

Research report

The role of coherence and cohesion in text comprehension: an event-related fMRI study

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Accepted 26 December 2000

Abstract

Text processing requires inferences for establishing coherence between successive sentences. In neuropsychological studies and brain imaging studies, these coherence-building processes have been ascribed to the right hemisphere. On the other hand, there is evidence for prefrontal brain damage causing non-aphasic language disorders, in which text level processes are impaired. In this study, we used an event-related, whole-head fMRI methodology to evaluate the contributions of prefrontal areas and the right hemisphere to coherence building. We scanned 12 participants while they read 120 sentence pairs and judged their coherence. Four conditions were used, resulting from crossing coherence and cohesion (i.e. the presence of a lexical connection). A behavioral pretest confirmed that cohesion aided establishing coherence, whereas it hindered the detection of coherence breaks. In the fMRI study, all language conditions yielded activation in left frontolateral and temporolateral regions, when compared to a physical control task. The differences due to coherence of the sentence pairs were most evident in larger activation for coherent as compared to incoherent sentence pairs in the left frontomedian wall, but also in posterior cingulate and precuneal regions. Finally, a left inferior prefrontal area was sensitive to the difficulty of the task, and in particular to the increase in processing costs when cohesion falsely indicated coherence. These results could not provide evidence for a special involvement of the right hemisphere during inferencing. Rather, they suggest that the left frontomedian cortex plays an important role in coherence building. © 2001 Elsevier Science B.V. All rights reserved.

Theme: Neural basis of behavior

Topic: Cognition

Keywords: Text comprehension; Event-related functional magnetic resonance imaging; Frontal lobe

1. Introduction

An important process during natural language understanding is the establishment of coherence. In order to correctly interpret the current utterance, it is necessary for the comprehender to link its meaning to the prior context by using general knowledge of the world. In many cases, the specific relationship between the input just encountered and the communicative context is left implicit. However, the comprehender's assumption is that the speaker or writer follows an intention, and thus, that the utterance is relevant to the prior context.

The process needed for establishing coherence is called

inferencing. In psycholinguistic research, a taxonomy of inferences has been attempted. The question of interest is which types of inferences are made automatically and on-line (for reviews see Refs. [21,47]). For instance, it has been proposed that only bridging inferences required to establish local coherence between subsequent sentences, and those inferences based on easily accessible knowledge are made automatically [37]. According to this so-called minimalist framework, all other types of inferences, such as causal, predictive, or elaborative inferences, are dependent on strategic processes determined by the comprehender's goals. In contrast, Trabasso and van den Broek [52] argue that causal and goal-related inferences are always included during comprehension, and even more, that finding out *why* certain things happen and *why* certain actions are carried out is one of the most fundamental functions of comprehension.

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In neuropsychological research, inference processes have been studied in the context of so-called non-aphasic language deficits [44]. While in right handers there is abundant evidence for a left-hemispheric dominance of language processes on the word and sentence level, the prevalent conclusion from the available empirical studies on inferences is that text level processes are located somewhere in the right hemisphere, both for automatic and controlled inferences. For instance, Beeman [2] found that bridging inferences based on associative relationships between content words are difficult after right-hemispheric lesions. Based on these results and converging results from hemifield priming studies (for a summary see Ref. [12]), Beeman [3] proposed the so-called *coarse coding hypothesis*. This hypothesis holds that the activation of a wide semantic field of related concepts is a process subserved by the right hemisphere, while the inhibition of contextually irrelevant associations takes place in the left hemisphere. Thus, Beeman argues, the right hemisphere patients' failure to draw bridging inferences is due to their failure to activate a sufficiently large field of world knowledge associations.

Regarding more controlled inferences, studies on right hemisphere patients' deficits have focused on pragmatic functions [9,10]. For instance, the comprehension of indirect requests, understanding jokes and metaphors, or the appreciation of an utterance's social implications, are processes said to be impaired after right hemisphere lesions. Inferences required for this type of non-literal language comprehension are, of course, much more dependent on the use of general world knowledge and interpretative functions than the bridging inferences studied by Beeman [2]. Underlying processes suggested to cause this type of deficit include difficulties with revising previous interpretations, deficits in monitoring, detection and repair of comprehension problems, the failure to go beyond the literal meaning and consider alternative readings, or the failure to take into account situational constraints.

As pointed out by McDonald ([36]; see also Ref. [48]), patients with frontal lobe lesions and patients with right-hemisphere damage exhibit remarkably similar non-aphasic language deficits. In empirical research, these two patient groups are often not clearly separable; however, when an attempt is made to differentiate lesion lateralization, the special role of the left prefrontal cortex for text level language processing becomes apparent [15,25,42]. An alternative approach to dissociating frontal and right-hemispheric language functions is the mapping of brain activity in healthy subjects.

In contrast to neurolinguistic research, neuroimaging studies on language processes have only recently begun to venture beyond the word level. Besides first investigations of syntactic processes [13,24,26,38], there are a few positron emission tomography (PET) or functional magnetic resonance imaging (fMRI) studies on the processing of language in a discourse context. Using PET, Mazoyer et

al. found extensive, predominantly left-lateralized, temporolateral and inferior prefrontal activation for listening to stories compared to a resting baseline ([35]; see also Ref. [53]). The regions specifically implicated in processing of continuous speech, as compared to the processing of single words, were the polar region of the temporal lobes (BA 38) bilaterally. However, the only region activated solely during listening to stories, but not during processing of other meaningful language stimuli, was in the left superior frontal gyrus (BA 8).

Converging evidence for this finding was reported by Fletcher et al. [17] from a PET study. Their direct comparison of story processing with the comprehension of unrelated sentences yielded an increase of brain activity in the polar region of the temporal lobe (BA 38) bilaterally, but also in the posterior division of the left superior temporal gyrus (STG; BA22/39) and in the posterior cingulate region (BA 23/31). A left frontomedian region (BA 8) presumably close to that reported by Mazoyer et al. [35] was found to be active only during the processing of 'Theory of Mind' stories, i.e. stories that required the attribution of a character's motivations and mental state (see also Ref. [19] for a replication). While Mazoyer et al. did not use any comprehension task, Fletcher et al. explicitly instructed the participants to attempt a motivational attribution for the Theory of Mind stories, but not to do so for other stories. Using instructions to induce different levels of processing as well, Nichelli et al. [40] presented Aesop's fables during PET scanning. When comparing a task requiring semantic analysis of the input with a text level task requiring the deduction of the fable's moral or theme, the latter activated the orbital part of the inferior frontal gyrus (BA 47) and the anterior portion of the middle temporal gyrus (BA 21) in the right hemisphere. Because the derivation of the gist of a story requires the integration of disparate text information across sentence boundaries, the authors interpreted this result as evidence for the coarse coding hypothesis.

Two recent imaging studies explicitly targeted coherence processes [33,49]. Both are based on a classic paradigm in which comprehension processes are manipulated by providing or withholding theme information prior to reading short stories [8]. The wording of the stories is kept so vague that comprehenders cannot succeed in establishing global coherence, unless they are given a title or an organizing picture. When this theme information is available, it activates a mental model or *situation model* of the text, i.e. a global cognitive representation of what the text is about [55]. Each sentence in the story can now be linked to this situation model. Consider, for example, the incoherent sentence pair 'First you have to sort everything into piles. Powder is needed.'. When theme information is missing, these sentences cannot be connected into a unitary, coherent representation. When the topic 'Washing clothes' is given, however, the sorted laundry of the first sentence and the laundry detergent of the second can be

associatively connected. Thereby, the sentences become easily comprehensible and locally coherent.

Testing the hypothesis that the right hemisphere is involved in coherence building, St. George et al. [49] presented stories visually with or without a title. The data from fMRI were then analyzed in an inferior prefrontal and three (superior, middle, inferior) temporal regions of interest. Consistent with the hypothesis, there were differential effects for the two hemispheres. In the left hemisphere, activation was comparable for the two conditions. In the right hemisphere, in contrast, the untitled, and thus incoherent condition, yielded more active voxels than the titled, coherent condition. This result was particularly pronounced in the temporal cortices. Once more, these findings of an involvement of right hemispheric brain areas during the processing of language in context, were interpreted as being consistent with the coarse coding hypothesis. Maguire et al. [33] used the pictorial version of the paradigm [8]. A picture showing an unusual scenario is presented before the presentation of its verbal description. Without the picture, the text information alone does not suffice for the comprehender to derive a situation model and thus, to render the text coherent. Maguire et al. [33] report results from PET scanning of participants while they listened to stories with or without having seen a relevant picture. Surprisingly, there was almost no overlap with the results of St. George et al. [49]. When the unusual stories presented with a relevant picture were compared to the same stories without pictures, a posterior cingulate area (BA 31) proved active. Moreover, when other, inherently coherent stories, were compared to the stories without a picture, activation was found in the polar region of the left temporal lobe (BA 38) and in a ventromedial orbital region (BA 11).

Another means to manipulate coherence, while holding semantic and pragmatic features of the language input constant, was employed by Robertson et al. [46]. They presented lists of sentences with unrelated content. When the articles in these sentences were all indefinite (e.g. 'A carpenter walked down the street. Some children were crying. '), the comprehenders were less likely to link the sentences into one situation model. In contrast, when the articles were replaced with definite articles ('The carpenter walked down the street. The children were crying. ') it is more likely that the sentence lists are considered coherent, and that a common situational representation is formed. fMRI showed more activation in right-sided prefrontal areas for the coherent sentence lists (with definite articles) than for the less coherent sentence lists (with indefinite articles).

Taken together, the results from neuroimaging studies provide a somewhat inconsistent picture. While there was evidence for right hemispheric involvement during inferencing ([40,46,49]; see also Ref. [7]), the regions of activation reported in other studies were predominantly left lateralized or bilateral [17,33,35]. There is some evidence

on the contribution of the frontomedian wall, but its specificity remains unclear.

Of course, there are important methodological differences between these studies, such as the comprehension task, the choice of a baseline and the reported comparison, the extent of the regions scanned or the regions of interest used for analysis. However, the most important difference causing the disparate results may concern the language materials used. In all studies, the coherent stimuli were narrative texts consisting of several sentences, and more than 100 words in length. During the comprehension of such stories, global processes, such as setting up a situation model, play a crucial role. These processes are greatly influenced by the macro-structure of the text [27,28], by the familiarity of the content, by its affective connotations, and by the comprehender's goals. For example, the stories in the Maguire et al. study differ from those used by St. George et al. with respect to the familiarity of the topic.

The present study was designed to map local coherence processes independent of global text factors or task induced strategic processes. Taking advantage of an event-related fMRI methodology we are able to scan the hemodynamic response for trials lasting a few seconds only. Thus, it is possible to use materials for which local and global coherence coincide. Instead of stories consisting of a number of sentences with differing degree of coherence to each other and to the global theme we used 'minimal stories' made up of pairs of sentences. Because we were interested in identifying prefrontal brain structures involved in text level processes, the sentence pairs were not linked via simple associative connections between content words, but required the active retrieval and use of general world knowledge. Examples are provided in Table 1.

To be able to contrast successful coherence building with the detection of incoherence, while holding lexical, syntactic and semantic features constant, we switched the first sentences of pairs of trials and thereby created unrelated sentence pairs. In order to avoid task artifacts, we used a simple coherence judgment task. Participants were asked to decide whether the two sentences were pragmatically related to each other or not. To manipulate the ease of the coherence judgment, we used a lexical feature. In half of the sentences, we added *cohesive ties*, i.e. lexical information explicitly signaling the relationship between sentences. Cohesive ties, such as pronouns or conjunctions, influence sentence processing (e.g. Refs. [39,46]), but their use is often difficult for brain-injured patients (e.g. Ref. [30]). Note, that cohesion does not render inference processes superfluous, it just facilitates them. For instance, in the first example in Table 1, the causal connective 'therefore' indicates the type of inference, but not its pragmatic content. The comprehender still has to infer the full causal chain: palms become sweaty when someone is nervous, and exams make people nervous. In the third example, on the other hand, the cohesive tie 'that's when' provides the temporal relationship be-

Table 1

Example materials for the four conditions of the experiment (translated from the original German); cohesive ties are printed in italics

[1] Coherent/Incohesive

Mary's exam was about to start. The palms were sweaty.
 Laura got a lot of mail today. Some friends had remembered the birthday.
 Sometimes a big truck drives by the house. The dishes start to rattle.
 The lights have been on since last night. The car doesn't start.

[2] Coherent/Cohesive

Mary's exam was about to start. *Therefore, her* palms were sweaty.
 Laura got a lot of mail today. *Her* friends had remembered *her* birthday.
 Sometimes a truck drives by the house. *That's when* the dishes start to rattle.
 The lights have been on since last night. *That's why* the car doesn't start.

[3] Incoherent/Incohesive

Laura got a lot of mail today. The palms were sweaty.
 Mary's exam was about to start. Some friends had remembered the birthday.
 The lights have been on since last night. The dishes start to rattle.
 Sometimes a big truck drives by the house. The car doesn't start.

[4] Incoherent/Cohesive

Laura got a lot of mail today. *Therefore, her* palms were sweaty.
 Mary's exam was about to start. *Her* friends had remembered *her* birthday.
 The lights have been on since last night. *That's when* the dishes start to rattle.
 Sometimes a big truck drives by the house. *That's why* the car doesn't start.

tween the first and second sentence. However, the underlying causal connection of the heavy truck making the ground shake still needs to be inferred by the reader.

We assumed that crossing cohesion and coherence would lead to the following effects: When a cohesive tie is present in the coherent trial (Condition [2]), the inference becomes easier, because of additional, explicit lexical information. In contrast, when a cohesive tie falsely indicates a relationship between the sentences (Condition [4]), processing is rendered more difficult. This might be due to a competition between the pragmatic incoherence and the linguistic cohesion. Furthermore, in many cases, this condition yields a pragmatic garden-path effect, i.e. the usual communicative assumption of coherence leads to implausible or funny scenarios (as, for instance, in the last example in Table 1). These hypotheses were confirmed in a behavioral pretest (see Section 2.3).

With this type of material we conducted an event-related fMRI study. As a control condition, we used a baseline task in which non-word strings, similar in appearance to the experimental materials, were shown in the context of a purely physical task. The question of interest was whether we could dissociate processes related to language comprehension on the word and sentence level from those used for establishing coherence across sentence boundaries. In particular, we were interested in the lateralization of those latter processes and in the involvement of prefrontal brain regions indicating the use of executive functions.

2. Methods

2.1. Participants

Eight men and four women received reimbursement for

participating in the experiment. Eleven of the 12 participants were students; and all were right-handed. None of the participants had any history of neurological disorder or other health problems preventing them from being exposed to the magnetic field. The average age was 23 years (SD=3.1, range 19–31). All participants had given informed consent.

2.2. Design and materials

The language trials were made up of 120 sentence pairs in which the second sentence (the target) was pragmatically related to the first (the context). Each target occurred in two versions: the cohesive version contained one or two lexical items (for instance, pronouns, conjunctions) that explicitly signaled the connection between the sentences. In the incohesive version, these so-called cohesive ties were omitted or replaced, so that the relationship between the two sentences had to be inferred based on pragmatic information alone. The incoherent conditions were created by switching the context sentences of two coherent trials. Thus, the experiment used a 2×2 within-subjects design with the factors Cohesion (yes/no) and Coherence (yes/no). Four different lists of 30 trials per condition were then created with the following constraints: in each list each target sentence appeared exactly once, and across lists, each target sentence appeared exactly once in each of the four conditions. The sentences were printed in upper and lower case. Following the rules of German orthography, the initial letters of words were printed in upper case when the word was at the beginning of a sentence or when the word was a noun. All other letters were printed in lower case.

Care was taken that the incoherent sentence pairs did not yield unintended pragmatic relationships. To confirm this

and to test the hypothesis that Cohesion affects inference processes, the sentence pairs were pretested in a behavioral experiment (see Section 2.3).

For the control condition in the fMRI experiment, we used an additional 30 trials made up of non-word sentences. These stimuli were created by replacing letters in real words, so that the resulting displays resembled the language trials in appearance. The resulting non-words did not adhere to the orthographic and phonemic rules of German and were therefore not pronounceable. Half of the sentences were printed in all upper case, and half in upper and lower case, to closely resemble the experimental sentences in appearance. The non-word sentences were combined so that in 15 trials, the context and target had consistent case, and in 15 trials they were in different case.

Each of the four lists of experimental items was combined with the control condition trials. The order of the resulting 150 trials was then randomized, so that within each of three blocks of 50 trials, each condition appeared ten times.

The length of the target sentences was 6.9 words on average, with a range of 4–10 words. To avoid potential eye movement artifacts, we split the sentences into two displays to be presented successively. When possible, the line break coincided with phrase boundaries. The cohesive and incohesive versions of the target sentences were always split at the same position in the sentence. Since coherence was manipulated by switching the context sentences, rather than the target sentences, the line breaks and the presentation formats were identical in the coherent and the incoherent conditions. 60% of the context sentences were split into two displays as well, whereas the shorter context sentences were shown in only one display.

2.3. Pretest

The materials were pretested in a reading time experiment. The 120 trials were intermixed with 40 filler trials and presented one sentence at a time. Twenty-four students were instructed to read the sentences for comprehension and press a key on a button box whenever they had finished reading a sentence. After the presentation of the second sentence, a question mark appeared prompting the participants for a coherence judgment. The reading times for the two sentences, the proportion of correct responses and the judgment times were recorded. All dependent

variables were then subjected to a 2×2 analysis of variance (ANOVA) with the factors Coherence and Cohesion.

The results confirmed the efficacy of the experimental manipulations. The error rates were very low overall, as can be seen in Table 2. There was a main effect of Coherence ($F(1,23)=5.6$, $P<0.05$), indicating that errors were more frequent for the coherent trials than for the incoherent trials.

For the reading times of the context sentences, there were no significant effects. Because the cohesive target sentences were slightly longer than the incohesive targets, it was necessary to factor out sentence length in the analysis of the target sentence reading times. For each participant separately, we first regressed the reading times on the number of words in the sentence. The residuals were then used in the statistical analysis. As shown in Table 2, the expected interaction between Coherence and Cohesion resulted ($F(1,23)=20.6$, $P<0.0001$). Cohesive ties facilitated comprehension of coherent sentence pairs, while they rendered the detection of coherence gaps more difficult. Planned pairwise comparisons confirmed that this interaction was mostly due to the inconsistent condition [4] in which cohesive ties falsely suggested a relationship between incoherent sentences ($F(1,23)=7.8$, $P<0.02$ for the main effect of Coherence in cohesive trials; $F(1,23)=2.2$, $P>0.15$, for the effect of Coherence in the incohesive trials). Despite the fast reaction times for the coherence judgments, the interaction between Cohesion and Coherence was significant for this dependent measure as well ($F(1,23)=5.7$, $P<0.05$).

The pretest confirmed that felicitous cohesive ties can facilitate coherence processes, and that misleading cohesive ties can render the detection of a coherence break more difficult. These effects were present most clearly in the sentence reading times, rather than in the accuracy or speed of the coherence judgments.

2.4. Procedure

The participants received written instructions before the scanning session started. Using examples for coherent and incoherent sentence pairs, the participants were told to indicate with a button press whether they considered the sentence pairs to be pragmatically related to each other or not. The participants were informed that trials with non-

Table 2
Results of the pretest of the sentence materials (mean (SD); $n=24$)

	Coherent		Incoherent	
	Incohesive [1]	Cohesive [2]	Incohesive [3]	Cohesive [4]
Correct responses (%)	92.8 (6.3)	94.9 (6.8)	97.2 (3.9)	96.5 (5.4)
Judgment times (ms)	461 (198)	459 (176)	451 (210)	475 (215)
Reading times for context sentence (ms)	2313 (717)	2300 (728)	2276 (595)	2274 (695)
Reading times for target sentence (ms)	2348 (539)	2359 (514)	2261 (527)	2550 (595)
Residuals of target sentence reading times (ms)	−95 (222)	−162 (254)	−193 (173)	37 (176)

word sentences would be interspersed. The task for these trials was to indicate whether the appearance (i.e. the typing in either all upper case or upper and lower case) was the same or different for the two non-word sentences. For this control task, examples were provided in which the letter case was either consistent across the two non-word sentences or not. For their YES-responses, half the participants were instructed to use the key on right side of the response box, and the other half to use the key on the left.

During the scanning session, the participants lay flat inside the magnet, with a response box placed into their right hands. The stimuli were projected onto a ground glass screen placed in the magnet bore above the subject's head. The subject viewed the screen using mirrored glasses with corrective lenses when necessary. The letters were printed in white on black background to avoid glaring, and a font size was chosen to allow for comfortable reading.

The functional measurement was conducted in three separate blocks, after each of which the participant could take a short break. Each block of 50 trials was preceded by one additional practice trial. The five conditions were presented in a pseudo-randomized order so that successive trials were from different conditions, and not more than three successive trials required the same response. Each trial lasted 20 s, with the following time course: After presentation of the fixation cross for 2 s, the one or two displays of the context sentence and the two displays of the target sentence were presented for 2 s each. If no response had been given before the offset of the last display, a question mark appeared as a reminder for the participant to provide the coherence judgment or the letter size consistency judgment. After the response, the screen was cleared and stayed blank for the remainder of the trial.

2.5. Data acquisition

A Bruker Medspec 30/100 system was used for magnetic resonance imaging at 3.0 Tesla. Prior to the functional scans, two anatomical scans were acquired for each participant using MDEFT sequences [54]. The first was a whole brain image acquired with a T1-weighted three-dimensional (3D)-segmented sequence ([29]; 128 sagittal, adjacent slices, 1.5 mm thick, 256×256 pixel matrix per slice). To enable alignment of the functional scans with this high-resolution image, anatomical 2D images were acquired, using the same number and orientation of slices as the functional scans ([41]; TE=6.1 ms, TR=1300 ms, 256×256 matrix).

During the functional scans, the BOLD response was measured using a single-shot gradient EPI-sequence (matrix 64×64, TE=30 ms, flip angle 90°, field of view 192 mm). Horizontal images were acquired for 16 slices (5 mm thickness, 2 mm spacing), parallel to the bicommissural plane (AC–PC). For most participants, six slices were below the AC–PC line, while ten slices were above, but care was taken that the temporal lobes, as well as

prefrontal regions, were covered in full. In-plane resolution was 3×3 mm. We used a repetition time of 2 s (TR=2), and the presentation of the displays was triggered by the acquisition of the first slice of the current image.

2.6. Data analysis

Data analysis was conducted using the software package LIPSIA, developed as a tool for analyzing functional MRI data [32].

For each participant, the signal acquired during the functional scans was preprocessed as follows: First, a sinc-interpolation algorithm was applied to correct for the temporal spacing between the 16 slices of each image. Motion correction consisted of a global affinity linear transformation that optimized for each time step the linear correlation between the image at that time step and a predefined reference image. A baseline correction was then conducted using a temporal high pass filter with a cutoff frequency of 1/120 Hz. Furthermore, a spatial Gaussian filter was applied with a standard deviation of $\sigma=0.6$. With a voxel size of 3 mm, this standard deviation is equivalent to a full width at half maximum of 4.2.

For the statistical analysis we used a random effects model, with an algorithm identical to that used in SPM99 [18]. Specifically, we carried out the following sequence of processing steps: For each subject, the 2D-data were analyzed using the General Linear Model based on the aforementioned five conditions (four experimental conditions, one control condition). For the event-related model we time-locked the responses at the onset of the last display of the target sentence, and we assumed a lag of the hemodynamic response of 6 s from this event. Contrast codes were then used to detect significant activations by calculating *t*-statistics based on the parameter estimates of the full linear model.

We carried out the following six comparisons. The first contrast tested all four experimental conditions against the control condition, to see whether the resulting activations properly reflect language processing. For the language trials, the next three contrasts corresponded to testing the effects of the 2×2-design; specifically, one contrast tested the effect of Cohesion, one the effect of Coherence, and one contrast the interaction between these two factors. Finally, we used two planned pairwise comparisons to further specify the resulting interaction.

For the statistical analysis across participants, the six contrast images of each participant were fitted into a standard stereotaxic space [50] as follows: First, the 2D anatomical scan was rotated and shifted so that it mapped onto the 3D whole brain image. Then, linear scaling factors were calculated to transform the image to the standard size. The resulting co-registration matrices were finally applied to the six contrast images using trilinear interpolation [31]. For inferential statistics across participants, the standardized 3D-images for each contrast were

Table 3
Behavioral data for the coherence judgments during the fMRI scanning ($n=12$)

	Coherent		Incoherent	
	Incohesive [1]	Cohesive [2]	Incohesive [3]	Cohesive [4]
Correct responses: mean and SD in percent	92.8 (6.3)	94.2 (6.8)	95.3 (3.9)	93.1 (5.4)
Judgment times: mean and SD in ms	2041 (576)	2026 (590)	2091 (495)	2129 (506)

used to calculate voxelwise t -tests. The resulting t -values were then transformed into Z -scores. Only those voxels with $|Z|>3.09$ were considered significantly activated ($P<0.001$). Since this probability level is uncorrected for multiple comparisons, we defined an additional spatial extent threshold as follows: Areas of activation smaller than 125 mm^3 were neglected. This threshold roughly corresponds to the requirement that more than two adjacent voxels in the original image (of volume $3 \times 3 \times 5 \text{ mm} = 45 \text{ mm}^3$) be significantly activated.

3. Results

3.1. Behavioral data

For each participant and each condition, the percentage of correct responses was calculated. In the baseline condition, participants answered 93% of the questions correctly ($SD=7.1\%$). For the coherence judgments in the experimental trials, accuracy was just as high (mean=94%, $SD=3.0$). None of the effects in the 2×2 -analysis with the factors Cohesion and Coherence were significant (see Table 3).

The reaction times were measured from the onset of the last display to the button press. Thus, times shorter than 2 s indicate that the response was given while the last display was still on the screen. Before averaging, all reaction times were first corrected by replacing high and low values with a cutoff value of 2 standard deviations above or below each participant's mean. For each participant and each condition, we then calculated mean reaction times.

In the baseline condition the mean reaction time was

1994 ms ($SD=673$). The means for the coherence judgments are shown in Table 3. Once more, none of the effects in the ANOVA with the within-subjects factors Cohesion and Coherence was significant ($F(1,11)=2.9$, $P=0.11$ for Coherence, $F(1,11)<1$ for Cohesion, and $F(1,11)=2.0$, $P=0.18$ for the interaction Cohesion \times Coherence). A similar result obtained when the reaction times were corrected for the length of the last display.

The reason for the failure to find significant results in the behavioral data was that, in contrast to the reading time pretest, the fMRI experiment required fixed presentation times. Although the response could be given as soon as the last display was shown, a majority of the participants waited almost always until its offset to provide their judgment. Thus, for these subjects, the reaction times did not properly reflect processing difficulty of the target sentence. Because of the clear results of the pretest, and the trends shown in the fMRI experiment, we can nevertheless be confident that the experimental conditions indeed required the different processes targeted.

3.2. fMRI results

Table 4 shows the areas of activation for the comparison of the language trials with the control task. The absence of activation in the visual cortex confirms that the control condition was appropriate for filtering out activation related to perceptual processing of the visually presented stimuli.

As expected, reading and comprehending sentences involved an extended frontotemporal area on the lateral surface of the left hemisphere. For better reference, we included in Table 4 the coordinates of local maxima within

Table 4
Brain regions significantly activated for the language conditions compared to the control condition

Language vs. control	Size (mm^3)	Z-Score	Side	Talairach–Fox coordinates		
				x	y	z
Superior frontal gyrus (BA 6) [1]	145	3.42	L	-10	15	52
Superior frontal gyrus (BA 8) [2]	2425	4.54	L	-8	44	42
Superior temporal sulcus (anterior) (BA 38/21) [3]	18434	4.90	L	-50	-12	-7
Superior temporal sulcus (posterior) (BA 21/37) [4]		4.84	L	-59	-49	13
Inferior frontal sulcus/precentral sulcus (BA 44/6) [5]		4.26	L	-46	20	19
Inferior frontal gyrus: pars triangularis (BA 45) [6]		4.23	L	-46	28	5
Posterior cingulate cortex/precuneus (BA 23/30) [7]	1188	3.93	L	-8	-54	23
Inferior frontal gyrus (BA 45) [8]	238	3.67	R	44	27	11
Superior temporal sulcus (anterior) (BA 22) [9]	1372	4.75	R	43	-10	-8
Cerebellum [10]	492	4.06	R	18	-79	-20

Language – Control

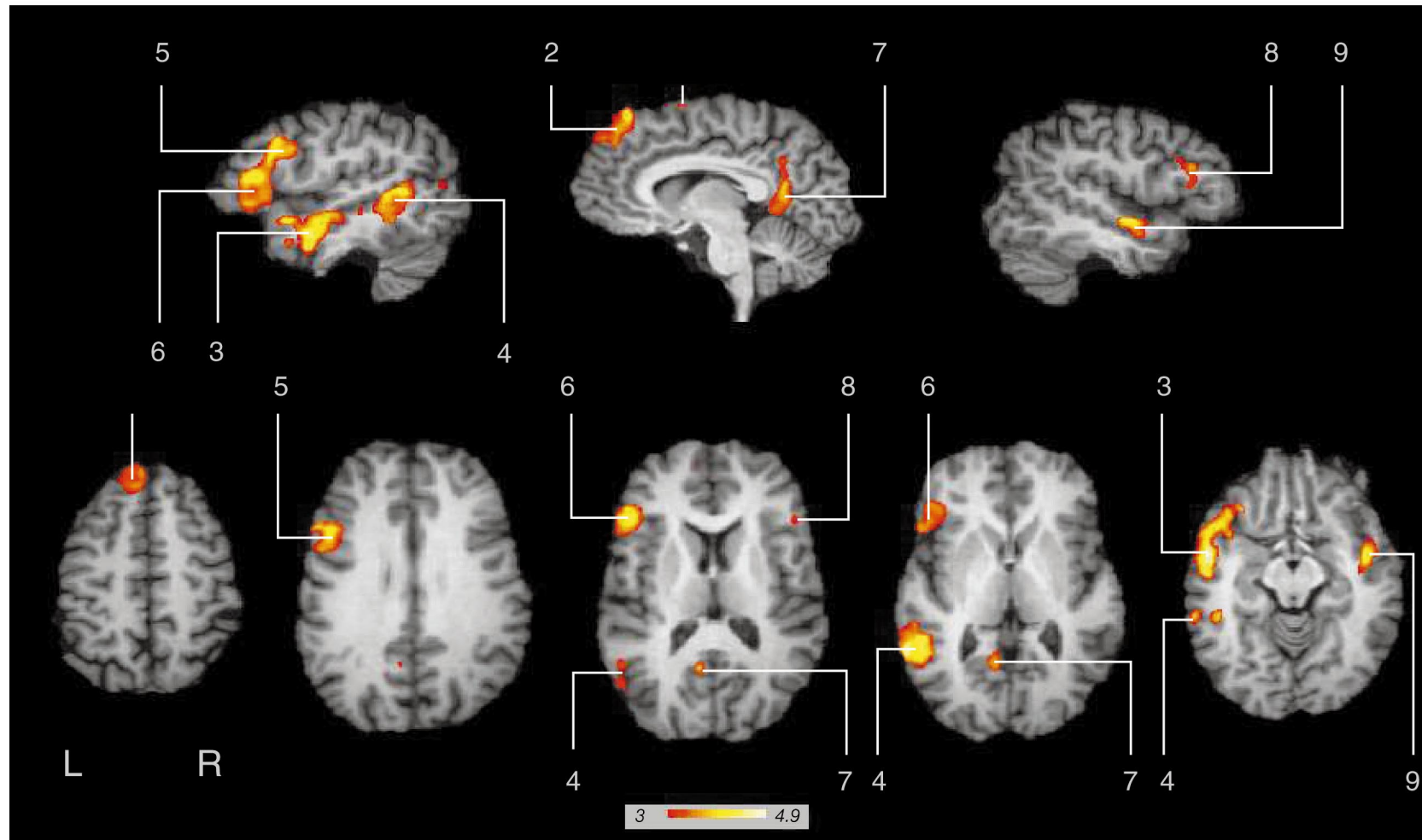


Fig. 1. The Z-map from the contrast comparing the language conditions to the physical control condition. The group data based on all 12 participants are superimposed on an individual brain. The upper row contains sagittal slices illustrating the left-lateral ($Y=-48$), the left-medial ($Y=-8$) and the right-lateral ($Y=+44$) views. The second row shows corresponding horizontal slices in five planes ($Z=+38, +22, +10, +1, -9$), with the left side of the brain being on the left side of the images. The identification numbers for the activated regions are those provided in Table 4. Refer to the table for a more detailed description of the regions' characteristics.

this large region. As can be seen in Fig. 1, the temporal activation extended along the bank of the superior temporal sulcus (STS), reaching into the posterior division of the middle temporal gyrus (MTG; BA 21/37), but sparing most of the superior temporal gyrus (STG), and in particular, its posterior portion. The inferior temporal gyri were not active either. Besides a large activation peak covering the posterior part of the STS, there was a second peak in its anterior portion, extending into the polar region of the temporal lobe (BA 21/38).

The lateral prefrontal activation consisted of two adjacent regions in the ventrolateral frontal cortex. The more ventral peak centered on the pars triangularis of the inferior frontal gyrus (IFG; BA45), whereas there was almost no involvement of the neighboring pars opercularis (BA 44, Broca's area) during this language processing task. The second left frontolateral peak was located more superiorly, extending to the inferior frontal sulcus (IFS) and posteriorly to the inferior precentral sulcus (IPcS; BA 44/6). For both the anterior temporal and the inferior prefrontal activation we also found the right-hemispheric homologues to be somewhat involved, but clearly to a much smaller extent. Furthermore, the deep right cerebellum proved active.

Along the left superior frontal gyrus (SFG) we found two regions of activation, a small one in BA 6 and a more prominent one in BA 8. The latter extended from the dorsal surface of the SFG into its median division. Furthermore, we found an area of activation in the inferior precuneus (BA 23), extending downwards to the retrosplenial area (BA 30).

To shed light on the influence of the experimental variables, we now considered differences between the four

conditions. In analogy to the 2×2-ANOVA reported for the behavioral data, we calculated the contrasts corresponding to the two main effects and their interaction. To further specify the interaction, we also conducted pairwise comparisons: for both the incoherent and the coherent conditions separately, we calculated the contrast testing the effect of Cohesion. The semantic and pragmatic content is identical for both cohesive and incohesive sentence pairs, as is the required response. Thus, these pairwise comparisons test the effect of lexical cohesion only, without possible confounds (e.g. retrieval of general world knowledge, response type or response success). Recall that we know from the pretest that, depending on coherence, cohesion has just the opposite effect: While cohesive ties aid inference processes in coherent trials, they hinder the detection of a coherence gap in the incoherent trials. The coordinates of the resulting activations are shown in Table 5.

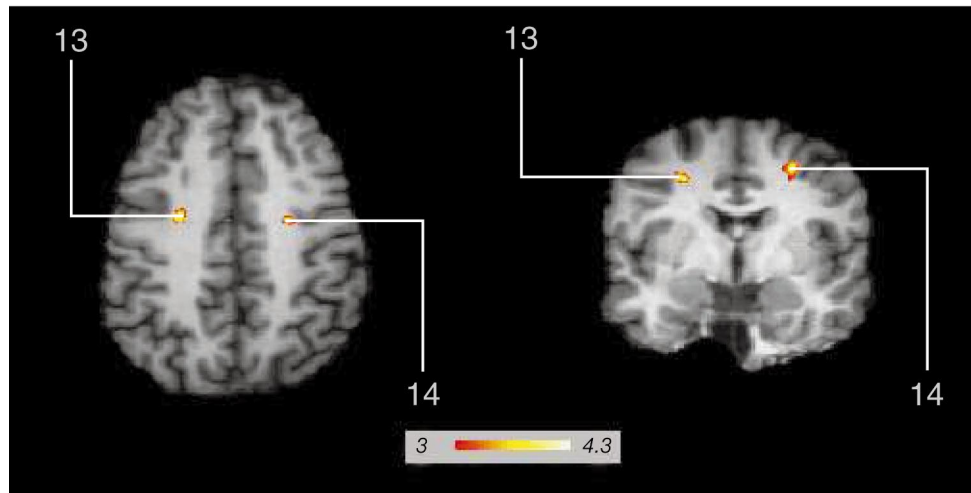
The first contrast compared cohesive and incohesive trials. The most apparent difference between these conditions was the sentence length. Consistent with an impact of this feature on reading processes, independent of comprehension processes, we found activation in the vicinity of the frontal eye fields bilaterally (BA 6), which is displayed in Fig. 2. For no other brain regions were there increases in regional cerebral blood flow, and there were no significant activations in the comparison of incohesive vs. cohesive trials.

More central to the questions posed in this study is the comparison between coherent and incoherent trials. Unexpectedly, incoherent trials did not differentially activate any brain regions. The rejection of pragmatically unrelated sentence pairs did not yield measurable activation differ-

Table 5
Brain regions significantly activated for the contrasts testing the effects of Cohesion and Coherence

	Size (mm ³)	Z-Score	Side	Talairach–Fox coordinates		
				x	y	z
Main effect of Coherence:						
Coherent vs. Incoherent ([1],[2]–[3],[4])						
Posterior cingulate cortex/inferior precuneus (BA 23/31) [11]	178	3.42	L	–5	–34	39
Frontomedian wall/superior frontal gyrus (BA 9/10) [12]	1843	5.18	L	–4	58	13
Main effect of Cohesion:						
Cohesive vs. Incohesive ([2],[4]–[1],[3])						
Superior frontal sulcus/superior precentral sulcus (BA 6) [13]	133	4.03	L	–25	0	34
Superior frontal sulcus/superior precentral sulcus (BA 6) [14]	217	4.35	R	24	1	37
Interaction: Coherence×Cohesion:						
<i>(a) difficult vs. easy ([1],[4]–[2],[3])</i>						
Inferior frontal sulcus/inferior precentral sulcus (BA 44) [15]	143	3.77	L	–40	22	15
<i>(b) Incoherent only:</i>						
<i>cohesive–incohesive ([4]–[3])</i>						
Inferior precentral sulcus (BA 44/6) [16]	296	3.69	L	–44	9	19
Inferior frontal sulcus/inferior precentral sulcus (BA 44) [17]	328	4.02	L	–31	17	17
<i>(c) Coherent only:</i>						
<i>cohesive–incohesive ([2]–[1])</i>						
Intraparietal sulcus (BA 39/7) [18]	415	4.66	L	–28	–60	48
Supramarginal gyrus (BA 40) [19]	342	4.47	L	–45	–40	43

Cohesive - Incohesive



Coherent - Incoherent

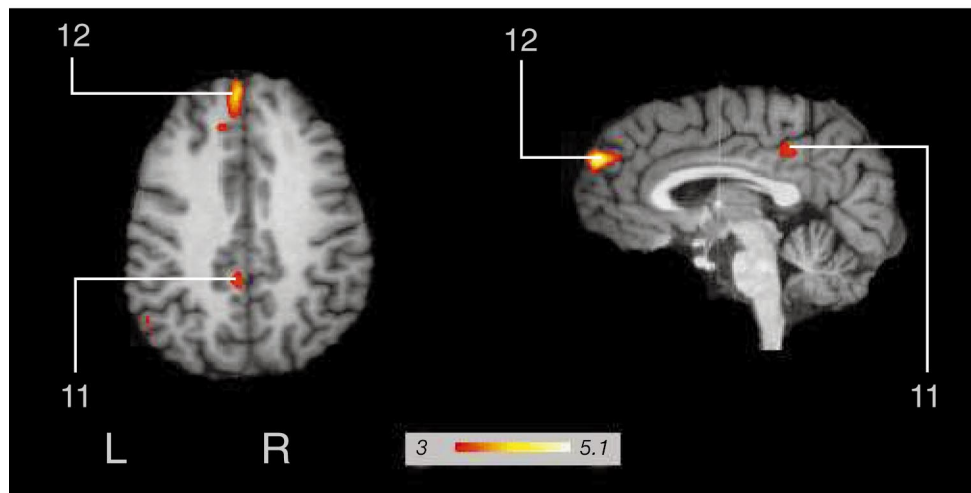


Fig. 2. Activations due to the experimental factors Coherence and Cohesion. The upper panel displays the Z-map for the main effect of Cohesion, independent of Coherence. The two significant brain regions in the subtraction of incohesive trials from cohesive trials are illustrated in a horizontal and a coronal view, centered in the Talairach–Fox coordinates of the left-sided region ($X=-25, Y=0, Z=34$). The lower panel illustrates the main effect of Coherence: displayed is the Z-map for the contrast subtracting the incoherent sentence pairs from the coherent sentence pairs, centered in the frontomedian region ($X=-4, Y=58, Z=13$). The identification numbers refer to the labels in Table 5, which contains further characteristics of the activated regions.

ences. In contrast, the successful establishment of a pragmatic connection, i.e. the derivation of an inference, activated two areas in the median wall of the left hemisphere, shown in the lower panel of Fig. 2. The posterior activation involved posterior cingulate (BA 31) and inferior precuneal (BA 23) areas. The much more prominent anterior activation, located in the medial portion of BA 10/9, seems to be the anteriormost extension of the

frontomedian area that was equally activated in all language conditions.

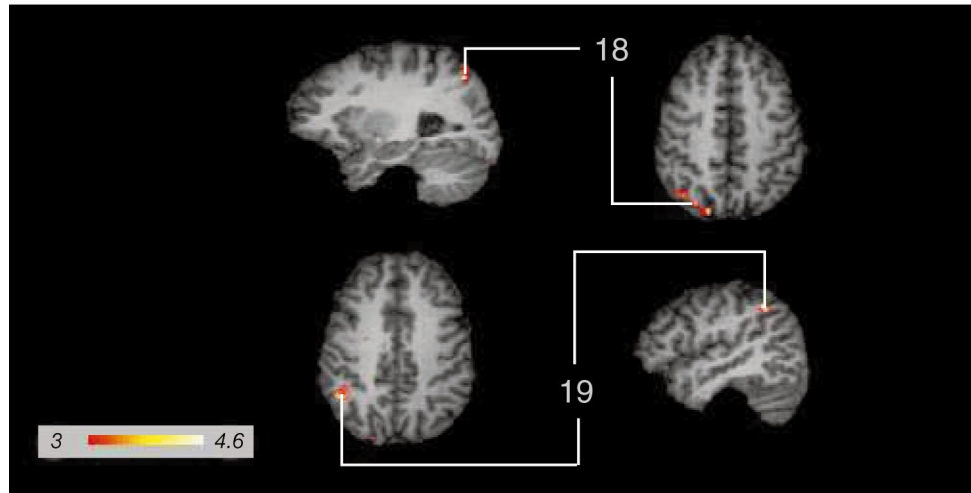
When looking at the contrast reflecting the interaction between Cohesion and Coherence, we found one small region to be activated. The more difficult conditions elicited activation along the inferior bank of the IFS (BA 44), corresponding to the area activated in all language trials. Thus, this region was involved in the processing of

all conditions, but more so when the task was more demanding (coherent/incohesive, incoherent/cohesive).

To further specify this interaction we calculated pairwise comparisons for each of the coherence conditions separately. In these comparisons, whose results are shown in Fig. 3, response, memory demands, and pragmatic knowledge are controlled. The sentences differ in one lexical feature only, namely the presence or absence of a cohesive

tie. For the coherent condition, cohesion yielded small activations in the left supramarginal gyrus (BA 40) and along the intraparietal sulcus (BA 39/7). In contrast, for incoherent trials, for which the reaction time difference indicated a garden-path for the misleading cohesive sentences, cohesion yielded activation in the left inferior frontolateral cortex. One peak was close to the junction of the IFS and the IPcS, and the second peak lay within the

Coherent: Cohesive - Incohesive



Incoherent: Cohesive - Incohesive

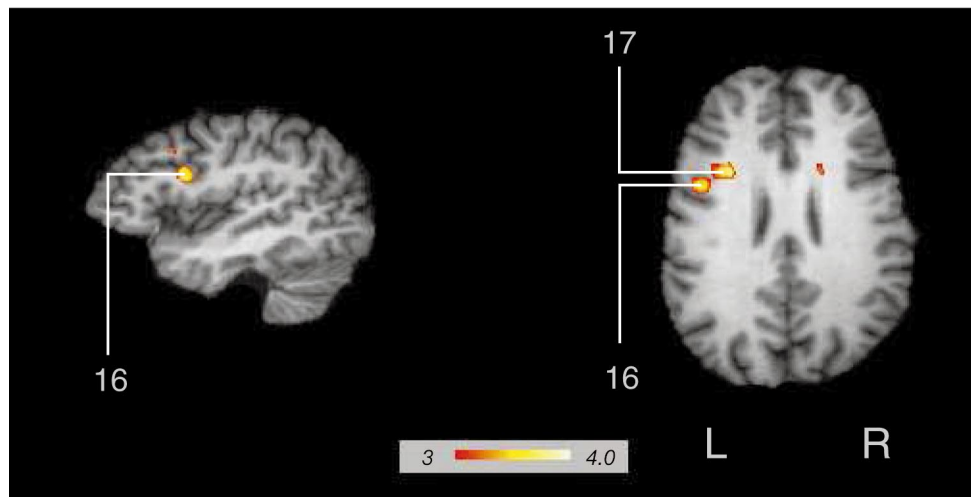


Fig. 3. Activations due to the interaction between Coherence and Cohesion. The upper panel displays the contrast testing the effect of cohesion for the coherent sentence pairs only. Images for the two regions that reached significance are shown separately. The first row displays the activation with the peak in ($X=-28, Y=-60, Z=48$), while the second row shows the activation with the peak in ($X=-45, Y=-40, Z=43$). The lower panel displays the effect of Cohesion on the coherent sentence pairs. Activation elicited by incohesive, coherent trials is subtracted from activation elicited by cohesive, coherent trials. Shown are a lateral and a horizontal view, centered in ($X=-44, Y=9, Z=19$). The identification numbers refer to the labels in Table 5 containing the characteristics of the areas of activation.

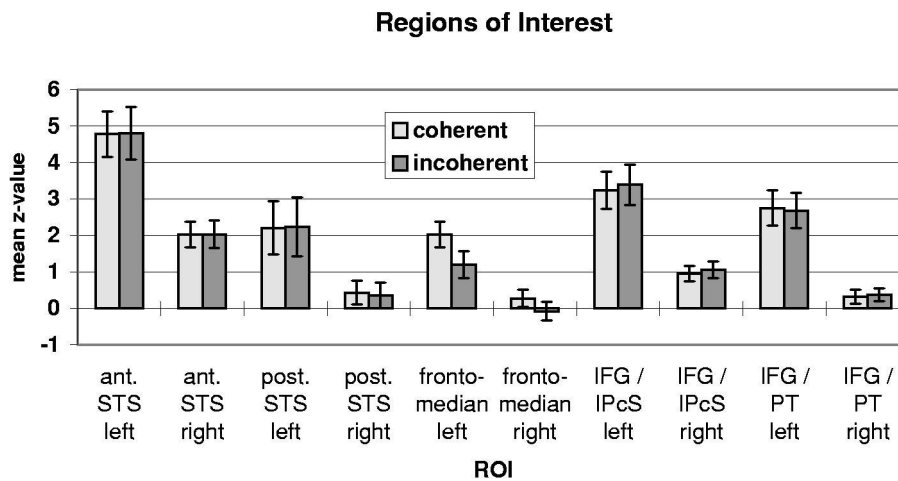


Fig. 4. Regions of interest analysis for lateral frontotemporal areas and the frontomedian wall. The means of the average Z-values in each of five regions of interest are displayed as a function of Coherence and Hemisphere. The error bars indicate one standard error above and below the mean. The left-hemispheric regions are defined as the spheres of radius 6 mm around the frontotemporal activation peaks provided in Table 4: ant.STS=[3], post. STS=[4], IFG/IPcS=[5], IFG-PT=[6]. The right hemispheric regions are defined as the homologue areas. The frontomedian ROI includes both the peak of area [2], as well as the peak for the contrast comparing coherent to incoherent trials [12].

lower branch of the left IPS. This result suggests that the significant interaction was mostly due to increases in processing demands for the incoherent, cohesive condition, rather than due to processing difficulties caused by missing cohesive ties in the coherent condition.

3.3. Regions of interest analysis

In order to further evaluate the apparent lateralization differences found in the group statistics, we conducted an additional analysis based on the activations in specifically defined regions of interest (ROIs). To each of four left-lateral regions of activation identified above, we defined a ROI of size 925 mm³ as the sphere with radius 6 mm around the activation peak. To all four regions, we also considered the right-sided homologue. The activation levels in each of the resulting eight ROIs were obtained using the procedure suggested by Bosch [6]: for each participant separately, we first calculated individual Z-maps for both the contrast comparing coherent trials to the control task, as well as for the contrast comparing incoherent trials to the control task. After normalization and co-registration into a standard 3D-space, the average Z-values in the eight ROIs were determined for each participant. These means, whose averages are shown in Fig. 3, were then entered into a 2 (Hemisphere) × 2 (Coherence) × 4 (Region) ANOVA. There was a highly significant main effect of Region ($F(3,33)=10.7$, $P<0.0001$), a highly significant main effect of Hemisphere ($F(1,11)=44.1$; $P<0.0001$), but none of the effects involving the factor Coherence came close to significance (all $F_s<1$). Thus, this analysis confirms that the right-sided activations were considerably smaller than the left-sided

ones, and suggests that Coherence did not modulate this left-hemispheric dominance.

To evaluate the frontomedian activation, we defined a larger ROI of size 2579 mm³, including both the activation peak in the SFG found during all language trials, as well as the peak significant in the comparison of coherent vs. incoherent trials. Once more, the homologue area in the right-sided median wall was also considered. The centers were slightly shifted away from the median, so that there was no overlap between the left-sided and the right-sided ROIs. Average Z-values were then obtained for each participant as described above, and their means are also displayed in Fig. 4. In the 2 (Coherence) × 2 (Hemisphere)-ANOVA, the clear main effect of Hemisphere confirmed the left-sided dominance ($F(1,11)=12.7$, $P<0.01$). Moreover, there was a highly significant main effect of Coherence ($F(1,11)=20.6$, $P<0.001$). The interaction of Coherence with Hemisphere shows that this effect was mostly driven by activation differences in the frontomedian wall of the left hemisphere ($F(1,11)=10.4$, $P<0.01$).¹

¹Because of well-known lateralization differences between men and women, we included in a second analysis the between-subjects factor Gender. Despite the small sample size of four women and eight men, the results showed marginally larger activation for women in the frontotemporal ROIs ($F(1,10)=4.6$, $P=0.07$), but Gender neither interacted with Hemisphere nor with Coherence. Contrary to the expectation of women's patterns of activation being less lateralized than men's, we obtained for the frontomedian ROI a significant interaction between Gender and Hemisphere, indicating that the difference between left and right-sided mean Z-values was even larger for women (mean=2.7, SD=1.4) than for men (mean=0.9, SD=1.1). This post hoc analysis suggests that gender differences might be an interesting topic for future research, but they do not seem to account for the lateralization effects found in this study.

4. Discussion

The present study was designed to investigate coherence processes during written language comprehension. Using whole-head fMRI with stimuli targeting local coherence processes rather than global text comprehension processes, we aimed at evaluating the respective contributions of prefrontal areas and the right hemisphere. First, we compared the language trials to a control task to confirm the consistency of our results with previously reported findings on language processing in the visual modality. Because in both language and control trials the stimuli consisted of letters and were similar in appearance, no additional activation in the striate and extra-striate visual cortices was seen for the language stimuli [22,23]. Thus, the judgment of a physical aspect of non-words properly controlled for visual perception and character recognition, without requiring lexical or semantic processing.

For the coherence judgment paradigm, we crossed the factors coherence, i.e. the pragmatic relatedness, and cohesion, i.e. the presence of a lexical connective. The accuracy of the coherence judgments was very high, showing that the conditions were easily separable. A reading time pretest, as well as the trends in the reaction times during the fMRI experiment, confirmed that lexical cohesion facilitates inference processes, while it renders the detection of incoherence more difficult. The factorial design enabled to separate those brain regions in the large network of activation that are involved in language processing on the sentence level from those activated by text level processes.

4.1. *The left lateral convexity cortex*

The frontotemporal activation found when comparing all language trials to the control trials, independent of condition, was predominantly left-lateralized. The left temporal lobe has been reported to be involved in language processing by numerous authors. In many studies, the activation for lexical or semantic tasks is located in the inferior lateral and basal temporal lobe (e.g. Refs. [16,51]). Other studies reported superior and middle temporal activation as well, not only for auditory but also for visual presentation [11,45]. Price [43] summarizes several findings and argues that the posterior temporal lobe is involved in the phonological and lexical aspects of word retrieval, while more anterior temporal activation seems to reflect the specific requirements of semantic decisions using verbal material. In contrast, Bavelier et al. [1] argue that anterior temporal areas are specifically involved during language comprehension in sentence contexts. Mazoyer et al. [35] report anterior temporal activation in all context conditions, even when the sentences were made up of pseudo-words or when they were semantically anomalous.

Consistent with the proposal of temporal activation

being related to word and sentence level processes, we found activation both in anterior and posterior temporal regions along the banks of the left STS, and to a lesser extent, in the right anterior temporal region. These activations did not differ as a function of coherence. In contrast, Fletcher et al. [17] report posterior STG activation for the processing of coherent vs. incoherent language, i.e. for a comparison on the text level. However, more than posterior temporal areas, the polar temporal regions have been connected with text processing, in part based on the clinical observation that patients with anterior temporal lobectomies have specific difficulties with story recall. Neuroimaging results also indicate a role of the left or both temporal poles for processing language across sentence boundaries [17,19,33,35]. The temporal activation found in the present experiment extended into the polar region (BA 38), but the peak was located clearly more posteriorly, at the anterior end of the STS. One possible explanation for the result that this region was equally active in both coherence conditions is that the temporo-polar regions contribute to the construction of representations for larger units of text. The aforementioned studies used passages comprising narratives, so that text processing was guided by a story schema. In our experiment, the sentence pairs described minimal scenarios comprehensible without the need to develop or encode a global structure. Consistent with this account is the fact that Maguire et al. [33] found temporo-polar activation only for their standard stories that followed a canonic story schema. When the structurally unusual texts with and without the illustrating picture were compared, the left temporal pole was not significantly activated, despite the differences in global coherence.

The large left-sided, lateral prefrontal activation had two distinct foci. The peak of the activation in the inferior frontal gyrus was located in the pars triangularis (BA 45). In contrast to the pars opercularis (BA 44), an area shown to be involved during phonological and syntactic processing [13,26], the more anterior left IFG has been implicated in tasks requiring semantic activation, or more specifically, the goal-directed retrieval of semantic information [56] or the selection among competing semantic alternatives [51]. While the exact location within the IFG varies, it seems clear that inferior frontal regions become active in tasks requiring semantic processes (see Ref. [16]). In our experiment, the level of activation in the pars triangularis was comparable across conditions, so that it seems to reflect semantic processing on the sentence level.

In contrast, the second peak, located at the junction area of the IFS and the IPCS, was found to be specifically involved during processing of the more difficult conditions, and in particular, during processing of the incoherent condition with misleading cohesive ties. Therefore, activation in this region does not only reflect sentence level processing, but task-dependent processing influenced by the context condition. It is possible that this activation

reflects the increased demand of semantic organization in these conditions (cf. Ref. [51]). However, because of the variety of tasks known to elicit activation in this area, we propose a functional role going beyond language-specific processes. Common to the tasks activating the junction area, including a Stroop paradigm [57] and a task-switching paradigm [14], is that they all require resolving the conflict between competing task sets. Similarly, responding correctly to our incoherent, but cohesive sentence pairs required resolving the conflict between a lexically based versus a pragmatically based response strategy.

4.2. *The median wall*

During all language trials, an area in the posterior cingulate cortex and the adjacent inferior precuneus (PCC) was active, and only the precuneal activation was modulated by coherence. Maguire et al. [33] report a similar region for their comparison of unusual stories with and without pictures, i.e. for the comparison of coherent vs. incoherent stories. They argue that it is involved in forming a mental model by integrating the current input with the background knowledge, in this case provided in the form of an illustrating cartoon. Fletcher et al. [17] report PCC activation for story comprehension as compared to the comprehension of unlinked sentences, whose exact localization depended on the type of stories presented. Once more, the authors explain this activation with the on-line attempt of integrating the current input with the previously established situation model of the story. A similar activation during a plausibility judgment task [7] suggests that these situational processes can take place on the sentence level, and several experiments using a complex categorization task on the word level also reported PCC activation [4,5]. The results of the present experiment also confirm the role of the PCC region in the encoding of a newly formed situation model representation. While for all sentences, a situation model is being constructed, an updating of the existing one is needed for coherent sentence pairs only.

The most prominent region distinguishing coherent and incoherent trials was the medial portion of BA 9/10, to which the frontomedian activation during all language trials was posteriorly adjacent (BA 8). In the study by Mazoyer et al. [35] a left superior prefrontal focus was the only region exclusively activated by the story condition. Frontodorsal or frontomedian activations were also reported for inductive reasoning [20] and the aforementioned complex categorization and plausibility judgment tasks [4,5,7]. Common to these tasks is that an evaluation is required based on the integration of a verbally presented stimulus with both the experimental context, as well as the general background knowledge. Most importantly, Fletcher et al. [17] implicated a frontomedian area as the region where 'Theory of Mind' is located (see also Refs. [19,20]). In their comparison of stories requiring the attribution of

the protagonist's mental state with stories without this component, the frontomedian region was active. Fletcher et al. discuss this similarity with the Mazoyer results and note that the stories used for the latter study also involved Theory-of-Mind attributions. In our experiment, frontomedian/frontodorsal structures were significant both for the comparison of all language trials to the control trials, and, even more clearly, for the comparison of coherent to incoherent sentence pairs. It is possible that, even without explicit instructions to consider the Theory of Mind, this frontomedian activation was mostly caused by those 50% of the trials that contained human protagonists and thus allowed to consider the thoughts and feelings of the people mentioned. To rule out this possibility we carried out a post hoc analysis, testing the contrast for the interaction between Animacy and Coherence. This comparison did not yield any significant areas of activation, indicating that the frontomedian activation was unlikely to depend on Theory-of-Mind attributions to animate protagonists.

An alternative account for the function of the frontomedian wall is related to clinical observations after, for instance, anterior cerebral artery infarctions. The symptoms described concern a reduction of motivation and volition, which in extreme cases can go as far as apathy [34]. In particular, the frontomedian wall is implicated for the internal generation of ideas and plans. Establishing coherence in the present experiment required a presumably non-automatic inference process for the integration of non-overlapping, externally presented information with general world knowledge. We believe that the frontomedian area has a function for the self-initiation of a cognitive process in the context of tasks that require the active utilization of the individual's background knowledge (cf. Ref. [20]). In the Theory-of-Mind studies [17,19], this cognitive process was caused by explicit instructions to identify with the feelings of the main character. In our experiment this process consisted of an inference process going beyond an associative, purely lexico-semantic elaboration.

4.3. *Inference processes and the right hemisphere*

Given our data, the role of the right hemisphere during inferencing remains unclear. In contrast to the good correspondence to the results of Fletcher et al. [17], and the partial overlap with the results reported by Maguire et al. [33], we could not replicate the involvement of right frontotemporal regions reported by St. George et al. [49] or Robertson et al. [46]. During language processing overall, the right hemispheric homologues of the left sided fronto-temporal regions were less strongly activated and they were smaller in extent. Furthermore, there was no lateralization shift in fronto-temporal regions when comparing coherent, plausible trials to incoherent, unrelated sentence pairs.

One explanation for this discrepancy not only with these

imaging studies, but also with the neuropsychological literature on inferencing, might be that resources in the non-dominant hemisphere do not become recruited unless the dominant hemisphere is lesioned, or unless unusual or erroneous stimuli are presented. Mazoyer et al. [35] found a reduction of their clear-cut left-hemispheric dominance for processing of syntactic prose and pseudo-word sentences (see also Refs. [38,40]). Following this hypothesis, the absence of right-hemispheric activation in the Maguire et al. study [33], in contrast to the St. George et al. study [49] might have been due to task differences. While there was no experimental task in the latter study — a setting in which the lack of a good situation model becomes apparent — the former study used memorization instructions, thereby drawing attention away from the insufficient situation model to the preserved textbase level. The left-hemispheric dominance found in the present study is also consistent with this explanation. There were no confusing or erroneous stimuli, because incoherence was task relevant. The participants did not get the feeling of being ‘at loss’, so that an additional recruitment of right hemispheric resources was unnecessary.

4.4. Conclusions

The experiment reported here enabled to identify the brain areas involved in distinct, but interacting processes during language comprehension in context. Consistent with previous results on word and sentence level processes we found extensive left fronto-temporal brain regions involved equally in all conditions. Neuropsychological theories proposing a particular role of the right hemisphere for inference processes could not be supported by the present data. Instead, we confirmed the role of posterior cingulate and adjacent precuneal areas for the successful construction of situation model representations. Most importantly, crossing the factors coherence and cohesion enabled us to attribute different components of language processing to distinct areas in the left prefrontal cortex. Besides the role of the left inferior frontal gyrus for lexico-semantic processes, and the function of the inferior frontal junction area for task set management, we found evidence for the involvement of the left frontomedian wall in the initiation of non-associative inference processes.

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