, comprehenders were long finished with their representations and had turned their attention elsewhere (for corroborating evidence with the processing of ironic statements, see Giora et al., 1998). The fact that the response times in these conditions were still significantly shorter than the response times in the affirmative filler conditions does not speak against this interpretation. In the experimental conditions, the word that comprehenders needed to produce in the picture-naming task had been mentioned in the previous sentence. The same did not hold in the filler conditions. Thus, the facilitation effect in the experimental conditions does not allow drawing conclusions with respect to the question of which meaning representations were available, as it may just as well reflect surface level priming.

Thus, taken together, the results support the view that when processing a sentence such as *The door was not open* comprehenders eventually have available a representation of a closed door, just as they would with the corresponding affirmative sentence with the same truth conditions, i.e., *The door was closed*. The difference between negative and affirmative sentences with the same truth conditions lies in the involved representational processes: In the affirmative versions comprehenders represent only the closed door. In the negative versions, comprehenders represent both, the open and the closed door, whereby they first focus their attention on the open door and then focus attention on the closed door.

To our knowledge this is the first clear cut demonstration that a representation of the actual state of affairs becomes available over time after the processing of negative sentences. Previous studies that addressed the time course of comprehension with negative sentences provided evidence that the availability patterns observed after affirmative and negative sentences are qualitatively equivalent at first and begin to diverge only later in the comprehension process. These studies did not however demonstrate that form a certain point in the comprehension process on, the actual state of affairs is in fact better available than the negated state of affairs after reading negative sentences. For instance, in the no-delay condition in the study by Kaup et al. (2005), participants responded significantly faster to a picture of a giraffe above an elephant than to a picture of an elephant above a giraffe, after reading *The giraffe was above the elephant* (affirmative) as well as after reading *The giraffe was not above the elephant* (negative). In the long-delay condition, in contrast, the difference in the negative conditions disappeared. As was argued in detail in the introduction, these results are in line with the view that comprehenders focus on a representation of the actual state of affairs from a certain point in time in the comprehension process on, but this evidence is indirect at best. Similarly, in a recent study by Hasson and Glucksberg (2006) participants were presented with affirmative and negative metaphors (e.g., *My lawyer is/is not a shark*) and subsequently solved a lexical decision task, with the probes being either affirmative-related (e.g., *vicious*) or negative-related (*gentle*). When the delay between presenting the sentence and presenting the probes was short (150 ms and 500 ms), affirmative-related probes were facilitated, both after reading affirmative and after reading

negative metaphors. When the delay was long (1500 ms), there was no facilitation after negative metaphors, neither for the affirmative-related nor for the negative-related probes. Thus, these results are similar to the results of our previous study (Kaup et al., 2005). Interestingly however, a post-hoc analysis carried out by Hasson and Glucksberg allows stronger conclusions: If only low-irony negated metaphors are taken into account, negative-related probe words *are* facilitated in the long-delay condition. Thus, the results of this post-hoc analysis corroborate the findings obtained in the present study.

It could be hypothesized that different types of negative sentences lead to different representational processes. For instance, one might assume that negative sentences with contradictory predicates (allowing definite conclusions with respect to the actual state of affairs) trigger the creation of a representation of the actual state of affairs, whereas negative sentences with other types of predicates (e.g., *The dress was not red*) trigger the construction and subsequent rejection of a representation of the negated state of affairs. In fact, such a view comes close to assumptions made by Mayo et al. (2003). There are two main reasons for why we do not believe the first part of this hypothesis, namely that comprehenders of negative sentences with contradictory predicates create a representation of the actual state of affairs right away. First, the two delay conditions investigated in the present experiment employed the exact same contradictory predicates but still produced different results. As was argued in detail above, the difference between the two delay conditions is in line with the view that comprehenders first have available a representation of the negated state of affairs and then a representation of the actual state of affairs. The second reason is a theoretical one: If negative sentences with contradictory predicates (e.g., *The door was not open.*) would lead to a creation of a representation of the actual state of affairs right away, then the representations created for these sentences would be indistinguishable from those conducted for the truth conditionally equivalent affirmative sentences (e.g., *The door was closed.*). But if so, why would the speaker use a negative sentence in the first place? If all the hearer does is translate it back into the affirmative from, the speaker could have used this easier affirmative form right away. Thus, we find it more plausible to assume that subtle differences between *The door was not open* and *The door was closed* not only prompt the speaker to use one or the other form in a particular communicative situation, but are also reflected in the hearer's mental representations of the communicated content. In many cases, the negated state of affairs may even be functional for the upcoming text segment. For instance, a sentence such as *Fred noticed that the door was not open* may indicate that the protagonist wanted the door to be open. A logical continuation in this case would be that the protagonist opened the door. Research on motor control (e.g., Hommel et al., 2001) indicates that the goal state of an action is represented and used as guidance in action planning. If the comprehender is doing the same (as implicated for instance by the experiential-simulations-view of language comprehension, see below), then having available a representation of the negated state of affairs would greatly reduce the complexity of the required representational processes in the upcoming text segment. Taken together, we believe that there are good arguments for assuming that comprehenders routinely represent the negated state of affairs when processing a negative sentence.

What about the second part of the hypothesis, namely that the processing of negative sentences with non-contradictory predicates does not involve the creation of a representation of the actual state of affairs? This question cannot be answered on the basis of the data presented here. The answer to this question will be highly context dependent. In natural discourse, negative sentences do not occur in isolation. Thus, comprehenders will usually have available a representation of the actual state of affairs prior to encountering the negation. Moreover, in most

circumstances, comprehenders will expect to receive additional information concerning the actual state of affairs subsequent to the negative sentence. In this case it seems plausible to assume that comprehenders shift attention back towards the representation of the actual state of affairs once they are finished creating the representation of the negated state of affairs after having processed the negative sentence. Whether the same holds for the processing of isolated negative sentences with non-contradictory predicates is unclear. In the few cases where these sentences do not provide any information regarding the actual state of affairs (e.g., *There was no eagle*) comprehenders might have indeed only created a representation of the negated state of affairs that they will later reject. However, in most cases, the sentences do provide some information regarding the actual state of affairs. For instance in *There was no eagle in the nest* the comprehender is told that the actual state of affairs contains a nest, and in *The dress is not red* he or she is told that the actual state of affairs contains a dress. We don't see any reason why the comprehender should not insert these entities in his or her representation of the actual state of affairs when processing the negative sentence. Thus, we believe that the processing of negation in this case involves the creation of a representation of the actual state of affairs. What *does* seem possible in principle, is that the representation of the actual state of affairs is kept in the background in these cases. Admittedly, it will be difficult to distinguish empirically between this idea and the idea that comprehenders in these cases only create a representation of the negated state of affairs.

Before closing we will now turn to the different accounts of language comprehension and their assumptions concerning the processing of negation. As was mentioned in the introduction, the different accounts all in one way or the other assume that the processing of negation involves the construction of a representation of the negated state of affairs that is then mentally rejected. The theories also agree on that once the respective representation has been rejected, the comprehender may turn to the implications of the sentence with respect to the actual state of affairs and modify his or her representation accordingly. The main difference between the theories lies in the exact rejection mechanism that is proposed, and as a result also in the role that the representation of the actual state of affairs is assumed to play in the processing of negation.

In propositional theories of comprehension (Kintsch and van Dijk, 1978; McKoon and Ratcliff, 1992; Kintsch, 1988), the meaning representation of a negated sentence consists of a representation of the negated proposition (e.g., CLOSED(DOOR)) to which a mental negation operator is being applied (e.g., NOT(CLOSED(DOOR)); Clark and Chase, 1972; Trabasso et al., 1971; MacDonald and Just, 1989). Thus, rejection in this case is achieved by explicitly tagging the proposition representing the negated state of affairs as not-holding for the state of affairs under consideration. What about the information that the negative sentence provides with respect to the actual state of affairs? A sentence such as *The door is not closed* carries the presupposition that a particular door exists in the state of affairs under consideration. Moreover, by negating that the door is closed, the sentence implicitly specifies the door as being open. The propositional representation given above does not capture this additional information. However, proponents of propositional representation could assume that comprehenders infer the respective aspects and add the two corresponding propositions to their propositional representation, provided they are reasonably motivated.

Similar assumptions are made by theories of discourse comprehension that propose the construction of a referential discourse model or situation model (e.g., Van Dijk and Kintsch, 1983; see also Kamp, 1981; Kamp and Reyle, 1993). Referential-discourse models are hybrid representations consisting of a referential level of representation at which mental tokens stand for the referents of linguistic expressions. This referential level of representation is augmented by a
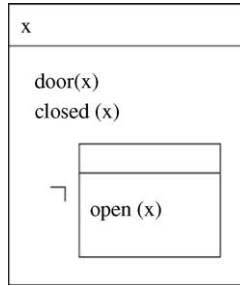
Fig. 2. Referential model representation of *The door is not open*. *Note*: The inference that the door is closed (light grey) is an optional inference that may or may not be represented.

propositional level at which properties and relations are assigned to the referents in form of propositions. As before, negation is considered an explicitly represented operator, with the only difference being that negation is not applied to the proposition but to the embedded discourse-representation structure that represents the negated state of affairs (cf. Kamp and Reyle, 1993; see Fig. 2). As these theories put special weight on the referential level of representation, existential presuppositions such as the one concerning the existence of the door, are routinely represented. In the representation depicted in Fig. 2 this presupposition is captured by the fact that the discourse referent standing for the door is represented at the top referential level, and not inside of the negated discourse-representation structure. With respect to non-presuppositional information that the negative sentence implies about the actual state of affairs, this theory resembles propositional theories in assuming that this is an optional process that depends on the degree to which inferencing takes place. Thus, a sentence such as *The door was not open* may or may not lead to the inference that the door was actually closed (see Fig. 2).

A completely different rejection mechanism seems necessary for theories of comprehension in the framework of embodied cognition. In general, comprehenders are assumed to mentally simulate the described state of affairs in a representational format that is experiential in nature in the sense that it is grounded in perception and action (e.g., Barsalou, 1999; Glenberg, 1997; Glenberg and Kaschak, 2002; Kelter et al., 2004; Stanfield and Zwaan, 2001; Zwaan et al., 2002; Zwaan and Yaxley, 2003). In accordance with what was proposed above, the processing of negative sentences is assumed to involve mentally simulating the negated state of affairs. However, in a non-linguistic experiential representational format it is not possible to represent a linguistic operator such as negation explicitly. Thus, mentally rejecting the negated state of affairs cannot be achieved by means of explicitly tagging the corresponding simulation as being false. Instead, we recently proposed an alternative mechanism, according to which the negated state of affairs is being simulated in an auxiliary representational system. Thus in contrast to simulations corresponding to affirmative information, the simulation of the negated state of affairs is not integrated with the representation of the described world. Rather the two representations can be juxtaposed in order to recapitulate the negated information (cf. Langacker, 1991). In other words, the simulation of the negated state of affairs is mentally rejected by the fact that it is simulated but not integrated with the representation of the described world (see Kaup et al., in press). For sake of illustration, let us take a look at our example sentence *The door is not open*. According to the experiential account of negation, processing of the initial noun phrase (*The door*) will lead to a simulation of a door that is integrated into the representation of the described world. When then processing the negated

verb phrase (*is not open*), the comprehender will simulate an open door in the auxiliary representational system, with the result being that this simulation is not integrated with the rest of the information concerning the described world but kept separate from it. Finally, in principle, the comprehender now may shift his or her focus of attention back towards the representation of the described world (actual state of affairs), and possibly modify this representation with respect to additional information that the negative sentence provides (e.g., that the door in fact must be closed). As was the case with the other two theories that we discussed, this latter processing step is not proposed to be an integral part of processing negation but an optional process that depends on the amount of inferencing that takes place, as in Fig. 3.

On the basis of the results of the current study it is not possible to distinguish empirically between the different theories. Moreover, empirically distinguishing between representational theories on the basis of reaction time data is extremely difficult when the respective theories are relatively vague with respect to the processes that operate on the proposed representations. However, that said, we *do* think that some of the earlier findings related to the processing and representation of negated information at least favor the experiential view. For instance, the results reported in Kaup (2001) and Kaup and Zwaan (2003) indicate that from a certain point in the comprehension process on, availability of mentioned concepts depends on whether or not they are *present* in the described situation. Moreover, in Kaup and Zwaan (2003) this effect proved
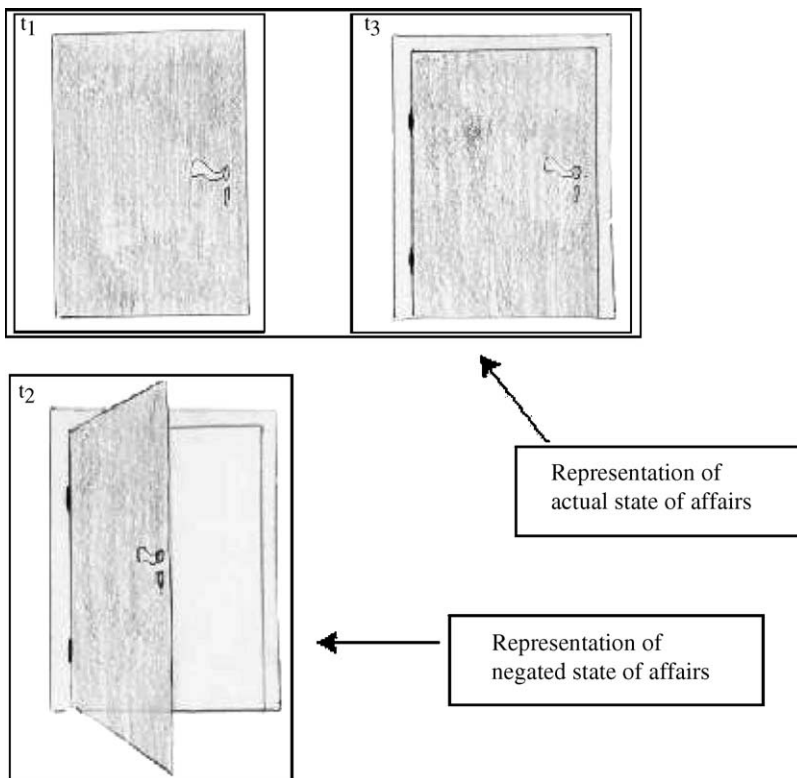

Fig. 3. Experiential-simulations representation of *The door is not open*.

independent of the linguistic form of the phrase that introduced these concepts into the discourse (explicit negative or not). This suggests that availability was based on a representation of the actual state of affairs in which only those entities and concepts are being represented that are present in the described situation. Obviously, this assumption fits well with the experiential-simulations view. Accounts assuming a rejection mechanism by which the representation of the negated state of affairs is explicitly being tagged as false can only account for these findings by proposing post hoc that inferences regarding the presence of concepts and entities in the actual state of affairs are being routinely drawn in language comprehension.

Similarly, in the above mentioned studies involving negative sentences such as *There was no eagle in the sky* we found significantly faster response times when the subsequent picture matched the shape of the critical entity in the negated situation (eagle with outstretched wings) than when the picture mismatched this shape (eagle with its wings drawn in). This finding is well in line with the experiential view, according to which comprehenders mentally simulate the negated state of affairs in a representational format that is similar to the one utilized in directly experiencing or re-experiencing the respective state of affairs. Again, theories proposing a propositional format can explain this finding post hoc by assuming that comprehenders routinely infer propositions concerning the shape of the mentioned entities in the negated state of affairs, even when processing sentences that do not focus on shape information, or in any other way highlight the importance of this property dimension. However, although possible, these assumptions would conflict with the assumptions concerning the type and amount of inferencing that is usually proposed to take place in language comprehension according to proponents of these theories. Finally, if one additionally takes into account the steadily growing number of studies that find evidence for the experiential-simulations view for the processing of affirmative information (for an overview, see Zwaan, 2004), it in our view seems justified to assume that the two states of affairs that come to the comprehenders mind when processing a negative sentence are indeed represented in a representational format that is grounded in perception and action.

5. Conclusions

The study reported in this manuscript was concerned with the question of whether comprehenders of negative sentences eventually have available a representation of the actual state of affairs. The results clearly demonstrate that this is the case for negative sentences with contradictory predicates. 1500 ms after reading a sentence such as *The door was not open* the comprehender has available a representation of a closed door. Thus, the question raised in the title of this manuscript can be answered in the affirmative without qualification: A door that is not open is eventually mentally closed. Future research is necessary to clarify the exact conditions under which the comprehension of negation involves representations of the actual state of affairs.

References

Barsalou, Lawrence W., 1999. Perceptual symbol systems. Behavioral and Brain Sciences 22, 577–660.

Carpenter, Patricia A., Just, Marcel A., 1975. Sentence comprehension: a psycholinguistic processing model of verification. Psychological Review 82, 45–73.

Clark, Herbert H., 1974. Semantics and comprehension. In: Sebeok, T.A. (Ed.), Current Trends in Linguistics. Mouton, DenHaag, pp. 1291–1428.

Clark, Herbert H., Chase, William G., 1972. On the process of comparing sentences against pictures. Cognitive Psychology 3, 472–517.

Deutsch, Roland, 2002. What does it take to negate? How processing negated information affects cognition and behavior. Unpublished doctoral dissertation, Julius-Maximilians-Universität Würzburg.

Fauconnier, Gilles, 1985. Mental Spaces: Aspects of Meaning Construction in Natural Language. MIT Press, Cambridge.

Ferreira, Fernanda, 2003. The misinterpretation of non-canonical sentences. Cognitive Psychology 47, 164–203.

Giora, Rachel, Balaban, Noga, Fein, Ofer, Alkabets, Inbar, 2004. Negation as positivity in disguise. In: Colston, H.H., Katz, A. (Eds.), Figurative Language Comprehension: Social and Cultural Influences. Erlbaum, Hillsdale, pp. 233–258.

Giora, Rachel, Fein, Ofer, Schwartz, Tamir, 1998. Irony: Graded salience and indirect negation. Metaphor and Symbol 13, 83–101.

Giora, Rachel, 2006. Anything negatives can do affirmatives can do just as well, except for some metaphors. Journal of Pragmatics 38, 981–1014.

Givon, Talmy, 1978. Negation in language: pragmatics, function, ontology. In: Cole, P. (Ed.), Syntax and Semantics. Academic Press, New York, pp. 69–112.

Glenberg, Arthur M., 1997. What memory is for. Behavioral and Brain Science 20, 1–41.

Glenberg, Arthur M., Kaschak, Michael P., 2002. Grounding language in action. Psychonomic Bulletin Review 9, 558–565.

Glenberg, A.M., Robertson, David A., Jansen, Jennifer L., Johnson-Glenberg, Mina C., 1999. Not propositions. Journal of Cognitive Systems Research 1, 19–33.

Hasson, Uri, Glucksberg, Sam, 2006. Does understanding negation entail affirmation? An examination of negated metaphors. Journal of Pragmatics 38, 1015–1032.

Hommel, Bernhard, Müsseler, Jochen, Aschersleben, Gisa, Prinz, Wolfgang, 2001. A theory of event coding (TEC). A framewok for perception and action planning. Behavioral and Brain Sciences 24, 869–937.

Horn, Laurence R., 1989. A Natural History of Negation. University of Chicago Press, Chicago.

Kamp, Hans, 1981. A theory of truth and semantic representation. In: Groenendijk, J., Janssen, T., Stokhof, M. (Eds.), Formal Methods in the Study of Language: pt: 1. Mathematish Centrum, Amsterdam, pp. 277–322.

Kamp, Hans, Reyle, Uwe, 1993. From Discourse to Logic. Kluwer, Dordrecht.

Kaup, Barbara, 1997. Processing of negatives during discourse comprehension. In: Shafto, M.B., Langley, P. (Eds.), Proceedings of the Nineteenth Conference of the Cognitive Science Society, Erlbaum, Mahwah, pp. 370–375.

Kaup, Barbara, 2001. Negation and its impact on the accessibility of text information. Memory & Cognition 29, 960–967.

Kaup, Barbara, Lüdtke, Jana, Zwaan, Rolf A., 2005. Effects of negation, truth value, and delay on picture recognition after reading affirmative and negative sentences. In: Bara, B.G., Barsalou, L., Bucciarelli, M. (Eds.), Proceedings of the 27th Annual Conference of the Cognitive Science Society, Erlbaum, Mahwah, NJ, pp. 1114–1119.

Kaup, Barbara, Yaxley, Richard H., Madden, Carol J., Zwaan, Rolf A., Lüdtke, Jana, submitted for publication. Experiential simulations of negated text information.

Kaup, Barbara, Zwaan, Rolf A., 2003. Effects of negation and situational presence on the accessibility of text information. Journal of Experimental Psychology: Learning, Memory and Cognition 29, 439–446.

Kaup, Barbara, Zwaan, Rolf A., Lüdtke, J., in press. The experiential view of language comprehension: how is negation represented? In: Schmalhofer, F., Perfetti, C.A. (Eds.), Higher Level Language Processes in the Brain: Inference and Comprehension Processes. Erlbaum, Hillsdale.

Kelter, Stephanie, Kaup, Barbara, Claus, Berry, 2004. Representing a described sequence of events: a dynamic view of narrative comprehension. Journal of Experimental Psychology: Learning, Memory, and Cognition 30, 451–464.

Kintsch, Walter, van Dijk, Teun A., 1978. Toward a model of text comprehension and production. Psychological Review 85, 363–394.

Kintsch, Walter, 1988. The role of knowledge in discourse comprehension: a construction-integration model. Psychological Review 59, 163–182.

Langacker, Ronald W., 1991. Foundations of Cognitive Grammar, vol. 2. Stanford University Press, Stanford.

MacDonald, Maryellen C., Just, Marcel A., 1989. Changes in activation levels with negation. Journal of Experimental Psychology: Learning, Memory, and Cognition 15, 633–642.

Mayo, Ruth, Schul, Yaacov, Burnstein, Eugene, 2003. ''I am not guilty'' versus ''I am innocent'': successful negation may depend on the schema used for its encoding. Journal of Experimental Social Psychology 40, 433–449.

McKoon, Gail, Ratcliff, 1992. Inference during reading. Psychological Review 99, 440–466.

Russell, Bertrand, 1948. Human Knowledge, it's Scope and Limits. Simon & Schuster, New York.

Stanfield, Robert A., Zwaan, Rolf A., 2001. The effect of implied orientation derived from verbal context on picture recognition. Psychological Science 12, 153–156.

Trabasso, Tom, Rollins, H., Shaughnessy, E., 1971. Storage and verification stages in processing concepts. Cognitive Psychology 2, 239–289.

Van Dijk, Teun A., Kintsch, Walter, 1983. Strategies of Discourse Comprehension. Academic Press, New York.

Van Selst, Mark, Jolicoeur, Pierre, 1994. A solution to the effect of sample size on outlier elimination. The Quarterly Journal of Experimental Psychology 47A, 631–650.

Wason, Peter C., 1965. The contexts of plausible denial. Journal of Verbal Learning and Verbal Behavior 4, 7–11.

Zwaan, Rolf A., 2004. The immersed experiencer: toward an embodied theory of language comprehension. In: Ross, B.H. (Ed.), The Psychology of Learning and Motivation, vol. 44. Academic Press, New York, pp. 35–62.

Zwaan, Rolf A., Stanfield, Robert A., Yaxley, Richard H., 2002. Language comprehenders mentally represent the shapes of objects. Psychological Science 13, 168–171.

Zwaan, Rolf A., Yaxley, Richard H., 2003. Spatial iconicity affects semantic-relatedness judgments. Psychonomic Bulletin & Review 10, 954–958.

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