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Brain and Language 95 (2005) 383–394

Brain and Language

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The propositional structure of discourse in the two cerebral hemispheres ☆

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Accepted 28 February 2005
Available online 22 April 2005

Abstract

Readers construct at least two interrelated representations when they comprehend a text: (a) a representation of the explicit ideas in a text and the relations among them (i.e., a propositional representation) and (b) a representation of the context or situation to which a text refers (i.e., a discourse model). In a recent study, Long and Baynes (2002) found evidence that readers' representations were structured according to propositional relations, but only in the left hemisphere. Both hemispheres, however, appeared to represent contextually relevant semantic information. The goal in the current study was to examine further the organization of explicit text concepts in the two hemispheres. We used an item-priming-in-recognition paradigm in combination with a lateralized visual-field manipulation. We found evidence for a propositionally structured representation in the left hemisphere, that is, priming effects that reflected the linear distance between primes and targets in the propositional structure of passages. We also found that the right hemisphere represented explicit text concepts, but we found no evidence that these concepts were organized structurally. In a second experiment, we found our item priming effects reflected the representation of text information in memory and did not reflect lexical-semantic priming at test.

Keywords: Laterality; Neurolinguistics; Left hemisphere; Right hemisphere; Discourse processing; Language representation

1. Introduction

Recent research suggests that the distinction between a reader's representation of explicit information in a text and the reader's representation of what the text is about may be important with respect to how discourse is represented in the brain (Long & Baynes, 2002). This representational distinction is found in most current theories of sentence and discourse processing. These theories claim that readers construct and store in memory at least two interrelated representations during comprehension: a propositional representation and a discourse model (Gernsbacher, 1990; Graesser, Singer, & Trabasso, 1994; Greene, McKoon, & Ratcliff, 1992; Kintsch, 1988; Kintsch & van Dijk, 1978; McKoon & Ratcliff, 1990, 1992, 1998).

A propositional representation contains the individual ideas (propositions) that are derived from each sentence and the relations among them (Kintsch, 1974). A proposition is a structured, coherent unit consisting of a predicate (e.g., verb, adjective, and adverb) and one or more associated arguments (i.e., concepts that are related or modified by the predicate). The propositional representation is "locally" coherent; that is, propositions in each incoming sentence are mapped to propositions currently active in working memory, usually those from the immediately preceding sentence or two. The relations

☆ The research described in this manuscript was supported by a National Institute of Health Grant 1R01DC/NS04442-01.
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doi:10.1016/j.bandl.2005.02.004

among propositions are often referential (Kintsch, 1974; McKoon & Ratcliff, 1980; Ratcliff & McKoon, 1978); propositions are connected when their arguments refer to the same entity. Propositions that cannot be connected by means of a referential link require one or more inferences to fill the gap.

The propositional representation serves as a foundation for constructing the discourse model. The discourse model is a representation of what the text is about and is "globally" coherent (Graesser et al., 1994; Kintsch, 1988). Explicit text information is integrated with relevant prior knowledge to represent features of the real or imaginary world that the text describes. To construct a discourse model, readers must engage in active inferential processing to reorganize and restructure text information in light of their prior understanding of the knowledge domain.

How are the propositional representations and discourse models stored in the two cerebral hemispheres? Long and Baynes (2002) have conducted one of the few studies to examine this question directly. They considered three possibilities. One is that the propositional representation resides in the left hemisphere, whereas the discourse model resides in the right hemisphere. This possibility is founded in previous research on the language comprehension abilities of the two hemispheres. The left hemisphere has much better syntactic processing abilities than does the right hemisphere (Baynes & Eliassen, 1998; Caplan, 1992; Kaan & Swaab, 2002; Zaidel, 1990). Syntactic analysis is an essential process involved in deriving propositions from sentences because propositions roughly correspond to syntactic constituents. Moreover, propositions are typically connected by means of referential relations; establishing these relations would seem to depend on knowledge about "who did what to whom" in a sentence. The right hemisphere, in contrast, may represent the discourse model. Considerable evidence suggests that the right hemisphere is involved in integrating ideas among sentences and in making inferences, processes that are essential to constructing a coherent and referential discourse model (Beeman, 1993; Brownell, Gardner, Prather, & Martino, 1995; Brownell, Potter, Bihrle, & Gardner, 1986; Delis, Wapner, Gardner, & Moses, 1983; Hough, 1990; Meyers, 1994; Rehak, Kaplan, & Gardner, 1992).

A second possibility is that both the propositional representation and discourse model are represented in the left hemisphere. The two representations are strongly interrelated (Graesser et al., 1994; Kintsch, 1988). Indeed, most theories of discourse processing claim that the propositional representation is central to text comprehension and that readers construct a propositional representation before elaborating it to form a complete discourse model (Kintsch & van Dijk, 1978; McKoon & Ratcliff, 1990, 1992; but see Sanford & Garrod, 1998 for an alternative view). Thus, it may be unreasonable to assume that they are stored independently in different hemispheres. If the propositional representation resides in the left hemisphere, then the discourse model, which is based on this representation, may reside in the left hemisphere as well.

The challenge with respect to these first two possibilities would be in understanding how the right hemisphere plays an important role in constructing the discourse model in the absence of access to the propositional representation on which it is based. At the very least, limited access to the propositional representation would place constraints on the means by which the right hemisphere is involved in constructing discourse-level relations.

The final possibility is that the propositional representation and discourse model are distributed across the two hemispheres even though the hemispheres may play different roles in constructing them. The left hemisphere may be involved in deriving and connecting propositions, but once the propositional representation has been constructed, it may be stored such that both hemispheres have equal access to it.

Long and Baynes (2002) investigated these possibilities using a paradigm called "item priming in recognition." The logic of the paradigm is that activation of a concept in memory facilitates recognition of other concepts to which it is linked (Long, Oppy, & Seely, 1997; McKoon & Ratcliff, 1980; Ratcliff & McKoon, 1978). Participants received a series of study-test trials in which a set of passages was presented for study, followed by a recognition test consisting of single words. Embedded in the recognition list were sets of prime–target pairs. Sample passages and prime–target pairs appear in Table 1.

Table 1
Sample passages and example prime–target pairs (from Long and Baynes, 2002)

Priming relation	Prime	Target
The townspeople were amazed to find that all the buildings had collapsed except the *mint*. Obviously, the architect had foreseen the danger because the structure withstood the natural disaster		
Propositional priming pairs		
Same-proposition	Disaster	Structure
Different-proposition	Danger	Structure
Associate priming pairs		
Appropriate-associate	Townspeople	Money
Inappropriate-associate	Townspeople	Candy
Topic priming pairs		
Appropriate-topic	Architect	Earthquake
Inappropriate-topic	Architect	Breath
The guest ate garlic in his dinner, so the waiter brought a *mint*. The worried guest soon felt comfortable socializing with his friends		
Propositional priming pairs		
Same-proposition	Guest	Garlic
Different-proposition	Waiter	Garlic
Associate priming pairs		
Appropriate-associate	Dinner	Candy
Inappropriate-associate	Dinner	Money
Topic priming pairs		
Appropriate-topic	Friends	Breath
Inappropriate-topic	Friends	Earthquake

Each passage was two sentences long and contained a homograph that appeared as the final word of either the first or second sentence in the passage. Each test list contained three types of priming pairs interleaved among true and false filler items. *Propositional-priming* pairs consisted of a target (e.g., structure) that was preceded by a prime from the same proposition (e.g., disaster) or by a prime from a different proposition in the same sentence (e.g., danger). *Associate-priming* pairs consisted of a target that was either the appropriate (e.g., money) or the inappropriate associate (e.g., candy) of a homograph in the sentence and was preceded by a prime from the sentence containing the homograph (e.g., townspeople). Finally, *topic-priming* pairs consisted of a target that was either the topic of a passage (e.g., earthquake) or was an unrelated word (e.g., breath) and was preceded by a prime from the final sentence of the passage (e.g., architect). It should be noted that the correct response to the associate and to the topic words was "no." These items did not appear in the sentences. Primes were presented in the center of a computer screen; targets were lateralized to the left visual field/right hemisphere (LVF/RH) or to the right visual field/left hemisphere (RVF/LH).

Long and Baynes (2002) used the priming manipulation to examine three aspects of readers' sentence representations. First, they examined the representations for evidence of propositional structure. If both hemispheres have access to sentence representations structured by means of propositional relations, then both should show a propositional priming effect, faster responses to a target that is preceded by a prime from the same proposition relative to a prime from a different proposition in the same sentence. Second, they examined readers' memory representations for evidence that the hemispheres represented important semantic relations. Specifically, they asked whether the representations contained information about the context-appropriate senses of ambiguous words and information about the themes or topics of the passages.

The results from Long and Baynes (2002) appear in Fig. 1. The priming patterns suggested both differences and similarities in how discourse was represented in the two hemispheres. Only the left hemisphere showed evidence for a representation that was structured propositionally. Participants showed propositional priming, faster responses to targets in same-proposition than in different-proposition pairs, but only when targets were presented in the RVF/LH. No propositional priming was found for targets presented in the LVF/RH. It should be noted that propositional structure is confounded with syntactic structure in this study, as it is in other studies examining the representation of propositions in memory (Long et al., 1997; McKoon & Ratcliff, 1980; Ratcliff & McKoon, 1978). Nouns in the same proposition are almost always arguments of a verb; thus, the nouns are in the same clause as well as in the same proposition. The priming effects that Long and Baynes

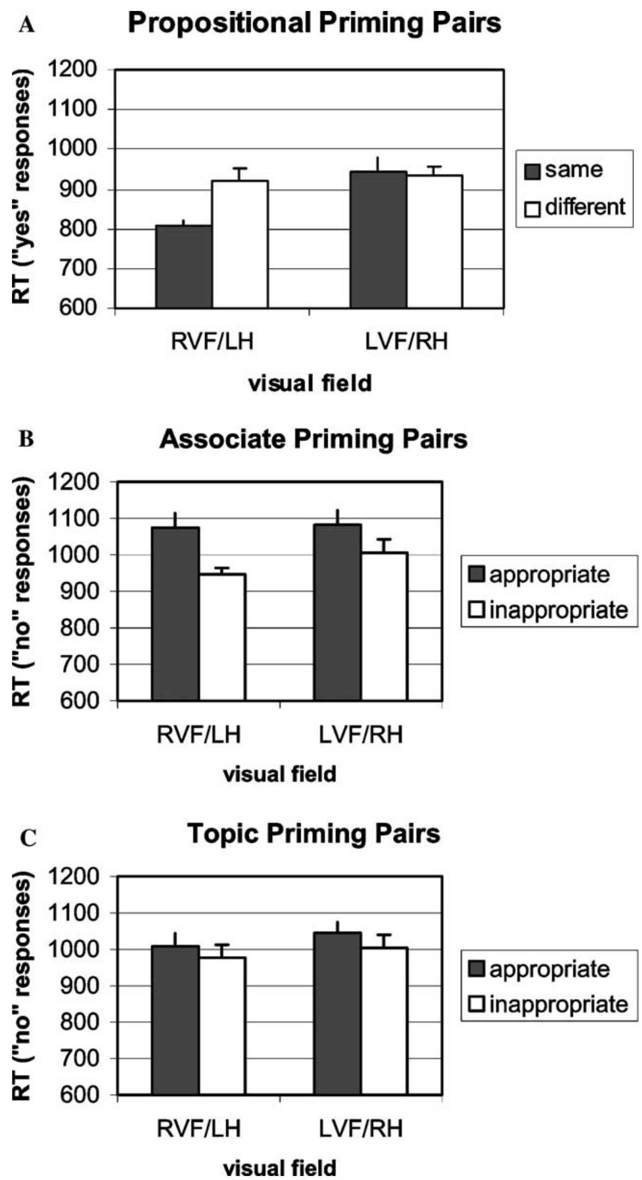

Fig. 1. Item priming results from Long and Baynes (2002, Experiment 1). Mean response times (in milliseconds) to targets as a function of visual field: (A) "yes" responses to targets in propositional priming pairs, (B) "no" responses to targets in associate priming pairs, and (C) "no" responses to targets in topic priming pairs. Error bars depict standard errors.

observed could be due to the left hemisphere's sensitivity to syntactic structure rather than its sensitivity to propositional structure. We refer to these structural effects as propositional priming to be consistent with previous research; however, we acknowledge that propositional structure cannot be distinguished from syntactic structure in these experiments.

With respect to the representation of contextually appropriate semantic information, the priming patterns in the two hemispheres were similar. Participants had difficulty rejecting both appropriate associates and topics when they were presented in either visual field. This suggests that information about the context-appropriate senses of ambiguous words and information about the topics of the passages were incorporated into readers' representations in both hemispheres. Participants had difficulty rejecting the targets because these items resonated with information contained in their memory representations.

The purpose of the current study was to examine further the nature of discourse representation in the two hemispheres, in particular, the nature of the propositional representation. Long and Baynes's (2002) propositional priming results suggest differences in how the two hemispheres represent propositions. The left hemisphere has a representation in which concepts in a sentence are organized structurally. The propositional priming results, however, tell us less about how discourse is organized in the right hemisphere. It may be that the right hemisphere made no connection among the explicit concepts in the sentence. Thus, we found no propositional priming effects because the primes and targets were not linked in memory. Alternatively, the right hemisphere may have a representation of sentence structure that is more loosely organized than is the one in the left hemisphere. That is, the right hemisphere may link concepts in a sentence, but it may not form closer connections among concepts within a clause than it does among concepts across clauses in the same sentence. If this were the case, the right hemisphere might be sensitive to more distant, inter-sentential relations. That is, it may form closer connections among concepts within a sentence (although not within a clause) than concepts across sentences. Thus, we conducted a follow-up study to determine whether the right hemisphere represented concepts within a sentence differently from concepts in other sentences in the same passage.

2. Experiment 1

Long and Baynes (2002) examined how the two hemispheres represent discourse concepts within a sentence by comparing responses to targets preceded by primes from the same proposition to targets preceded by primes from a different proposition in the same sentence. In this experiment, we were interested in whether the right hemisphere might represent inter-sentential relations, even though it does not represent intra-sentential relations. Thus, we used the item-priming-in-recognition paradigm to examine propositional relations both within and across sentences.

Participants read sets of brief, two-sentence passages and then received a recognition test consisting of single words. Four types of prime–target pairs were embedded in the test list. Sample passages and test items appear in Table 2. In the *same-proposition condition*, a target from one of the sentences (e.g., hunter) was preceded by a prime from the same proposition (e.g., pheasant). In the *different-proposition condition*, the target was preceded by a prime from a different proposition in the same sentence (e.g., deer). In the *different-sentence condition*, the target was preceded by a prime from a different sentence in the same two-sentence passage (e.g., birds). Finally, in the *different-passage condition*, the target was preceded by a prime from a different passage in the same block of passages (e.g., apples). In Experiment 1a, primes and targets were presented centrally to determine whether response latencies would reflect the distance between the primes and targets in the propositional structure of the passages. If so, then we should see a linear relation between priming and propositional distance; response latencies in the same-proposition condition should be fastest, followed by latencies in the different-proposition, different-sentence, and different-passage conditions. In Experiment 1b, we added a lateralized visual field (VF) procedure to examine differences in priming across the two hemispheres. Primes were always presented centrally and targets were presented either to the LVF/RH or to the RVF/LH.

Table 2
Sample passages and example prime–target pairs (Experiments 1a and 1b)

Priming relation	Prime	Target
While the hunter (who was wearing an orange vest) stalked the pheasant, the deer ate leaves in the meadow. The birds sang as they roosted in the trees and watched the creatures below		
Same-proposition	Pheasant	Hunter
Different-proposition	Deer	Hunter
Different-sentence	Birds	Hunter
Different-passage	Apples	Hunter
The children laughed at the silly sight. The elephant (that was large and gray) pulled the cart, while the monkey juggled the apples		
Same-proposition	Elephant	Cart
Different-proposition	Monkey	Cart
Different-sentence	Sight	Cart
Different-passage	Creatures	Cart

We manipulated one other variable in this experiment, the syntactic structure of the sentences. In the Long and Baynes (2002) materials, concepts in the same-proposition condition always appeared as the nouns in a simple noun–verb–noun (NVN) phrase. Thus, priming in their experiment may have been affected by syntactic structure. That is, the left hemisphere may have exhibited particularly fast responses to targets in the same-proposition condition because of its sensitivity to propositional structure or because of its sensitivity to the canonical NVN syntactic structure. In the current experiment, concepts in the same-proposition condition also appeared as nouns in a NVN phrase; however, we manipulated the syntactic structure such that the nouns were sometimes separated by an intervening clause. If priming in the left hemisphere is affected by the canonical structure of a sentence, then we should see more robust priming when the embedded clause is absent than when it is present.

3. Experiment 1a

3.1. Method

3.1.1. Participants

Participants were 40 undergraduate psychology students who received course credit for their participation (28 women and 12 men). All participants spoke English as their first language and none had a diagnosed reading or learning disability. In addition, all were right-handed and had normal or corrected-to-normal vision.

3.1.2. Materials

The study materials consisted of 48 two-sentence passages similar to those used by Long and Baynes (2002). Each of the passages was analyzed to determine its underlying propositional structure. A proposition was defined as a relation (verb or modifier) and its arguments (see Kintsch, 1974). Each passage contained a sentence that had at least two propositions with a NVN structure (e.g., While the hunter stalked the pheasant, the deer ate leaves in the meadow). Strictly speaking, each of these sentences also contained a third proposition that was a conjunction of the other two and many sentences contained propositions in which an adjective modified a noun in the sentence or contained propositions that were prepositional or adverbial phrases. A second version of each passage was constructed. These versions contained an embedded clause consisting of at least one proposition (While the hunter who wore an orange vest stalked the pheasant, the deer ate leaves in the meadow). We also constructed four additional passages in the manner described above. These passages were used as practice to familiarize participants with the procedure. The total set of 52 passages was divided in 13 lists: 12 experimental and 1 practice. Each list contained 4 passages.

A recognition test followed each study list. Embedded in the test list were four prime–target pairs. One pair of each type was associated with each passage in the study list. The prime–target types were defined as follows: (1) *same-proposition pairs* consisted of a target noun that was preceded by another noun from the same proposition, (2) *different-proposition pairs* consisted of a target noun that was preceded by another noun from a different proposition in the same sentence, (3) *different-sentence pairs* consisted of a target noun preceded by a noun from a different sentence in the same passage, and (4) *different-passage pairs* consisted of a target noun preceded by a noun from a different passage in the same block of passages. We controlled for the proximity between the prime and target words in the passages; the same number of words, on average, separated primes and targets in the same-proposition and different-proposition conditions. We were not able to control for the proximity between targets and primes in the different-sentence and different-passage conditions. Different-sentence and different-passage primes were necessarily more distant from the targets in the surface structure than were primes from the same-proposition and different-proposition conditions. We also controlled for the linear order of primes and targets in the passages. Some primes preceded targets in the passages; others followed the targets. The prime–target pairs in each list were interleaved among 16 filler items (4 true and 12 false). The various priming conditions and the two embedded clause conditions were counterbalanced within and across material sets.

3.1.3. Procedure

Each passage in the study list was presented individually in the center of a computer screen for 14 s. Each study list was followed by a recognition test. The recognition test consisted of 24 single words, including the 4 priming pairs (same-proposition, different-proposition, different-sentence, and different-passage). Each test list was preceded by an asterisk presented for 500 ms in the middle of the screen as a cue that the test was about to begin. Test items were presented in the center of the screen for 100 ms each. The test list began with three filler items. The priming pairs were presented randomly in the remainder of the list, separated by intervening filler items.

Participants pressed a key labeled "yes" if a test word had appeared in one of the preceding passages and a key labeled "no" if it had not appeared. Participants were told to keep their index fingers on the yes and no keys at all times. We recorded their responses and response latencies to each item. Latencies were recorded from the offset of the test item. Participants received the 12 study-test trials in random order. These trials were preceded by the practice trial.

3.2. Results and discussion

We performed separate 2(clause) × 4(prime) repeated-measures ANOVAs on accuracy and reaction times to the recognition targets. Clause (present and absent) and prime (same-proposition, different-proposition, different-sentence, and different-passage) were within-participants factors. Only correct responses were included in the analyses of the reaction-time data. All latencies more than three standard deviations from a participant's mean were treated as missing data. All effects were tested at a significance level of $p < .05$ unless otherwise indicated. One participant had accuracy performance that was not reliably different from chance; thus, we excluded her data from the analyses. Mean accuracy rates and response times to targets in the four priming conditions appear in Table 3 and Fig. 2.

Our analysis of the reaction-time data revealed a reliable effect of prime condition, $F(3, 114) = 8.63$, $MSe = 23{,}578$. We found no reliable effect of clause, nor did we find a reliable prime × clause interaction, both

Table 3
Mean reaction times (RT, in milliseconds) and accuracy rates (AR, in percentages) as a function of prime and clause condition

Prime condition	Embedded clause			
	Absent		Present	
	RT	AR	RT	AR
Same-proposition	784	94	792	91
Different-proposition	822	90	829	91
Different-sentence	848	85	865	88
Different-passage	882	81	935	86

*F*s < 1. Responses to targets in the same-proposition condition were reliably faster than responses to targets in the other conditions, $F(1,38) = 4.75$, $F(1,38) = 17.89$, $F(1,38) = 16.56$, different-proposition, different-sentence, and different-passage, respectively. Responses to targets in the different-proposition condition were reliably faster than responses to targets in the different-passage condition, $F(1,38) = 10.79$. Response times in the different-proposition were faster than those in the different-sentence conditions, but not reliably so, $F(1,38) = 1.83$, $p = .18$. Finally, responses to targets in the different-sentence condition were faster than responses to targets in the different-passage condition, $F(1,38) = 4.88$.

Our analysis of the accuracy data also revealed a reliable effect of prime condition, $F(3,114) = 4.78$, $MSe = .94$. Responses to targets in the same-proposition condition were more accurate than responses to targets in the between-sentence and between-passage conditions, $F(1,38) = 6.48$ and $F(1,38) = 15.86$, respectively, but were not reliably different from responses to targets in the between-proposition condition, $F < 1$. Responses to targets in the different-proposition condition were also more accurate than responses in the between-passage condition, $F(1,38) = 6.87$. Participants were more accurate in the different-proposition condition than in the different-sentence condition, but not reliably so, $F(1,38) = 1.51$, $p = .22$. Finally, accuracy was also somewhat higher in the different-sentence than the different-passage condition, but the difference was not reliable, $F(1,38) = 1.34$, $p = .25$.

The pattern of priming in this experiment was as predicted. Distance in the propositional structure of the passages was reflected in participants' response times. The closer the propositional distance between the primes and targets the greater the facilitation in item recognition. The fact that we found no effect of embedding a clause between primes and targets in the same-proposition condition suggests that the response advantage in this condition was due to the propositional relation between the primes and targets and not due to their physical proximity in the passages.

4. Experiment 1b

The goal of Experiment 1b was to examine item priming in the two cerebral hemispheres for evidence of propositional structure. We used the same materials and procedure as we did in Experiment 1a, except that we added a lateralized VF procedure to our item priming manipulation.

4.1. Method

4.1.1. Participants

Participants were 82 undergraduate psychology students who received course credit for their participation

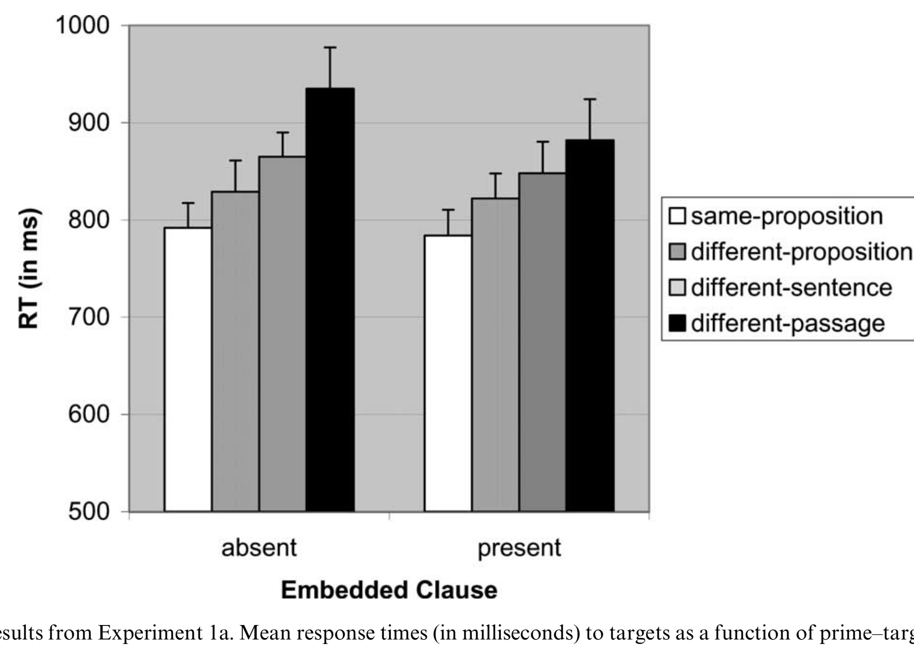

Fig. 2. Item priming results from Experiment 1a. Mean response times (in milliseconds) to targets as a function of prime–target and clause conditions. Error bars depict standard errors.

(47 women and 35 men). All participants spoke English as their first language and none had a diagnosed reading or learning disability. In addition, all were right-handed and had normal or corrected-to-normal vision.

4.1.2. Materials and procedure

The materials were the same as those used in Experiment 1a. The prime conditions and VF presentation (i.e., target in the LVF/RH or RVF/LH) were counterbalanced within and across material sets. For example, a passage that was associated with a same-proposition priming pair in one set was associated with the different-proposition priming pair in another set. In addition, a target in the same-proposition condition that was presented in the LVF/RH in one set was presented in the RVF/LH in another set. The same was true for the other prime conditions.

Participants were seated 57 cm from a computer screen. Each passage in the study list was presented as described in Experiment 1a. Each study list was followed by a recognition test. The test list was preceded by a fixation point in the middle of the screen. The fixation point remained on the screen until all recognition items had been presented. Participants were told to keep their eyes on the fixation point throughout the test. Test items were presented for 100 ms each and appeared in one of three positions: (1) in the center of the screen, immediately above the fixation point; (2) in the LVF/RH, such that the end of the word was 1.5° of visual angle to the left of fixation; or (3) in the RVF/LH, such that the beginning of the word was 1.5° of visual angle to the right of fixation. The lateralized test word subtended approximately 1.5° to 3.5° of visual angle. The test list began with three filler items. The priming pairs were presented randomly in the remainder of the list, separated by intervening filler items. A filler item followed the last priming pair in the list. Primes were always presented centrally; targets appeared equally often to the left and the right of center. Filler items were presented randomly in one of the three positions on the screen.

Participants received the same instructions as in Experiment 1a. Response hand was counterbalanced across participants. We recorded responses and response latencies to each recognition item. Latencies were recorded from the offset of the test word. Participants received the 12 study-test trials in random order. These trials were preceded by the practice trial.

4.2. Results and discussion

We performed separate 2 (clause) × 2 (VF) × 2 (response hand) × 4 (prime) repeated-measures ANOVAs on accuracy and reaction times to the recognition targets. Clause (present and absent), VF (LVF/RH and RVF/LH), and prime (same-proposition, different-proposition, different-sentence, and different-passage) were within-participants factors. Response hand was a between-participants factor. Only correct responses were included in the analyses of the reaction-time data. All latencies three standard deviations from a participant's mean were treated as missing data. All effects were tested at a significance level of $p < .05$ unless otherwise indicated.

Our analysis of the reaction-time data revealed a reliable main effect of VF, $F(1,80) = 26.33$, $MSe = 61{,}208$. This effect was modified by a reliable VF × prime interaction, $F(3,240) = 2.86$, $MSe = 66{,}035$. We found no reliable effects involving response hand or clause; therefore, the data presented in Table 4 and Fig. 3 are collapsed across these two variables. The pattern of response latencies to targets presented in the RVF/LH was similar to that seen in Experiment 1a. Participants responded faster to targets in the same-proposition condition than to those in the other conditions, $F(1,81) = 7.05$, $F = 14.25$, and $F(1,81) = 20.35$, different-proposition, different-sentence, and different-passage, respectively. Participants also responded faster to targets in the different-proposition condition than to those in the different-passage condition, $F(1,81) = 9.78$. The difference in response times between the different-proposition condition and the different-sentence condition was marginally reliable, $F(1,81) = 2.79$, $p = .10$. Finally, responses to targets in the different-sentence condition were faster than those in the different-passage condition, $F(1,81) = 4.89$.

We also found reliable priming effects for targets presented in the LVF/RH, but the pattern was very different from that described above. We found reliable priming only when targets in the different-passage condition were compared to targets in the other conditions. Participants responded faster to targets in the same-proposition, different-proposition, and different-sentence conditions than to targets in the different-passage condition, $F(1,81) = 5.32$, $F(1,81) = 4.211$, $F(1,81) = 4.28$, respectively. Response times to targets in the same-proposition, different-proposition, and different-sentence conditions did not differ from each other, $F\text{s} < 1$.

Our analysis of the accuracy data revealed a reliable effect of VF, $F(1,80) = 11.91$, $MSe = .55$. The pattern of means was very similar to the one that we observed in the reaction-time data; however, the VF × prime interaction was not reliable, $F(3,240) = 1.46$, $MSe = .53$, $p = .23$.

Table 4
Mean reaction times (RT, in milliseconds) and accuracy rates (AR, in percentages) as a function of prime and VF

Prime condition	Visual field			
	LVF/RH		RVF/LH	
	RT	AR	RT	AR
Same-proposition	715	89	659	95
Different-proposition	718	87	716	92
Different-sentence	717	88	752	88
Different-passage	776	83	845	83

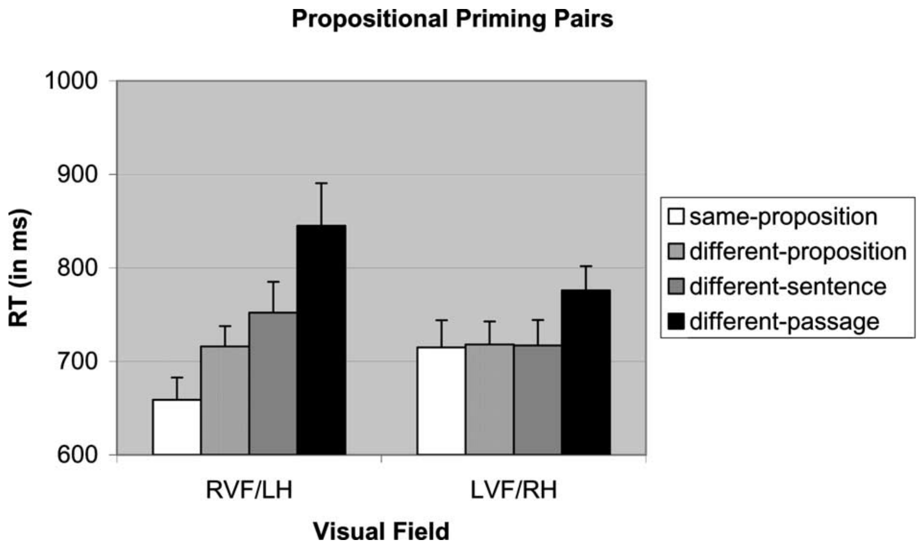

Fig. 3. Item priming results from Experiment 1b. Mean response times (in milliseconds) to targets as a function of prime–target condition and VF. Error bars depict standard errors.

The results of Experiment 1b are similar to those reported by Long and Baynes (2002), suggesting that the LH has a representation of discourse that is structured in terms of propositional relations. We found priming effects that reflected the linear distance between primes and targets in the propositional structure of the passages. We also found that embedding a clause between the nouns in the same-proposition condition did not affect the priming results. This addresses our concern that the LH propositional priming results observed in Long and Baynes merely reflected the LH's sensitivity to the canonical syntactic structure of their sentences. In the current experiment, the primes and targets in the same-proposition condition were still part of a syntactic constituent, but the canonical NVN structure was disrupted by an embedded clause in the clause-present condition. Nonetheless, participants experienced the greatest facilitation in the same-proposition condition and this facilitation did not differ by clause condition. Thus, it appears that the LH was sensitive to the underlying structural relations among the concepts in the sentences, not merely to their physical proximity in the surface structure of the passages.

With respect to priming in the LVF/RH, we found that the RH was insensitive to the structural relations among concepts within a passage. We found no reliable priming differences among the same-proposition, different-proposition, and different-sentence conditions. We did find, however, that participants responded faster in these three conditions than they did in the different-passage condition. Thus, the RH appeared to represent concepts within a passage separately from concepts in other passages.

One explanation for the priming results in the right hemisphere is that the nouns within a passage were linked by virtue of the semantic information conveyed by the passage. That is, concepts such as *hunter*, *pheasant*, *deer*, and *birds* were associated in the right hemisphere because they were all entities in the same context. Thus, responses were faster when primes and targets were from the same passage than when they were from different passages. Of course, it is also possible that the priming results in the RH may have nothing to do with how it represented the passages. Rather, priming may have reflected pre-existing semantic relations between primes and targets on the test list. That is, primes and targets in the same-proposition, different-proposition, and different-passage condition may have been similarly related, whereas primes and targets in the different-passage condition may have been more distantly related.

We examined the possibility that our priming results reflected processing that occurred at test by first examining association norms for evidence that test items in the different-passage condition were more distantly related than were test items in the other conditions. We used the Florida Free Association Norms as our source (Nelson, McEvoy, & Schreiber, 1998). We found that most of our targets were not produced as associates to our primes. Of the 192 primes, 175 appeared in the norms. Of these 175 primes, only 7 had one of our targets produced as an associate. The mean association was low for all prime–target types ($M = .00$, $M = .35$, $M = 1.80$, $M = .00$, same-proposition, different-proposition, different-sentence, and different-passage, respectively). Given that our targets were rarely produced as associates to our primes, the association norms provide limited information about semantic relatedness. Thus, we conducted Experiment 2 to investigate the role of pre-existing semantic relations in our priming results.

5. Experiment 2

We used a lexical decision task in Experiment 2 to examine the semantic relatedness among our primes and targets. Participants received blocks of trials in which they made word/non-word judgments to a series of letter strings. Embedded in each block were the prime–target pairs from Experiment 1, as well as the filler items and a number of non-words. Primes were always presented centrally; targets were presented to the LVF/RH or the RVF/LH. Participants never saw the passages associated with the primes and targets. If the priming results that we observed in Experiment 1b were due to processes that occurred at test, then we should find facilitation to targets preceded by primes in the same passage relative to targets preceded by primes from different passages.

5.1. Method

5.1.1. Participants

Participants were 114 undergraduate psychology students who received course credit for their participation (71 women and 43 men). All participants spoke English as their first language, and none had a diagnosed reading or learning disability. In addition, all were right-handed and had normal or corrected-to-normal vision.

5.1.2. Materials

The set of lexical-decision items included the prime–target pairs and filler items from Experiment 1. In addition, we selected an equal number of pronounceable non-words from a previous study by Long, Golding, and Graeser (1992). The items were arranged in 12 blocks as in Experiment 1. Each block contained 4 prime–target pairs, 16 fillers (words), and 24 non-words. We also constructed a list of items to be used in a practice block. This list contained 24 words and 24 non-words. The prime–target pairs were counterbalanced both within and across material sets.

5.1.3. Procedure

Participants were seated 57 cm from a computer screen. Each block of lexical-decision items was preceded by an instruction to press the space bar when ready to begin the task. The participants' key press was followed by presentation of a fixation point in the middle of the screen. The fixation point remained on the screen until all items had been presented. Participants were told to keep their eyes on the fixation point throughout the test. Test items were presented for 100 ms each and appeared in one of three positions: (1) in the center of the screen, immediately above the fixation point; (2) in the LVF/RH, such that the end of the word was 1.5° of visual angle to the left of fixation; or (3) in the RVF/LH, such that the beginning of the word was 1.5° of visual angle to the right of fixation. The block of letter strings began with three items (fillers and non-words). The priming pairs were presented randomly in the remainder of the list, separated by intervening fillers and non-words. A filler or non-word followed the last priming pair in the list. Primes were always presented centrally; targets appeared equally often to the left and right of center. Fillers and non-words were presented randomly in one of the three positions on the screen.

Participants pressed a key labeled "yes" if a letter string was a word and a key labeled "no" if it was not a word. Participants were told to keep their index fingers on the yes and no keys at all times. Response hand was counterbalanced across participants. We recorded responses and response latencies to each item. Latencies were recorded from the offset of the test item. Participants received the 12 blocks in random order. A practice block preceded the 12 experimental blocks.

5.2. Results and discussion

We performed separate 2 (VF) × 2 (response hand) × 4 (prime) repeated-measures ANOVAs on accuracy and reaction times to the lexical-decision targets. VF (LVF/RH and RVF/LH) and prime (same-proposition, different-proposition, different-sentence, and different-passage) were within-participants factors. Response hand was a between-participants factor. Only correct responses were included in the analyses of the reaction-time data. All latencies three standard deviations from a participant's mean were treated as missing data. All effects were tested at a significance level of $p < .05$ unless otherwise indicated. Mean response times appear in Table 5 and Fig. 4.

Our analysis of the reaction-time data revealed a reliable effect of prime condition, $F(3,336) = 3.25$, $MSe = 83616.75$, and an effect of response hand that was marginally reliable, $F(1,112) = 3.11$, $MSe = 597{,}029$, $p = .08$. Participants responded faster with their right hand ($M = 704$) than with their left hand ($M = 766$). We also found a marginal VF × prime interaction, $F(3,336) = 2.50$, $MSe = 108{,}703$, $p = .06$. With respect to targets presented in the RVF/LH, responses were somewhat faster in the different-proposition and different-sentence conditions than in the same-proposition and different-passage conditions; however, the effects were

Table 5
Mean reaction times (RT, in milliseconds) and accuracy rates (AR, in percentages) as a function of prime and VF

Prime condition	Visual field			
	LVF/RH		RVF/LH	
	RT	AR	RT	AR
Same-proposition	758	75	738	82
Different-proposition	751	81	715	84
Different-sentence	762	78	704	83
Different-passage	754	78	721	83

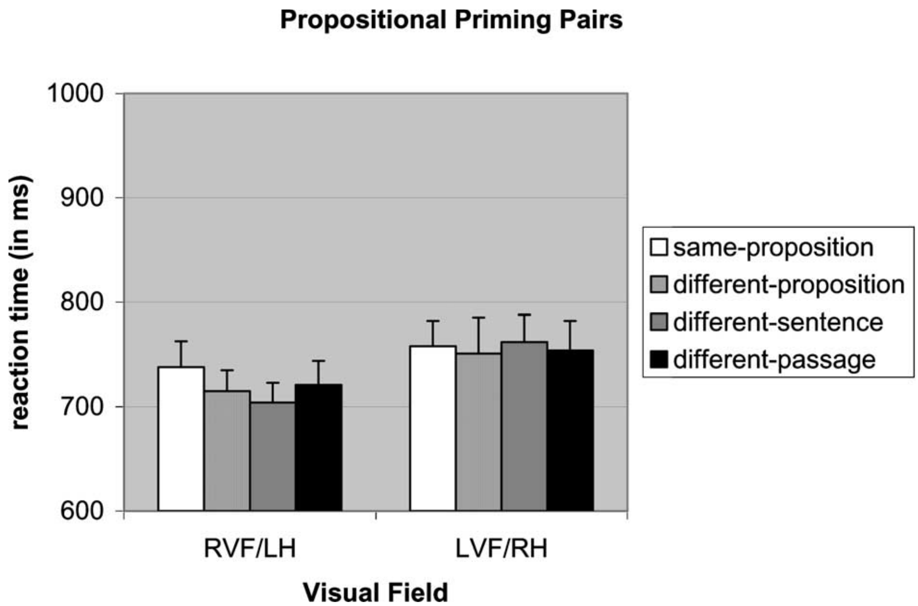

Fig. 4. Lexical decision results from Experiment 2. Mean response times (in milliseconds) to targets as a function of prime–target condition and VF. Error bars depict standard errors.

not reliable, Fs < 1. We found no priming differences for targets presented in the LVF/RH.

Our analysis of the accuracy data revealed reliable effects of response hand, $F(1,112) = 12.68$, $MSe = 4.00$, and prime condition, $F(3,336) = 3.97$, $MSe = .71$. Participants were more accurate when they responded with their right hand ($M = 86\%$) than when they responded with their left hand ($M = 75\%$). Participants were also more accurate in the different-proposition condition than in the same-proposition condition, $F(1,112) = 5.17$, $MSe = .14$. None of the other comparisons were reliably different.

Our goal in this experiment was to determine whether the priming effects in Experiment 1b were due to processes that occurred at test and had nothing to do with how readers represented information in the passages. A visual examination of our materials clearly suggests that some of our prime–target pairs are thematically related. For example, the primes, *pheasant*, *deer*, and *birds*, are thematically related to the target, *hunter*. Likewise, in another of our passages, the primes, *musician*, *lights*, and *audience*, are thematically related to the target, *stage*. The results of this experiment, however, suggest that, in the absence of the contexts that the passages provide, the primes and targets are not sufficiently related to yield robust priming in a lexical-decision task. Although we found a reliable main effect of prime condition in our analysis of the reaction-time data, the follow-up analyses yielded no significant effects. Moreover, the pattern of reaction times differed from the pattern observed in Experiment 1b. In Experiment 1b, we saw faster responses in the same-proposition condition relative to the other conditions when targets were presented in the RVF/LH. In contrast, the pattern in Experiment 2 showed almost no response differences among the various prime–target conditions.

6. General discussion

Our results suggest that the two cerebral hemispheres represent explicit information in a short passage quite differently. The left hemisphere contains a representation that reflects the distance among concepts in the propositional structure of the passage. Participants in Experiment 1b responded faster when a target was preceded by a prime from the same proposition than when it was preceded by a prime from a different proposition in the same sentence. Likewise, participants responded faster when a target was preceded by a prime from the same sentence than when it was preceded by a prime from a different sentence in the same passage and faster when a target was preceded by a prime from the same passage than when it was preceded by a prime from a different passage in the same block of passages. We found this linear-distance effect, however, only when targets were presented in the RVF/LH.

Although we have discussed our left hemisphere priming results as evidence of a representation that is structured propositionally, consistent with similar results in the discourse processing literature (Long et al., 1997; Ratcliff & McKoon, 1978), we acknowledge that the relations among our primes and targets are not just propositional; they are also syntactic. In our materials, as well as the materials used in other studies of discourse representation, propositional structure is confounded with syntactic structure. Nouns in the same proposition are almost always also nouns in the same syntactic constituent. Thus, we cannot say that our priming effects are due to propositional distance rather than syntactic distance in a hierarchically organized sentence representation. We can say, however, that nouns in the same proposition do not have to be part of a canonical NVN structure to produce the pattern of priming that we saw in Experiments 1a and 1b. Embedding a clause between the nouns in the same-proposition condition had no effect on priming.

When targets were presented to the LVF/RH in Experiment 1b, we also observed a priming effect. The pattern, however, was quite different from the one that we observed when targets were presented to the RVF/LH. In the LVF/RH, participants responded faster when targets were preceded by primes from the same passage (same-proposition, different-proposition, and different-sentence conditions) than when they were preceded by primes from a different passage. This result extends previous research by Long and Baynes (2002) on the nature of discourse representation in the right hemisphere. They examined only the representation of concepts within a sentence and found no evidence for a structured representation in the right hemisphere. In the current study, we examined relations among concepts within sentences, across sentences, and across passages. Our results suggest that the right hemisphere represents the concepts within a passage separately from concepts in other passages. However, the right hemisphere, unlike the left hemisphere, does not appear to represent the structural relations among concepts within a passage.

In Experiment 2, we tested one explanation for our right hemisphere priming effects. We hypothesized that lexical priming at test might be responsible for closer relations among concepts within a passage than those between passages. Specifically, we hypothesized that our primes and targets in the within-passage conditions (same-proposition, different-proposition, and different-sentence conditions) might have stronger pre-existing, lexical-semantic relations than our primes and targets in the between-passage condition. This might result in priming at test even if participants never saw the passages from which the primes and targets were selected. Our results, however, were not consistent with this hypothesis. The targets were not related enough to the primes to be produced as associates in a free association task, nor were they related enough to produce robust priming in a lexical-decision task.

Although lexical-semantic priming at test does not appear to explain our right hemisphere priming results, we do not claim that lexical-semantic information played no role in how the right hemisphere established connections among concepts within a passage. Rather, we claim that semantic associations among the primes and targets are insufficient to produce priming in the absence of the passages, nor do they provide a basis for the pattern of results that we have observed. The passages provide a necessary context for establishing connections among concepts contained in the same passage.

Pre-existing semantic or thematic relations provides one means by which the right hemisphere may be organizing explicit information from discourse. In the context of the passage, activated words and phrases may have sufficient semantic overlap for connections to be formed in memory. There are other ways in which these connections might be formed, however. For example, the right hemisphere may form an episodic connection among the concepts in a passage. In this study, words and phrases within a passage were always presented as a single item on the screen, distinct from other passages, which appeared on separate screens. If the right hemisphere is sensitive to temporal information, concepts within a passage will have closer temporal connections than will concepts across passages. Further research will be necessary to determine the precise nature of the connections that organize discourse concepts in the right hemisphere.

In summary, this study extends our knowledge about how discourse is represented in the two cerebral hemispheres. Both hemispheres contain a representation of explicit information from a text, but appear to organize this information differently. The left hemisphere contains a representation that is structured according to propositional (or syntactic) relations. The right hemisphere represents concepts within a passage, but we found no evidence that these concepts are organized structurally. Rather, the right hemisphere represents concepts within a passage similarly, but distinct from concepts in other passages.

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