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11

The Experiential View of Language Comprehension: How Is Negation Represented?

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Consider the following anecdote: *A young boy is separated from his mother on an afternoon visit to a very busy fair. After a while he starts questioning the passers-by: "Have you seen a lady who is without a young boy who looks a little like me?"* What is odd about the boy's question? Describing his mother in terms of what is missing might seem natural to the boy, but to the listener, who is facing the task of identifying the boy's mother from a group of many potential referents, it most likely constitutes a rather useless description of the target entity. After all, what does a woman look like, who is without a particular boy, who may be wearing a green jacket? Doesn't she, at least without further knowledge, look exactly like a woman who went to the fair without her five-year-old daughter who happened to be wearing a blue sweatshirt that day, or for that matter like any other woman of appropriate age who went to the fair by herself? To the listener, the problem must therefore seem nearly unsolvable. The boy's description simply does not allow for construction of a specific mental representation of the target referent, which could then be compared with the previously formed perceptual representations of the various female visitors to the fair.

The difficulty of creating a specific mental representation of the boy's mother seems to spring from the fact that, apart from specifying the target entity as being female, the boy's description concerns only properties of an entity whose presence is explicitly negated. What the anecdote illustrates is that the information conveyed by negative assertions of this type is not useful when it comes to creating a visual representation. However, does this imply that negated information is not represented in a nonlinguistic fashion?

There is growing evidence in the literature that the creation of nonlinguistic representations is an important component of language comprehensiort Considering that negation is an important and frequently used linguistic Operator, it seems unlikely that negative information would simply not be included in nonlinguistic representations. Instead, our cognitive apparatus is probably more flexible and provides some kind of mechanism by which negative information can be represented—even when the representations in question are nonlinguistic in nature and therefore do not allow an explicjt representation of negation. This prompts the question of how negation is represented in a nonlinguistic format.

The present chapter addresses this question. The first section briefly outlines the experiential view of language comprehension. This view conceptualizes comprehension as the construction of an experiential Simulation of the described Situation. This Simulation can be thought of as a vicarious experience of the described Situation. The second section provides an overview of empirical findings relevant to the question of how negation is represented in language comprehension. The third section introduces a hypothesis of how negation might be implicitly represented in experiential simulations. The fourth section addresses the question of whether the findings reported in the second section are consistent with this hypothesis. The fifth section reports the results of a series of experiments that directly tested our hypothesis regarding the nonlinguistic representation of negation. Finally, the sixth section summarizes our main conclusions.

THE EXPERIENTIAL VIEW OF LANGUAGE COMPREHENSION

There is growing evidence in the literature that comprehending a text should be conceived of as the construction of a so-called *Situation model* or *mental model,* a mental representation of the described State of affairs (Glenberg, Meyer, & Lindem, 1987; Graesser, Millis, & Zwaan, 1997; Johnson Laird, 1983; Morrow, Bower, & Greenspan, 1990; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). Situation modeis are nonlinguistic representations, as their components are not propositions about particular aspects of the described State of affairs, but tokens standing for the entities and properties that make up this State of affairs.

Recently, the notion that Situation modeis are of a representational format that is the same as that utilized in other nonlinguistic cognitive processes (e.g., perception, action, imagery) has been gaining in importance in text comprehension research (e.g., Barsalou, 1999; Glenberg, 1997; Glenberg & Kaschak, 2002; Glenberg & Robertson, 2000; Kelter, 2003; Kelter, Kaup, & Claus, 2004; MacWhinney, 1999; Stanfield & Zwaan, 2001; Zwaan, 2004; Zwaan & Madden, 2005; see also Johnson-Laird, 1983). Proponents of this no-

tion of situation models believe that comprehenders construct mental simulations of the states of affairs described in the text. These mental simulations are considered to be experiential in nature, as they are assumed to be grounded in perception and action. Accordingly, as Johnson Laird put it already in 1983, "A major function of language is thus to enable us to experience the world by proxy" (p. 471).

There is already some empirical evidence for the experiential view of language comprehension (for an overview see Zwaan, 2004, and the contributions in Pecher & Zwaan, 2005). On the one hand there are neuroscience studies that directly show a considerable overlap between the mental subsystems in which linguistically conveyed situational information is represented and those that are involved when these situations are directly perceived or enacted (e.g., Pulvermüller, 2002; Pulvermüller, Härle, & Hummel, 2000). On the other hand, behavioral data suggest that language comprehension leads to the creation of representations in those mental subsystems that are utilized in other nonlinguistic cognitive processes such as action planning, perception, or imagery. Two different types of findings can be distinguished.

The first type of finding indicates that the representations constructed in language comprehension have properties in common with representations constructed in nonlinguistic cognition. These kinds of equivalence effects have been demonstrated in a number of studies—for instance, with respect to the representations' spatial extendedness, which provides a basis for mental scanning processes (e.g., Glenberg et al., 1987; Morrow et al., 1990; Rinck & Bower, 1995), with respect to the size-resolution trade-off principle (Kaup, Kelter, & Habel, 1999), and with respect to the representations' dynamic nature (Kelter et al., 2004; Zwaan, Madden, Yaxley, & Aveyard, 2004; Kaschak et al., 2005). All of these are well-documented properties of representations constructed in visual-spatial imagery (mental scanning and size-resolution trade-off: e.g., Baddeley, 1986; Kosslyn, 1994; dynamic nature: e.g., Freyd, 1987, 1993). Equivalence effects have also been shown with respect to processing costs associated with switching between the different modalities. In perceptual tasks, processing a stimulus in an unexpected modality leads to prolonged response times (Spence, Nicholls, & Driver, 2001). In a semantic priming study, Pecher, Zeelenberg, and Barsalou (2003) obtained the same pattern of results when participants were presented with noun-adjective pairs and evaluated whether the corresponding property held for the object under consideration. Response times were shorter when the evaluated property of an object was from the same modality as the property of the previous pair compared with when it was from a different modality. Finally, recent eye-tracking studies indicate that participants listening to the description of a complex scene tend to make eye movements that mimic the kinds of eye movements that would be made if they were viewing that actual scene (e.g., Spivey, Tyler, Richardson, & Young, 2000).

The second type of finding concerns facilitation or interference effects due to similarities or dissimilarities between the experimental task on the one hand and the content of the described state of affairs on the other hand. For instance, Glenberg and Kaschak (2002) found that responses to a sentence-sensibility judgment task, involving sentences such as *He closed a drawer*, were faster when the hand movement required for correctly responding to the task matched the movement implied by the sentence (e.g., movement toward the comprehender) compared with when there was a mismatch (e.g., movement away from the comprehender; see also Klatzky, Pellegrino, McCloskey, & Doherty, 1989). Similarly, Zwaan and colleagues (e.g., Stanfield & Zwaan, 2001; Zwaan, Stanfield, & Yaxley, 2002) demonstrated in a series of experiments that responding to a depicted object (e.g., an eagle) after reading of a sentence mentioning this object (e.g., *The ranger saw an eagle in the sky*) was easier when the depicted shape or orientation of the object matched the shape or orientation implied by the sentence (e.g., the depicted eagle has its wings outstretched) compared with when there was a mismatch (e.g., the depicted eagle has folded wings). Match/mismatch effects were also found when participants were presented with individual words instead of sentences. More specifically, Zwaan and Yaxley (2003a, 2003b) presented pairs of words (e.g., *attic–basement*) on a computer screen, with one word appearing below the other. Participants were faster in judging the semantic relatedness of the words when their spatial relation on the computer screen matched their spatial relation in the world (i.e., *attic* on top) than when the relations mismatched (i.e., *basement* on top).

Interference has also been demonstrated in studies that investigated the impact of spatial or visuospatial secondary tasks on the success of constructing nonlinguistic representations during text comprehension. Fincher-Kiefer (2001), for instance, presented readers of short stories with either a visuospatial or a verbal memory load and found that situation-model construction was significantly impaired with the former but not with the latter secondary task. The results of a study by Kaup et al. (1999) suggest that spatial aspects of a described situation are easier to represent when the corresponding narrative was presented auditorily than when it was presented visually. The disadvantage in the visual condition can be attributed to the fact that reading but not listening requires the control of eye movements, which in turn can be considered a spatial task that may cause interference with creating a nonlinguistic spatial representation (cf. Baddeley, 1986).

To summarize, research conducted in the context of the experiential view of language comprehension has produced a number of findings suggesting that comprehenders mentally simulate the state of affairs described by the linguistic input in a way that is similar to directly experiencing or reexperiencing this state of affairs. These findings therefore illustrate that language comprehension is in important ways equivalent to creating representations in the same mental subsystems as those used in other sensorimotor processes. As such, these findings support the experiential view of language comprehension.

The linguistic materials used in these studies were mostly simple descriptions of concrete situations, making it relatively straightforward to hypothesize about experiential representations to which they would give rise. It has been proposed that abstract concepts are grounded in perception and action via the process of metaphorical extension (Lakoff, 1987; Lakoff & Johnson, 1980; however, see Barsalou & Wiemer-Hastings, 2005, for an alternative account). Recent studies have demonstrated experiential effects with abstract concepts. For instance, Glenberg and Kaschak (2002) presented subjects with sentences such as *He told me the story* or *I told him the story*, describing states of affairs in which—metaphorically speaking—information moves toward or away from the comprehender. These sentences produced action-compatibility effects similar to those of the more concrete sentences (e.g., *He opened the drawer*; see also Boroditsky, 2000; Boroditsky & Ramscar, 2002).

However, a potentially even bigger hurdle for experiential theories is produced by the existence of linguistic operators, such as negation or disjunction, for which there does not seem to be a direct equivalence in experience. Obviously this hurdle needs to be cleared if the experiential view is meant to hold for language processing in general. With respect to negation, the experiential view faces two challenges. First, the experiential view needs to clarify how negated text information can be captured in a representation that does not allow for the explicit representation of negation. Second, the experiential view needs to account for existing empirical findings pertaining to the representation of negation in language comprehension. Before outlining a hypothesis regarding the representation of negation in experiential representations, we provide an overview of empirical findings concerning negation in language comprehension.

EMPIRICAL FINDINGS RELATED TO THE REPRESENTATION OF NEGATION

The Impact of Negation on Processing Difficulty

A considerable amount of research into the processing of negation was conducted in the 1960s and 1970s. In numerous studies employing a variety of different methods and materials, participants were presented with sentences or sentence fragments that either did or did not contain negative particles. Most of these studies employed sentence-verification tasks in which the sentences were to be verified either against background knowledge (e.g., Arroyo, 1982; Eiferman, 1961; Wales & Grieve, 1969; Wason, 1961; Wason & Jones, 1963) or against a picture that was presented before or after the corresponding sentence (e.g., Carpenter & Just, 1975; Clark & Chase, 1972; Gough, 1965, 1966; Just & Carpenter, 1971; Trabasso, Rollins, & Shaughnessy, 1971). Other studies employed sentence completion tasks (e.g., Donaldson,

1970; de Villiers & Tager Flusberg, 1975; Wason, 1959, 1961, 1965). Yet other studies investigated the impact of negation more indirectly, for instance by measuring the number of inferences that were drawn from negative sentences compared with the number of inferences drawn from affirmative sentences (e.g., Just & Clark, 1973), by measuring how well negative instructions are followed (e.g., Jones, 1966, 1968), or by investigating the impact of a negative object description in object-selection tasks (Donaldson, 1970). In all of these studies, negative sentences were harder to process than affirmative sentences, as evidenced by longer processing times and/or higher error rates for negative sentences compared with affirmative sentences. A negation effect was observed across a variety of different experimental paradigms and with a variety of different negative sentences. A negation effect was not only observed with explicit negation (e.g., 1a, 2a), but also with implicit negation (e.g., 1b, 2b) or when explicit negative particles were replaced with artificial syllables with equivalent function (e.g., Trabasso et al., 1971; Wason & Jones, 1963). A negation effect was observed for regular sentence negation (e.g., 3a), but also when the sentence was embedded in an *It is true* . . . phrase (e.g., 3b), which forces a reading in which the negation operator applies specifically to the predicate of the sentence. Moreover, the negation effect seems to be independent of the negation operator's position in the sentence as long as the operator's semantic scope is not affected (e.g., 4a and 4b). Finally, negative sentences are harder to process not only when they are less specific than their affirmative counterparts (e.g., 5a and 5b), but also when affirmative sentences with the same truth conditions can be inferred either because the sentences contain complementary terms (6b follows from 6a) or because the experiment employs only two different contrary predicates (e.g., 7b "follows" from 7a):

(1) a: The circle is not present.
    b: The circle is absent. (Chase & Clark, 1971)
(2) a: None of the dots are red.
    b: Few of the dots are red. (Just & Carpenter, 1971)
(3) a: The dots are not red.
    b: It is true that the dots are not red. (Carpenter & Just, 1975)
(4) a: That the dots are red is not true.
    b: It is not true that the dots are red. (Carpenter & Just, 1975)
(5) a: There is both green and yellow.
    b: There is not both green and yellow. (Wason, 1959)
(6) a: Seven is not an even number.
    b: Seven is an odd number. (Wason, 1961)
(7) a: The dots are not red.
    b: The dots are black. (Just & Carpenter, 1971)

Various explanations have been proposed to account for the difference in processing difficulty between affirmative and negative sentences. An obvious explanation is that negative sentences necessarily contain an extra syllable compared with the corresponding affirmative sentences. However, the reading time differences that are due to this extra syllable can at best account for a small part of the processing differences between affirmative and negative sentences (Clark & Chase, 1972). First, the time needed to process the extra syllable is estimated to be between 25 and 90 ms (cf. Clark & Chase, 1972) but the negation effect is of a magnitude of several hundred milliseconds. Second, in sentence-picture verification tasks, negative sentences are significantly harder to verify than affirmative sentences, even when the picture is not presented until 3 seconds after the end of the sentence read (Gough, 1966). A related explanatory attempt was based on Chomsky's (1957) transformational grammar. Negative sentences are assumed to be harder to process than affirmative sentences, because the former presumably involve a greater number of grammatical transformations than the latter. However, this explanation has proved to be untenable for theoretical (cf. Jackendoff, 1969; Partee, 1970) as well as empirical (cf. Gough, 1965; 1966; Slobin, 1966) reasons.

Another explanatory attempt is related to connotation. Participants often report that negative sentences have an unpleasant connotation because of their association with prohibition (cf. Wason & Johnson-Laird, 1972). Studies that addressed this hypothesis directly mostly produced ambiguous results (Eiferman, 1961; Wason & Jones, 1963; for a discussion see Clark, 1974).

The most convincing explanation for the processing difficulty associated with negative sentences is a pragmatic one, which was first put forward by Wason (1965). Outside of the laboratory, negative sentences are typically not uttered unless the proposition being negated was explicitly mentioned by one of the discourse partners (A: *I was told you went to Paris last year.* B: *No, I did not.*) or could plausibly be inferred from the discourse context (*My train was not late this morning*, uttered in a context in which the speaker's train is usually late; Wason, 1972; see also Clark, 1974, p. 1312; Givon, 1978). In a majority of the studies that produced a main effect of negation, the negative sentences were presented without a context that would have pragmatically legitimized the negation. Negative sentences may therefore have been particularly difficult to process because participants needed to infer such a legitimizing context retrospectively. In accordance with this pragmatic hypothesis, the negation effect is considerably diminished when negative sentences are presented within an adequate context (Wason, 1965; Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999; see also Arroyo, 1982; Cornish, 1971; Greene, 1970; de Villiers & Tager Flusberg, 1975). It should be noted, however, that even in pragmatically felicitous contexts, negative sentences are often still harder to process than the corresponding affirmative sentences. Thus, the negation effect may only be partially explained by the pragmatic hypothesis.

The Impact of the Sentence's Truth Value

As mentioned earlier, most of the studies discussed above employed a sentence-verification task. Thus, these studies provided information not only with respect to the affirmation/negation manipulation, but also with respect to the truth value of the sentence that was being verified. Although very stable results were obtained with respect to the impact of the negation operator, the various studies do not allow definite conclusions about the impact of the sentence's truth value. In some studies, false sentences were generally harder to process than true sentences, independent of whether or not they contained a negation operator (Arroyo, 1982; Eiferman, 1961; Gough, 1965; Trabasso et al., 1971; see also Wason, 1959, 1961). The majority of the studies, however, have produced a negation by truth value interaction. Whereas true affirmative sentences [e.g., (8)] are easier to evaluate than false affirmative sentences [e.g., (9)], the opposite holds for negative sentences; here, true sentences [e.g., (11)] are more difficult to process than false ones [e.g., (10)].

(8) The star is above the plus. (true affirmative)
(9) The plus is above the star. (false affirmative)
(10) The star is not above the plus. (false negative)
(11) The plus is not above the star. (true negative)

Processing Strategies

To account for the two patterns of verification latencies, it was suggested that comprehenders encode the pictures, just like the sentences, in a propositional format. The two representations are then compared constituent by constituent, with the comparison process being easier when the two constituents are congruent than when they are incongruent (for a detailed description of the model, see Carpenter & Just, 1975; Clark & Chase, 1972). Two strategies can be distinguished that produce the two observed response time patterns (main effect of truth value vs. truth value by negation interaction).

The negation by truth value interaction arises when participants are using the original sentence representation for the comparison process. For true affirmative sentences [e.g., (8)], the predicate in the sentence representation matches the predicate in the picture representation [both: above (star, plus)], whereas for false affirmatives [e.g., (9)] the two predicates mismatch [sentence: above (plus, star); picture: above (star, plus)]. This explains why false affirmatives take longer to verify than true affirmatives. In contrast, for negatives, it is the false case in which the predicates match [e.g., (10); sentence: not(above(star,plus)); picture: above(star,plus))], and the true case where there is a mismatch [e.g., (11); sentence: not(above(plus, star)); picture: above(star, plus))]. This explains why true negatives take longer to verify

than false negatives. Thus, the negation by truth value interaction can be accounted for by these assumptions. The main effect of negation is explained similarly. For negative sentences, the sentence representation contains a negation marker that mismatches with the affirmative picture representation. Accordingly, negative sentences take longer to verify than affirmative sentences.

The strategy producing a main effect of truth value differs from the preceding strategy in that participants convert the negative sentence into an affirmative one with the same truth conditions before starting the comparison process [e.g., (10) is converted into (9) and (11) into (8)]. After this conversion, true sentences imply a match and false sentence imply a mismatch, which explains the main effect of truth value. The main effect of negation is attributed to the fact that converting a negative sentence into an affirmative sentence takes time.

Despite the many studies in which negation and truth value were being manipulated, there are still no definite criteria for when participants employ one or the other strategy. However, all in all, the conditions that produced a main effect of truth value are more or less consistent with the conversion assumption. A main effect of truth value has mainly been observed under conditions in which conversion is possible and plausible, namely (1) when the experimental task was extensively practiced (e.g., Carpenter & Just, 1975), (2) when the sentence was presented prior to the picture (e.g., Trabasso et al., 1971), (3) when there was a delay between presenting the sentence and presenting the picture (e.g., Carpenter & Just, 1975), (4) when the predicates were complementary (*odd* and *even*) or when the experiment employed only two contrary predicates (*red* and *black*) (e.g., Trabasso et al., 1971; Wason, 1961; Wason & Jones, 1963; see also Mayo, Schul, & Burnstein, 2004; Kroll & Corrigan, 1981), (5) when participants were instructed accordingly (cf. Clark, 1974), and (6) when participants were adults as opposed to children (Slobin, 1966).

Some researchers have pointed out that a main effect of truth value is consistent with a pictorial strategy in which participants encode the sentence pictorially and then directly compare this representation to the representation of the picture. In a study by MacLeod, Hunt, and Mathews (1978), the group of participants who produced a main effect of truth value was found to have higher spatial abilities than the group of participants who produced a truth value by negation interaction, whereas the two groups did not differ in linguistic abilities. Also, for the former group sentence verification times were correlated with spatial abilities, whereas for the latter group they were correlated with linguistic abilities (see also Mathews, Hunt, & MacLeod, 1980). This finding is usually taken as positive evidence for the claim that the truth value main effect reflects a pictorial rather than a recoding strategy. However, some authors have noted that it is problematic to divide the participants into different strategy groups on the basis of their performance on the experimental task alone, because the same response time patterns may reflect very different strategies (Marquer & Pereira, 1990). It has also been argued that di-

agnosed high spatial or verbal abilities do not allow the researcher to deduce that a particular subject is using a pictorial or verbal strategy (Roberts, Wood, & Gilmore, 1994). Other studies have explicitly instructed participants to use one or the other strategy, and the similarity of the results to the respective response time patterns in the "free choice" condition is again taken as evidence for the claim that pictorial strategies are being used (e.g., Mathews et al., 1980; Reichle, Carpenter, & Just, 2000; Richards & Frensch, 1987). However, as before, it seems questionable that the mere similarity of the response time patterns affords the inference that the same strategies were being employed.

To summarize, in the context of sentence-verification studies, most authors believe that sentences are by default encoded in a propositional format in which negation is explicitly represented and takes a whole proposition into its scope. Different response time patterns are attributed to different modification processes that operate on these propositional representations. Strategies involving other kinds of representations (i.e., spatial representations) are considered special cases that (at best) are exhibited under conditions in which participants are specifically instructed.

Negation and Accessibility

More recent studies have been concerned with more local effects of negation, namely with the question of whether negation has an impact on the accessibility of information mentioned within its scope. For instance, in a study by MacDonald and Just (1989), participants were presented with sentences such as (12), and immediately afterward the accessibility of the relevant concepts was measured by means of a probe-recognition or word-naming task. Probe words that had been mentioned in the negated phrase (*cookies*) yielded significantly longer response times than probe words mentioned in the nonnegated phrase (*bread*) (for a similar effect with inferred concepts, see Lea & Mulligan, 2002). MacDonald and Just took their results as support for the hypothesis that readers construct a propositional representation in which the negation operator encapsulates the information mentioned in its scope and thereby specifically reduces the accessibility of this information.

(12) Almost every weekend Mary bakes some bread but no cookies for the children.

A study by Kuschert (1999) similarly showed that resolving a pronominal anaphor takes more time if the referent is introduced in the context of a double negation [e.g., (13)] than when it is introduced within an affirmative phrase [e.g., (14)]. The same results were not obtained for entities outside of the negation's scope (e.g., *I had met him in the mall this morning.*), which rules out that the effect is due to a general increase in processing times for material that follows a negated sentence.

(13) I contradicted Jim's report that Oliver does not have a big sister. I had met her in the mall this morning.

(14) I confirmed Jim's report that Oliver has a big sister. I had met her in the mall this morning.

An accessibility-reducing effect of negation is not obtained, however, when instead of explicitly mentioned concepts, associates of these concepts are being probed. More specifically, MacDonald and Just did not find evidence for the hypothesis that reading a sentence containing a negative such as *no bread* also reduces the accessibility of a word associated with the negated noun (e.g., *butter*). In line with this latter finding, Giora, Balaban, Fein, and Alkabets (2004) found that associates (e.g., *piercing*) were activated independently of whether the activating concept (e.g., *sharp*) was or was not negated in the sentence (e.g., *This instrument is sharp* versus *This instrument is not sharp*). Similarly, in an evaluative priming study by Deutsch (2002), priming effects were independent of whether the primes were modified by an affirmative or negative determiner (e.g., prime: *a party* versus *no party*; see also Draine, 1997). These latter findings may of course reflect a fast-acting surface-level priming component of language processing (cf. Albrecht & Myers, 1998; Kintsch, 1988; McKoon & Ratcliff, 1998). In other words, different priming results may emerge with longer SOAs.

To summarize, there is considerable evidence that negation has an accessibility-reducing effect in language comprehension, the effect being restricted to concepts explicitly mentioned within the negation operator's scope. Most authors take this finding as indirect evidence for the view that comprehenders construct a propositional representation of the linguistic input in which negation is being explicitly encoded. Let us now turn to an alternative view, according to which negation is not explicitly but only implicitly encoded during language comprehension.

HOW IS NEGATION REPRESENTED IN EXPERIENTIAL SIMULATIONS?

The experiential view conceptualizes language comprehension as the performance of a sensorimotor simulation of the described sequence of events. Negation, being a linguistic operator, cannot be assumed to be represented explicitly in these nonlinguistic experiential simulations. This prompts the question of how negated text information can be captured in terms of a sensorimotor simulation. In some cases, negative statements allow inference of affirmative propositions with equivalent truth conditions. In these cases, it seems possible that negative text information is represented via representa-

tion of the affirmative inference. Thus, for instance, for (15), the comprehender would represent a female surgeon:

(15) Ann entered the office and was surprised to find out that the surgeon was not male.

However, first, there are aspects of meaning other than those related to the truth conditions (e.g., pragmatic aspects), and these typically go missing when a negative statement is transformed into an affirmative statement with the same truth conditions. Second, and more important, in most cases, the sentence or text does not allow inference of an affirmative statement with the same truth conditions. Take for instance text (16):

(16) Charles had been very lucky to get hold of tickets for a concert by the Berlin Philharmonic Orchestra for tonight. He was now sitting in the fifth row of the concert hall, from where he had a real good view of the stage. Finally, the musicians entered the hall. Charles knew that the concert would begin any minute now. Then, he suddenly realized that the conductor was not present.

Here the presence of the conductor is explicitly negated, and intuitively, the experiential simulation constructed for (16) therefore does not contain a representation of the conductor. Yet, if this were the case, then the simulation would not allow the comprehender to determine what the text was about. More specifically, on the basis of the experiential simulation alone, the comprehender would not be able to tell whether the text specified the conductor as being absent, or whether there just had not been any information regarding the conductor. Moreover, the experiential simulation would be exactly the same, independently of the particular entity mentioned in the fifth sentence of the text. Thus, the experiential representation would not even allow the comprehender to rule out that, for instance, Elvis Presley had been mentioned as not being present.

It does not seem plausible to assume that negated text information is absent from the experiential representations constructed in language comprehension. If the experiential view is intended to hold for language comprehension in general, then there must be a mechanism by which negated text information can be captured in these representations. One possibility suggests itself when the pragmatics of negation is taken into account.

As mentioned earlier, the contexts in which negative utterances occur are rather limited. Typically, negative statements are uttered when the negated proposition was either explicitly mentioned before by one of the discourse partners or at least constitutes a plausible assumption in the respective context. Thus, negation is used to communicate deviations from expectations (Givón, 1978; Glenberg et al., 1999; Wason, 1965; see also Arroyo, 1982; Cor-

nish, 1971; Greene, 1970; de Villiers & Tager Flusberg, 1975). Applied to the example text in (16), this implies that a sentence such as *The conductor was not present* should only be produced in a context where a conductor's presence can be presupposed. Assuming that comprehenders not only represent explicitly stated information, but also infer information that is highly likely in the current context (see Singer, 1994, for an overview on inferencing), a conductor representation should be present in the mental simulation that is available prior to encountering the sentence containing the negation. If so, the negation would give rise to the deletion of this representation and the new mental simulation would deviate from the expected mental simulation by not containing a conductor representation. A comparison of the two simulations would allow the comprehender to determine what the text was about. The new simulation implicitly contains the information that a conductor was not present.

However, it is not warranted to assume that the mental simulation prompted by a negative sentence necessarily contains the exact information that the sentence negates. For instance in (17), the negation seems pragmatically felicitous, but the expectation regarding the presence of a teacher's aid is presumably not strong enough to insert a respective token into the simulation during processing of the first part of the text.

(17) Mr. Brigham works as a high school teacher. Tonight was open house. He entered the meeting room at 8 pm and quickly scanned the room to see whose parents were present. Lots of parents had come, but Mrs. Simonis, the teacher's aid, was missing.

Yet this does not mean that the mental simulation could not implicitly contain the information about the aid's absence. Given the assumptions about the pragmatic licensing conditions for negative sentences, it is possible to assume that negative sentences convey information not only about the actual state of affairs (the teacher's aid is absent), but also about the expected state of affairs (the teacher's aid is present), with this latter information constituting the presupposition that is being denied in the sentence (cf. Clark, 1986; Horn, 1989; Wason, 1965; see also Moxey, Sanford, & Dawydiak, 2001). Thus, the negative sentence in (17) presumably introduces or activates the expectation that a teacher's aid is present at a high school open house. As a consequence, a simulation of the expected state of affairs most likely contains a representation of a teacher's aid. Comparing this simulation to the mental simulation for the actual state of affairs allows the comprehender to determine that the teacher's aid was absent from the meeting.

In view of these considerations, we hypothesize that negative text information is implicitly encoded in the deviation between the mental simulations of the actual and the expected state of affairs. Two cases are to be distinguished. The first case is where the negated text information is already rep-

resented in the mental simulation that is available prior to encountering the negation (cf. Kaup, 1999). In this case, all the comprehender needs to do is create a mental simulation of the actual state of affairs, which deviates from the prior simulation with regard to the negated information. The second case is where the negated information is not represented in the model that is available upon encountering the negation, be it because the negative sentence was presented out of context, or because the respective expectation was not strong enough to trigger forward inferences of the required type. For this case, we assume that the comprehender does two things: first, construct a mental simulation of the expected state of affairs, which corresponds to the state of affairs that is being negated in the sentence, and second, construct a mental simulation of the actual state of affairs (cf. Fauconnier, 1985; Langacker, 1991). Thus, for instance, when processing an isolated sentence such as *The conductor was not present in the concert hall*, the comprehender first simulates a concert hall with a conductor and then a concert hall without a conductor. We will call this the *two-step simulation hypothesis of negation*.

Negative sentences often do not specify the actual situation with respect to the dimension that was affected by the negation. For instance, the sentence *Susan's dress was not red* does not specify the actual color of Susan's dress. In cases such as these, the actual simulation leaves unspecified the dimension of the negated property; it only contains the affirmative information (if any) that the negative sentence conveys. Thus, for the given example, the actual simulation would contain Susan with a dress of an unspecified color. Experiential simulations are radically different in this sense from pictorial representations. They are much less restricted with respect to what can be left unspecified. For instance, whereas a picture cannot contain the information that a particular entity A is next to an entity B without specifying whether A is to the left or to the right of B, an experiential representation does not need to specify spatial relations in this manner (cf. Barsalou, 1999, section 2.2.4). Thus, in processing a sentence such as *The star is not above the plus*, the simulation of the actual state of affairs would contain a star and a plus while leaving the spatial relation between the two unspecified. After all, the star could be next to the plus, on the right or left, or below it, or at a range of oblique angles. Of course, the comprehender could under certain conditions make an inference about the actual property on the negated dimension. For instance, if the star can be either above or below a plus, a sentence like *The star is not above the plus* most likely prompts the inference that the star must be below the plus. If so, the actual simulation would be specified with respect to the negated dimension. Sentences with complementary negation (e.g., *The surgeon was not male*) provide an interesting case in point. On the one hand they do not explicitly specify the actual situation with respect to the negated dimension, but on the other hand they provide enough information that the actual property can be inferred with 100% certainty. Again, whether the actual simulation is specified with respect to the negated dimension (i.e., surgeon's gender) depends

on whether the comprehender made the respective inference. Complementary negation differs from the previous cases only in the likelihood that such an inference is actually made.

ACCOUNTING FOR THE FINDINGS IN SECTION 2

General Processing Difficulty

The *two-step simulation hypothesis* of negation can readily account for the elevated processing times and high error rates associated with negative sentences. Processing a negative sentence typically involves the manipulation of two simulations, whereas processing an affirmative sentence normally involves only one. This additional step required for negative sentences compared with affirmative sentences provides a likely explanation for the difference in processing cost. The fact that this difference in processing cost between affirmative and negative sentences is attenuated when the negative sentences are presented in a pragmatically adequate context is predicted by the hypothesis. In a pragmatically appropriate context, the negated information had already been simulated when the negation was encountered, or at least fits particularly well with contextually appropriate background knowledge. Thus, the first step of the two-step process either has already been performed or should be fairly easy to perform, resulting in shorter overall response times compared with a condition without an adequate context.

Truth Value

The two-step simulation hypothesis can also account for the two different patterns that were observed in sentence-verification studies with respect to the impact of the sentence's truth value on processing times. A negation by truth value interaction comes about when response times are faster for false negatives than they are for true negatives. Responses are fast when the picture matches the *negated* situation. In contrast, a main effect of truth value is observed when true negatives lead to shorter response times than false ones. Response times are short when the picture matches the *actual* situation. *The two-step simulation hypothesis* posits that two simulations are involved in the processing of a negated sentence, a simulation of the expected (negated) situation and a simulation of the actual situation. This predicts match effects for both simulations.

The interesting question is whether the conditions under which one or the other match effect is observed correspond to the predictions of the *two-step simulation hypothesis*. Directly in line with this hypothesis is the finding that inserting a delay between the end of the sentence and the presentation of the picture enhances the probability of finding a main effect of truth value (e.g.,

Carpenter & Just, 1975). With no delay, comprehenders are likely still simulating the negated state of affairs. From a certain delay on, however, they have presumably started simulating the actual situation. As a consequence, responses after a certain delay depend on the match or mismatch with the actual situation, not with the negated situation. Similarly, the reason that extensive practice (e.g., Carpenter & Just, 1975) and high spatial ability (e.g., MacLeod et al., 1978) led to a main effect of truth value suggests that practiced and high-spatial ability comprehenders arrive at the second stage at an earlier point in time than other comprehenders, which should enhance the probability of a match effect with respect to the actual situation. A similar account explains the fact that a main effect of truth value was found only for adults, but not for children (e.g., Slobin, 1966). Finally, the *two-step hypothesis* explains why a main effect of truth value has mainly been found in experiments using two complementary predicates or the same contrary predicates throughout (e.g., Trabasso et al., 1971; Wason, 1961). Only in these conditions is it possible to specify the actual situation when given the negated aspect. In all other conditions, the negative sentences simply do not provide enough information about this aspect of the actual situation. Why a main effect of truth value has primarily been observed in studies in which the sentence was presented prior to the picture (e.g., Trabasso et al., 1971) remains unclear from the perspective of the two-step simulation hypothesis.

To be sure, these considerations are only post hoc speculations, which cannot be taken as direct support for the two-step simulation hypothesis. It is plausible that a sentence verification task engenders strategic processes on the part of the comprehender. It is also possible that the different response time patterns are indeed due to a variety of different strategies. This is particularly likely when participants were explicitly instructed to use one or the other strategy (e.g., Mathews et al., 1980; Reichle et al., 2000; Richards & Frensch, 1987). These considerations show, however, that there is an alternative to the view that sentences per default are encoded in an amodal propositional representation (which in the case of a picture sentence-verification task is then compared with a propositional representation of the picture). Similar response time patterns are expected when comprehenders mentally simulate the described state of affairs in the way specified by the two-step simulation hypothesis. For a recent study conducted in our lab that provides evidence for an interpretation of the results in terms of the two-step simulation hypothesis, see Kaup, Lüdtke, and Zwaan, 2005.

It should be noted that Clark and Chase (1972) explicitly discussed the possibility that the sentences are encoded in the form of mental images. They ruled out this possibility for logical as well as empirical reasons. The logical problem that these authors addressed springs from the view that negative sentences cannot be encoded by mental images because they are typically consistent with a variety of different states of affairs, rendering impossible the construction of a single model that encodes the state of affairs described by the sentence. However, as noted earlier, uncertainty about the actual

situation does not appear to pose a problem for the two-step simulation hypothesis. Negation is implicitly encoded in the sequencing of two different mental simulations. Even in cases where it is unclear what the actual situation is like, this representational mechanism still allows one to encode what the sentence is about. In an extreme case, the actual simulation is empty, and the expected simulation contains the negated state of affairs, that is, the representation contains only the information that a particular state of affairs does not hold, without specifying what holds instead.

The empirical counterargument against visual imagery models was based on the finding that differential effects were obtained with the prepositions *above* and *below* (cf. Clark & Chase, 1972). The argument was based on the assumption that visual images do not include a point of reference, such that two sentences with the same truth conditions, such as *The star is above the plus* and *The plus is below the star*, lead to the same representation (Clark & Chase, 1972, p. 499). However, these assumptions do not hold for the experiential simulations proposed here. These simulations do not convey an objective state of affairs, but a specific interpretation of a particular state of affairs, a construal (Langacker, 1987)—simulations are separated into figure and ground and do have foregrounded regions. Thus, the experiential simulations constructed for *The star is above the plus* and *The plus is below the star* are not equivalent, but differ with respect to which of the two entities is foregrounded (e.g., Langacker, 1987). The differential behavior of the two prepositions therefore poses no problem for the experiential view of language comprehension.

Accessibility

The accessibility-reducing effect of negation that was observed by MacDonald and Just (1989) for sentences such as *Almost every weekend Mary bakes some bread but no cookies for the children* is easily explained by the two-step simulation hypothesis. There is bread present but no cookie. Accordingly, the mental simulation of the actual state of affairs involves an experiential trace for bread but not for cookie, which may well be the reason why *bread* leads to faster response times than *cookies*. In fact, the results of earlier studies (Kaup, 1997, 2001; Kaup & Zwaan, 2003) confirm the hypothesis that the putative negation effect is due at least in part to the fact that in sentences of this type, the negated entity is absent from the actual situation. Admittedly, it may seem a little arbitrary to assume that here the simulation of the *actual* situation (containing only bread) is decisive, whereas in most of the sentence-verification studies it was the simulation of the negated situation that was considered to be decisive. However, the sentences used by MacDonald and Just (1989), unlike the sentences used in most of the sentence-verification studies, *explicitly* specified the actual situation (i.e., bread is being baked). When the sentence explicitly specifies the actual situation, the comprehender possibly first simulates the actual situation and then updates his or her expected

simulation according to the presupposition of the negated sentence. If so, it would be of no surprise that response times measured immediately after the end of the sentence reflected the content of the actual and not the content of the negated situation.

Kuschert (1999) found that resolving an anaphor takes more time when the antecedent was mentioned in a double negative construction compared with the case where the introductory construction was affirmative. This finding can be explained by the fact that a discourse entity that was introduced within a double negative construction (*I disconfirmed his supposition that Carl does not have a sister*) is present in the actual situation but absent in what we have called the expected situation. Assuming that the comprehender may still be engaged in simulating the expected situation when encountering the anaphor in the subsequent sentence, resolving the anaphor should lead to difficulties compared with the versions in which the target entity was introduced within an affirmative phrase. It should be noted that in contrast to the materials employed by MacDonald and Just (1989), the negative versions employed by Kuschert (1999) did not provide explicit information regarding the actual situation, but only allowed inference of the target entity's existence.

Giora et al. (2004) found that a sentence containing an explicit property negation (*not sharp*) shows the same priming effects as the corresponding affirmative sentence (*sharp*). This finding is consistent with the two-step simulation hypothesis, in that the two sentences initially give rise to the exact same simulation processes. To summarize, the two-step hypothesis can account for the extant empirical findings on negation. Comprehenders mentally simulate the negated as well as the actual situation when processing a negative sentence. In the next section we report a series of experiments that directly addressed this hypothesis.

AN EMPIRICAL STUDY EVALUATING THE TWO-STEP SIMULATION HYPOTHESIS OF NEGATION

The first three experiments reported in this section focus on the first part of the two-step simulation hypothesis, the claim that negative sentences, when presented without a context in which the negated state of affairs is highly available, are a cue to the comprehender to construct a mental simulation of the negated state of affairs. We asked the question: "Are negated states of affairs initially present in comprehenders' simulations?" The fourth experiment addresses the second part of the two-step simulation hypothesis, the claim that negative sentences eventually lead to a simulation of the actual state of affairs. All experiments used the paradigm developed by Zwaan et al. (2002) for testing the experiential view with affirmative sentences (see Kaup, Yaxley, Madden, Zwaan, & Lüdtke, in press, for details on Experiments 2 and 3, and Kaup, Lüdtke, & Zwaan, 2006, for details on Experiment 4).

In the study by Zwaan et al., participants were presented with sentences such as *The ranger saw an eagle in the sky* or *The ranger saw an eagle in the nest*, and afterward saw a picture of the object mentioned in the verb phrase of the sentences. Participants judged as quickly as possible whether the object in the picture was mentioned in the sentence. For experimental trials, the correct response was always yes, but the picture either matched the implied shape of the object (outstretched wings for . . . *in the sky*; folded wings for . . . *in the nest*) or not (folded wings for . . . *in the sky*; outstretched wings for . . . *in the nest*). Zwaan et al. found a strong match/mismatch effect. Response latencies were significantly shorter when there was a match between the sentence and the picture with respect to the object's shape than when there was a mismatch. This finding suggests that comprehenders routinely infer the implied shapes of objects mentioned in a sentence, which in turn can be considered positive evidence for the idea that the processing of affirmative sentences of the type investigated by Zwaan et al. triggers experiential simulations of the referent situations.

What can be predicted about negated sentences in this paradigm? If it is true that comprehending an isolated negative sentence in a first step requires the construction of an experiential simulation of the negated states of affairs, then the negated sentences should initially yield effects similar to those of the affirmative sentences. Thus, if comprehending a sentence such as *There was no eagle in the sky* requires a simulation of an eagle in the sky, then this should be reflected in the response latencies elicited by pictures of an eagle with outstretched or folded wings, respectively. Latencies should be shorter if the picture matches the negated state of affairs (i.e., outstretched wings) than when the picture matches some other state of affairs (i.e., folded wings). Conversely, *There was no eagle in the nest* should lead to the reversed latency pattern. In this case, latencies should be shorter for a picture with folded wings than for a picture with outstretched wings. In short, a response-time pattern should be obtained that is analogous to the pattern observed with affirmative sentences. This prediction was investigated in Experiments 1 through 3, in which the picture was presented with a delay of only 250 ms after the end of the sentence. Differential response time patterns should be observed later in the comprehension process, when comprehenders begin simulating the actual state of affairs. In Experiment 4 we therefore presented the picture with longer delays, 750 ms and 1500 ms.

In Experiment 1, participants were presented with 28 experimental sentences of the form *There was no X in/on the Y* and 56 filler sentences (14 negative and 42 affirmative). There were two versions of each experimental sentence that differed only with respect to the noun that was used in the locational phrase (e.g., *There was no eagle in the sky/There was no eagle in the nest*). The sentence pairs were constructed such that the corresponding affirmative sentences (*There was an X in/on the Y*) implied a different shape of the same object. For instance, *There was an eagle in the sky* implies that the eagle has its wings outstretched, whereas *There was an eagle in the nest* implies that the eagle has its wings folded. A picture followed each sentence. Subjects

indicated whether the depicted object had been mentioned in the sentence. For the experimental sentences, the correct answer was always yes, but the picture either matched the shape of the object in the negated situation (outstretched wings for *There was no eagle in the sky;* folded wings for *There was no eagle in the nest*) or not (folded wings for . . . *in the sky;* outstretched wings for . . . *in the nest;* see Fig. 11–1).

As predicted, participants responded significantly faster to a picture that matched the negated state of affairs than to a picture that matched a different state of affairs (the means in the two conditions are shown in Fig. 11–1). Apparently, comprehenders represented the shape that the object had in the negated state of affairs. In fact, the similarity between the present results and the results obtained for affirmative sentences (Zwaan et al., 2002) suggests, as was hypothesized, that the processing of negative sentences triggers (at first) the same simulations as the processing of the corresponding affirmative sentences does.

However, the similarity between the results for the two sentence types also presents a challenge for a coherent interpretation of the findings. The experimental task did not require participants to pay attention to the polarity of the sentence (affirmative vs. negative). They only needed to decide whether a particular object had been named in the sentence. Maybe par-

			Depicted Situation	
			Negated	Other
Experiment 1 and 2				
Sentences	*There was no eagle in the sky.*			
	There was no eagle in the nest.			
Mean Response Time (in ms)		**Exp1**	699	730
		Exp2	811	889
Experiment 3				
Sentences	*The eagle was not in the sky.*			
	The eagle was not in the nest.			
Mean Response Time (in ms)		**Exp3 indefinite**	855	884
		Exp3 definite	877	927

Note: The negated condition is the condition in which the picture matches the negated situation.

FIGURE 11–1. Sample sentence-picture pairs used in Experiments 1 through 3, and mean recognition times as a function of the depicted state of affairs.

ticipants simply ignored the negation markers in the sentences and processed the sentences as if they had been affirmative. This alternative hypothesis seems all the more plausible, considering that paying attention to the meaning of the negative sentences might lead to interference with the experimental task. After all, participants had to respond with "yes" to a picture of an object that was mentioned within the scope of the negation operator in the sentence. If it is true that participants ignored the negation operators in the experimental sentences of this experiment, then finding shorter response times in the negated condition would not be surprising and would not constitute support for the hypothesis that the first step in processing a negated sentence is to simulate the negated situation. The result would merely constitute further evidence for the experiential simulation view of language comprehension.

Experiment 2 was designed to address this concern. We presented participants with comprehension questions after some of the filler sentences. The questions were designed so that a correct answer indicated that the participant had not only attended to the polarity of the sentence, but had also understood the meaning of the corresponding sentence. For instance, a sentence such as *There was no light bulb in the lamp* was followed by *Was the lamp useless for illuminating the room?*, and a sentence such as *There was a flower in the vase* was followed by *Was the vase empty?* We reasoned that this modification would (a) prevent participants from adopting the potential strategy to ignore the negation operator in the experimental sentences, and (b) allow us to exclude post hoc those participants who nevertheless seemed to have adopted this strategy (as indicated by a relative high occurrence of incorrect answers to questions after negative sentences in particular).

The results again supported the predictions. As in Experiment 1, there was a significant effect of the depicted state of affairs with shorter latencies in the negated than in the "other" condition, and analyses of the comprehension question indicate that this effect cannot be due to participants strategically ignoring the negative particles: The mean comprehension accuracy for affirmative sentences was not higher than that for negative sentences (77%; SD ∇ .16 and 80%; SD ∇ .17, respectively). Furthermore, a significant effect of the depicted state of affairs was observed even when particular subgroups of the total set of participants were analyzed, namely the group of participants who had a mean accuracy of at least 83% (i.e., at least 20 out of 24 correct responses; N ∇ 20), or the group of participants (N ∇ 25) who made fewer than two mistakes with the overall 12 negative questions. For both subgroups, the accuracy scores indicate that they could not have adopted the ignoring strategy. That they nevertheless showed a significant effect therefore rules out that this effect reflects this particular strategy. These results thus provide further evidence for the hypothesis that the processing of negated sentences involves mentally simulating the negated states of affairs.

The goal of a third experiment was to investigate whether the effect of the depicted state of affairs would generalize to other kinds of negated sentences.

In addition to the negative sentences of the form *There was no X in/on the Y*, we presented participants with negative sentences of the form *The X was not in/on the Y*. Thus, we compared the indefinite negations from the previous experiments with definite negations. These two types of negations differ with respect to the scope of the negation operator. In the indefinite negative sentences (*There was no X in/on the Y*), the negation operator has wide scope—the only affirmative information in the sentence is the presupposition that there is a particular unambiguously identifiable Y. Thus, a sentence of this kind does not provide much information about the actual state of affairs. In contrast, the definite negative sentences (*The X was not in/on the Y*) carry the additional presupposition about the existence of a particular X. Moreover, this is the subject of the sentence and therefore suggests an agent for a simulation of the actual state of affairs. Therefore, a negative sentence of this kind provides the comprehender with more specific information about the actual state of affairs than does the corresponding indefinite negative sentence. If indefinite but not the definite negations produced a significant effect of the depicted state of affairs, then this would suggest that our two-step simulation hypothesis holds only for very specific cases of negation, namely cases in which the negative sentence is so nonspecific that it provides nearly no information about the actual state of affairs. In other words, such a result would indicate that comprehenders construct an experiential simulation of the negated state of affairs only if there is nothing else to simulate. Obviously this would reduce the scope of our account dramatically. However, the results of this experiment speak against this view: The effect of the depicted state of affairs did not interact with definiteness but proved significant for both types of negations (see Fig. 11–1). That response times were not faster in the definite than in the indefinite conditions speaks against the interpretation that comprehenders simulate the negated *and* the actual state of affairs in parallel right from the beginning. As was mentioned earlier, the definite negations carry a presupposition about the existence of the critical entity (the eagle), which provides an agent for the simulation of the actual state of affairs, whereas the indefinite negations do not. Accordingly, it can be assumed that in the definite conditions, the actual state of affairs contains an eagle, whereas in the indefinite conditions it does not. Hence, had comprehenders had available a simulation of the actual state of affairs as early as 250 ms after processing the negative sentence, this should have been reflected in shorter response latencies in the definite than in the indefinite conditions (for details see Kaup et al., in press).

Experiment 4 was designed to examine whether the processing of negative sentences would eventually result in a simulation of the actual state of affairs. To this end, we prolonged the delay with which the picture was being presented after the sentences from 250 ms to 750 ms and 1500 ms in Experiment 4 (for details see Kaup et al., 2006). Because we were interested in detecting

effects based on simulations of the actual state of affairs, we used negative sentences that left little ambiguity about the actual state of affairs. Negative sentences with contradictory predicates (e.g., *The umbrella was not open / The umbrella was not closed.*) satisfy this condition. Also, we used a picture-naming task instead of a recognition task in this experiment. Furthermore, to allow a direct comparison between the effects obtained with negative sentences and those obtained with affirmative sentences, we presented the set of participants not only with the two negative versions of the sentences, but also with the two corresponding affirmative versions (e.g., *The umbrella was open / The umbrella was closed*). Thus, on a given trial, the image could depict the actual state of affairs of the preceding negative or affirmative sentence, or the image could depict the respective "other" state of affairs (which corresponds to the negated state of affairs for negative sentences; see Fig. 11–2). If comprehending a negative sentence does indeed result in a simulation of the actual state of affairs, there should be a main effect of the depicted state of affairs, with shorter response times in conditions where the picture matches the actual state of affairs than in conditions where the picture matches the negated or other state of affairs. No clear-cut predictions can be made with respect to the

		The umbrella was closed		
Sentences		*The umbrella was open*		
Mean Response Time				
(in ms)	750 ms delay		642	619
	1500 ms delay		626	624

Negative

		The umbrella was not open		
Sentences		*The umbrella was not closed*		
Mean Response Time				
(in ms)	750 ms delay		648	643
	1500 ms delay		634	611

Note: The negated/other condition is the condition in which the picture matches the negated situation for negative sentences and a situation other than the actual situation for the affirmative sentences. The actual condition is the condition in which the picture matches the actual situation.

FIGURE 11–2. Sample sentence-picture pairs used in Experiment 4 and mean picture-naming latencies as a function of sentence polarity and the depicted state of affairs.

delay manipulation, because we do not know in advance the time in the comprehension process at which participants will switch from simulating the negated state of affairs to simulating the actual state of affairs when processing negative sentences. If the facilitation effect for the actual state of affairs turns out to be stronger for the 1500-ms delay condition than for the 750-ms delay condition, this would indicate that some participants in some conditions were still engaged in simulating the negated state of affairs 750 ms after reading the negative sentences. In summary, participants were presented with 40 experimental sentence-picture pairs in one of eight versions intermixed with 40 filler sentences (20 affirmative, 20 negative).

In accordance with the hypotheses, there was a main effect of the depicted state of affairs with shorter 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 other state of affairs. However, there was also a significant three-way interaction of delay, sentence polarity, and depicted state of affairs. 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 with a picture that mismatched this state of affairs, but no such difference was found for the negative versions. 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 with a picture that mismatched this state of affairs, but no such difference was found for the affirmative versions.

The overall main effect of the depicted state of affairs, with shorter response times for actual than for negated/other, suggests that comprehenders eventually simulated the actual state of affairs when processing affirmative and negative sentences. Moreover, the fact that there was no two-way interaction of depicted state of affairs and sentence polarity indicates that this simulation was similar for the affirmative and the negative versions of the sentences. In other words, as far as the resulting simulation is concerned, a sentence such as *The door was not open* is equivalent to *The door was closed*, and a sentence such as *The door was not closed* is equivalent to *The door was open*. The former two sentences lead to a simulation of a closed door, and the latter two lead to a simulation of an open door. In this respect the results support the idea that comprehending a negative sentence results in a simulation of the actual state of affairs. The finding that the main effect of the depicted state of affairs was qualified by an interaction of depicted state of affairs, delay, and sentence polarity indicates that affirmative and negative sentences *do* differ with respect to temporal characteristics of the simulation process. For negative sentences, an advantage of the actual state of affairs was found with a 1500-ms delay but not with a 750-ms delay. This supports the view that for negative sentences the actual state of affairs is not simulated right away, but

only after the negated state of affairs has been simulated. In contrast, for affirmative sentences, an advantage of the actual state of affairs already occurred at 750 ms, supporting the view that the actual state of affairs is simulated right away for affirmative sentences. The absence of an advantage effect with affirmative sentences at 1500 ms was not predicted, but is not surprising. Obviously, comprehenders will not keep their simulations accessible indefinitely. Considering that affirmative sentences presumably involve only one simulation step, it seems plausible that comprehenders were long finished with their simulations and had turned their attention elsewhere 1500 ms after self-paced reading of an affirmative sentence.

It could be argued that the differences in results obtained in the experiments with the short and long delays are not due to the differences in the delays but rather to properties of the predicates in the experimental sentences. In Experiments 1 through 3, in which the pictures were presented after a 250-ms delay, the predicates were locational specifications (e.g., to be in the nest / to be in the sky), the negation of which usually does not provide specific information about the actual location of the target entity. In contrast, in Experiment 4, in which the pictures were presented with longer delays (750 ms and 1500 ms), the predicates were contradictory state descriptions (to be open / to be closed), the negation of which does provide specific information about the actual state of the critical entity. At first sight, this seems to suggest that participants represent the negated state of affairs for sentences with predicates of the first type, and the actual state of affairs for sentences with predicates of the second type. Such a view comes close to assumptions made by Mayo et al. (2004). These authors propose that negative sentences with unipolar adjectives (e.g., *He is not responsible*) lead to *schema-plus-tag* representations, in which a core supposition is combined with a negation tag, whereas sentences with bipolar adjectives (e.g., *He is not warm*) lead to *fusion* representations, in which the core proposition and the negation are integrated into one meaning unit. There are two main reasons for why we do not believe in an account based solely on the type of predicate. First, the two delay conditions examined in Experiment 4 employed the exact same contradictory predicates but still produced different results. When the picture was presented with a 750-ms delay, there was an advantage of the actual state of affairs in the affirmative conditions but not in the negative conditions. When the picture was presented with a 1500-ms delay, the affirmative conditions produced a null result, whereas the negative conditions produced an advantage of the actual state of affairs. These findings indicate that delay does have an effect on the response latencies. In addition, they suggest that there is a point in the comprehension process at which participants switch from simulating the negated state of affairs to simulating the actual state of affairs. Around this point in time, the negated state of affairs should still be more available than the actual state of affairs in some cases, and the actual state of affairs should already be more available than the negated state of affairs in others. Overall, this should produce a null result. Thus, although the two-step simulation

hypothesis does not predict the null result specifically for the 750-ms delay condition, the null result is predicted for some intermediate delay condition. An account based solely on the type of predicate does not predict these results in any way. We conclude therefore that participants do not simulate the actual state of affairs right away with contradictory predicates. Rather, the results of Experiment 4 suggest that they first simulate the negated and then the actual state of affairs, just as with any other negative sentence. This interpretation is also supported by the results of a recent study by Hasson & Glucksberg (2006): Participants were presented with a lexical-decision task after reading affirmative and negative metaphors (e.g., *My lawyer is / is not a shark*). When presented after a 1000-ms delay, probes related to the affirmative version of the metaphor (e.g., *vicious*) led to faster response times after affirmative than after negative metaphors, whereas probes related to the negative version of the metaphor (e.g., *gentle*) led to faster response times after negative than after affirmative metaphors. After shorter delays (150 ms and 500 ms) this prime-by-target interaction was not significant. Under these conditions, probes related to the affirmative version of the metaphor seemed to be facilitated after both the negative and the affirmative version of the metaphor.

The second reason we do not believe in an account based solely on the type of predicate is a theoretical one. If negative sentences with contradictory predicates (e.g., *The door was not open.*) would lead to a simulation of the actual state of affairs right away, then the simulation processes conducted for these sentences would be indistinguishable from those conducted for the affirmative sentences with the same truth conditions (e.g., *The door was closed.*). But if this is 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 form, the speaker could have used this easier affirmative form in the first place. It is more plausible to assume that the subtle (pragmatic) differences between *The door was not open* and *The door was closed* that prompt the speaker to use one or the other form in a particular communicative situation are also reflected in the hearer's mental representations of the communicated content.

CONCLUSIONS

We focused on the question of how negation is captured in experiential representations in language comprehension. In contrast to linguistic representations, experiential representations do not allow negation to be represented explicitly. Taking into account the pragmatic licensing conditions of negative utterances, we hypothesized that negation is implicitly encoded in the sequencing of two mental simulations: The simulation of the actual state of affairs, as the sentence or text describes it, and the simulation of the expected state of affairs. We distinguished two cases. The first case is where the negated state of affairs was already present in the discourse representation prior to encountering the negative sentence. In this case, processing the

negative statement consists of correcting the expectation by simulating the actual state of affairs according to the negative sentence. The second case is where the negated state of affairs was not included in the discourse representation prior to encountering the negative sentence. In such a case, the comprehender first constructs a mental simulation of the negated state of affairs and then turns toward simulating the actual state of affairs.

In arguing for the two-step simulation hypothesis, we first reexamined empirical findings reported in the literature that are relevant to the question of how negation is represented in language comprehension. We examined three findings in particular: the impact that negation has on processing difficulty, the impact that the truth value of a negative sentence has on sentence-verification latencies, and the impact that negation has on the accessibility of text information. All three classes of findings are usually explicitly or implicitly interpreted as positive evidence for the claim that comprehenders construct a propositional representation in which negation is explicitly represented. A reevaluation of the findings showed that the majority of the findings can be accounted for by the two-step simulation hypothesis. Of course, this accounting is post hoc and should not be taken as positive evidence for the two-step simulation hypothesis. However, it does suggest that there is an alternative account for these findings, meaning that they cannot be taken as positive evidence for propositional representations either.

We also reported four experiments that directly addressed the two-step simulation hypothesis. Their results support the predictions. Shortly after reading a sentence that denied that a particular kind of target entity (e.g., an eagle) was in a particular location (e.g., the sky / the nest), participants were faster to respond to a picture of the target entity if the depicted shape matched the shape that the target entity would have had in the negated situation compared with when the depicted shape did not match the negated shape. Thus, at this point in the comprehension process (namely 250 ms after reading the sentences) comprehenders' response time patterns obtained with negative sentences (*There was no eagle in the sky / nest*) were equivalent to the response time patterns obtained in previous experiments employing the corresponding sentences without negation (*There was an eagle in the sky / nest*). This equivalence supports the assumption that negative sentences at first lead to exactly the same simulation processes as the corresponding sentences without negation. The results obtained with longer delays (750 ms, 1500 ms) suggest that comprehenders from a certain point in time on are simulating the actual state of affairs. One and a half seconds after reading negative sentences that denied that a particular target entity (e.g., door) was in a particular state (e.g., open / closed), participants were faster to respond to a picture of the target entity when the depicted state corresponded to the actual state of the target entity compared with when this was not the case. In fact, at this point in the comprehension process, the effects obtained with negative sentences (e.g., *The door was not closed*) resembled the effects obtained with affirmative sentences (e.g., *The door was open*), except that in the affirmative case,

the effects come to light earlier in the comprehension process (namely, by 750 ms instead of by 1500 ms). Thus, in summary, the results of the four experiments are in line with the two-step hypothesis.

In conclusion, we would like to note that the two-step simulation hypothesis of negation also accords well with findings from outside of the psychology of language. We briefly mention three different findings. First, in social and pedagogical psychology, it is well known that negations, when used in explicit behavior-controlling instructions, are counterproductive in that they often cause the opposite of what the instructor intended (e.g., Brehm & Brehm, 1981). Children at a certain age, when explicitly told not to do something, almost certainly will go ahead with the forbidden action. It seems as if the action is even more likely after an explicit negation than without an explicit instruction altogether. It is therefore usually recommended not to tell a child what he or she is not supposed to be doing but to state what he or she is supposed to be doing instead. There are different explanations for this counterproductive effect of negation. One of the most prominent ones is based on Brehm's reactance theory (Brehm, 1966), according to which forbidden behavior becomes particularly attractive. Another explanation can be based on propositional theories of comprehension: In a propositional representation the negation operator is applied to a complete proposition. Thus in case the negation operator is lost, a proposition remains that corresponds to the negated state of affairs. The two-step simulation hypothesis points to another reason that may contribute to the counterproductive effect of negative instructions. In order to understand the negation, the child needs to mentally simulate the negated state of affairs before turning to the question of what action should be done instead. It seems likely that children are less able than adults to mentally simulate states of affairs and accordingly often overtly act out the to-be-simulated state of affairs by accident. Consistent with this idea, counterproductive effects of negation also have been observed in conditions for which reactance is not a likely explanation. In a study by Wegner, Ansfield, and Pilloff (1998), one group of participants was instructed to prevent a pendulum from swinging along a particular axis that was marked on a piece of paper in front of them, whereas the other group did not receive such an explicit instruction. Participants in a condition in which they were being distracted by having to solve a secondary task showed more swinging along the particular "forbidden" axis than a group that did not receive such an instruction.

Second, research on mental control has shown that counterproductive effects of negation also occur when mental processes are being targeted by explicit instruction instead of overt behavior. Participants who are being explicitly told not to think about a particular concept are usually unable to effectively suppress the corresponding thoughts (Wegner & Erber, 1992; Wegner, Schneider, Carter, & White, 1987). Obviously, the two-step simulation hypothesis would predict these problems in thought suppression, because according to this hypothesis, understanding the explicit instruction

that a particular concept is not to be thought of requires simulating this concept.

Third, research on social judgment has shown that media audiences are influenced by information they are explicitly told is not true (e.g., Fiedler, Armbruster, Nickel, Walther, & Asbeck, 1996; Wegner, Wenzlaff, Kerker, & Beattie, 1981). Thus, the reputation of a person can be severely damaged simply by spreading the news that a particular undesirable attribute does not hold for the person in question (e.g., *Mr. Smith did not sell drugs to minors*!). Again, there are different explanations for this *incrimination by innuendo* effect. The most convincing explanation is that this type of negation pragmatically suggests that there was reason to believe that the undesirable attribute did in fact hold for the person in question, which in and of itself may be reputation-damaging. The two-step simulation hypothesis is based on these pragmatic aspects of negation, but goes one step further in explaining the effect. When processing the news, a simulation is run in which the undesirable attribute is in fact actively applied to the person in question. As a result, the connection between the person and the attribute may seem even more plausible.

In conclusion, we have introduced a mechanism by which a linguistic operator such as negation is implicitly represented in the experiential simulations created during language comprehension. Such a mechanism is a necessary ingredient of the experiential view of language comprehension if this view is intended to hold for language processing in general. The specific mechanism we propose is grounded in assumptions concerning the pragmatic licensing conditions of negative sentences and appears to be in accordance not only with the extant empirical findings on negation in the literature but also with the results of the four experiments that we reported in this chapter.

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