Title

Effects of Negation, Truth Value, and Delay on Picture Recognition after Reading Affirmative and Negative Sentences

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 27(27)

ISSN

1069-7977

Authors

Kaup, Barabara
Ludtke, Jana
Zwaan, Rolf A.

Publication Date

2005

Peer reviewed

Effects of Negation, Truth Value, and Delay on Picture Recognition after Reading Affirmative and Negative Sentences

Barbara Kaup (barbara.kaup@tu-berlin.de)
Department of Psychology (FS-1), TU Berlin
10587 Berlin, Germany

Jana Lüdtke (janaluedtke@gp.tu-berlin.de)
Department of Psychology (FS-1), TU Berlin
10587 Berlin, Germany

Rolf A. Zwaan (zwaan@psy.fsu.edu)
Department of Psychology, Florida Sate University
Tallahassee, FL 32306-1270, USA

Abstract

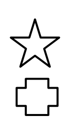
Participants read sentences of the type *The X is (not) above/below the Y* and were subsequently presented with a picture of the two objects mentioned in the sentence, either in the correct or in the incorrect spatial relation. Participants judged as quickly as possible whether both depicted objects were mentioned in the sentence. A negation-by-truth-value interaction was observed when the picture was presented without delay; a main effect of truth value was observed when the delay was 1500 ms. Both response-time patterns are well known from studies employing a sentence-picture verification task. Our results indicate that these findings are not dependent on verification. They moreover indicate that temporal characteristics of the task help explain why and when one or the other response-time pattern emerges. An account in terms of the experiential-simulations view of comprehension is discussed.

Keywords: Negation; Embodied Cognition

Introduction

A considerable amount of research into the processing of negation was conducted in the 1960's and 1970's. Most of these studies employed sentence-verification tasks in which the sentences were to be verified either against background knowledge or against a picture that was presented before or after the corresponding sentence (for an overview see Carpenter & Just, 1975; Kaup, Zwaan, & Lüdtke, in press). Although very stable results were obtained with respect to the response-slowing 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. The majority of the studies, however, have produced a negation-by-truth-value interaction. Whereas true affirmative sentences [e.g., (1)] are easier to evaluate than false affirmative sentences [e.g., (2)], the opposite holds for negative sentences; here, true sentences [e.g., (4)] are more difficult than false ones [e.g., (3)].

(1) The star is above the plus.
(2) The plus is above the star.
(3) The star is not above the plus.
(4) The plus is not above the star.



To account for the two patterns of verification latencies, it was suggested that comprehenders encode the pictures, just as the sentences, in a propositional format. Both representations are then compared constituent by constituent, whereby an internal response parameter is changed from true to false and vice versa each time an incongruency is being detected. Each incongruency prolongs the time needed to verify the picture against the sentence (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.

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., (1)], the order of the arguments in the sentence representation matches that in the picture representation [both: above (star, plus)], whereas for false affirmatives [e.g., (2)] there is a 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 there is a match with respect to the order of the arguments [e.g., (3); sentence: not(above(star,plus)); picture: above(star,plus))], and the true case where there is a mismatch [e.g., (4); sentence: not(above(plus, star)); picture: above(star, plus))]. This explains why true negatives take longer to verify than false ones. These assumptions account for the negation-by-truth-value interaction. 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 strategy discussed earlier in that negative sentences are converted into affirmative ones with the same truth conditions before starting the comparison process [e.g., (4) is converted into (1), and (3) into (2)]. After this conversion, true sentences imply a match and false sentences a mismatch, which explains the main effect of truth value. 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.

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), participants who produced a main effect of truth value were found to have higher spatial abilities than participants who produced a negation-by-truth- value interaction, whereas the two groups did not differ in linguistic abilities. This finding is sometimes taken as positive evidence for the claim that the truth value main effect reflects a pictorial strategy. However, some authors have noted that high scores on spatial or verbal abilities tests do not allow the researcher to deduce that a particular participant 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., Reichle, Carpenter, & Just, 2000). 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. Strategies involving other kinds of representations (i.e., spatial representations) are considered special cases that (if at all) are exhibited under conditions in which participants are specifically instructed. The next section discusses an alternative hypothesis for why (and when) the different response-time patterns emerge.

An experiential-simulations account

There is growing evidence in the literature that language comprehension is tantamount to mentally simulating the described situations and events in a representational format that is experiential in nature. In other words, the processes and representations employed when comprehending a linguistic description of a particular state of affairs resemble those that are employed when directly experiencing or re-experiencing the respective state of affairs (e.g., Barsalou 1999; Glenberg, 1997; Zwaan, 2004). An obvious question that arises for the experiential-simulations view is how linguistic operators, such as negation, are represented in language comprehension. We believe that negation is implicitly encoded in the simulation processes that are undertaken when comprehending a negative sentence: More specifically, when processing negation, the comprehender is assumed to create a simulation of the negated state of affairs which he or she keeps separate from the simulation of the actual state of affairs. The negation is then captured in the deviations between the two simulations (Kaup & Zwaan, 2003; Kaup, et al., in press). For instance, when reading a sentence such as *Sam is not wearing a hat* in the context of a story about Sam, the comprehender would create a simulation of Sam with a hat which he or she keeps separate from the simulation of the actual state of affairs (Sam without a hat). By comparing the two simulations, the comprehender can recapitulate that he or she was told that Sam was not wearing a hat, rather than, for instance, that Sam was not wearing glasses, should this information become relevant later on. In previous research, we obtained initial evidence for this experiential-simulations account of negation with different availability measuring tasks: Evidence for a simulation of the negated state of affairs was obtained shortly after the processing of negative sentences. Evidence for a simulation of the actual state of affairs was obtained only at a later point in the comprehension process, and only if the negative sentences were presented in the context of a longer narratives, or contained contradictory predicates (for an overview, see Kaup et al. in press). We concluded that comprehenders of negative sentences simulate the negated state of affairs, and routinely focus their attention on this simulation during and shortly after the processing of negative sentences. At a later point in the comprehension process, comprehenders may shift their attention (back) towards the simulation of the actual state of affairs. Such attention shifts are particularly likely when the simulation of the actual state of affairs serves an independent function, as is the case when the sentences are part of longer narratives or imply information with regard to the actual situation that does not also pertain to the negated situation (e.g., *The door is not open* → door closed).

How do these considerations relate to the results of the sentence-verification studies mentioned before? The experiential-simulations view of negation offers an alternative account with regard to the question of why and when the two different response time patterns should be observed. A negation-by-truth-value interaction comes about when response times are faster for false negatives than they are for true negatives. Thus, in terms of our hypothesis, 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. Thus, in terms of our hypothesis, response times are short when the picture matches the *actual* situation. Our hypothesis posits that two simulations are involved in the processing of a negated sentence, one of the negated situation and one 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 experiential hypothesis. Directly in line with this hypothesis is the observation that a main effect of truth value is observed when there is a delay between the end of the sentence and the presentation of the second source of information (cf. Carpenter & Just, 1975, p. 66; for evidence with a sentence-sentence verification task, see Carpenter, 1973). With no delay, comprehenders are likely still focusing on the negated state of affairs. From a certain delay on, however, they may have shifted their attention towards the simulation of the actual situation. As a consequence, responses after a certain delay depend on the match or mismatch with the *actual* situation. Similarly, that extensive practice (e.g., Carpenter & Just, 1975) and high spatial ability (e.g., MacLeod et al., 1978) lead to a main effect of truth value suggests that practiced and high-spatial ability comprehenders arrive at the second stage (focusing on the actual state of affairs) at an earlier point in time than other comprehenders, which should enhance the probability of a match effect with respect to the actual situation. Moreover, our 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). As mentioned above, in these conditions it is particularly likely that comprehenders indeed shift their attention to the actual state of affairs once comprehension is completed.

If the experiential-simulations account of the respective empirical phenomena is correct, then the results obtained with sentence-verification tasks should generalize to experimental tasks that do not require verification. According to the experiential-simulations view, the processing of sentences routinely leads to mental simulations of the described states of affairs. These simulations in turn potentially affect responses to subsequently presented pictures. Picture identification is assumed to be facilitated when the picture matches the experiential simulation that comprehenders have available from processing the sentence, independent of whether or not the pictures are verified against the sentences.

To test this prediction, we presented participants with sentences of the form *The X is (not) above/below the Y* followed by pictures of two objects, one above the other. The participants' task was to quickly decide whether both of the depicted objects had been mentioned in the sentence. In experimental trials, the correct response was always 'yes', but in half of the trials the picture matched the situation described by the sentence (true) whereas in the other half of the trials the picture mismatched this situation (false). For negated sentences, the picture in the latter condition matched the negated situation. For instance, for *The lion is not above the mouse*, the picture in the true condition would depict a mouse above a lion, whereas in the false condition, it would depict a lion above a mouse. In addition to the polarity of the sentence (affirmative vs. negative), the predicate mentioned in the sentence (above vs. below) and the "truth value" of the picture (true vs. false), we varied the delay with which the picture was presented after the sentences. For half of the participants, the delay was 0 ms whereas for the other half, the delay was 1500 ms.

If our hypotheses are correct, then participants should be faster to respond to the pictures in the true condition than in the false condition after reading affirmative sentences in both delay conditions. The reason is that in the true affirmative condition, the picture matches the mental simulation that participants presumably construct when processing the sentence. For negative sentences, however, the response-time pattern should be affected by the delay with which the picture is presented after the sentences. In the short-delay conditions, participants are likely still focusing on the negated situation. Thus, in this condition, we would expect shorter response times in the false than in the true conditions, because it is the false condition, where the picture matches the negated situation. For the long delay conditions, in contrast, participants may have already shifted their attention towards the actual situation. Attention shifts are expected, because two contrary predicates (*above* and *below*) are used throughout the experiment, and the negative sentences therefore allow inferences with regard to the actual situation (see above). Hence, in this condition, we would expect a reduced match effect with respect to the negated situation, or ideally even a match effect with respect to the actual situation. In short, ideally we expect to find a negation-by-truth-value interaction for the short delay, and a main effect of truth value in the long delay.[1]

Method

Participants. One hundred and twenty four students at the Berlin University of Technology participated in the experiment. Sixty four of these were assigned to the 0 ms delay condition and sixty to the 1500 ms condition.

Materials. Forty experimental sentences were constructed. All of these were of the form *The X is (not) above/below the Y*, with X and Y denoting concrete objects such as lion or refrigerator. Thus, each sentence was available in four versions, two affirmative (*is above* and *is below*), and two negative (*is not above* and *is not below*). Forty additional filler sentences were constructed. Half of these were affirmative and half were negative, and of each of these, half contained the preposition *above* and half the preposition *below*. For 32 of sentences, a second sentence (probe sentence) was constructed that mentioned the same objects, but deviated from the respective sentence with respect to the polarity of the sentence, the preposition mentioned, and/or the order in which the objects were being mentioned.

There were 120 black-and-white pictures, each depicting two objects, one above the other. Eighty of these pictures were comprised of 40 pairs with the two members of a pair depicting the same two objects but in opposite spatial relation. The objects depicted in these forty picture-pairs corresponded to the objects mentioned in the experimental sentences. Of the remaining 40 pictures, 20 depicted two objects that were not mentioned in any of the sentences, and 20 depicted one object mentioned in a filler sentence and one object not mentioned in any sentence. All pictures were scaled to 140 by 282 pixels, with each of the two objects appearing in a framed rectangle of 131 by 131 pixels centred horizontally on the computer screen (see Figure 1).

Design and Procedure. For each of the delay conditions we created eight lists that counterbalanced items and conditions. Each list included a different one of the eight possible versions (4 sentences x 2 pictures) for each item. In half of the versions, the picture matched the situation described in the sentence (true) and in the other half, it mismatched this situation (false). For each of the eight lists, a second list was created that deviated from the original list only with respect to the order in which the two objects were mentioned. Each

[1] One may wonder why effects of delay are expected with self-paced reading. The reason is that spill-over effects are often observed with self-paced reading. Thus, comprehenders seem to lack some sort of meta-cognitive awareness that would allow them to judge when processing is complete.

participant saw one of these 16 lists. Thus, we employed a 2(delay) x 2(order of mention) x 2(negation) x 2(preposition) x 2(truth value) x 16(list) design with delay and order of mention being manipulated between participants and within items, and negation, preposition and truth value being manipulated within participants and items. For our hypotheses only delay, negation and truth value are of interest. For the statistical analyses we therefore collapsed across order of mention and preposition. This also allowed us to collapse across certain lists, reducing the number of levels of this variable to four and eight for the by-participants and the by-items analyses, respectively.

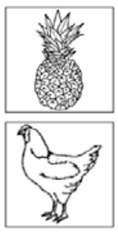


Figure 1: Sample picture

Each participant saw 40 affirmative and 40 negative sentences. Twenty of each of these contained *above*, and 20 *below*. Ten of each of these were paired with a picture that depicted the two objects mentioned in the sentence (experimental items), five in the correct spatial relation (true), and five in the incorrect spatial relation (false). Of the remaining ten pictures (filler items), five depicted two objects not mentioned in the sentence, and five depicted one object that was and one that was not mentioned. Thirty-two of the sentences were paired with a probe sentence. For each participant, half of these probe sentences described the same situation as the respective sentence, and the remaining half described a different situation.

At the beginning of the experimental session, participants were presented with a cover story. The cover story informed participants that the experiment was about playing a particular card game (similar to the game *Memory*), in which they would read sentences and subsequently see cards that either did or did not depict the objects mentioned in the sentences. The purpose of this cover story was to make the otherwise arbitrary sentences more plausible.

During each trial, participants first saw a sentence that either did or did not mention the objects they would later see. They pressed the space bar when they had understood the sentence. Subsequently the picture was presented either with a delay of 0 ms or with a delay of 1500 ms. Participants decided as quickly as possible whether both depicted objects were mentioned in the sentence, by pressing a 'yes' or 'no' key, respectively. For trials with a probe sentence, this was presented next.[2] Participants decided whether this sentence was congruent with the first sentence, again by pressing the 'yes' or 'no' key. Participants were given feedback on their responses. The experimental session took approximately 20 minutes.

Results

Picture-response latencies in the experimental trials were submitted to 2 (delay) x 2 (negation: affirmative vs. negative) x 2 (truth value: true vs. false) x 4/8 (list) analyses of variance (ANOVAs) with repeated measurement on truth value and negation in both the by-participant and the by-items analysis, and delay being manipulated between participants but within items. The analyses were performed on correct responses only. The data of six participants were discarded because they had made more than 15/80 errors in the picture-recognition task. Responses longer than 5000 ms or shorter than 200 ms were omitted. Outliers were determined according to the procedure suggested by Tukey (1977), whereby the *fences* were determined on the basis of the distributions of response times per item and condition. The mean latencies are displayed in Table 1.

Table 1: Mean latencies, standard deviations and percentages of errors in the picture-recognition task.

	Truth Value	
	True	False
Negation	M/SD (%err)	M/SD (%err)
	Delay: 0 ms	
Affirmative	1387 / 295 (1)	1482 / 320 (1,4)
Negative	1504 / 317 (1)	1454 / 284 (2)
	Delay: 1500 ms	
Affirmative	1315 / 263 (1)	1374 / 298 (1,4)
Negative	1370 / 268 (5)	1382 / 275 (1,7)

There was a main effect of delay ($F_1(1,110) = 3.9$, $p = .05$; $F_2(1,32) = 62.0$, $p < .01$), a main effect of negation ($F_1(1,110) = 11.4$, $p < .01$; $F_2(1,32) = 7.2$, $p < .05$), and a main effect of truth value, which however was only significant in the analysis by participants ($F_1(1,110) = 6.2$, $p < .05$; $F_2(1,32) = 2.1$, $p = .16$). In addition there was a negation-by-truth-value interaction ($F_1(1,110) = 16.3$, $p < .01$; $F_2(1,32) = 8.6$, $p < .01$). Most important, there was a significant three-way interaction of delay, truth value and negation ($F_1(1,110) = 5.1$, $p < .05$; $F_2(1,32) = 6.4$, $p < .05$).

Analyzing the data separately for the two delay conditions, produced for the short delay a significant main effect of negation ($F_1(1,55) = 8.4$, $p < .01$; $F_2(1,32) = 4.2$, $p < .05$), and a significant negation-by-truth-value interaction ($F_1(1,55) = 20.6$, $p < .01$; $F_2(1,32) = 16.7$, $p < .01$), but no main effect of truth value ($F_1(1,55) = 1.9$, $p = .17$; $F_2 < 1$). For the long delay, in contrast, there was no interaction ($F_1(1,55) = 1.5$, $p = .22$; $F_2<1$), and at best a trend towards a main effect of negation $F_1(1,55) = 3.6$, $p = .06$; $F_2(1,32) = 2.0$, $p = .17$). There was a main effect of truth value, which however was

[2] The probe sentences were presented to ensure that participants were reading for comprehension. One may argue that responding to these probes requires verification and the computation of truth values. However, for our purpose it is only important that truth values are not required for correctly responding to the pictures, as these response times constitute the dependent variable.

only significant in the by-participants analysis ($F_1(1,55) = 4.4$, $p < .05$; $F_2(1,32) = 1.3$, $p = .28$). Analyzing the three-way interaction from the other perspective revealed that for affirmative sentences there was a significant main effect of truth value ($F_1(1,110) = 17.8$, $p < .01$; $F_2(1,32) = 8.4$, $p < .01$), which did not interact with delay ($F_1(1,110) = 1.2$, $p = .27$; $F_2(1,32) = 2.4$, $p = .13$), whereas for negative sentences there was no main effect of truth value ($F_1(1,110) = 1.6$, $p = .22$; $F_2(1,32) = 2.6$, $p = .12$), but a truth-value-by-delay interaction, which in the by-items analysis was only marginally significant ($F_1(1,110) = 4.9$, $p < .05$; $F_2(1,32) = 2.8$, $p = .10$).

Planned comparisons revealed that for affirmative sentences response times were shorter in the true than in the false condition for both delays, whereby the effect for the long delay was only significant by participants (short: $F_1(1,55) = 14.4$, $p < .01$; $F_2(1,32) = 9.23$, $p < .01$; long: $F_1(1,55) = 4.7$, $p < .05$; $F_2(1,32) = 2.1$, $p = .16$). Response times for the negative sentences were *not* shorter in the true condition. Rather, for the short delay, response times were significantly longer in the true condition ($F_1(1,55) = 6.5$, $p < .05$; $F_2(1,32) = 7.5$, $p = .01$), and for the long delay, response times did not differ (both Fs < 1).

Discussion

The results of the experiment correspond to the predictions. For the short-delay condition we found a negation-by-truth-value interaction, whereas for the long-delay condition, we found a main effect of truth value. The difference between the two delay conditions manifested itself in a significant three-way interaction of delay, negation, and truth value. Both patterns of results are well documented response-time patterns in research employing sentence-picture-verification tasks. The main contribution of the present experiment is to show that these patterns of results are obtained with an experimental task that does not require participants to compute truth values. A second contribution of the present experiment is that it produced direct evidence that temporal characteristics of the experimental task may indeed help explain when one or the other of the two response-time patterns emerges. As predicted, a negation-by-truth-value interaction seems to be an early effect, whereas a main effect of truth value seems to be a late effect. To our knowledge, there is no other empirical study that has directly manipulated the delay of picture presentation after the sentences within one set of materials (see Carpenter, 1973, for evidence with sentence-sentence verification).

What can be concluded from these findings with respect to the different explanatory accounts discussed in the introduction? The classical accounts hold that response-time differences in the four negation-by-truth-value conditions reflect differences in the number of times that an internal response parameter has to be changed from true to false and vice versa before the final decision is made. Given that the experimental task employed in this experiment did not require the computation of truth values, it seems that the classical accounts are not applicable. In order to account for the findings, one would need to assume that participants verified the pictures against the sentences although the experiential task did not require them to do so. Considering that verification according to these accounts implies actively comparing two representations constituent by constituent and manipulating an internal response parameter in accordance with this step-wise comparison process, we consider this possibility highly unlikely. It seems more plausible that the differences in the response times in the various conditions reflect differences in the degree to which the picture is primed by the representations that are available from processing the sentences. This in turn is what the experiential simulations view of comprehension would predict: Comprehenders routinely create experiential simulations of the described state of affairs when processing sentences. If the sentence is followed by a task that requires the identification of a depicted scene, then responses in this task should be fast when the picture matches the mental simulation available from processing the sentence, and slow when it mismatches this mental simulation. The response-time pattern observed in the affirmative conditions of the present experiment support this prediction: Responses were faster in the true than in the false condition, independent of the delay with which the picture was being presented after the sentences. The response-time patterns observed in the negative conditions can also be explained in terms of the experiential-simulations view. It was predicted that different response time patterns should emerge in the different delay conditions. We did indeed observe an interaction of delay and truth value in the negative conditions: In the short-delay condition, a match effect occurred with respect to the negated situation, which is in line with the view that participants at this point focused on a simulation of the negated situation. In the long-delay condition, the match effect disappeared in the negated conditions. This may suggest that some participants in some conditions were still focusing on the negated situation whereas other participants in other conditions had already shifted attention towards the actual simulation.

The argument for ruling out an explanation in terms of the classical accounts was based on the fact that truth-value computation plays a key role in these accounts. However, what are the implications for propositional accounts that do not require verification? On the basis of our data, these cannot be ruled out. The reason is simply that it is nearly impossible to falsify propositional accounts on the basis of reaction-time data in case there is enough degree of freedom with respect to the processes that operate on the proposed representations. A possible propositional account of the present findings would be that comprehenders use the content of the sentence to guide their eye-movements when processing the picture. If the preposition is *above* they go from top to bottom, and if it is *below* they go from bottom to top, both for affirmative and for negative sentences. If we additionally assume that response times in the picture-recognition task are fast when the order in which comprehenders focus on the entities in the picture, corresponds to the order in which they are mentioned in the sentence, then the response-time pattern for the short delay condition is explained. For the long delay condition, one would simply need to assume that comprehenders recode negative sentences into affirmative ones before looking at the picture. Thus, a propositional account of the present findings is possible. It should be noted however that this propositional account is clearly post-hoc: The findings in question can be explained but they are in no way predicted. In contrast, our experiential-simulations account predicts these findings, and would in principle be falsified should the effects of delay, truth value and negation be consistently absent from studies employing experimental tasks that do not require the computation of truth values.

Conclusion

We argued that the experiential-simulation view of language comprehension offers an alternative explanation for why and when a negation-by-truth-value interaction or a truth value main effect is being observed in sentence-picture-verification tasks. This alternative explanation differs from classical accounts mainly in two respects. First, instead of assuming that differences in response time reflect differences in the time needed to compare the representation of the picture to the representation of the sentence, it is assumed that they reflect differences in the degree to which the processing of the picture is primed by the simulation processes carried out when comprehending the sentence. Second, instead of attributing the two different response-time patterns (interaction vs. main effect) to different processing strategies, these patterns are related to different stages of one and the same processing mechanism. In line with the first aspect, the two response-time patterns were observed even though the response-time-eliciting task did not require the computation of truth values. In line with the second aspect, the delay between presenting the sentence and the picture indeed determined whether one or the other response-time pattern emerged.

To be sure, our results do not rule out the possibility that the classical accounts correctly explain what participants do in *sentence-verification tasks*. It seems well possible that a verification task engenders strategic processes on the part of the comprehender. We also concede that our results do not offer a water proof argument against alternative propositional accounts that do not rely on the computation of truth values. What our results *do* show, however, is that there is an alternative to propositional accounts. In the present experiment we realized conditions that would have allowed falsifying the main implication of this alternative, namely an experimental task that does not require the computation of truth values. Our alternative account survived this test. We therefore conclude that the experiential-simulations view of language comprehension can in principle account for the effects of negation and truth value in sentence-picture-verification studies. This is relevant for research in language comprehension as these effects have typically been attributed to propositional representations. It also shows that in contrast to popular prejudices, the experiential-simulations view can deal with linguistic operators such as negation. In experiential simulations, negation is not explicitly represented but rather implicitly encoded in the simulation processes that are undertaken when processing a negative sentence.

Acknowledgments

We thank L. Schalk, R. Schindele, and M. Zirngibl for assistance with data collection. This research was supported by grant KA 1389/2-1 to B. Kaup (DFG) and grant MH 63972 to R. A. Zwaan (NIMH).

References

Barsalou, L.W. (1999). Perceptual Symbol System. *Behavioural and Brain Sciences*, *22*, 577-660.

Carpenter, P.A. (1973). Extracting information from counterfactual clauses. *Journal of Verbal Learning and Verbal Behavior, 12*, 512-521.

Carpenter, P.A., & Just, M.A. (1975). Sentence comprehension: A psycholinguistic processing model of verification. *Psychological Review*, *82*, 45-73.

Clark, H.H., & Chase, W.G. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology, 3*, 472-517.

Glenberg, A. (1997). What memory is for. *Behavioural and Brain Sciences*, *20*, 1-41.

Johnson Laird, P.N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Kaup, B., & Zwaan, R.A. (2003). Effects of negation and situational presence on the accessibility of text information. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 439-446.

Kaup, B., Zwaan, R.A., & Lüdtke, J. (in press). The experiential view of language comprehension: How is negation represented? In F. Schmalhofer & C. Perfetti (Eds), *Higher level language processes in the brain: Inference and comp. processes*. Mahwah, NJ: Erlbaum.

MacLeod, C.M., Hunt, E.B., & Mathews, N.N. (1978). Individual differences in the verification of sentence-picture relationships. *Journal of Verbal Learning and Verbal Behavior, 17*, 493-507.

Reichle, E.D., Carpenter, P.A., Just, M.A. (2000). The neural bases of strategy and skill in sentences-picture verification. *Cognitive Psychology*, *40*, 261-295.

Roberts, M., Wood, D.J., & Gilmore, D.J. (1994). The sentence-picture verification task: Methodological and theoretical difficulties. *British Journal of Psychology*, *85*, 413-432.

Trabasso, T., Rollins, H., & Shaughnessy, E. (1971). Storage and verification stages in processing concepts. *Cognitive Psychology*, *2*, 239-289.

Tukey, J.W. (1977). *Exploring data analysis*. London: Edison-Wesley.

Van Dijk, T.A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. New York: Academic Press.

Zwaan, R.A. (2004). The immersed experiencer: toward an embodied theory of language comprehension. In B.H. Ross (Ed.), *The Psychology of Learning and Motivation*, (Vol. 44.) New York: Academic Press.