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Experiential Simulations of Negated Text Information

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Abstract

We investigated the question of whether comprehenders mentally simulate a described situation even when this situation is explicitly negated in the sentence. In two experiments, participants read negative sentences such as There was no eagle in the sky, and subsequently responded to pictures of mentioned entities in the context of a recognition task. Participants' responses following negative sentences were faster when the depicted entity matched rather than mismatched the negated situation. These results suggest that comprehenders simulate the negated situation when processing a negated sentence. The results thereby provide further support for the experiential-simulations view of language comprehension.

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Most researchers in language comprehension generally agree that comprehending a text entails the construction of a so-called *situation model* or *mental model,* a mental representation of the described situation (Glenberg, Meyer, & Lindem, 1987; Graesser, Millis, & Zwaan, 1997; Johnson Laird, 1983; Morrow, Bower, & Greenspan, 1990; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). Recently, the notion that situation models share the same representational format as other non-linguistic cognitive processes (e.g., perception, action, imagery) has been gaining support 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 notion of situation models hypothesize 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.

The last decade has produced a number of findings that demonstrate the validity of this mental-simulation view (for an overview, see Zwaan, 2004, and the contributions in Pecher & Zwaan, 2005). For example, 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). Also, behavioral data suggest that language comprehension results in the creation of representations in those mental subsystems that are utilized in other non-linguistic cognitive processes such as action planning, perception or imagery. For instance, behavioral studies have shown that the representations constructed in language comprehension have properties in common with representations constructed in non-linguistic cognition. Such functional equivalence effects have been demonstrated, for instance, with the representations' spatial extendedness which provides a

basis for mental scanning processes (Baddeley, 1986; Kosslyn, 1994): Aforementioned entities are faster to access if they are spatially close to the protagonist in the described situation compared to when they are far away from the protagonist of the story (e.g., Glenberg et al., 1987; Morrow et al., 1990; Rinck & Bower, 1995). Functional equivalence has also been demonstrated with respect to the size-resolution trade-off principle (Kosslyn, 1994): Aforermentioned entities are harder to access after the text zoomed-in on a small detail compared to when the text continues at the same granularity level (Kaup, Kelter, & Habel, 1999). Finally, functional equivalence has been demonstrated with respect to the representations' dynamic nature (e.g., Freyd, 1987; 1993). For instance, after reading a sentence describing a motion towards the observer (e.g., "The pitcher hurled the softball to you"), participants were significantly faster in judging the equivalence of two sequentially presented pictures in case the second picture was slightly enlarged (indicating a movement towards the observer). The opposite response time pattern emerged after participants read sentences describing a motion away from the observer (Zwaan, Madden, Yaxley, & Aveyard, 2004).

A second type of finding concerns effects due to similarities or dissimilarities between the experimental task and the content of the described state of affairs. 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 away from the comprehender) compared to when there was a mismatch (e.g., movement towards the comprehender; see also Klatzky, Pellegrino, McCloskey, & Doherty, 1989; Richardson, Spivey, Barsalou, & McRae, 2003). Recently, Zwaan and Taylor (in press) showed that motor processes are active during online comprehension, rather than merely during off-line sensibility judgments. 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 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 to 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 (e.g., Zwaan and Yaxley, 2003a, 2003b).

The linguistic materials used in these studies were mostly simple descriptions of concrete situations. As such, these results cannot rule out that experiential simulations are only an optional by-product of comprehension that has no functional relevance: When the materials are simple, and enough mental resources are available, comprehenders create experiential simulations. Amodal propositional representations, however, may be needed to capture the whole spectrum of linguistic meaning conveyed in narrative texts. However, if creating experiential simulations is necessary for comprehension, all aspects of linguistic meaning should be captured in experiential-simulations during language comprehension.

Initial support for this strong version of the experiential view comes from studies concerned with the representation of abstract concepts. 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 towards or away from the comprehender. These sentences produced similar action-compatibility effects as the more concrete sentences (e.g., *He opened the drawer*; see also Boroditsky, 2000; Boroditsky & Ramscar, 2002). If experiential-simulations were only a non-functional by-product of comprehension, why should comprehenders bother representing

abstract information in an experiential-simulations format? Finding effects indicative of an experiential format with abstract concepts supports the view that abstract concepts are represented in an experiential-simulations format by means of metaphorical extension. This in turn is in line with the view that experiential simulations are not only created with simple and concrete materials. Rather, it seems that creating experiential simulations is an integral component of comprehension.

Additional support for the view that experiential-simulations are created even in demanding conditions comes from recent studies that were concerned with how flashback information is being represented in narrative comprehension (Claus & Kelter, in press; Kelter & Claus, 2005). In these studies, participants were presented with passages that described four events E1-E4 occurring in the described world in the order E1, E2, E3, E4. In the passages E1 was mentioned after E3 (i.e., as a flashback). At the end of the narrative, the mental availability of E1 was tested by means of a probe-recognition task. Probe-recognition times were significantly faster when the duration of event E2 was short (e.g., *for half an hour they fly above the countryside*) than when it was long (e.g., *for five hours they fly above the countryside*). In contrast, the reading times of the sentence immediately preceding the probe-recognition task were unaffected by the duration manipulation, which rules out an explanation according to which processing is generally slowed down after reading long-lasting compared to short-lasting events (cf. Matlock, 2004). The results thus strongly suggest that E1 was inserted into the chronologically appropriate location in the created mental simulation of the four events. Why else should the duration of E2 (which was mentioned before E1) affect the availability of E1 at the end of the narrative? When assuming that E1 was retroactively inserted into the simulation before E2, then this effect is easy to explain: Previous studies have shown that a previously mentioned event becomes gradually less accessible as time moves forward in the described world (e.g., Kelter et al., 2004; Rinck & Bower, 2000). The results of this study thus indicate that comprehenders

create a chronologically organized representation of the described events even in conditions where this implies a time-consuming re-organization of the previously created simulation. This finding seems to speak against the view that experiential-simulations are only a non-functional by-product of comprehension. Rather, they suggest that comprehension is tied to the creation of representations that are similar in nature to the representations created when directly experiencing or re-experiencing the respective situations and events.

The present study is concerned with an even harder test for the experiential-simulations view. We investigated whether comprehenders create experiential-simulations of negated situations, i.e., situations that explicitly do not hold for the world under consideration. Two experiments used the paradigm developed by Zwaan et al. (2002) for testing the experiential-simulations view with affirmative sentences. As was already briefly mentioned above, in Zwaan et al.'s study, participants were presented with sentences such as *The ranger saw an eagle in the {sky/nest}*, and afterwards saw a picture of the object mentioned in the verb phrase of the sentences. Participants decided as quickly as possible whether or not 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, in which 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 indicates that comprehenders routinely infer the implied shapes of objects mentioned in a sentence, which in turn supports the idea that the processing of affirmative sentences triggers an experiential simulation of the situation described.

What can be predicted about negated sentences in this paradigm? If it is true that comprehenders create an experiential simulation of the described situation even if this situation

is being negated in the sentence, then the negated sentences should yield similar match/mismatch effects as the affirmative sentences. Thus, if comprehending a sentence such as *There was no eagle in the sky* involves 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 implied shape of the object in the situation that is being negated (outstretched wings) than when there is a mismatch (i.e., folded wings). Accordingly, *There was no eagle in the nest* should lead to the reversed latency pattern. Latencies should be short for a picture with folded wings and long for a picture with outstretched wings.

Thus, finding a match/mismatch effect with negative sentences in this paradigm would support the strong version of the experiential-simulations view. According to this view, creating experiential simulations is an integral component of comprehension that is also utilized when reading about situations that do not hold for the world that is under consideration. In contrast, not finding such an effect with negative sentences might be interpreted as support for a weaker version of the experiential-simulations view, according to which its scope is limited to the representation of factual information. Obviously, pure amodal propositional theories would also not predict such an effect. According to these theories negation is an explicitly represented operator that is applied to the proposition that is being negated and thereby reduces the accessibility of concepts mentioned in its scope. Thus, these theories predict that after reading a sentence such as, *There was no eagle in the nest,* the eagle should be relatively low in accessibility (see Kaup, 2001 and Kaup & Zwaan, 2003 for a test of this hypothesis). However, these theories would not a-priori predict differences in response times with respect to the availability of the eagle in the two different shapes (i.e., would not predict a match/mismatch effect with negative sentences; see also General Discussion).

Experiment 1

Method

Participants. Forty students at Florida State University participated in the experiment for course credit.

Materials. Twenty-eight experimental sentence pairs were constructed. All of these sentence pairs were of the form *There was no X in/on the Y*, and the surface structure of the two sentences of a given pair only differed with respect to the noun that was used in the locational phrase (i.e., Y) [e.g., *There was no eagle in the sky* / *There was no eagle in the nest*]. The sentence pairs were constructed in such a way that both of the negated situations implied a different shape of the same object. For instance, *eagle in the sky* implies that the eagle has its wings outstretched, whereas *eagle in the nest* implies that the eagle has its wings folded in. Two black-and-white images, depicting the target object in the two implied shapes, were also constructed to correspond to each experimental sentence pair. This yielded two sentences and two pictures for each of the 28 target objects. Each experimental sentence could be paired with a picture that matched or mismatched the implied shape of the target object in the negated situation, yielding four possible sentence-picture combinations. Participants were to see only one of these four possible combinations for each target object (see below). Examples for other objects used are an egg (in the refrigerator vs. in the skillet), a newspaper (on the rack vs. on the driveway), or a balloon (in the pack vs. in the air).

Fifty-six additional filler sentences were constructed. Fourteen of these filler sentences were of the same negative format as the experimental sentences (*There was no X in/on the Y*) and the remaining 42 were affirmative sentences (*There was an X in/on the Y*). Fourteen of these 42 affirmative sentences were followed by pictures of the objects named in the preceding affirmative filler sentences. The rest of the filler sentences were followed by pictures of objects

not named in any of the sentences. All pictures were scaled to occupy a 3 inch square on the screen.

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. The questions were constructed in such a way that correctly responding would require processes that go beyond understanding the meaning of the individual words mentioned in the sentences. 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?*, or a sentence such as *There was a flower in the vase* was followed by *Was the vase empty?*. Thus, a high number of correct responses to these questions indicates that the participant did not simply ignore the negative particles in the negative sentences of the experiment.

In summary, each participant saw 28 negative experimental sentences that were paired with pictures that required a 'yes' response. In addition, each participant saw 14 negative filler sentences that were paired with pictures requiring a 'no' response, 28 affirmative filler sentences that were paired with pictures requiring a 'no' response, and 14 affirmative filler sentences that were paired with pictures requiring a 'yes' response. Hence, overall, half of the sentences each participant saw were negative and the other half were affirmative. Also, the correct response to the picture was 'yes' for half of the sentence-picture pairs and 'no' for the other half.

Design and Procedure.

We created four lists that counterbalanced items and conditions. Each list included a different one of the four possible versions (2 sentences x 2 pictures) for each object. Each participant saw one of these lists. For two of the overall four versions the picture matched the negated situation, and for the other two the picture matched a different situation (see Figure 2).

Thus, for the statistical analyses we combined the two former and the two latter conditions respectively, resulting in a 2 (depicted situation: negated vs. other) x 4 (list) design.

Participants were instructed to read each sentence and then to decide whether the pictured object that followed had been mentioned in the preceding sentence. They were informed that reaction times and accuracy were being measured and that it was important for them to make the decisions about the picture as quickly and accurately as possible. 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 the space bar when they had understood the sentence, and then a fixation point appeared at the center of the screen for 250 ms, followed by a picture. Participants then determined whether the pictured object had been mentioned in the preceding sentence, by pressing the appropriate key (f-key, marked with 'y', j-key, marked with 'n'). On trials with a comprehension question, the question was presented next. Participants were asked to respond to the questions as accurately as possible by pressing the 'y' or 'n' key, respectively (no time pressure). Participants were not given feedback on their responses. The experiment took approximately 20 minutes to complete.

Results and Discussion

Response latencies of experimental trials were submitted to 2 (depicted situation: negated vs. other) x 4 (list) analyses of variance (ANOVAs) with repeated measurement on depicted situation in both the by-participant analysis and the by-items analysis. The latency analysis was performed on correct responses only. Responses longer than 3000 ms or shorter than 300 ms were omitted, as well as responses falling outside two standard deviations from the participant's mean in the respective condition (this eliminated 6 % of the data). The mean latencies, standard deviations, and the percentages of errors are displayed in Table 1.

Responses were significantly faster when the depicted situation matched the negated situation than when it did not match this situation, $F1(1,36) = 8.62$, $MSE = 14017$, $p < .01$;

$F2(1,24) = 17.66$, $MSE = 5650$, $p < .001$. There also was a significant effect on response accuracy: Responses were more accurate when the picture matched the negated situation, $F1(1,36) = 4.4$, $p < .05$, $MSE = 0.5$; $F2(1,24) = 4.78$, $MSE = 0.6$, $p < .05$. The results support the prediction that comprehenders construct an experiential simulation of the negated situation when processing a negative sentence. Apparently, comprehenders represented the shape that the object had in the negated situation, so that responses to the pictures were faster when the picture matched this shape than when there was a mismatch between the picture and the negated shape. In fact, the similarity between the present results and the results obtained for affirmative sentences (Zwaan et al., 2002) suggests that the processing of negative sentences triggers the same simulations as the processing of the corresponding affirmative sentences does[1].

Could the effect possibly be due to participants adopting the strategy to ignore the negation markers in the sentences, and processing the sentences as if they had been affirmative? The comprehension data allow ruling out this possibility: Participants responded to the comprehension questions regarding affirmative sentences with a mean accuracy of 77% (SD = .16) and to those regarding negative sentences with a mean accuracy of 80% (SD = .17). The difference between the two accuracy scores was not significant, $t1(39) = 1.18$, $p = .25$; $t2(22) = 0.147$, $p > .80$. This null effect speaks against the hypothesis that participants ignored the negative particle in the experimental sentences. Had they consistently done so, lower accuracy scores should have been obtained for the negative conditions than for the affirmative ones. In an attempt to further evaluate the relationship between the effect and the potential strategy to ignore the negative particle in the experiment, we repeated the response latency analysis with a subgroup of participants. For this post-hoc analysis we selected all those participants who had a mean accuracy of at least 83% (i.e., at least 20 out of 24 correct responses). The relatively high overall accuracy with which these participants responded to the questions makes it highly unlikely that they adopted the strategy of ignoring the negative particles in the experiment.

Nevertheless, the effect was significant for the 20 participants who satisfied this condition, $F1(1,16) = 4.34$, $MSE = 13349$, $p = .05$; $F2(1,24) = 10.32$, $MSE = 10192$, $p < .01$; see Table 2, Subgroup 1. Similar results were obtained when participants were selected only based on their accuracy in the negative condition. The 25 participants who made fewer than two mistakes with the overall 12 negative questions, produced a significant effect, $F1(1,21) = 4.6$, $MSE = 9244$, $p < .05$; $F2(1,24) = 7.46$, $MSE = 7258$, $p < .05$ (see Table 2, Subgroup 2), indicating that the effect of the depicted situation on the response latencies cannot be explained (away) by assuming that the negative particles were ignored by the participants of the experiment. Together with the comprehension question data, the present results provide evidence that described situations are simulated even when they are explicitly negated in the sentence processed.

One may argue that the sentences employed in Experiment 1 (e.g., *There was no eagle in the sky*) were very vague as they provided nearly no information with respect to the actual situation. Perhaps comprehenders only simulated the negated situation because there was nothing else to simulate? The goal of Experiment 2 was to investigate whether the mismatch effect would generalize to negated sentences that provided more information with respect to the actual situation. 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 to 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 a wide scope-- the only affirmative information in the sentence is the presupposition that there is a particular unambiguously identifiable Y. In contrast, in the definite negative sentences (*The X was not in/on the Y*), there is the additional presupposition about the existence of a particular X, which is moreover the subject of the sentence and accordingly provides an agent for a potential

simulation of the actual situation. Maybe comprehenders in this case create a simulation of the entity referred to in subject position (the eagle) to which they then attach the negated verb phrase information in a non-experiential format (e.g., amodal propositions). If so, the match/mismatch effect should not be observed with definite negations. If on the other hand comprehenders mentally simulate the negated situation in general when processing a negative sentence, then the match/mismatch effect should also be present with definite negations.

Experiment 2

Method

Participants. Sixty-four students at Florida State University participated in the experiment for course credit.

Materials.

The materials were the same as those in Experiment 1, with three exceptions. First, for each of the experimental items, two additional versions were constructed. In these additional versions, the target entity was mentioned within a definite phrase rather than an indefinite phrase. Thus, there were four different versions of each experimental sentence, with the first two being of the form *There was no X in/on the Y* (indefinite) and the second two being of the form *The X was not in/on the Y* (definite). Second, the filler sentences of Experiment 1 were modified such that half of them were definite and the other half indefinite. Thus, of the overall 56 filler sentences, 21 were affirmative and definite, 21 affirmative and indefinite, 7 negative and definite, and 7 negative and indefinite. Third, four of the experimental items used in Experiment 1 were identified as problematic when the definite sentences were constructed. These four items could be treated as either count or mass nouns (e.g., apple), and created an undesirable degree of ambiguity in the materials. All four items were replaced.

All of the 28 negative experimental sentences each participant saw were paired with pictures that required a ‘yes’ response. Half of these sentences were definite, and half were

indefinite. Of the 56 filler sentences, 14 were also paired with pictures requiring a 'yes' response. Seven of these were affirmative and definite, and the other seven were affirmative and indefinite. The remaining 42 filler sentences were paired with pictures requiring a 'no' response. The 24 comprehension questions of Experiment 1 were slightly modified so that there were six questions for each of the four different types of filler sentences. Half of the comprehension questions required a 'yes' response, the other half a 'no' response.

Design and Procedure

The design and procedure were the same as those in Experiment 1, except that half of the experimental and filler sentences each participant saw were definite and half were indefinite. We created eight lists that counterbalanced items and conditions. In accordance with the procedure in the previous experiment, we combined the two conditions in which the picture matched the negated situation as well as the two conditions in which the picture matched a different situation for the definite condition as well as for the indefinite condition, resulting in a 2 (definiteness: indefinite v. definite) x 2 (depicted situation: negated vs. other) x 8 (list) design, with definiteness and depicted situation being manipulated within participants and items.

Results and Discussion

The data were analyzed in the same way as in Experiment 1. Outlier elimination reduced the data set by 3.9%. Three items were identified as problematic (fillet of fish, chewed piece of gum, and ball of tissue). All three items were similar in that they were relatively amorphous compared to the other stimuli. These items yielded unusually long response latencies and high error rates. More specifically, the mean response latency for each of these items was more than 300 ms above the overall mean (more than 2 standard deviations). Moreover, whereas the error rate for the other items was approximately 0.9%, the mean error rate for these three items was approximately 7%. Accordingly, all three items were excluded from the analyses. It should be noted however, that qualitatively the results are not influenced by this omission. The mean

latencies, standard deviations, and the percentages of errors of the remaining data are displayed in Table 1. There was a significant effect of the depicted situation: Responses to the pictures were faster when the depicted situation matched the negated situation then when it matched a different situation, $F1(1,56) = 5.5$, $MSE = 18387$, $p < .05$; $F2(1,45) = 8.16$, $MSE = 13731$, $p < .01$. The main effect of definiteness was also significant. Participants responded slower in the definite than in the indefinite condition $F1(1,56) = 5.07$; $MSE = 13184$, $p < .05$; $F2(1,45) = 5.80$, $MSE = 44118$, $p < .05$. The interaction of depicted situation and definiteness was not significant ($F1 < 1$; $F2 < 1$). Response accuracy was not affected by the depicted situation, $F1 < 1$; $F2 < 1$, nor by definiteness, $F1(1,56) = 1.47$, $p > .20$; $F2 < 1$. The results of this experiment replicate those of the previous experiment in that participants responded more quickly to the pictures when the depicted shape matched the shape that the target object had in the negated situation. The results extend those of the previous experiment in showing that the effect does not only occur with indefinite sentences, but also with definite ones.

As in Experiment 1, the comprehension question data enable us to rule out the hypothesis that this effect is due to participants ignoring the negative particles in the experimental sentences. Participants responded to the comprehension questions regarding affirmative sentences with a mean accuracy of 82% (SD = .19) and to those regarding negative sentences with a mean accuracy of 81% (SD = .14). The difference between the two accuracy scores was not significant, $t1(63) = 0.23$, $p > .80$; $t2(22)=0.29$, $p > .77$. As in the previous experiment we selected all those participants who had a mean accuracy of at least 83%. The response time patterns found with the complete participant set was replicated with this subgroup. There was a main effect of the depicted situation, which however was only significant in the by-items analysis, $F1(1,31) = 3.5$, $MSE = 20587$, $p = .07$; $F1(1,45) = 10.32$, $MSE = 25885$, $p < .05$. There was also a main effect of definiteness, $F1(1,31) = 4.9$, $MSE = 12544$, $p < .05$; $F2(1,45) = 4.71$, $MSE = 18224$, $p < .05$ (see Table 2, Subgroup 1). For the

subgroup of participants who made fewer than two mistakes with the overall 12 negative questions, a main effect of the depicted situation was found but no main effect of definiteness, depicted situation: $F1(1,30) = 11.84$, $MSE = 11460$, $p < .01$; $F2(1,45) = 9.1$, $MSE = 29824$, $p < .01$; definiteness: $F1<1$, $MSE = 10217$; $F2 < 1$, $MSE = 23384$, (see Table 2, Subgroup 2).

The fact that the match/mismatch effect did not interact with the definite/indefinite manipulation is inconsistent with the hypothesis that an experiential simulation of the negated situation is only constructed if the negative sentence is extremely unspecific. In contrast to the indefinite negations, the definite negations in this experiment at least provided the comprehender with an agent for a potential simulation of the actual situation. Thus, the results of this experiment suggest that it is not the case that comprehenders construct experiential simulations of the negated situation only if there is nothing else to simulate.

Admittedly, the definite negations employed in this experiment do not provide much information about the actual situation. In particular, they do not allow definite conclusions with respect to the actual location and shape of the target entity. One might therefore argue that comprehenders did not simulate the actual situation with the definite negations simply because they did not have enough information about the target entity. However, it should be noted that not knowing the location or shape of entities mentioned in a text is nothing special, and certainly not specific to negated sentences. Comprehenders are regularly confronted with the task of creating a simulation without knowing the details. Consider a sentence such as *On his daily trip through the park the ranger saw an eagle he had never seen before*. Was the eagle in the sky, on the ground or in a nest? From the perspective of the experiential-simulations view of language comprehension it would be implausible to assume that comprehenders do not create mental simulations of the described scenes in cases such as these. It seems more plausible to assume that comprehenders in this case either infer the respective properties on the basis of their

general world knowledge, or create a simulation that is underspecified with respect to the unknown attributes (cf. Barsalou, 1999).

Thus, to conclude, the definite negations employed in this experiment provided the comprehender with a potential agent for a simulation of the actual situation. The fact that comprehenders nevertheless simulated the negated situation when reading these sentences (as indicated by the significant match/mismatch effect) demonstrates that a simulation of the negated situation is not limited to cases where there is nothing else to simulate. In the General Discussion we will report a recent study of ours (Kaup, Lüdtke & Zwaan, in press) in which participants read negative sentences with contradictory predicates, which allowed definite conclusions with respect to the actual shape of the target entities. The results of this study suggest that comprehenders in this case do not create a simulation of the actual situation right away, although the sentences provided specific information with respect to the actual situation. Thus, the results of this study are well in line with the view that the negated situation is routinely being simulated when a negative sentence is being processed, even if the sentence provides as much information about the actual situation as it provides about the negated situation.

The fact that response times were slower in the definite than in the indefinite conditions was not predicted. The fact that comprehenders were also more accurate numerically in the definite than in the indefinite condition might indicate that the response-time difference reflects a speed-accuracy trade-off. However, the respective numerical difference in response accuracy was far from significant which seems to speak against a speed-accuracy trade off in the respective comparison. In interpreting this unexpected difference in response times in the definite and the indefinite conditions, it should be noted that the sentences in the definite conditions began with an affirmative definite noun phrase (i.e., *The eagle*), and it therefore seems plausible that comprehenders started simulating an eagle (in a prototypical shape) before

encountering the negation marker in the verb phrase of the sentences. In some cases the initially simulated shape of the eagle may have matched the shape of the eagle in the negated situation, and in others it may have mismatched this shape. Prolonged response times in this condition relative to the indefinite condition may therefore be due to a time-consuming correction mechanism that spills over to the processing of the pictures in this condition. Alternatively, the longer response times may have incurred because comprehenders initiated a time consuming search for some aforementioned eagle when processing the definite noun phrase at the beginning of the sentence. Finally, longer response times in the definite condition may have to do with the fact that the definite but not the indefinite versions imply that there is a particular alternative location where the eagle is. Accordingly, longer response times may reflect time-consuming inference and/or simulation processes concerning this alternative location.[2]

General Discussion

We were concerned with the question of whether comprehenders create experiential simulations of situation described in a sentence, even when these situations are explicitly negated. Two experiments were conducted in which participants were presented with negative sentences of the form *There was no X on the Y* or *The X was not on the Y*, and afterwards responded to a speeded picture-recognition task. In both experiments, responses in the picture-recognition task were significantly shorter when the picture matched the shape of the target entity in the negated situation than when it mismatched this shape. This suggests that comprehenders mentally simulated the negated situation. The fact that the results were obtained for indefinite negations (*There was no eagle in the sky*) and also for definite negations (*The eagle was not in the sky*) indicates that the match/mismatch effect with negative sentences occurs regardless of how much information is available with respect to the actual case. In contrast to the indefinite negations, the definite negations provide the comprehender with a

target entity that is present in the described world and that could have been used as an agent for a potential simulation of the actual situation. The fact that comprehenders nevertheless simulated the negated situation (as indicated by the significant match/mismatch effect with definite negations) suggests that simulating the negated situation is a routine processing step in the comprehension of negative sentences. It seems that comprehending a negative sentence requires comprehending what it is that is being negated, and this in turn requires a mental simulation of the negated situation. The results of the two experiments are highly relevant to the experiential-simulations view of language comprehension as they have implications with respect to the scope of the view. Previous results have demonstrated the adequacy of the experiential-simulations view as far as the representation of factual situations is concerned. In principle it would have been conceivable that this view is limited to the case of factual situations. However, the present results speak against such a limitation. Rather, it seems that comprehenders represent factual and non-factual simulations in an experiential simulations format. More specifically, our results indicate that not even the negation operator leads comprehenders to strategically opt-out of an experiential-simulation of the respective situation.

Proponents of amodal propositional theories might argue that the match/mismatch effect obtained with negative sentences in the present experiments does not speak against the view that the negated situation is represented in an amodal propositional format. Obviously, the results of the present experiments speak against an amodal propositional format of the negated situation only to the extent to which the results of the original studies employing the same paradigm with affirmative sentences (Stanfield & Zwaan, 2001; Zwaan et al., 2002) are taken as evidence against an amodal representational format of the actual situation. As stated in these previous studies, we do not find it a convincing assumption for propositional views of language comprehension that shape information is routinely inferred, especially in cases where the

sentences do not explicitly refer to the shape of objects or highlight this attribute dimension in any way.

In our view, the present experiments demonstrate that comprehenders of negative sentences mentally simulate the negated situation in an experiential representational format. Obviously, however, this cannot be the whole story. If negative sentences led to the exact same simulation processes as the corresponding affirmative sentences, then negation would not be captured at the experiential-simulations level of representation. In addition to representing the negated situation, the comprehender obviously needs to represent the fact that this situation is not true for the world under consideration. In an experiential-simulations format mental simulations of situations cannot be explicitly represented as being false. We therefore recently proposed an alternative rejection mechanism, in which a negated situation is being simulated in an auxiliary representational system. In contrast to simulations corresponding to affirmative information, the simulation of the negated situation 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. Fauconnier, 1985; Langacker, 1991). In other words, the simulation of the negated situation is mentally rejected by the fact that it is simulated but not integrated with the representation of the described world (see Kaup & Zwaan, 2003; Kaup, Zwaan, & Lüdtke, in press).

To illustrate, consider the sequence *The ranger arrived at the clearing and looked up into the air. There was an/no eagle in the sky.* In both cases, the comprehender simulates a ranger at a clearance who is looking up into the sky. Also, in both cases, the comprehender additionally simulates an eagle in the sky. In the affirmative case, this simulation is integrated with the previous simulation, with the two simulations together constituting the representation of the described world. In the negative case, however, the simulation of the eagle in the sky is not integrated into the previous simulation but kept separate in an auxiliary representational system.

The negation is thereby implicitly captured in the deviation between the two representations. In the simulation in the auxiliary representational system, there is an eagle in the sky, in the representation of the described world, however, there is not. Thus, the information that there is no eagle in the sky can be retrieved by comparing the two representations.

In the above example, the negative sentence is embedded in a context that provides rich information with respect to the actual state of affairs. Moreover, prior to encountering the negated information, the comprehender already has available a representation of the described situation. However, we propose that the simulation processes undertaken when processing isolated negative sentences (as in the present experiments) are not qualitatively different: In the extreme case in which the sentence does not provide any information with regard to the actual state of affairs (e.g., *There was no eagle*), the comprehender presumably contrasts the simulation of the negated situation (an eagle) that is created in the auxiliary representational system with an "empty" simulation of the actual situation. In other cases, in which the sentence does provide some information with respect to the actual situation (for instance by presupposing the existence of another entity as in *There is no eagle in the nest*), comprehenders probably insert this information (a nest) into their simulation of the actual situation. However, whether or not they do so is a matter of depth of processing rather than an integral part of the processing of negation.

A recent study of ours (Kaup, Lüdtke & Zwaan, in press) is in line with the view that comprehenders create a simulation of the actual situation when processing isolated negative sentences with contradictory predicates. The results of this study also suggest that the simulation of the actual situation is created in a second step, presumably after comprehenders have simulated the negated situation: Participants were presented with sentences such as *The door was not open* and afterwards named out loud the name of a depicted entity, which in experimental trials either matched or mismatched the actual situation (match: picture of a closed

door after The door was closed / The door was not open; mismatch: picture of a closed door after The door was open / The door was not closed). When the picture was presented with a delay of 750 ms, a match effect with respect to the actual situation was only observed for the affirmative versions of the sentences. In contrast, when the delay was 1500 ms, latencies after reading the negative versions of the sentences were significantly shorter when the picture matched the actual situation (closed door) than when the picture matched the negated situation (open door). This indicates that 1500 ms after reading the negative sentences, participants were focusing on a simulation of the *actual* situation. Furthermore, the null effect observed in the 750 ms delay condition indicates that comprehenders did not create the simulation of the actual situation right away. Combined with the results of the present experiments, these results suggest that when processing isolated negative sentences, comprehenders first simulate the negated situation and afterwards turn their attention away from this simulation towards a simulation of the actual situation (see Hasson & Glucksberg, in press, for corroborating results).

Conclusion

The study reported in this manuscript was concerned with the question of whether comprehenders mentally simulate a described situation that is explicitly negated in the sentence. The results of two experiments supported this hypothesis. After processing a sentence such as *There was no eagle in the sky* or *The eagle was not in the sky* comprehenders are significantly faster to respond to a picture of an eagle with outstretched wings (negated situation) than to a picture of an eagle with its wings folded in (other situation). This indicates that comprehenders had available an experiential simulation of the negated situation at the time of testing. The results are thereby not only in line with the experiential-simulations view of language comprehension but even enlarge the scope of this view: The experiential-simulations format is not only utilized in representing factual situations in language comprehension but also in

representing non-factual situations such as the negated situation when processing a negative sentence.

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Table 1

Mean Latencies / Standard Deviations of Correct Responses (in ms), and Error Percentages as a Function of Depicted Situation in the Picture-Recognition Task of Experiments 1 and 2

	Depicted Situation	
	Negated	Other
Definiteness	M / SD (%Error)	M / SD (%Error)
	Experiment 1	
Indefinite	811 / 196 (1.6)	889 / 274 (3.9)
	Experiment 2	
Indefinite	855 / 208 (1.9)	884/ 216 (3.1)
Definite	877 / 245 (1.5)	927 / 240 (1.8)

Table 2

Mean Latencies / Standard Deviations of Correct Responses (in ms) in the Picture-Recognition Task of Experiments 1 and 2 for two Subgroups of Participants

	Depicted Situation			
	Negated		Other	
	Subgroup 1	Subgroup 2	Subgroup 1	Subgroup 2
Definiteness	M / SD	M / SD	M / SD	M / SD
	Experiment 1			
Indefinite	772 / 177	828 / 214	840 / 238	887 / 267
	Experiment 2			
Indefinite	893 /226	905 / 236	928 /236	929 / 236
Definite	925 / 263	886 / 258	970 / 251	975 / 248

Note: Subgroup 1: Participants who responded to the overall 24 comprehension questions with a mean accuracy of at least 83% (Experiment 1: N=20; Experiment 2: N=39). Subgroup 2: Participants who responded to the overall 12 comprehension questions pertaining to negative sentences with a mean accuracy of at least 83% (Experiment 1: N=25; Experiment 2: N=38).

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Footnotes

[1] It should be noted that the particular task that is being used in the experiments does not in any way highlight shape properties. First, shape is not an explicitly mentioned property in any of the sentences. Rather it is being implicitly manipulated by manipulating the location of the objects. Second, the shape of the target entity is completely irrelevant for the task. Participants are to decide whether or not the depicted object had been mentioned in the sentence. Thus, irrespective of the shape of the target entity, the correct response is always "yes" in experimental trials. Taken together, the fact that comprehenders seem to represent the shape of the target objects (in the negated situation) cannot be attributed to the task highlighting the importance of shape attributes. What is conceivable in principle is that the picture-recognition task constitutes a particularly favorable condition for simulation effects in the sense that comprehenders tend to simulate the described situation just because they know they later will possibly see a picture of the described scene. However, the literature on language comprehension to date includes a large number of studies demonstrating simulation effects, and only a small amount of these employ picture-recognition or picture-naming tasks. Thus, simulation effects do not seem to depend on the visual properties of this task. We therefore feel safe in assuming that the results reported in the present article are also not dependent on the particular choice of task.

[2] We thank an anonymous reviewer for suggesting this explanation.

Figure Captions

Figure 1. Sample Materials Employed in Experiments 1 and 2

Experiments 1 and 2:

There was no eagle in the sky.
The eagle was not in the sky.

There was no eagle in the nest.
The eagle was not in the nest.

Depicted Situation

Negated **Other**