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Neural and Behavioral Indicators of Integration Processes across Sentence Boundaries

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A fundamental characteristic of a text is that its sentences are not unrelated but cohere. To understand a text, a reader must therefore cognitively establish specific relations between a new statement and the previously read text. The coherence between sentences can be established by different kinds of integration processes: anaphora resolution, memory processes that resonate for words with related meanings (O'Brien, Rizzella, Albrecht, & Halleran, 1998), and more effortful inference processes that are driven by a search for meaning (Graesser, Singer, & Trabasso, 1994). These processes may work at different levels of a text representation (cf. van Dijk & Kintsch, 1983; Fletcher, 1994). Anaphora resolution may occur at a linguistic level creating argument overlap (Kintsch & van Dijk, 1978), resonance processes may be strongly memory-based, and the more effortful inference processes may occur at the situational level, as suggested by Schmalhofer, McDaniel, and Keefe (2002).

Readers process a text sequentially word by word. We can thus investigate how the proposed integration processes unfold at one word or another or at two subsequent words (e.g., a noun followed by a verb) that reference a proposition. Such two-word combinations may also be employed in verification tasks (cf. Griesel, Friese, & Schmalhofer, 2003).

So far, research on word-level effects across sentence boundaries is relatively sparse. In one example of "on-line" word comprehension research, Van Berkum, Zwitserlood, Haagort, and Brown (2003) investigated when and how listeners bring the knowledge from the prior discourse to bear on the processing of the final word in a new sentence. They presented sentences like *Jane told the brother that he was exceptionally slow* and measured ERPs on the word *slow*, when the preceding two sentences had established that her brother was indeed fast. In a second experimental condition, the previous sentence context had established that her brother was indeed slow. The discourse-anomalous words (e.g., the word *slow* after sentences had established that the brother was indeed fast) elicited an N400 effect that started 150–200 ms after the acoustic word onset.

In similar experiments, van Berkum, Hagoort, and Brown (1999) investigated how the presence of one or two possible referents in a preceding sentence would influence the processing of a noun phrase in the middle of the next sentence. In their ERP experiment, the waveforms showed that within 280 ms after the onset of the critical noun, the brain was already differentially influenced by whether the noun phrase had a unique referent in the earlier discourse. Their results show that the discourse context from preceding sentences can affect the comprehension of a word quite rapidly. van Berkum et al. (2003) thus concluded that the contact between a preceding discourse and the unfolding of the visual or acoustic signal of the newly presented word occurs quite early during the processing of a word in sentence-medial and sentence-final positions.

Integration across sentence boundaries has been most prominently discussed in the literature on inference processes in text comprehension (McKoon & Ratcliff, 1992; Graesser et al., 1994; Graesser et al., this volume). Automatic and memory-based processes (McKoon & Ratcliff, 1992; Gerrig & O'Brien, 2005), as well as explanation-based or "search after meaning" related processes (Long & Lea, 2005), have been explored by numerous experimental studies for almost two decades. The results of these behavioral experiments show that both types of processes may occur in establishing coherence across sentence boundaries.

In this chapter, we explore whether ERP and brain imaging (fMRI) studies can contribute any additional knowledge to our understanding of inference and integration processes in text comprehension that has not already been unraveled by behavioral experiments on inferencing and integration processes in text comprehension. It is sometimes argued that ERP and brain imaging data would provide no more than additional correlates for the systematic effects in human behavior without enhancing our scientific understanding of human cognition and comprehension processes.

We thus proceed as follows. First, we focus on a set of experiments that—at least for some time—had attained pivotal significance in the inferencing literature concerning memory-based and explanation-based processes in online inferencing. We then review three experiments that used essentially the same experimental materials, and similar procedures and tasks. The first experiment was intended to replicate a previously established experimental finding so that the particular procedures would also be well suited for an ERP as well as an fMRI experiment. In other words, we designed the behavioral experiment so that we would get a maximum of overlap in materials, independent variables, and experimental procedures among the behavioral, EEG, and fMRI experiments. The experiments, of course, differ in what they measure. The behavioral experiments measure response latencies, the EEG experiments measure voltage shift components (N400; P300), and the fMRI experiment records the brain areas that become differentially activated (as indicated by the bold signal).

EXPERIMENTS ON WORD-TO-TEXT INTEGRATION AND INFERENCE PROCESSES

Our general question is how prior contexts affect the processing of a single or a few words at the beginning of a new linguistic processing unit (e.g., the beginning of a sentence) or when a statement has to be verified with respect to a previously read text. Across the three experiments that address this question, materials and procedures were very similar, with only a few modifications needed to obtain the necessary sensitivity in the dependent measures. These modifications concerned the task instructions and some minor differences in the analyzed stimulus segments.

Experimental Conditions

There were four different conditions in which the preceding context was manipulated. In the *explicit repetition condition*, the first content word at the beginning of the second sentence had appeared toward the end of the first sentence. (More specifically, what was repeated was the word's morphological stem, with inflectional variations counting as explicit repetition.) In the three other conditions, the beginning of the second sentence was also identical to the explicit repetition condition, but the first sentence was slightly modified. In the *repetition by paraphrase* condition, a synonym or paraphrase of the critical word was used in the first sentence. In the *implicitly primed condition*, the first sentence was modified so that the critical event might be inferred by a predictive inference. The critical event was thus not explicitly mentioned. Finally, in the *novelty condition*, the first sentence was again slightly modified so that it neither contained the critical word that began the second sentence nor implied any referential link to it. In short, we will refer to the four conditions as 1) *explicit*, 2) *paraphrase*, 3) *implicit*, and 4) *novelty* conditions. Table 7–1 shows example materials for the four conditions. (Yang et al. (under review) labeled the last two conditions as inference and baseline, respectively.)

The presentation of the texts in the three experiments was as follows. Each word was presented for 300 ms, with an inter-word interval also of 300 ms. In the ERP experiment, an additional blank interval of 300 ms was added at the end of the first sentence. In the behavioral and fMRI experiments, a somewhat longer interval of 1.7 sec was used so that the bold signal from reading

TABLE 7–1.
Example Materials for the Four Experimental Conditions (Explicit, Paraphrase, Implicit and Novelty) and the Two Additional Conditions That Were Used in Experiment 2 and 3 (Filler and Pseudoword)

Phases	*Words*	*Explicit*	*Paraphrase*	*Implicit*	*Novelty*	*Filler*	*Pseudoword*
Header	1	Garden	Garden	Garden	Garden	The	Euwi
	2	work	work	work	wok	Dog	qaszo
Reading	3	Steve	Steve	Steve	With	Michael	With
phase	4	saw	saw	saw	the	committed	anbyv
	5	that	that	that	turn	to	Naa
	6	the	the	the	of	take	kentragle
	7	grass	grass	grass	the	care	Uode
	8	was	was	was	seasons,	of	Uv
	9	dry,	dry,	dry,	Steve	the	God
	10	went	went	went	went	neighbours'	II
	11	outside	outside	outside	outside,	dog	lizle
	12	to	and	to	across	during	im
	13	turn	turned	turn	the	their	heene
	14	on	on	on	dry	holidays.	od
	15	the	the	the	grass,	He	wonuxe
	16	hose	hose	hose,	and	fed	rusq
	17	and	and	which	brought	him	uob
	18	watered	sprinkled	was	in	twice	risy
	19	the	the	quite	the	a	hiw
	20	lawn.	lawn.	long.	hose.	day.	nez
Verification	21	Lawn	Lawn	Lawn	Lawn	Holiday	hiw nez
task	22	watered	watered	watered	watered	postponed	
(exp. 2 and 3)							
Continued	The	The	The	The	The		
reading	water	water	water	water	water		
(exp. 1)	was	was	was	was	was		
	. . .	. . .	. . .	. . .	. . .		

Note. Experiment 1 employed the continued reading task and collected the ERP signals on the critical ward of the second sentence (e.g. "water"). The headers and the filler and pseudoword conditions were only used in Experiment 2 and 3. Instead of continued reading, Experiments 2 and 3 employed the verification task where the statement "lawn watered" indicated the statement "The lawn was watered." In Experiment 3, the BOLD response was analyzed for the 1.8 second time period during which a statement was typically processed.

the sentence would have more time to settle before the processing of the critical words of the statement verification task.

There were also differences in the particular task the subjects had to perform and in the dependent measure. In the first experiment, EEG signals were recorded when subjects read the critical word (e.g., *water*) of the second sentence (see Table 7–1). In the second experiment, two words (e.g., *lawn* *watered*) were presented, but now the task became to verify whether the statement that was implied by these words (i.e., *the lawn was watered*) was true or false. This verification was to be performed with respect to the situation that has been described by the preceding sentence (see Table 7–1). The response and its latency were recorded as dependent measures. Verification explicitly requires integration, and reading requires integration implicitly, because readers usually relate a newly read statement to the previous context (Singer, 2004; van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005). The third experiment was an fMRI experiment and was identical to the second one, except that the participants were now lying in a scanner so that the BOLD-signal could be recorded as an additional dependent measure.

Combining the Experiments to Draw Conclusions

We thus report the three experiments (with behavioral data, ERP, and BOLD responses collected), which uniformly employed 1) explicit repetition, 2) repetition by synonym, 3) implicitly primed, and 4) novelty as the crucial independent manipulation. We expected that the differences among experimental conditions would signify the relative duration and results (Experiment 1), the critical timing (Experiment 2), and the location (Experiment 3) of the effects of these conditions on the specific instantiation of the cognitive integration process across a sentence boundary.

EXPERIMENT 1

For the four experimental conditions, the participants' responses as well as the latencies of the responses were recorded as the dependent measures. A filler condition and a pseudo-word condition, for which the participants performed a recognition rather than a verification task, were also included.

Participants

Forty students (19 women and 21 men) from the University of Osnabrück between 19 and 29 years of age (average 21 years) participated in the experiment for course credit. The design and experimental procedure were completely identical to the subsequently reported fMRI experiment.

Results

The left side of Table 7–2 shows the proportion of correct responses in the four experimental conditions together with the pseudo-word condition and the mean latencies for the correct responses. There was a significant difference in the mean latencies among these five conditions ($F(4,156) = 19.7$, $p <$

TABLE 7–2.
Mean Response Latencies and Response Frequencies
From Experiment 2 and Experiment 3.

	Behavioral Study N = 40 (Experiment 2)			*fMRI-Experiment N = 13 (Experiment 3)*		
Condition	**Response freq. (SE)*	*Response time in ms (SE)*	*t-test (Response time difference)*	**Response freq. (SE)*	*Response time in ms (SE)*	*t-test (Response time difference)*
Pseudo-word	.94 (.02)	826 (43)	$t(39) = .62$, $p > .05$	1 (.00)	828 (37)	$t(12) = 3.01$, $p < .01$
Explicit	.99 (.00)	850 (28)	$t(39) = 3.45$, $p < .01$	.99 (.01)	961 (54)	$t(12) = 1.19$, $p > .05$
Para-phrase	.98 (.01)	886 (29)	$t(39) = 4.59$, $p < .01$	.98 (.01)	999 (57)	$t(12) = 2.45$, $p < .05$
Implicit	.89 (.02)	994 (45)	$t(39) = 2.04$, $p < .05$	.89 (.04)	1085 (61)	$t(12) = 2.56$, $p < .05$
Novelty	.93 (.01)	1058 (38)		.90 (.02)	1207 (65)	

* Response frequencies denote the relative frequency of correct responses (hits and correct rejections) in the pseudoword conditon and the relative frequency of "yes"-responses in the explicit, paraphrase and implicit conditions. In the novelty condition the proportion of "no" responses is indicated.

This behavioral experiment clearly indicated latency differences between various conditions. It thus becomes a quite interesting question whether different ERP-components can be found for those conditions and whether such results would then be contradictory or consistent to the latency differences of the behavioral experiment.

.001). Pairwise *t*-tests furthermore showed that the latencies of explicit, paraphrase, implicit, and novelty conditions were all significantly different from each other (see Table 7–1). The latencies increased monotonically from the explicit condition to the paraphrase, implicit, and novelty conditions, which showed the longest latency. The largest latency difference of 108 ms between adjacent experimental conditions occurred between the paraphrase and the implicit conditions. This condition difference was also most reliable with the highest *t*-score. The latency difference between the explicit and the paraphrase conditions, on the other hand, was only 36 ms, and the difference between the inference and the novelty condition was 66 ms.

EXPERIMENT 2

In the experiment by Yang, Perfetti, and Schmalhofer (submitted), 16 native English-speaking students from the University of Pittsburgh read 120 two-sentence texts, ranging between 13 and 43 words, with an average of

28 words. Each of these passages occurred in one of the four different conditions, as is shown in Table 7–1. The experimental manipulations were counterbalanced across 4 groups of 4 subjects each and the four sets of materials by a Latin-square. Each participant read about each setting and event only once while contributing 30 trials to each of the four experimental conditions. Participants were individually tested in a series of two experimental blocks which lasted between 60 and 90 minutes. The 120 trials were presented in a random order.

Instruction and visual stimuli were presented on a 15-inch CRT monitor. The experimental trials were controlled by experimental software that presented the trials and recorded relevant trial information and sent event information to the electroencephalogram (EEG) recording system (Net Station, Electrical Geodesics Inc., Eugene, Oregon). The EEG was recorded using the 128 Electrical Geodesics system (Tucker, 1993) consisting of Geodesic Sensor Net electrodes, Netamps and Netstation software running on an Apple Macintosh 1000MHz computer. The data were recomputed off-line against the average reference, the vertex (Lehmann & Skrandies, 1980). Impedances were maintained below 50 kΩ, an acceptable level for the electrodes and amplifier used (Ferree, Luu, Russell, & Tucker, 2001; Tucker, 1993). The EEG was amplified and analog filtered with .1 Hz to 100 Hz bandpass filters, referenced to the vertex, and a 60 Hz notch filters then digitized at 250 Hz. Six eye channels were used to monitor the trials with eye movement and blinks. The EEG signals were recorded continuously at 250 Hz by the Net Station with a 12 bit A/D converter. The EGI Net Station also recorded all event onset times, and accuracy for later analysis.

To orient a participant's visual attention, a fixation mark was presented at the center of the computer screen at the beginning of each trial. After a subject started a trial by pressing the space-bar, a text passage was then presented one word at a time in the center of the screen. Each word was presented for 300 msec with an additional 300 ms blank interval before the next word. A comprehension question was presented intermittently, approximately every fourth trial. After answering the two alternative forced choice questions, the subjects were informed of whether or not their answer was correct.

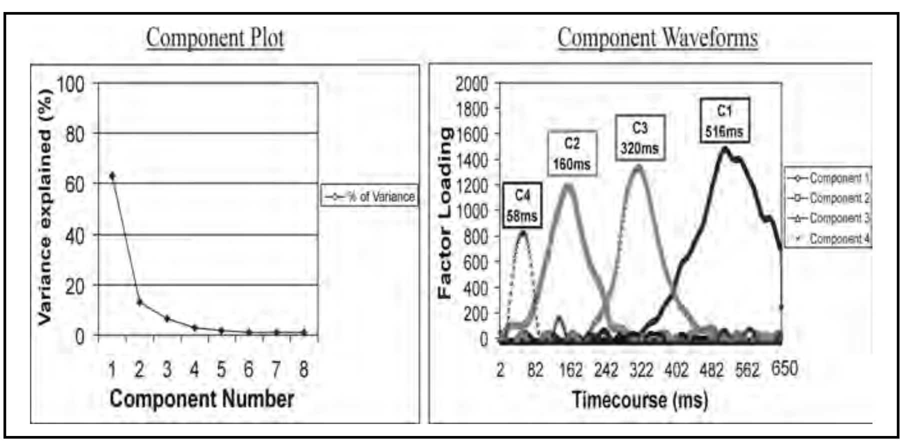
Yang et al. segmented the EEG data into 900 ms epochs spanning 200 ms pre-stimulus to 700 ms post-stimulus for the critical word (e.g. "water"). There were a total number of 30 possible trials per participant per condition. Preprocessing and filtering procedures for eliminating noise were applied in a standard manner. The 200 ms pre-stimulus period was used for baseline correction. The ERP-data were also re-referenced to an average reference frame so that a possible topographic bias that can result from selecting a specific reference site was removed.

Results

Three different types of analyses were performed. A temporal PCA analysis was performed to identify the number and types of significant components which are present in the EEG-data of processing the critical word. Such a PCA analysis resembles a factor analysis in that it determines how many orthogonal components or factors are needed to account for the statistically reliable variation in the data. A PCA analysis is therefore suited to determine which and how many components there are in the data, without specifying in which condition these components have occurred. Each factor can be considered to represent a particular pattern of neural activity over time associated with the cognitive process of integrating across a sentence boundary. More specifically, when we observe a difference between two experimental conditions, this difference would be attributed to differences in how the preceding context affect the processing of the critical word. In other words, differences among the experimental conditions may be attributed to the differences in the cognitive processes of immediate integration across sentence boundaries.

The results from the PCA-analysis are shown in Figure 7–1. The PCA extracted 4 significant factors that accounted for 85% of the total variance from the 325 sampling points corresponding to each 2 ms ERP time frame. The components C1, C2 and C3, together explained 82% of the total variance. The component C4 is an exogenous component (3% additional variance) and thus an artifact with respect to our interest of analyzing brain waves. It was therefore excluded from the analysis. On the basis of their profiles, the C1, C2 and C3 components can be described as N400, P300 and N200.

Furthermore, analyses of Variance (ANOVAs) were performed on the component scores of the three temporal factors (C1, C2, and C3). Thereby, the three midline electrodes (Fz, Cz, and Pz) were used to assess the medial areas. The lateral areas were assessed by four pairs of bilateral electrodes (F3–F4, C3–C4, P3–P4, and T3–T4). Figure 7–2 shows the grand average ERPs for the four different experimental conditions during the processing of the critical



AU: Pls. provide figure caption

FIGURE 7–1. (Caption ?)

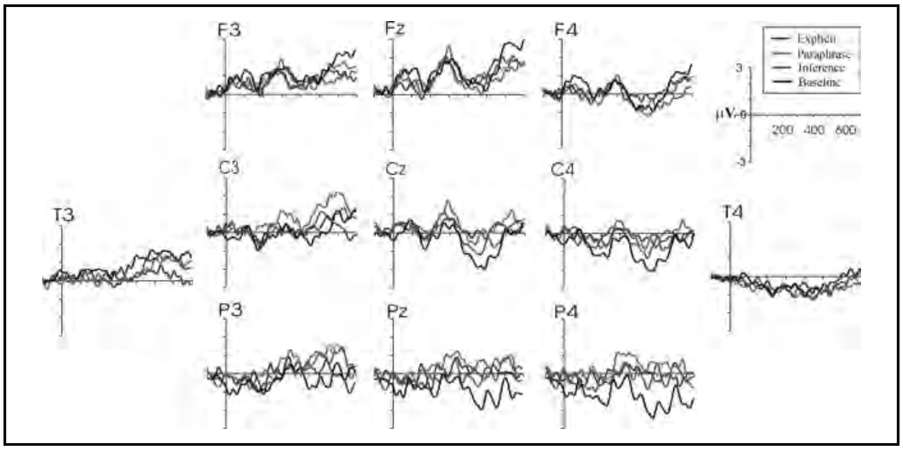


FIGURE 7–2. (Caption ?)

AU: Pls. provide figure caption

target word. The recording sensors that correspond to the international 10/20 system are shown.

The analysis of the midline area revealed significant differences among the four experimental conditions for the N400 component ($F(3,45) = 5.14$; $p = 0.004$ and the P300 component ($F(3,45) = 4,03$; $p = 0.015$). For both of these components, there were also significant differences among the electrodes but no significant interaction between the electrodes and the experimental conditions. The N200 component did not show any significant differences in this analysis.

The analysis of the lateral areas did not show any significant main effect among the experimental conditions for the three components (all Fs < 1). For the P300 component there was a significant effect for the electrodes ($F(3,45) = 7,73$, $p = 0.001$). For the N200 component, the experimental conditions interacted significantly with the electrodes ($F(9,135) = 2.03$, $p = 0.040$), possibly due to a significant difference between the hemispheres ($F(1,15) = 8,70$, $p = 0.010$). Finally, for the N200 component, there was also a significant electrodes by hemisphere interaction $F(3,45) = 3,84$; $p = 0.035$. None of the other comparisons yielded significant differences.

In sum, the most convincing differences were observed in the analyses of the medial locations where main effects of the experimental conditions occurred for the P300 and the N400 component but not for the N200 component. Although Yang et al have performed more detailed analyses for the N200 component which yielded some significant interaction effects, in reporting the pair-wise comparisons, we will restrict our attention to those components which showed a main effect among the experimental conditions, namely the P300 and the N400 components.

Pair-wise comparisons of the P300 component showed that the paraphrase condition yielded a significantly higher amplitude than the novelty condition

($t(15) = 3{,}13$; $p < 0.01$), while the difference between paraphrase vs. explicit condition was only marginal ($t(15) = 2{,}01$; $p = 0.06$). The average of the explicit condition and the paraphrase condition was higher than the mean amplitude of the implicit and the novelty conditions, but this difference was not significant ($t(15) = 1{,}84$, $p = 0.08$). The paraphrase condition had a significantly larger amplitude than the average of the implicit and the novelty condition ($t(15) = 2{,}52$, $p < 0.05$), but the explicit condition was not significantly higher than the average of the implicit and the novelty condition ($t(15) = 0.33$, $p = 0.75$).

In summary, these comparisons suggest that at about 300 ms, a paraphrase word attracts additional processing relative to all other conditions. Although we specifically targeted the N400 as the indicator of integration, we may need to consider the P300 component as part of the cognitive integration process across a sentence boundary. Such early integration processes may not occur in the implicit and the novelty conditions because the informational prerequisites for such processing are not present in the respective stimulus materials. An early integration process at around three hundred milliseconds may only occur when there is a direct conceptual match with a preceding sentence.

In case these prerequisites are not satisfied, as in the implicit and the novelty conditions, the cognitive processes that achieve the integration occur somewhat later and possibly in a different manner. If so, a prediction is that an N400 effect should be observed only for those conditions that did not produce early effects in the ERPs, namely the implicit and the novelty conditions. Indeed, this prediction was actually confirmed.

For the N400 component (300–550 ms time window), both the implicit and the novelty conditions produced larger amplitudes than the explicit and the paraphrase conditions. The pair-wise comparisons showed significant differences between the explicit and the implicit conditions ($t(15) = 11{,}35$, $p < 0.001$), between the explicit and the novelty conditions ($t(15) = 6.96$, $p < 0.001$, and between the paraphrase and the novelty conditions $t(15) = 12.05$, $p < 0.001$. Neither the differences between explicit and paraphrase conditions nor between implicit and novelty conditions were significant.

These ERP results can thus be summarized in a concise way. When there is an explicit or a conceptual match between a word at the beginning of a sentence and the contents of a preceding sentence, integration across a sentence boundary may occur as early as 200 or 300 ms after the onset of the word. When there is only an implicit overlap or a concept is newly introduced, the integration processes may occur later because the informational prerequisites for an early integration are not given under these circumstances.

These ERP results thus hint at a differentiation of the integration process into two episodes and early one (around 200–300 ms) and a later one (around 300–550 ms). The four experimental conditions were clearly separated by these two episodes. The paraphrase (as well as the explicit) conditions were associated with the early episode and the implicit and the novelty condition were associated with the late episode.

Discussion

These results indicate that one can differentiate between early and late components. The early components were observed for the explicit and the paraphrase conditions and the late component for the implicit and the novelty condition For interpreting the results more fully, it will be useful to specify the cognitive processes which may occur when the first sentence is read as well as the subsequent processes which occur during the processing of the first content word of the following sentence.

In the novelty condition, a referent must be established and integrated into the previously established situation model. The integration processes across sentence boundaries can thus be subdivided into two components. One component may indicate the construal of the new referent associated with the newly read word. A second component may indicate the relational processes which are necessary to integrate this referent into the situation specified by the previous sentence. The substantial amplitude of the N400 component in the novelty condition may indicate that both of these processes are performed in the novelty conditions or, alternatively, that referent construction and discourse integration are so tightly interwoven that one may consider this to be only one immediate integration process.

The implicit condition is somewhat different. In order to achieve an integration a new referent must at least be partially constructed for the given situational context, when a predictive inference was not fully constructed in the preceding sentence (McKoon & Ratcliff, 1992, McDaniel, Schmalhofer & Keefe, 2001). To the extent that the predictive inferences were fully drawn, the implicit condition would be similar to the explicit and paraphrase conditions.

In the explicit condition, a referent has already been mentioned and situationally established by the preceding sentence. Therefore no construction processes but only memory maintenance and immediate integration processes would be required. Such processes should occur much earlier in processing time.

Paraphrases may also allow for a rather effortless integration, but a more coarse grained memory maintenance and integration would be required as compared to the repetition by of a lexical root in the explicit condition. An integration could thus be achieved via an episodic memory trace to the referent that was established by the preceding sentence. In comparison to the explicit condition such an episodic memory match would require a more coarsely grained rather than a fine grained match. The P300 effect could indicate this process.

The ERP results converge with the results of Experiment 1, despite the differences in tasks and measures. The ERP results, moreover, go beyond what can be obtained in the response times, by exposing both early and later components associated with integration, and further suggesting that differences in response latencies between conditions (e.g. between paraphrase and implicit conditions) may reflect neural processes that are temporally differentiated during the reading of the word.

EXPERIMENT 3

The third experiment was conducted with exactly the same materials as experiment 2 while the BOLD-signal was recorded by fMRI, which can provide a good spatial resolution of the physiological correlates of neural processing. In this fMRI-experiment, we can further corroborate the differences in the integration processes across sentence boundaries between the paraphrase condition and the implicit condition. If, in the paraphrase condition, the integration occurs by retrieving, activating and modifying a episodic memory trace, we should find brain areas active that are involved in memory processes. On the other hand, if the implicit condition requires more constructive processes at a situational level, we should find different areas active, in particular areas in the prefrontal brain.

Method

Participants. Thirteen right handed students with a mean age of 22.8 years, all native speakers of German (7 women, 6 men) participated and received course credit.

Procedure. All subjects received written instructions as well as a training session outside the scanner to become familiar with the type of stimuli and the corresponding tasks. Participants were instructed to press the YES key when the test statement was true with regard to the situation described by the just read sentence and the NO key otherwise. For the pseudo-word condition (see Table 7–1), they were told to press the YES key when the pseudo-words of the test statement were identical to the last two presented letter stings of the pseudo-word reading phase and the NO key otherwise.

After a training session in the scanner, participants were presented with the three functional scanning sessions. Each session took 16 min 12 sec. The participants were allowed to rest up to three minutes between sessions.

For each trial, the words of a sentence were displayed by a rapid serial visual presentation (RSVP) technique. All MR-images were acquired in a 1.5 T Siemens Sonata whole body MRT equipped with an 8-channel head coil (MRI-devices). Data analyses were performed by applying the customary analysis steps with SPM2 (for more details on these steps see Schmalhofer et al., 2005). A general linear model was applied to the individual data. For each condition, the processing of the title, the sentence and the test task were modeled. The modeling of sentence presentation was split into 3 blocks of equal length covering the entire sentence presentation to account for differences in sentence encoding before the verification.

The verification process was modeled by a block, beginning with the onset of the presentation of the test task. The length of the block was selected to coincide with the average response time in the inference condition of the slowest participant (1.8 seconds). t-test contrasts were calculated between test tasks in the inference, explicit, paraphrase, and control conditions. For statistical analyses, a Random Effects Model was used bringing the appropriate individual contrast measures into a simple t-test on 2nd level. Statistical maps were thresholded with $t = 3.93$ (uncorrected $p = .001$) and clusters surpassing a corrected p value of .05 on cluster level (approx. 110 voxels) are reported as significantly activated.

Results

Behavioral Results. The response latencies to the test statements showed again an increase from the explicit to the paraphrase and the inference conditions. The mean latency was longest in the novelty condition. While the difference between explicit and paraphrase was not significant, all other differences were (see Table 7–2). This pattern of results is in good agreement with the results from Experiment 1. Two differences may be worth noticing. The latency difference between the implicit and the novelty condition is somewhat larger in this experiment than in Experiment 1. Secondly, the latencies are overall somewhat longer than in Experiment 1, possibly due to the fact that the participants were lying in the scanner rather than sitting at a desk. But all structural aspects of the latency and response data are identical.

In previous research (Perrig & Kintsch, 1985; Schmalhofer & Glavanov, 1986; Fletcher, 1992), such results have been employed to determine the memory strengths of verbatim, propositional and situational representations in a level theory of representation (Kintsch, 1998). According to such reasoning, it was assumed that there are different representations which are jointly processed to determine a true or false response in the verification task. Potentially, the fMRI-data allow us to identify the neural sources of the processes that correspond to the levels of representation differences that were established in behavioral experiments. The contrast paraphrase—explicit of the BOLD signal would thus indicate those processes that operate only on a match at the semantic/propositional level rather than specific lexical level. The contrast implicit—paraphrase indicates the processing that occurs when there is no match at a semantic/propositional level but only at the situational level. The contrast novelty—implicit indicates the processes that occur when more extensive situational constructions and elaborations are needed, com-

TABLE 7–3.
Brain Regions, Cluster Size and Their Activation Level Which Were Found With a Lower Threshold.

Contrast / Area	*Side*	*Size*	P_{corr}	*Z-Max*	*X*	*Y*	*Z*
TEST							
paraphrase > explicit (T = 2.5)							
cuneus - BA 18/19							
temporal lobe - BA 22/21							
parietal lobe - BA 7/37/39	L	734	.019	3.21	−58	−62	10
cuneus - BA 17/18/19							
posterior cingulate - BA 29/30/31/23	L/R	659	.033	3.92	10	−60	8
inference > paraphrase (T = 2.5)							
IFG, MFG - BA 10/13/44/45/47							
temoral lobe - BA 38	L	777	.049	3.25	−52	34	−10
anterior cingulate - BA 24/32							
SFG, MFG - 6/8/9/10	L/R	3989	.00	4.9	−2	46	46
control > inference (T = 2.0)							
precuneus - BA7							
posterior cingulate = BA 29/30/31/23							
cuneus = BA 18/19	R/L	1484	.036	4.02	0	−66	38

pared with the straightforward mapping of the implicit condition. Finally, the explicit—pseudoword contrast of the verification task indicates those processes that are relevant for a lexical match (as opposed to a match of stings). We will therefore report the fMRI contrasts in this order and subsequently inform about other significant differences.

FMRI Results. Table 7–3 and Figure 7–3 show the different clusters that indicate the significant processing differences in the various contrasts.

The comparison *Paraphrase* > *Explicit* showed one significant cluster in the right posterior cingulate gyrus. The posterior cingulate gyrus has been consistently found in successful episodic memory retrieval (Cabeza & Nyberg, 2000; Wheeler & Bucker, 2004). Fletcher et al. (1995) attributed posterior cingulate regions to be involved in visual imagery and possibly the incorporation of information into an evolving discourse structure. Posterior cingulate and neighboring cuneal and precuneal regions are also activated when picture stories are processed (Gernsbacher & Kaschak, 2003). These areas may thus reflect either memory retrieval or mental imagery processes (or both) that occur in story comprehension (Maquire et al., 1999).

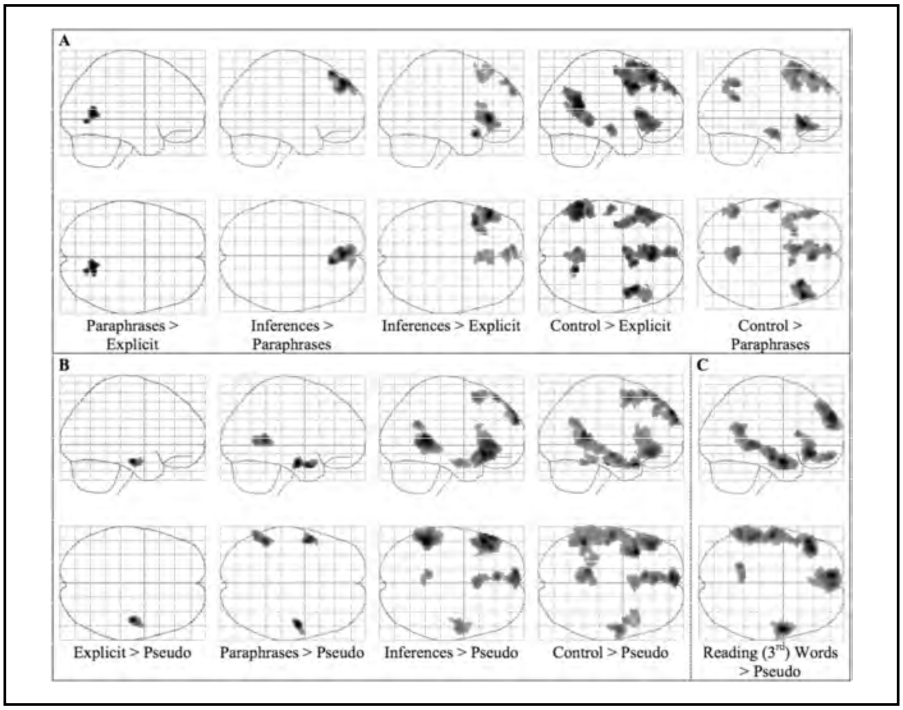


FIGURE 7–3. Statistical activation maps showing significant clusters in the statement verification task of the four experimental conditions

When the contrast Paraphrase > Explicit is calculated with the more relaxed criterion of $T = 2.5$, the already identified area becomes somewhat larger (see Table 7–4). In addition, a second cluster emerges. This second cluster is left lateralized and covers cuneal and pre-cuneal regions (BA 19, 39) extending into the posterior temporal lobe (BA 22, 21, 37). These regions of the posterior middle and superior temporal gyrus are associated with phonological, semantic and lexical processes involved in sentence reading (Bavelier, Corina, Jezzard, Padmanabhan, Clark, Karni et al., 1997). Using lists of unrelated words and a recognition task instead of a verification task, Wheeler and Buckner (2003) found that parietal areas were involved in successfully remembering and perceiving of the oldness of an item. In particular, they found that BA 40/39 increased activity when participants decided that items were old, regardless of whether the items were actually old or new. An important difference of the current findings to the results from Wheeler and Buckner concerns hemispheric differences. Whereas Wheeler and Buckner found activation in the left parietal areas, the current results show most activation in right parietal regions.

TABLE 7–4.
Brain Regions, Cluster Size and Their Activation Level of the Significant Clusters.

Region	*BA*		*Cluster size*	p_{corr}	*z-max*	*X*	*Y*	*Z*
Paraphrase > Explicit								
posterior cingulate gyrus	30	R	179	0.010	4.03	12	−62	6
Inference > Paraphrase								
SFG & MFG	8/9/6	R/L	733	0.000	4.68	−2	46	46
Inference > Explicit								
IFG	45	L	754	0.000	4.81	−50	32	0
SFG & MFG	8	R/L	269	0.001	3.62	2	22	52
SFG & MFG	8/9	L	160	0.015	3.87	−10	60	32
Control > Explicit								
SFG & MFG	6/8/9	R/L	1225	0.000	4.70	0	34	50
MTG, STG & supramarginal gyrus	21/22/39/40	L	1096	0.000	4.62	−60	−52	18
IFG	45/47	L	736	0.000	4.28	−54	24	4
MFG	6	L	410	0.000	4.13	−44	12	38
posterior cingulate gyrus	23/29/30	R/L	366	0.000	4.49	16	−56	14
MFG & precentral gyrus	9	R	356	0.000	4.74	40	14	40
IFG	47	R	154	0.013	3.51	42	22	−8
Control > Paraphrase								
SFG & MFG	6/8/9	R/L	1097	0.000	4.35	4	36	52
IFG	47	R	430	0.000	4.91	52	28	−8
Precuneus	7	R/L	270	0.001	4.14	0	−54	42
MFG	6/8	L	261	0.002	3.98	−46	16	46
STG, angular gyrus & supramarginal gyrus	39/40	L	250	0.002	4.13	−50	−56	24
IFG	47	L	239	0.000	3.88	−46	32	−10
MFG & precentral gyrus	8/9	R	181	0.011	3.92	40	18	40
ITG & MTG	21	L	171	0.015	4.10	−60	−6	−18

Note: IFG = inferior frontal gyrus; SFG = superior frontal gyrus; MFG = middle frontal gyrus; ITG = inferior temporal gyrus; MTG = middle temporal gyrus; STG = superior temporal gyrus.

This difference may be explained by the lateralization of coarse and fine semantic comparisons. Beeman (1998) has proposed that coarse semantic comparisons would be predominantly performed in the right hemisphere and fine semantic comparisons would be performed in the left hemisphere. Whereas Wheeler and Buckner presented exactly the same word as during the study phase, the contrast paraphrase > explicit reveals the areas that are especially involved when a synonym of a previously presented word is recognized as denoting the same object, thus producing a successful memory retrieval or memory resonance. If this is true one would then expect that word repetitions would be processed more to the left hemisphere (cf. Wheeler & Buckner, 2004) and a repetition by synonym would resonate more in the right hemisphere, as it was observed in this experiment.

The comparison *implicit > paraphrase* showed a large cluster in the medial portion of the left and right superior and middle frontal gyri. Such middle frontal activations have been attributed to theory of mind inferences and more generally, inferences that are needed to establish a coherent conceptual representation as it is established in situation models (Ferstl & von Cramon, 2001, 2002; Fletcher et al. 1995; Mazoyer, Tzourio, Frak, & Syrota, 1993). Fronto-median activations have also been implicated for the generation of plans and internally guided force in general (Vaillancourt, Thulborn & Corcos, 2003). These areas exceed the functions that are unique to memory and language processes and may in particular be relevant for constructing a particular situation to act in it. Ferstl and von Cramon (2002) have succinctly described the function of this area as being related to an integration of an inner world with the external stimulation. This function is also closely related to the comprehender's self and when an idiosyncratic response criterion needs to be established on the basis of prior knowledge and contextual information (Ferstl, this volume).

With a threshold of $T = 2{,}5$, the *implicit > paraphrase* contrast additionally showed activation in the left inferior prefrontal cortex (LI-PFC) and superior temporal pole (BA 47, 45, 10, 13, 38). As can be seen from Table 7–4, almost the same LI-PFC cluster was also found in the implicit–explicit contrast with the conservative threshold. The inferior frontal gyrus has been implicated for semantic integration (Ferstl, this volume) and the larger area of the inferior temporal cortex has been termed the prefrontal reasoning network by Mason and Just (2004).

The *novelty > implicit* contrast did not yield any significant clusters when a conservative criterion was used. With the liberal criterion of $T = 2.0$, an area extending from the precuneus (BA7), posterior cingulate (BA 29/30/31/23) and cuneus (BA 18/19) was shown as active (see Table 7–4). These areas show the closest overlap to the areas that were found in the paraphrase > explicit contrast and may thus indicate that for the novelty condition memory processes might play a larger role than in the implicit condition, where the reader is better prepared to process the specific statement than in the novelty condition.

The comparison *implicit* > *explicit* showed in addition to the significant results of the *implicit* > *paraphrase* contrast, a large area in the left inferior frontal gyrus overlapping with Broca's areas 45 and 47.

The comparison *Novelty* > *Explicit* showed once more the middle frontal gyri and the left inferior frontal gyrus to a somewhat larger extent and with higher activations than in the *implicit* > *explicit* comparison. In addition to these areas, a region at the junction of the left temporal and parietal lobes, covering parts of the middle and superior temporal gyri and the supra-marginal gyrus was significant. Furthermore clusters in the posterior cingulate gyri bilaterally, in the right middle frontal and pre-central gyri, as well as an area in the right inferior frontal gyrus were found. With a lower threshold this comparison yielded the same areas but with much larger extensions, possibly including right posterior areas as well.

The comparison *Novelty* > *Paraphrase* yielded similar results as the comparison of *Novelty* > *Explicit*. The regions most prominently activated were in the middle frontal gyri and the right inferior frontal gyrus. A posterior midline activation was found in the pre-cuneus. Further clusters in the left inferior frontal gyrus, the middle frontal gyrus, the left temporo-parietal junction, the right middle frontal and pre-central gyri as well as an area in the inferior and middle temporal gyri also showed significant activation.

When the contrasts were calculated in the opposite directions (e.g. explicit > paraphrase), no significant clusters were found with a high threshold. To provide a complete analysis of the data, we calculated all tests consecutively in the opposite direction (explicit < paraphrase < implicit < novelty) with a lower threshold as well. With the exception of the explicit > implicit contrast which yielded one cluster (post-central gyrus—BA2/3 extending to the inferior parietal lobule—BA 40) with a criterion of $T = 2.5$, no significant results were found in these comparisons either. These results thus clearly demonstrate that the processing demands do indeed increase from integrating an explicit statement to integrating a statement that requires an inference or even a more substantial adjustment in the representation of the referred situation as was the case in the novelty condition.

Finally, differences in the error variances and differences in the power of the respective tests may have caused activation differences in some areas to fall short of statistical reliability. For example, the cluster in the left inferior frontal gyrus that emerges in the implicit > explicit contrast, could also be present in the implicit > paraphrase contrast, and indeed a lower threshold showed such activation difference.

Discussion

The results of the fMRI experiment showed that at least four areas are implicated when a statement is to be integrated with a preceding discourse in a verification task. (1) Parietal areas showed differences most distinctly in the paraphrase > explicit condition, but also and to a larger extent (probably due to the larger power of the comparison) in the novelty > explicit comparison. (2) An area in the medial prefrontal cortex was most clearly seen in the implicit > paraphrase comparison, but also in the novelty > explicit and novelty > paraphrase comparisons. (3) An area of inferior prefrontal cortex produced differences in the novelty > explicit and also in the novelty > paraphrase conditions. (4) The middle and superior temporal gyri extending into the angular and supramarginal gyri showed differences in the novelty > explicit contrasts and the novelty > paraphrase contrasts.

Each of these areas may participate in support of higher level comprehension. In fact, Ferstle (this volume; also Ferstl & von Cramon, 2001; 2002) suggests that they all play an important role in establishing and maintaining coherence. The dorsal medial prefrontal cortex (BA 8/9/10) seems to be crucially involved in inferences, supporting the construction of a situation model from the reader's personal knowledge in interaction with the text (Ferstl & von Cramon, 2002; Ferstl, this volume). The posterior cingulate cortex may be important in situation model updating (Maquire et al., 1999; Ferstl, this volume). Generally, frontal regions may support strategic processes that could serve text comprehension (Ferstl, this volume, Crinion et al. 2003). Specifically, the lateral prefrontal cortex has been implicated in semantic analysis and semantic integration with a given context, and integration demands may also recruit the triangular part of the inferior frontal gyrus. Finally, the anterior temporal lobe may have specific higher level language functions when an integration of incoming words into a semantically based representation is needed (Ferstl, this volume). In the following paragraphs, we examine this "text comprehension network" further in terms of comprehension functions identified in text research.

Updating a Situation Model: Construction and Resonance

Fletcher et al. (1995) argued that the posterior cingulate regions were involved in visual imagery and possibly the incorporation of information into an evolving discourse structure. Posterior cingulate and neighboring cuneal and precuneal regions are also activated when picture stories are processed (Gernsbacher & Kaschak, 2003). These areas may thus also reflect mental imagery processes in story comprehension (Maquire et al., 1999). Memory retrieval, which has to be part of updating, may depend upon an interaction between posterior parietal association areas, prefrontal areas and mid temporal lobe structures: The medial temporal lobe retrieves information from memory and parietal regions maintain representations of the remembered information.

The prefrontal cortex modulates activated memory representations in the parietal lobe as well as less active memories in the temporoparietal regions. It sets up a retrieval mode, initiates the retrieval attempt in temporal regions and monitors and selects activated memory representations. Temporal and parietal regions are strongly interlinked to frontal regions via the arcuate fasciculus and the uncinate fasciculus. Particularly the retrosplenial cingulate (BA 30)—see the paraphrase > explicit contrast—next to its links to the mid temporal lobe and the thalamus, has connections to regions in the dorsolateral prefrontal cortex (BA9, BA9/46, BA46) and adjacent parietal regions (BA19) and may play a role in working memory processes (Morris et al., 1999).

Updating is not a strictly constructive process. It also makes use of a rapid and more passive resonance-like memory processes (O'Brien et al., 1998). For such processes, the posterior cingulate gyrus, rather than the midline prefrontal areas, may be a supporting structure. It has not been associated with effortful cognitive control and conscious reasoning. In our results, the observed posterior cingulate activation in the paraphrase minus explicit contrast could indicate this kind of a fast acting passive memory resonance process.

Reasoning with a Situation Model. (Mental analogies for moving objects, others, self and force exertion). A more general process of mental simulations characterizes cognitive activity such as visualizing and planning. Frontal midline activations have been associated with general non-linguistic inferences that help establish a coherent situational representation (Ferstl & von Cramon, 2001, 2002; Fletcher et al. 1995; Mazoyer, Tzourio, Frak, & Syrota, 1993) and with generating plans and mentally making comparisons between imagined forces (Vaillancourt, Thulborn & Corcos, 2003). These frontal areas may support internally guided (as opposed to stimulus-driven) situation model manipulation, including constructed inferences. (See Schmalhofer, McDaniel & Keefe, 2002).

Conceptual and Syntactic Structures. A large cluster of activation was found in the left inferior prefrontal cortex (LI-PFC) (BA 13, 46, 47, 45, 44), which reached slightly into anterior superior parts of the temporal pole (BA 38). Fletcher et al. (1995) hypothesized the temporal pole region to be involved maintaining coherence in narratives through linking text propositions. Studies by Maguire, Frith and Morris (1999) and Mazoyer et al. (1993) confirm temporal pole involvement in higher level language processes.

The linking of propositional information is a function that requires procedural knowledge about grammar to establish structural relations, as well as a declarative memory system that provides the entities that these grammatical procedures act upon. A procedural role of the temporal pole was suggested by Ullman (2004) who argued that this region in combination with the anterior superior temporal sulcus acts "as a storage repository of procedural knowledge" (Ullman, 2004, p. 243). Nearby regions in the left ventrolateral-prefrontal cortex (BA 44, 45, 47) may support similar functions in procedural and declarative memory systems. Broca's area (BA 44), which is strongly interconnected with the superior temporal sulcus (Rizolatti, Fogassi, & Gallese, 2001), is engaged in a range of sequential processes (Gelfand & Bookheimer, 2003), including those that operate on abstract, hierarchical information (Conway & Christiansen, 2001), phonological information in working memory (Smith & Jonides, 1999), and in mental rotation tasks (Jordan, Heinze, Lutz, Kanowski, & Jancke, 2001). These functions assign Broca's area a key role in implementing the syntactic, combinatorial work required to conceptually interlink the words of a sentence.

The left inferior prefrontal cortex (LI-PFC) is not limited to procedural memory functions. Research has suggested Broca's Area (BA 44) and the LI-PFC support general working memory functions by selecting and maintaining information that is currently activated in parietal lobes (Petrides, 1996; Ullman, 2004). Furthermore, this region links working memory to long term memory by retrieving and acting upon information which is stored in temporal and temporo-parietal regions (Ruchkin, Grafman, Cameron, & Berndt, 2003; Petrides, Alivisatos, & Evans, 1995). Particularly Ruchkin et al. (2003) as well as Sakai (2003) argue that the prefrontal working memory system corresponds to a "retention space" for activated long term memories in parietal regions.

Especially relevant for comprehension is the likelihood that left inferior prefrontal cortex (LI-PFC) has a role in encoding and semantic analysis of verbal information that goes beyond task difficulty (Demb, Desmond, Wagner, Vaidya, Glover, & Gabrieli, 1995). The activation of the LI-PFC in conditions that require semantic encoding predicts subsequent superior memory performance in recognizing the presented verbal information (Fujii et al., 2002; Otten et al., 2001). A study by Kohler, Paus, Buckner and Milner (2004), which applied transcranial magnetic stimulation (rTMS) in combination with fMRI, even suggests a causal connection between LI-PFC activation and successful verbal episodic encoding. A basis for this link is that increased LI-PFC activation during semantic processing of linguistic input leads to an enhanced item distinctiveness and firmer integration into long term memory.

Finally, text comprehension requires some degree of controlled processing, as the reader attends to words and considers their meaning in relation to the text. The controlled processing function of LI-PFC has been identified in memory research by Wheeler and Buckner (2003), who found that two left frontal regions (BA 45/47) and BA 44 showed increased activity during the retrieval of only minimally studied words in comparison to repeatedly studied words. They attributed this additional activity to an increased demand for controlled processing during the retrieval of weakly established memories. In text processing, we should expect this kind of controlled process to be involved when integration processes requires a weakly established word or referent memory to be retrieved.

The functions attributed to the left inferior prefrontal region and the temporal pole are well suited to implement the conceptual and syntactic encoding of a sentence. In our study, the implicit condition produced only a weakly established conceptual representation. Encountering a word across a sentence boundary that might be related to this weak representation approximates a condition of novel word. The implicit condition therefore requires more semantic analysis and conceptual coding of the verbal information than the explicit condition. The activation in the left inferior prefrontal cortex in combination with the temporal pole appears to reflect such processes.

CONCLUSIONS

Until recently, integration processes across sentence boundaries have been studied primarily with behavioral measures, e.g., when and how bridging inferences are built between sentences. As explained in the chapter by Singer and Leon (this volume) a sentence is processed faster when it contains a noun that was already introduced by the previous sentence. The sentence "The beer is warm," is thus more quickly read after the sentence "We got the beer out of the trunk" than after the sentence "We got the picnic supplies out of the trunk" (Haviland & Clark, 1974). Similarly, for sentences that are causally related, less processing time is required when a causal consequence has already been expressed by the preceding sentence rather than being only implicated. A statement that the lawn was watered is therefore verified faster after a sentence is read which states that Steve saw that the grass was dry, went outside to turn on the hose and watered the lawn, in relation to a sentence which only implies that the lawn was watered (e.g. Griesel et al., 2003; experiment 2).

The Processing of Explicit, Paraphrased, Implicit and Novel Statements

It is quite interesting to compare the results of the same experimental manipulations across the three different experiments and thus associate the ERP with the behavioral data and the fMRI-results. In the ERP and fMRI experiments, novelty and implicit conditions yielded similar results. In particular, there was no significant difference between the two conditions in either experiment. Differences did, however, occur, in both experiments between the paraphrase and the explicit conditions (P300 in experiment 1; posterior cingulate in experiment 3) as well as between the implicit and the paraphrase (N400 in experiment 1; dorsomedial prefrontal areas in experiment 3) in combination with other but less prominent differences. The behavioral experiment showed that the largest latency gap occurred between the paraphrase and the implicit conditions when adjacent experimental conditions (explicit < paraphrase < implicit < novelty) are compared.

The immediate integration hypothesis suggests that integration processes across sentence boundaries occur immediately, i.e., at the earliest possible time during processing. When a word at the beginning of a sentence repeats the morpheme of a word in a previous sentence, early perceptual encoding and related memory processes could determine this earliest possible time for building a connection. Propositions that were only implied or are completely new on the other hand (as in the implicit and the novelty conditions) would require additional analysis and a later point in time when the integration can be performed.

In accordance with this prediction, the ERP experiment showed that for the explicit and paraphrase conditions an early positivity between—around 150–200 ms, which was salient at the bilateral posterior regions with right-hemisphere prominence distinguished the explicit and paraphrase conditions from the other two conditions. Further supporting this finding, the fMRI experiment indicated that a right parietal area was clearly involved in the paraphrase as compared to the explicit condition.

Because, for the implicit and novelty conditions, the integration across a sentence boundary can not occur within this early time frame, the ERP experiment should show an indication of an additional processing effort at some later time for the implicit and novelty conditions. This prediction was clearly confirmed. There was an N400 effect, at the central electrode for the implicit as well as for the novelty condition. The fMRI results showed that for the implicit condition, the integration processes occurred mostly in the medial frontal cortex and in the left inferior frontal cortex. For the novelty condition, the integration processes furthermore included the right inferior prefrontal areas (compare the contrasts implicit > explicit and novelty > explicit in Table 7–4 and Figure 7–3).

The fMRI results thus showed that the integration and verification of a statement in relation to a previously read sentence may occur in posterior and frontal areas of the brain. As in the ERP-experiment there was a clear separation between the experimental conditions. In addition, the separation between the experimental conditions coincided between the fMRI and the ERP experiment. The paraphrase condition showed a P300 effect in the ERP experiment and an activation in the posterior cingulate gyrus in the fMRI experiment. The implicit and the novelty condition, on the other hand, showed an N400 effect and activations in medial frontal areas, in combination with other frontal, temporal and parietal areas.

For language and memory tasks (cf. Ullman, 2004), posterior and prefrontal regions form an interdependent network. The posterior cingulate's connections to prefrontal regions (Morris, Petrides & Pandya, 1999) show its link to a more integrative, structure-building region of the brain. Memory retrieval may depend on an interaction between posterior cingulate, posterior parietal association areas, prefrontal areas and mid temporal lobe structures. The medial temporal lobe supports the retrieval of information from memory and parietal regions maintain representations of remembered information. The prefrontal cortex exerts an important role concerning activated memory representations in the parietal lobe as well as offline memories in temporoparietal regions. It sets up retrieval mode, initiates the retrieval attempt in temporal regions and monitors and selects upon activated memory representations. The extensive connections between those regions would indeed allow for a coordinated interplay. Such an interdependency between automatic and strategic components in inferencing and integration has recently also been demonstrated in behavioral experiments as well (Calvo et al. in press).

The fMRI experiment showed which brain areas become differentially involved in relating one and the same statement to variations of a previously read text. The posterior cingulate gyrus, supposedly signifying routine processes, was found to be active when an integration is achieved via a paraphrase. The medial frontal gyrus, supposedly indicating more effortful and strategic construction processes, becomes involved when an additional coherence link needs to be established.

The constructive processes of the *novelty condition* require more extensive memory retrievals involving the posterior cingulate gyrus and the left STG. In addition, coarse semantic relations may become activated in the right hemisphere (e.g. the right IFG; cf. Mason & Just, 2004). The activated situational knowledge may then become integrated in the left IFG (cf. Hagoort et al. 2004). This hypothesis is empirically supported by the *Novelty* > *Explicit* and *Novelty* > *Paraphrase* contrasts which show these specific brain areas. In the explicit and paraphrase conditions such construction processes are not required because of the autonomous memory resonance process which achieves the linkage in a more economic way.

Overall, the current results provide a means for differentiating the role of a more passive process of inferencing and integration (O'Brien et al., 1998) and a more active construction process (Graesser et al., 1994) in relating a statement to a previously read text. The passive process could be termed memory resonance because it establishes a relation more or less automatically. This process may peak earlier (about 200–300 ms after the onset of the word) than the more effortful strategic process (400–500 ms). Thus, we can suggest that there are indeed two different processes that support inferences and meaning-based text integration processes generally. A more active meaning search process (e.g. Graesser, Singer & Trabasso, 1992) is slower and perhaps less robust; a more passive memory resonance process (O'Brien et al., 1998) is faster, more robust, but perhaps insufficient for complete coherence under some conditions, which then require the slower more active process. Both are important for establishing coherence in texts in terms of their neural correlates. Quite surprisingly and re-assuring for the behavioral results, the timing and location of these processes in the brain coincide very well with the theoretical conclusions derived from the behavioral experiments. Integration processes across sentences boundaries may therefore occur at the earliest opportunity that is afforded by the preceding context and the specific word which has to become integrated into the emerging discourse structure.

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