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Comprehending ambiguous texts: A high reading span helps to constrain the situation model

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Research has found that span measures of working memory often predict the quality of processes at the level of the text representation, but rarely at the level of the situation model. In the present study, the generality of this finding was reassessed. In two experiments, narratives conveying incremental amounts of diagnostic information about the situation described in the text were presented. The results indicated that comprehension processes at the situation model level were related to reading span. High-span readers had a better understanding than low-span readers of which situations were incompatible with the information they had read. High-span readers thus appeared better able to deactivate possible alternative representations of the situation constructed so far when those alternatives could be ruled out. The results are discussed in the context of text comprehension theories at the level of sentence versus situation model processing.

Keywords: Reading span; Situation models; Text comprehension; Working memory.

Research on working memory has repeatedly indicated that individuals with higher working memory capacity perform better on language comprehension tasks than do individuals with lower working memory capacity (e.g., Daneman & Merikle, 1996; Just & Carpenter, 1992). Early evidence for this claim originated from Daneman and Carpenter’s (1980) work on the reading span task. The reading span—a measure of how many end words of previously read sentences can be memorised while reading new sentences—has been shown to be related to sentence comprehension and recall (Daneman & Carpenter, 1980), performance in the verbal Scholastic Aptitude Test (Daneman & Hannon, 2001), anaphor resolution (Light & Anderson, 1985), comprehension of ambiguous syntactic structures (King & Just, 1991), strategy choice in reading expository text (Budd, Whitney, & Turley, 1995), and drawing inferences from texts (Whitney, Ritchie, & Clark, 1991), to name just a few correlates.

However, Radvansky and Copeland (2001, 2004) questioned the view that working memory capacity (as measured by the reading span) is a general and unspecific resource for language processing. They argued that reading span is related to the surface level of discourse processing, but not to the deeper levels of processing such as the situation model level. Their experiments showed that text comprehension—e.g., situation identification, detection of inconsistencies, establishment of causal connections—did not benefit from a higher reading span. Radvansky and Copeland (2004, p. 209) concluded that.

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“many aspects of comprehension and memory are unrelated to memory span, including many processes involved in cognition at the situation model level”. The present study demonstrates that at least one set of processes at the situation model level is related to reading span, namely constraining the situation model when processing referentially ambiguous texts.

In text comprehension research, a distinction is often made between cognitive representations of the text itself (its surface characteristics and meaning) and representations of the state of affairs to which the text refers (situation model or mental model, e.g., Garnham & Oakhill, 1996; Graesser, Millis, & Zwaan, 1997; Graesser, Singer, & Trabasso, 1994; Kintsch, 1998). The situation model is constructed by integrating the text representation with individual world knowledge (van Dijk & Kintsch, 1983). This construction process proceeds dynamically during reading. Each new piece of information from the text may add to the existing model, activate new knowledge, or specify the model in a new way. Accommodating the model to this information is often referred to as “updating” the situation model (e.g., Blanc, Kendeou, van den Broek, & Brouillet, 2008; Graesser et al., 1994; Kintsch, 1998; van Oostendorp, Otero, & Campanario, 2002; Zwaan & Radvansky, 1998).

Updating is especially important when the text representation is compatible with different situation models. Often, the description of a situation allows the reader to maintain different views of the situation described which (up to a certain point in the text) are all compatible with the text representation. For example, when reading a crime story, readers may imagine different scenarios, all of which are compatible with the story so far, but which imply different hypotheses about who may be the perpetrator. In the case of such referentially ambiguous texts (Russell & Taggart, 1995), comprehension essentially involves detecting and processing text information that allows the reader to constrain his or her situation model to those versions that are compatible with the full set of information and abandoning the other versions—those that were compatible with previous information but are not supported by the new information.

Effective specification and constraining of the situation model may depend on working memory resources. Reviewing the correlates of span tasks, Feldman Barrett, Tugade, and Engle (2004) concluded that low-span participants seemed more vulnerable to the interference of irrelevant information. Referring to Baddeley’s (1986) working memory model, Engle interpreted span tasks as measures of the central executive (e.g., Engle & Oransky, 1999). More specifically, Whitney, Arnett, Driver, and Budd (2001) identified two different components of performance in the reading span task: the capacity (1) to manipulate memorised information and (2) to resist distraction and interference. The first component is essential for integrating successive pieces of information into a coherent representation of the text’s contents (e.g., Budd et al., 1995). The second component may help to prevent interference between already outdated versions of the situation model and the updated, current model.

To date, no studies have provided direct evidence that reading span affects the process of constraining the situation model when ambiguous texts are read. However, experiments have investigated a similar process on the level of sentence comprehension. For example, MacDonald, Just, and Carpenter (1992) presented syntactically ambiguous sentences using a word-by-word reading procedure. Both possible interpretations of the ambiguous sentence were equally probable. Reading times indicated that understanding the ambiguous sentences required additional processing (probably for generating and maintaining both interpretations of the critical part of the sentence). Participants with higher reading spans maintained these multiple representations for longer than low-span readers (see also Mason & Just, 2007). Thus, high-span readers were better prepared for processing the disambiguating part of the sentence, because they had maintained both interpretations.

A slightly different focus was chosen by Bornkessel, Fiebach, and Friederici (2004), who used syntactically ambiguous sentences with a preferred and a dispreferred reading. In the last part of the sentence, the ambiguity was resolved towards the dispreferred interpretation; this resolution required a syntactic reanalysis, as indicated by an enhanced parietal positivity (P600; Friederici, Steinhauer, Mecklinger, & Meyer, 1998). However, this reanalysis effect was observed only in participants with a high reading span (Bornkessel et al., 2004; Friederici et al., 1998). The authors concluded that the reanalysis of the disambiguating information was necessary in high-span readers because they had already suppressed the dispreferred reading. Low-span readers, on the other hand, seem to have a lower capacity to suppress irrelevant information (Feldman Barrett et al.,
Thus, syntactic reanalysis of the disambiguating information was unnecessary, because the dispreferred alternative was still available.

To summarise, the contribution of a high reading span to supporting the comprehension of ambiguous sentences may be twofold. On the one hand, it facilitates the maintenance of multiple representations (as long as neither is preferred); on the other hand, it facilitates the more effective suppression of dispreferred readings.

We hypothesise high-span readers to benefit in a similar way at the level of situation model updating. We expect them to be more successful in disambiguating the relation between text representation and situation model. If necessary, high-span readers will be better able to maintain and discriminate different possible versions of a situation model. However, if disambiguating information is available, they will more effectively dismiss those variants of the situation model that were previously compatible with the text representation but cannot be reconciled with the new ( incompatible) information.

To test this prediction, we drew on an approach from social cognition research, namely the mental clique construct (Hummert, Crockett, & Kemper, 1990). Based on Heider’s (1958) balance assumptions, this approach suggests that people perceiving patterns of pairwise like/dislike relations in their social environment construct “mental cliques”. Specifically, observations of mutual understanding, cooperation, or other positive interactions between two people in the environment lead to these two people being mentally grouped together and perceived as closely linked within one and the same “clique”. In contrast, observations of avoidance behaviour, negative emotions, or any sort of antagonistic interaction between two people lead to them being mentally grouped separately and perceived as members of different “cliques”.

Reconstructing the social environment in this way produces a number of distinct cliques, with positive mutual liking within each clique and negative mutual liking between cliques. Although this idea oversimplifies the complexity of social perception to some extent, it has nevertheless received strong support in the laboratory (Hummert et al., 1990; von Hecker, 1997; von Hecker, Crockett, Hummert, & Kemper, 1996; von Hecker & Dutke, 2004; von Hecker & Sedek, 1999).

We explain the basic paradigm by reference to a schematic notation of individual relations (see Figure 1); the relations are fleshed out in the narratives of our text materials (see Figure 1). A plus sign denotes a relation of mutual liking between two fictitious protagonists in a narrative; a minus sign denotes a relation of mutual disliking. The reader might initially read about mutual liking between three pairs of protagonists, AB, CD, and EF, and mutual disliking between two pairs, BD and DF. We assume that, in their attempts to construct a comprehensive situation model, readers will integrate each relation successively into an overall clique representation of the social situation. Up to this point, the representation is still referentially ambiguous as to how many cliques need to be represented in the situation model. As the story unfolds further, relation BF, which disambiguates the relation between the textbase and the overall model, may be presented. If BF is presented as a relationship of mutual liking, a two-clique model should result, representing persons A, B, E, and F in one clique and persons C and D in another (Figure 1, left side). Conversely, if BF is presented as a relationship of mutual disliking, a three-clique model should result, consisting of three dyads: AB, CD, and EF (Figure 1, right side). That is, a version of the story that portrays relation BF as either positive or negative will constrain the situation model in different ways, as each

Figure 1. Schema of the stimulus materials. Letters A to F represent six different persons. In the experimental materials, European first names were used in place of the letters. Plus signs between persons indicate mutual liking; minus signs indicate mutual disliking.
alternative value of BF is compatible with exactly one of the two possible versions of the situation model.

Comprehending a narrative with a relational structure as just outlined involves integrating the successively presented pair relations, on the one hand, and constraining the resulting situation model to those clique structures that are still compatible with the incoming information, on the other. For example, in the beginning of the text, the social relations among the characters are completely indeterminate. After reading the first pair relation, however, the situation model can be specified to represent at least two persons who like each other and are members of the same clique. This specification constrains the number of potential situation models, as a social situation in which all persons dislike each other is no longer possible. Similarly, after integration of the first five pair relations, a situation model encompassing either two cliques (4 + 2 persons) or three cliques (2 + 2 + 2 persons) would still be valid, but a model representing one large clique would be incompatible with the relations presented. The situation model must be further constrained when the sixth relation (the critical relation) has been read, because now exactly one clique structure remains compatible with the text representation. We predict that readers with higher reading spans will process the constraining text information more successfully and thus have a more precise situation model after reading the complete text.

**EXPERIMENT 1**

For the present experiments, narratives describing actions and events in different social settings were constructed. Each narrative involved six persons and the description of interpersonal relations among them. Information describing five pair relations (the “basic relations”) was distributed across the text, constituting the ambiguous pattern presented in Figure 1. Later in the text, a sixth relation (the “critical relation”) was introduced, further constraining the situation model. After reading the narrative, participants were presented with six clique structures of which (a) four were incompatible with the five basic relations, (b) one was compatible with the basic relations but not with the sixth, critical relation, and (c) one was compatible with the basic relations and with the critical relation. We expected high-span readers to be better able than low-span readers to identify clique structures incompatible with the basic relations (Hypothesis 1). This prediction follows from the assumption that high-span readers are better able than low-span readers to maintain the situation model constructed during reading and to compare it with the clique structures presented after reading. This comparison is necessary to judge whether or not the clique structures represent the social configuration described by the text. Furthermore, high-span readers were expected to discriminate more effectively between clique structures compatible and incompatible with the critical relation (Hypothesis 2). This hypothesis follows from the assumption that high-span readers are better able to discard alternative situation models as soon as they recognised them as being incompatible with new incoming information.

**Method**

**Participants**

Forty-eight students (23 women) from different faculties of the University of Kaiserslautern participated in this experiment (mean age = 24 years, from 19 to 35 years). All participants were German native speakers or spoke German fluently. Each participant received a payment of 12 Euros for participating.

**Materials**

**Experimental narratives.** Nine narratives (eight experimental texts, one practice text) were constructed, each comprising 50 or 51 sentences (see the Appendix for a sample text). Each narrative described events such as a school outing or a theft from an art museum and the actions of six protagonists. In the *introduction* (the first 7 to 13 sentences), the protagonists and the setting of the story were depicted. In the *exposition* (27 to 34 sentences), the plot was outlined and the basic social structure was described. In particular, the five basic relations (in this order: CD, BD, AB, DF, and EF; see Figure 1) were embedded in this section of the narrative. Each basic relation described mutual liking or disliking between two individuals (e.g., “Carlo and Salvatore did not like each other”). Each sentence presenting such a relation (relation sentence) was preceded by a sentence introducing the two persons by name (person sentence) and followed by a sentence elaborating on the quality of their social relation.
The five basic relations were intended to initiate the construction of a situation model consisting of either two or three social cliques. In the resolution section, the critical relation was presented in the same format as the basic relations. The critical relation could be (1) a positive relation between persons B and F, indicating a two-clique structure or (2) a negative relation between persons B and F, indicating a three-clique structure. The final 2 to 4 sentences concluded the story.

Reading span task. The participants completed a modified German version of the reading span task designed by Oberauer, Süß, Schulze, Wilhelm, and Wittmann, 2000). The task followed the general reading span procedure (Daneman & Carpenter, 1980; La Pointe & Engle, 1990), with participants reading sets of sentences and trying to remember the last word of each. After three trials with the same number of sentences in each set, set size was increased by one sentence. Oberauer’s et al. (2000) version of this task was designed to measure the storage and processing functions of working memory (Oberauer, Süß, Wilhelm, & Wittmann, 2003): Participants not only memorised the final word of each sentence but also evaluated the truth of its content. Each sentence was displayed on the computer screen for 3 s followed by a pause of 1 s. Participants had to evaluate each sentence within the total interval of 4 s. After each set of sentences had been presented, participants wrote down the end words they remembered on a response sheet in the order of their appearance. There were no time constraints during the recall phase. Participants initiated the presentation of the next set of sentences by pressing the spacebar. Set size increased stepwise from three to seven sentences, with three sets of equal size at each level. The relative number of words correctly recalled was weighted by the relative number of correctly evaluated statements. The resulting reading span score could range between 0 and 1.0.

Dependent variables

Reading times for each sentence were measured in milliseconds and divided by the number of syllables in the sentence. Within each participant, reading times per syllable were averaged for sentences of the same type (basic relations 1 to 5 and critical relations).

After reading each text, participants were shown graphic representations of six potential clique structures on the computer monitor:

1. Two cliques, each consisting of three persons (3 + 3).
2. Two cliques plus one person not belonging to any clique (3 + 2 + 1).
3. One clique plus two persons not belonging to any clique (4 + 1 + 1).
4. One clique plus one person not belonging to any clique (5 + 1).
5. Two cliques, one consisting of four persons, one consisting of two persons (4 + 2).
6. Three cliques, each consisting of two persons (2 + 2 + 2).

The first four structures were incompatible with the pattern represented by the five basic relations (“BR incompatible”); the other two clique structures (5 and 6) were compatible with these basic relations (“BR compatible”). Depending on the value of the critical relation, Structure 5 was compatible and Structure 6 incompatible with the critical relation, or vice versa. The participants rated the subjective probability that the group described in each text corresponded with each of these six clique structures on a 7-point scale ranging from −3 (“very unlikely”) to +3 (“very likely”). The participants were encouraged to consider each alternative and to evaluate it independently of their ratings of the other clique structures.

Procedure

Each participant was tested individually. First, the reading span task was implemented. After being instructed by the experimenter, participants completed two practice items, and any arising questions were clarified. The test items were then administered.

After a short pause, the participants were instructed to read the texts at their own pace and to understand the contents, but not to memorise the text verbatim. In particular, they were asked to pay attention to the structure of the group presented in the text. The instructions also emphasised the importance of taking breaks only between the narratives, and not while reading. Participants then read the practice text, which was presented sentence by sentence on a computer screen. After reading each sentence, participants pressed the space bar to call up the next sentence.
After reading the whole text, participants were shown graphic representations of six potential clique structures and asked to judge the probability of each representing the social structure described in the text. If necessary, the experimenter answered questions about the experimental procedure. The participants then read the eight experimental narratives. Each participant was presented four experimental narratives with a positive critical relation (indicating the existence of two cliques) and four with a negative critical relation (indicating three cliques). Narratives and type of text were counterbalanced by generating a random order of the two text versions (with positive or negative critical relation), which was then rotated across the eight experimental narratives, resulting in eight experimental text sets. Each participant was randomly assigned to one of these sets under the condition that, across the whole sample, the sets were used equally often. After reading each narrative, participants rated the probability of the clique structures. No feedback was provided.

Finally, participants were debriefed and paid. The entire experiment lasted about 100 min. The experimental procedure was controlled by a program based on the Macintosh application RSVP (Williams & Tarr, 2002). All procedures were in accordance with the ethical standards of the German Psychological Association (DGPs).

**Design**

Number of cliques indicated by the critical relation (two vs. three cliques) was the within-participants factor. The reading span score was used as a covariate.

**Results**

The reading span score ranged from .24 to .91 and did not correlate with the reading times for sentences with basic relations, \( r = .13, \) ns, or sentences with critical relations, \( r = -.24, \) ns.

**Hypothesis 1**

Testing our hypotheses required to compare subjective probability judgements for different clique structures (varied within participants) based on the reading of different text versions (also varied within participants) and to evaluate the moderating impact of reading span (a stable individual difference variable) on these comparisons. Therefore, we chose analysis of covariance with within-participants factors and reading span as a continuous covariate as an appropriate methodological approach to analyse the data (cf. Judd, Kenny, & McClelland, 2001).

The probability ratings for the four clique structures that were incompatible with the basic relations (BR-incompatible structures) were subjected to an ANCOVA with type of clique structure (3 1+1, 3 3, 4 1+1, 5 1 persons) and number of cliques indicated by the critical relation (two vs. three cliques) as within-participants factors and reading span as a covariate. The ratings for the clique structures differed, \( F(3,138) = 5.03, \) \( p < .01, \) \( MSE = 1.65, \) but the mean ratings for all four clique structures were negative (see Table 1). Evidently, the readers were quite certain that the BR-incompatible clique structures did not represent the social structure described in the text. There were no significant differences between texts representing two or three cliques and no interactions with the

<table>
<thead>
<tr>
<th>Clique structure</th>
<th>3 2+1</th>
<th>3 3</th>
<th>4 1+1</th>
<th>5 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. Critical relation Clique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Diagnostic 2</td>
<td>-0.83 (1.7)</td>
<td>-0.90 (1.7)</td>
<td>-1.57 (1.4)</td>
<td>-2.10 (1.1)</td>
</tr>
<tr>
<td>3</td>
<td>-0.67 (1.9)</td>
<td>-1.18 (1.4)</td>
<td>-1.83 (1.2)</td>
<td>-2.65 (0.8)</td>
</tr>
<tr>
<td>2 Diagnostic 2</td>
<td>-0.47 (1.6)</td>
<td>-0.93 (1.4)</td>
<td>-1.78 (1.2)</td>
<td>-2.20 (1.2)</td>
</tr>
<tr>
<td>3</td>
<td>-0.95 (1.6)</td>
<td>-1.02 (1.5)</td>
<td>-2.19 (0.8)</td>
<td>-2.57 (0.7)</td>
</tr>
<tr>
<td>Nondiagnostic</td>
<td>-1.04 (1.3)</td>
<td>-1.10 (1.2)</td>
<td>-2.02 (1.0)</td>
<td>-2.43 (0.8)</td>
</tr>
</tbody>
</table>

Ratings could range from -3 (very unlikely) to +3 (very likely). A diagnostic critical relation allowed participants to decide between the 4 2 and the 2 2+2 structure; a nondiagnostic critical relation did not (cf. Figure 1). Cliques: Number of cliques indicated by the critical relation.
covariate. The main effect of the covariate, however, was significant, $F(1, 46) = 9.49, p < .01$, $MSE = 6.42$. The probability ratings (averaged across all four BR-incompatible structures) correlated negatively with the reading span score, $r = -.41$, $p < .01$. The higher the reading span, the more decisively the participant rejected the clique structures that were already incompatible with the set of basic relations. This result supported Hypothesis.

**Hypothesis 2**

Before testing the second hypothesis, we compared the mean probability judgements for the two clique structures that were compatible with the five basic relations (BR-compatible structures: 2 + 2 + 2 and 4 + 2 persons) across the two- and three-clique conditions (Table 2). The comparison showed that processing the critical relation strongly influenced the structure of the situation model. The 2 + 2 + 2 structure was judged to be significantly more probable in texts with a critical relation indicating three cliques than in texts with a critical relation indicating two cliques (see Table 2). Likewise, the 4 + 2 structure was judged to be significantly more probable in texts with a critical relation indicating two cliques than in three-clique texts (see Table 2). This pattern demonstrates that integration of the critical relation fundamentally influenced the overall structure of the situation model.

From these data, a measure was derived indicating how sensitively a reader reacted to the critical information. After reading about a negative relation between persons B and F, a reader should theoretically rate the 2 + 2 + 2 structure as highly probable and the 4 + 2 structure as highly improbable (and vice versa after reading about a positive relation between persons B and F). Thus, the differences between the ratings of the 2 + 2 + 2 and the 4 + 2 structure should be high if the reader processes the critical relation effectively. In other words, this difference provides a measure of sensitivity to the critical relation in updating the situation model. The sensitivity scores in the two-clique and the three-clique conditions were analysed in an ANCOVA with the number of cliques as a within-participants factor and reading span as a covariate. Only the main effect of the covariate was significant, $F(1,46) = 6.47$, $p < .05$, $MSE = 4.47$. The higher the reading span, the greater the sensitivity to the critical relation, $r = .35$, $p < .05$. Although the interaction between reading span and number of cliques was insignificant, the correlation between sensitivity and reading span was smaller in the three-clique texts, $r = .17$, ns, than in the two-clique texts, $r = .29$, $p < .05$.

The difference between these two correlations is in line with the observation that the 2 + 2 + 2 structure and the 4 + 2 structure were better differentiated when the critical relation indicated a three-clique structure (mean difference = 2.85, $SD = 2.25$; see Table 2) than when it indicated a two-clique structure (mean difference = 0.36, $SD = 2.51$), $t(47) = 4.84, p < .001$. It was evidently easier to align the situation model with a negative critical relation (that indicated three cliques) than with a positive critical relation. This asymmetry was consistent with the idea that three dyads represented a kind of “default” model that either was confirmed (negative critical relation) or had to be restructured when the critical relation was positive. Assuming that high-span readers are better able than low-span readers to deactivate an initially preferred structure, this would explain why the correlation between reading span and sensitivity was higher in the two-clique texts. In contrast, a negative critical relation did not require the default model to be deactivated or

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Clique structure</th>
<th>Negative</th>
<th>Positive</th>
<th>$t$(47)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 + 2 + 2</td>
<td>2.09 (1.3)</td>
<td>1.02 (1.7)</td>
<td>3.91</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>4 + 2</td>
<td>-0.76 (1.7)</td>
<td>1.39 (1.5)</td>
<td>7.36</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2</td>
<td>2 + 2 + 2</td>
<td>2.50 (0.7)</td>
<td>1.05 (1.7)</td>
<td>5.94</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>4 + 2</td>
<td>-1.01 (1.7)</td>
<td>1.48 (1.6)</td>
<td>9.16</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Ratings could range from $-3$ (very unlikely) to $+3$ (very likely). A positive BF relation indicated two cliques; a negative indicated three cliques (cf. Figure 1).

**TABLE 2**

<table>
<thead>
<tr>
<th>Clique structures compatible with the basic relations: Means and standard deviations (in parentheses) of the subjective probability ratings</th>
</tr>
</thead>
</table>

**Critical relation (BF)**
restructured. Therefore, integrating the critical relation required less working memory capacity than in two-clique texts.

**Exploratory analysis**

Whether or not the critical relation clarifies the model of the social situation depends on how precisely the basic relations had been integrated. For example, if a reader did not correctly represent the negative pair relations and therefore thought that the basic relations might also be compatible with two three-person cliques, he or she would not perceive the diagnostic value of the critical relation. This possibility can be explored by repeating the ANCOVA described earlier (sensitivity in two- and three-clique texts as a within-participants factor and reading span as a covariate) and including the ratings for the BR-incompatible structures as an additional covariate. In this analysis, all effects of the reading span score vanished. Instead, a significant main effect of the ratings for the two three-person cliques remained. This result suggests that high working memory capacity did not directly facilitate the integration of the critical pair relation. Instead, high-span readers seemed to process the critical pair relation more successfully than low-span readers because the former avoided considering models that were already incompatible with the basic relations. The more clearly the BR-incompatible structures were rejected (the more negative the subjective probability ratings), the more sensitively the participants responded to the critical relation, $r = -.46$, $p < .01$.

**Discussion**

The results of this experiment corroborated the first hypothesis. A significant relationship was found between reading span and probability ratings for the clique structures incompatible with the basic relations. The greater their reading span score, the more clearly readers indicated that these structures were unlikely to represent the social situation described in the narrative. Thus, high-span participants had a more precise representation of the social situation described by the basic relations. This difference cannot be attributed to having read the texts more or less carefully, as the sentence reading times did not correlate with the reading span (cf. Dutke, Baadte, Hähnel, von Hecker, & Rinck, 2010). We assume that high-span participants were better able than low-span readers to remember the situation model they had constructed while reading. When they were shown the six clique structures after reading the text, they had less difficulty in manipulating their models to compare them with the given clique structures.

Although the current data do not reflect the online process, they are consistent with the idea that participants recognised the diagnostic value of the critical relation and further constrained the situation model according to the contents of that relation. Consistent with the second hypothesis, the extent to which the situation model was aligned with the critical relation (as measured by the sensitivity score) also correlated with the reading span, particularly in the two-clique texts. However, controlling for the ratings for the BR-incompatible clique structures revealed that working memory capacity probably had an indirect rather than a direct influence on the integration of the critical information. It was probably easier for high-span readers to integrate the critical relation because they had already constrained their initial models more effectively. Consequently, the amount of nonintegrated pair information to be processed when the initial model was aligned to the critical relation was lower.

The results also show that it was harder for participants to discard the $2 + 2 + 2$ model when the critical relation indicated two cliques than the $4 + 2$ model when the critical relation indicated three cliques. Studies using a nontext version of the social clique paradigm (von Hecker, 1997) have demonstrated that three cliques with two persons each may be a kind of default model.1 Whereas this default model is corroborated by a negative critical relation, it has to be deactivated or restructured when the critical relation is positive. Readers evidently benefited primarily from a high reading span when comprehending texts that required the default model to be rearranged. When the critical relation confirmed the default model, the correlation between reading span and sensitivity was much lower.

The present experimental design limits the previous interpretations in two important ways. First, updating and constraining a situation model

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1In this study, clique structures of type $2 + 2 + 2$, as compared to those of type $4 + 2$, tended to be more easily learned and less prone to later memory intrusion errors (von Hecker, 1997, Tables 5 and 6).
is thought to be a continuous process during reading (e.g., van Oostendorp et al., 2002). Ideally, this process can be investigated using “online” measures of the state of the current situation model during reading (e.g., Morrow, Bower, & Greenspan, 1989). In the present experiment, however, we preferred not to disturb the reading process by probing the situation model during reading, and instead assessed its status “offline”, after the text had been read. As a consequence, it remains an open question whether the clique structures that were incompatible with the basic relations were discarded before or after processing of the critical relation. In other words, did knowledge of the basic relations suffice for participants to see how the group described in the text was not structured? Or were the BR-incompatible structures discarded only when the critical relation specified the final model? We addressed these questions in a second experiment.

Second, the idea that the \(2 + 2\) clique structure serves as a default model is borrowed from other experiments using different (though structurally comparable) materials (von Hecker, 1997). Our interpretation would be strengthened if it could be shown that the \(2 + 2\) structure is also favoured over the \(4 + 2\) model with the present materials. This question will be also addressed in the second experiment.

**EXPERIMENT 2**

In the first experiment, all texts contained a critical pair relation disambiguating the relation between text representation and situation model. This relation was diagnostic with regard to the number of cliques inasmuch as each value of this relation (positive or negative) was compatible with exactly one version of the remaining two possible situation models. In the second experiment, the same materials were used, but only four texts contained a diagnostic critical relation (positive or negative relation between persons B and F). In the other four texts, the critical relation was nondiagnostic (negative relation between persons C and E; see Figure 1). This relation had no diagnostic value because it was compatible with both remaining models \((2 + 2 + 2\) and \(4 + 2\) persons). In this case, all constraints on the updating of the situation model emerged from processing the basic relations; the critical relation did not constrain the model any further. If, under this condition, clique structures incompatible with the basic relations were rated as improbable, then this would demonstrate that these judgements were based on the correct representation of the basic relations alone, and cannot be attributed to the successful processing of the critical relation.

Moreover, texts without a diagnostic critical relation allow us to observe whether or not participants prefer one of the two remaining models over the other although the text does not specify which is meant. This gives us the opportunity to test the idea that the \(2 + 2 + 2\) clique structure serves as the default model in our text materials. This idea is motivated by the consideration that the three positive pair relations provide direct evidence of three cliques, whereas the question whether two of those three pairs may be also be positively related (resulting in a \(4 + 2\) configuration) remains unanswered until the (diagnostic) critical relation is read. Assuming that readers constantly engage in a “search after meaning” on the basis of the information provided so far (Graesser et al., 1994, p. 371), it seems reasonable to speculate that readers prefer the \(2 + 2 + 2\) model until disconfirming information is presented.

To summarise, we expect readers with higher reading spans to specify the initial situation model (based on the five basic relations) more rigorously than low-span readers, even when no further diagnostic relation is processed after the first five relations. In absence of a diagnostic critical relation, we expect participants to opt for the \(2 + 2 + 2\) model more frequently than for the \(4 + 2\) model. In the presence of a diagnostic critical relation, we expect to replicate the results from the first experiment (Hypotheses 1 and 2).

**Method**

**Participants**

Forty-eight students (23 women) from different faculties of the University of Kaiserslautern participated in this experiment (mean age = 24 years, from 20 to 35 years). All participants were German native speakers or spoke German fluently. Each participant received a payment of 12 Euros for participating.

**Materials**

The same narratives were used as in the first experiment. However, only four texts contained a critical relation that disambiguated the text–model
relationship. In two of them, a positive BF relation indicated the existence of two cliques; in the other two, a negative BF relation indicated three cliques. In the remaining four texts, the critical relation had no diagnostic value as it was compatible with both a two- and a three-clique structure (a negative relation between person C and E; see Figure 1).

The reading span task, the dependent measures, and the procedure were the same as in the first experiment.

**Results**

The reading span score ranged from .18 to .93 and did not correlate with the reading time per syllable for sentences representing basic relations, \( r = -0.14, \text{ns} \), or for sentences representing critical relations, \( r = -0.03, \text{ns} \).

**Hypothesis 1**

In a first step, only texts containing a diagnostic critical relation were considered. The probability ratings for the four clique structures that were incompatible with the basic relations were subjected to an ANCOVA with clique structure (3+1+1; 3+3; 4+1+1; 5+1 persons) and number of cliques (two vs. three persons) as within-participants factors and reading span as a covariate. Although the ratings for the clique structures differed, \( F(3, 138) = 4.26, p < 0.01, \text{MSE} = 1.53 \), the mean ratings for all four BR-incompatible structures were negative (i.e., in the rejection region of the response scale; see Table 1). Rejection was stronger in texts describing two cliques than in texts describing three cliques, \( F(1, 46) = 6.59, p < 0.05, \text{MSE} = 1.02 \). As in the first experiment, the main effect of the covariate was significant, \( F(1, 46) = 9.0, p < 0.01, \text{MSE} = 4.33 \). No significant interaction effects involving the covariate were observed. The probability ratings averaged across all four BR-incompatible structures correlated negatively with the reading span score, \( r = -0.40, p < 0.01 \). The higher the reading span, the more decisively the participants rejected the clique structures that were already incompatible with the basic relations. These findings supported Hypothesis 1.

The same pattern emerged for texts with a nondiagnostic critical relation. Although the probability ratings differed among the clique structures, \( F(3, 138) = 10.28, p < 0.001, \text{MSE} = 0.71 \), the mean ratings for all four BR-incompatible structures were negative (Table 1). As in the texts with a diagnostic critical relation, the main effect of the covariate was significant, \( F(3, 46) = 13.47, p < 0.01, \text{MSE} = 2.10 \). The probability ratings averaged across all four BR-incompatible clique structures correlated negatively with the reading span score, \( r = -0.48, p < 0.01 \). The higher the reading span, the more decisively the participants rejected the clique structures incompatible with the basic relations.

To summarise, whether the text contained a diagnostic or a nondiagnostic critical relation made no difference to the probability ratings of the BR-incompatible clique structures. In both cases, high-span readers rejected them more strongly than did low-span readers.

**Hypothesis 2**

To what extent the critical relation was used to finally disambiguate the text—model relation could be analysed only in texts containing a diagnostic critical relation. First, the mean probability judgements given for the two clique structures that were compatible with the basic relations (2+2 vs. 4+2 persons) were compared across the three- and two-clique texts. As in the first experiment, the comparison showed that processing the critical relation strongly influenced the final structure of the situation model. The 2+2 structure was judged to be significantly more probable in texts with a diagnostic relation indicating three cliques than in texts with a diagnostic relation indicating two cliques (Table 2). Likewise, the 4+2 structure was judged to be significantly more probable in texts with a diagnostic relation indicating two cliques than in texts with a diagnostic relation indicating three cliques (see Table 2).

The sensitivity scores (indicating how well a reader discriminated between the two- and three-clique situations) were analysed in an ANCOVA with the number of cliques (two vs. three) as a within-participants factor and reading span as a covariate. Sensitivity was higher in three-clique texts (\( M = 3.51, \text{SD} = 1.81 \)) than in two-clique texts (\( M = 0.43, \text{SD} = 2.28 \)), \( F(1, 46) = 14.42, p < 0.001, \text{MSE} = 4.08 \).
The significant interaction between the number of cliques and readings span, $F(1, 46) = 4.70$, $p < .01$, $MSE = 4.42$, showed that the reading span score correlated with the sensitivity score to different degrees, depending on the number of cliques. Whereas this correlation was near zero in the three-clique texts, $r = -.09$, ns, reading span correlated positively with sensitivity in the two-clique texts, $r = .34$, $p < .05$. This pattern is similar to the one found in the first experiment, although the difference between those two correlations was smaller, such that a main effect of reading span emerged, rather than an interaction effect.

**Default model?**

As in the first experiment, the $2 + 2 + 2$ structure and the $4 + 2$ structure were better differentiated when the critical relation indicated a three-clique structure (see the earlier ANCOVA). It was evidently easier to align the situation model with a negative critical relation (that indicated three cliques) than to discard the $2 + 2 + 2$ situation (as required when the critical relation was positive). We hypothesised that this asymmetry could be explained by the idea that three two-person cliques represent the default model. Indeed, when the relation between the text base and the situation model remained indeterminate (in texts in which the critical text base and the situation model remained compatible), participants responded to the critical relation, $r = -.46$, $p < .01$.

**Discussion**

The second experiment replicated the findings of the first experiment. The results were in line with the idea that high-span readers constrained the initial situation model more strictly. They were more certain about which social configurations were potentially represented by the set of basic relations and which were not. This effect emerged for texts with diagnostic critical relations and for texts with nondiagnostic critical relations. In other words, high-span readers constrained the initial model more strictly than low-span readers even when no unambiguous specification of the final model was possible. Thus, the alternative interpretation that the BR-incompatible clique structures are not discarded until the critical relation allows specification of the situation model is unlikely.

When the critical relation had no diagnostic value, more three-clique models than models with only two cliques were developed. This finding corroborates the idea that the three-dyad configuration serves as the default model, probably because many readers took the three positive pair relations as the starting point for the construction process. In line with this reasoning, we again found that the reading span score correlated more strongly with the sensitivity score in two-clique texts than in three-clique texts. We reason that high working memory capacity played a more critical role when the default model had to be deactivated or restructured (positive critical relation) than when the critical relation could be integrated without restructuring (negative critical relation).

The second experiment also corroborated our observation that the sensitivity with which a
reader responds to the critical relation was only indirectly influenced by working memory capacity. Analyses of sensitivity as a function of both reading span and the probability ratings for the BR-incompatible clique structures yielded an effect for the latter variable but not for reading span.

**GENERAL DISCUSSION**

When Radavsky and Copeland (2001, 2004) analysed the role of working memory in text comprehension, they concluded that span measures of working memory often predict the quality of processes at the level of the text representation, but rarely at the level of the situation model. Their results indicated that readers with greater working memory resources encode and recall specific text information more effectively, but that they do not necessarily construct more valid referential representations of what a text is about. The present experiments provide consistent evidence of processes at the situation model level that correlated with reading span, namely updating the situation model according to constraining text information. In our experiments, high-span readers had a clearer understanding of what kind of social situation the text did not refer to. Our participants read narratives about five like-dislike pair relations representing a social situation with either two or three cliques. The higher the participants' reading span, the lower their subjective probability ratings that a clique structure incompatible with this set of relations was represented by the text. Thus, high-span readers discriminated more effectively between clique structures compatible and incompatible with the text. This result supports our first hypothesis.

We attribute this effect to the high-span participants' greater capacity to maintain and recall the situation model constructed during reading. This capacity was critical because readers judged the compatible and incompatible clique structures after reading the complete text. Moreover, the recalled information about the social configuration had to be manipulated in order to gauge the extent to which a given clique structure may be a valid representation of the social situation described by the text. This capacity clearly reflects one of the two dimensions of reading span task performance identified by Whitney et al. (2001): the capacity to manipulate memorised information. And it is probably this capacity dimension that allows high-span readers to outperform low-span readers when ambiguous syntactical structures require multiple representations of single sentences to be maintained (MacDonald et al., 1992).

The participants were also given information about a sixth pair relation that did or did not disambiguate the final text-model relationship. When this critical information was diagnostic for one of the two remaining models of the social situation, readers aligned their situation models with the contents of the critical information (cf. Dutke et al., 2010). In both experiments, the data seemed to indicate that participants with higher reading spans also processed this critical relation more successfully than did participants with lower reading spans—particularly in texts in which the critical relation was diagnostic for two cliques. However, we consider this result a secondary effect. When we controlled not only for reading span but also for the certainty with which the participants rejected the clique structures that were already incompatible with the basic relations, the reading span effects vanished and sensitivity was better predicted by the probability ratings for the BR-incompatible structures. Thus, we think that high-span participants' main advantage was that they constrained the situation model appropriately before the critical information was processed. As a consequence, high-span readers inferred the correct final clique structure more frequently after integrating the critical information—not because the integration itself was easier for them, but because they had a clearer picture of the structure into which the critical relation had to be integrated. These results partly support our second hypothesis, inasmuch as high-span participants' greater sensitivity to the critical relation can be seen as an epiphenomenon of their better ability to discard incompatible representations earlier, and more conclusively. As a general caveat, however, it should be considered that the sensitivity score in the second experiment was based on just four texts (the other four were indeterminate), rather than on eight texts as in the first experiment). Thus, we cannot rule out the possibility that the reliability of the sensitivity score varied between the experiments.

This interpretation that correct integration of the diagnostic critical relation was only indirectly dependent on working memory capacity is in line with our reasoning on the role of the default model. We found that it was harder for participants to reject a three-clique model when the
critical relation indicated two cliques than to dismiss a two-clique model when the critical relation indicated three cliques. The reason may be that many participants used a $2 + 2 + 2$ structure as a default model. It was clearly harder to reject the default model than the nondefault model. In this sense, it was adequate to assume in our second hypothesis that deactivation of the outdated situation model was essential in this part of the task. In line with this argumentation, high-span readers were more successful than low-span participants in finally specifying the situation model when the critical relation indicated two cliques. When the critical information could be integrated into the default model, in contrast, working memory capacity played no important role.

The present results warrant some further comparison of resolving ambiguities at the syntactic level versus at the level of situation models. For example, Bornkessel et al. (2004, p. 11, referring to Gernsbacher & Faust, 1991), concluded “that low-span readers cannot effectively inhibit dispreferred readings” of ambiguous sentences. Based on their results and on the view of Whitney et al. (2001) that a high reading span implies a high capacity to avoid the interference of irrelevant information, one might predict that high-span readers would reject an outdated version of the situation model more rigorously than would low-span readers. Our data do not seem to warrant such a strong conclusion, however. This may be due to a difference in sentence-level and text-level processes relating to the quality of suppressing irrelevant information. For example, the beginning of a sentence such as “The soldiers warned about the dangers . . .” is ambiguous in that “warned” may be the verb of the main clause or may introduce a relative clause (MacDonald et al., 1992). Typically, the alternative interpretations are highly available to the reader and, depending on the context, more than one potential interpretation may be activated (e.g., Kintsch & Mross, 1985; MacDonald et al., 1992). This activation usually occurs in an effortless, automatic way, such that after processing the constraining (context) information, one of the two interpretations has to be suppressed again. In this sense, the low-span readers’ disadvantage may be described as a suppression deficit (Bornkessel et al., 2004; Gernsbacher, 1993; Gernsbacher & Robertson, 1995; but see McNamara & McDaniel, 2004). In contrast, at the level of understanding a complete text, different versions of a situation model are not automatically activated; rather, they are more or less deliberately constructed throughout the reading process. A situation model that is not supported by new information simply loses its relevance and is not pursued any further. Deactivation of this situation model is required to prevent interference. However, this deactivation is probably a much less active process consuming fewer resources than is rapidly suppressing the prestored meaning of a phrase that entered consciousness swiftly and automatically.

The way in which situation model construction is conceptualised here is germaine to other formulations in the mental model literature that assume relatively little demand on resources during initial stages (e.g., Johnson-Laird, Byrne, & Schaeck, 1992). In particular, some data support the idea that participants construct a single model that is compatible with the premises, and then “annotate” that model with tags referring to the possible existence of alternative models (Vandierendonck, Dierckx, & de Vooght, 2004).

With regard to external validity, certain limitations of the experimental situation should be considered. The participants probably developed reading goals involving understanding the social relationships among the protagonists. This kind of reader orientation was needed to test our hypotheses and was prompted by the instructions, the structural similarity of the texts, and the repeated requirement to judge the clique structures. The results showed that, within such an orientation, the validity of the situation model correlated with the reading span score. However, further research is needed to investigate whether this relation also holds under different reading orientations.

Another limitation relates to the status of the individual difference variable. The present sample reflected “natural” variance in working memory capacity, as indicated by reading span. Therefore, the main results are correlational and need to be verified in experimental designs. One option would be to impose working memory load through a secondary task either during reading or during rating the clique structures. This approach has been successfully applied within the social clique paradigm (von Hecker & Dutke, 2004, Exp. 3), but not yet with text-based descriptions of the pair relations. Such research may also be informative with regards to the processual aspects of situation model construction.
Finally, why we found that the validity of the situation model was related to reading span, whereas Radvansky and Copeland (2001, 2004) did not, warrants discussion. We attribute these contrasting findings to differences in the text materials used. First, our texts were constructed to be indeterminate and ambiguous. Consequently, participants had to pay attention to information that reduced this indeterminateness and ambiguity to comprehend the texts. Second, our texts required participants to construct a complex relational structure by integrating new pair relations stepwise. Adding new relations to the existing situation model can change its overall structure. The sample text used by Radvansky and Copeland (2004) did not share these features. Thus, the need to continuously specify and constrain the situation model might have been more salient in our text material than in Radvansky and Copeland’s material. It is thus necessary to add the caveat that the role of working memory capacity in constructing situation models may vary with the type of text.

It further remains to be seen to what extent the aspects of the present paradigm that relate to working memory are indeed located mostly or exclusively at the situation model level or, alternatively, also involve the textbase level at least to some extent. As a case in point, in a study by Sedek and von Hecker (2004) a sample of older participants with low working memory capacity were outperformed by younger controls with higher working memory capacity on a task involving the construction of a linear (transitive) mental model from a set of premises. Performance in the elderly sample—but not in the younger controls—was mainly predicted by short-term maintenance of the original premises, so was not accounted for by impairments at the model level. In fact, when their short-term memory disadvantage was controlled for, the elderly group’s capacity to construct correct models was at the same level as that of the younger controls. In a similar vein, Copeland and Radvansky (2007) argued that older adults’ reduced performance in a situation model task, relative to a younger control group, was mainly due to their difficulties in processing verbal materials at the textbase level. When graphic materials were used, the older group’s impairment was substantially reduced, possibly because some problems the elderly had with the verbal textbase were circumvented. These findings point to the potential importance of textbase-related processes in assessing the effects of working memory on the construction of situation models.

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AMBIGUOUS TEXTS AND READING SPAN


The Birth of Venus

The planning was done.
They were going to pull off the big job the next night.
If the coup went off without a hitch, they would make history.
The “master thieves” who succeeded in stealing the famous painting by Sandro Boticelli!
“Biggest theft of all ages” the newspapers would say.
The six men had gathered for the last time to discuss the details of their great plan.
Accuracy and perfect timing were vital for such a tremendous project.
The team consisted of international experts.
The head of the gang was Carlo.
He was the one who had stolen the Van Gogh painting.

Person sentence 1
Along with Carlo, Luigi had also been involved in that job.
Basic relation 1
Carlo and Luigi admired one another for being such professionals.
Elaboration 1
Carlo and Luigi liked working together.
Still, the theft of the Van Gogh painting had almost turned into a complete fiasco.
Neither of them had taken into account the enormous size of the painting, which had hampered its transport.
They had fallen behind schedule.
The watchmen had almost discovered the robbery ahead of time.

Person sentence 2
Additionally, Carlo remembered that Salvatore had parked the van at the wrong exit of the museum.
Basic relation 2
Carlo and Salvatore did not like each other.
Elaboration 2
Carlo frequently got the impression that Salvatore was somehow a bit clumsy.
But in the business they both were involved in, it was absolutely necessary to have confidence in each other.
Trust was indispensable for success.
Other exceptionally skilled experts were also needed.
Particularly those with great technical know-how at their disposal.
The best experts were needed to circumvent the museum’s high-tech monitoring systems.

Person sentence 3
For this coup, Salvatore had succeeded in hiring Angelo, another professional.
Basic relation 3
Salvatore and Angelo appreciated one another.
Elaboration 3
Salvatore and Angelo found working together inspiring.
With Angelo’s skills, the gang would surely outwit the museum’s security system.
To prevent another breakdown like in the Van Gogh job, the gang had to make sure that shipping went according to plan.
To that end, they had already hired a van.

Person sentence 4
Originally, Carlo had considered Franco to do this job.
Basic relation 4
But Carlo and Franco did not get along with each other.
Elaboration 4
Carlo and Franco had argued heatedly about the planning of the robbery.
The gang intended to ship the painting to a foreign art dealer.
The dealer had already contacted an art lover who would pay a tremendous amount of money for the Venus.
Even split six ways, it would make each member of the gang a very rich man.

Person sentence 5
Carlo had decided that Franco and Pablo would accompany the painting.
Basic relation 5
Franco and Pablo had always been best pals.
Elaboration 5
As Franco and Pablo were great connoisseurs, the Venus would be under permanent surveillance.
A plane chartered by the gang was supposed to bring the painting to its new owner.
Thus, everybody was eager for the plane to leave on schedule.
Unfortunately, the meteorological service had announced a nasty thunderstorm.
Some bad weather was on the way!

Critical person sentence
Franco had already revealed his worries to Salvatore.

Critical relation
Positive BF relation:
Franco and Salvatore relied on each other.
Negative BF relation:
Franco and Salvatore mistrusted each other.

Critical elaboration
Positive BF relation:
As Franco knew from experience, he would be well-advised to consider Salvatore’s worries.
Well, Carlo resumed, everything had been done to pull off the big job.
The planning seemed to be perfect.
Everybody was hoping that each tiny detail had been taken into account.
Otherwise their dreams of wealth and luxury would vanish into thin air.

The original material was in German.