

Neuroanatomical correlates of phrase structure generation: an fMRI study

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03.-06.07.03

Outline

- Introduction
 - localization of syntactic processing
 - neuroimaging studies
 - motivation for an fMRI-Experiment
- fMRI-Experiment
 - material
 - results
- Conclusion

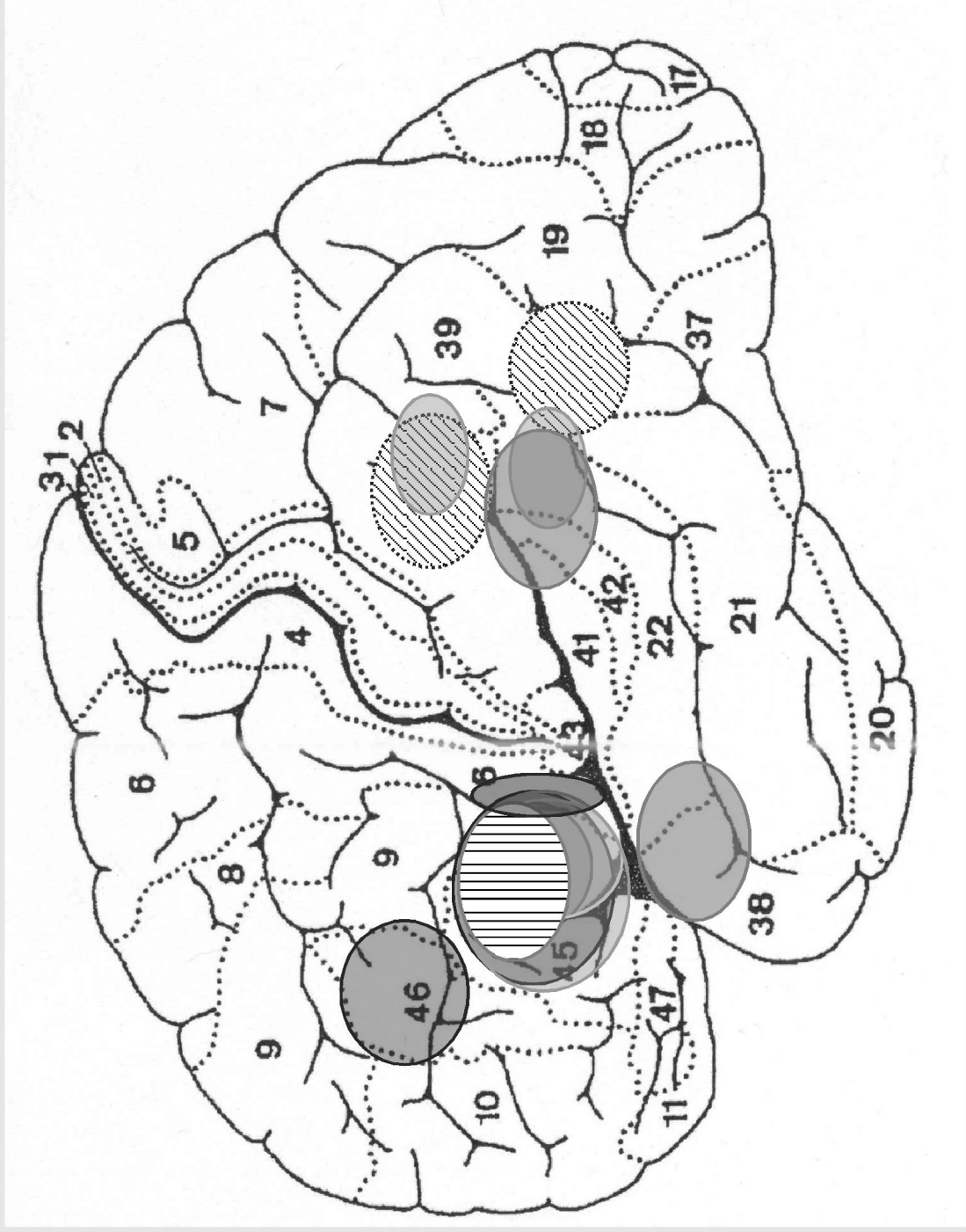
Introduction

- distinction of different linguistic levels of analysis: phonological, syntactic and semantic level
- are there neuroanatomical correlates of these levels in the human brain?
- by means of lesion studies assumption that localization of syntactic processing is the Broca area of the left frontal lobe (Broca 1861, Zurif 1980, Zurif & Grodzinsky 1983)

Introduction

Methods

- different methods to examine language processing in the human brain
 - monitoring electrophysiological brain activity
 - EP (Evoked Potentials)
 - MEG (MagnetoEncephaloGraphy)
 - EEG (ElectroEncephaloGraphy)
 - monitoring brain blood flow
 - SPECT (Single-Photon-Emission Computed Tomography)
 - PET (Positron-Emission Tomography)
 - fMRI (Functional Magnetic Resonance Imaging)



Stromswold et al. (1996), Kang et al. (1999), Dapretto&Bookheimer (1999),
Embick et al. (2000), Friederici et al. (2000a), Indefrey et al. (2001a)

template adopted from Pulvermüller & Preissl 1991

Introduction

Neuroimaging Studies

- no frontal activation for syntactic processing
 - Kuperberg et al. (2000)
 - Meyer et al. (2000)
 - Friederici et al. (2000b)
- syntactic working memory in Broca's area
 - Fiebach et al. (2001)
- frontal activation for non-syntactic processing
 - semantic processing: Müller et al. (2003)
 - phonological processing: Fiez et al. (1995)

Introduction

Neuroimaging Studies / Motivation

- differ in some aspects:
 - technique: PET / fMRI / MEG / EEG
 - verify the hypotheses of lesion studies
 - experiment design:
 - perception / production
 - language production experiment
 - test task / control task
 - block / event-related

Introduction

Neuroimaging Studies / Motivation

- differ in some aspects:
 - stimuli
 - sentences / words
 - examination of one aspect of sentence analysis
 - violated / non-violated
 - only non-violated stimuli
 - presentation: visual/ auditory

fMRI-Experiment

- Intention
 - identify connections between activated brain areas and language processes, such as syntactic processing
 - examination by isolating syntactic processing from general cognition
 - comparison of symbol manipulation and phrase-structure manipulation

fMRI-Experiment

Stimuli

- sentences
 - 14 syllables
 - three constituents, NP, VP and PP
- lists
 - names of the months

fMRI-Experiment Tasks

- two different tasks
 - Reading
 - reading of a presented sentence/list
 - Reserialization
 - changing the sentence order
 - changing the list order

fMRI-Experiment Tasks

- Reading
sentences

Neben der Leiche wurde die Tatwaffe gefunden.

fMRI-Experiment Tasks

- Reading
sentences

Neben der Leiche wurde die Tatwaffe gefunden.

→ Neben der Leiche wurde die Tatwaffe gefunden.

fMRI-Experiment Tasks

- Reading
sentences

Neben der Leiche wurde die Tatwaffe gefunden.

→ Neben der Leiche wurde die Tatwaffe gefunden.

word lists

Januar Februar März April

fMRI-Experiment Tasks

- Reading
sentences

Neben der Leiche wurde die Tatwaffe gefunden.

→ Neben der Leiche wurde die Tatwaffe gefunden.

word lists

Januar Februar März April

→ Januar Februar März April

fMRI-Experiment Tasks

- two different tasks
 - Reading
 - reading of a presented sentence/list
 - Reserialization
 - changing the sentence order
 - changing the list order

fMRI-Experiment Tasks

- Reserialization
sentences

Wolken haben sich über dem Atlantik gebildet.

fMRI-Experiment Tasks

- Reserialization
sentences

[_{NP} Wolken] [_{VP} haben sich [_{PP} über dem Atlantik] gebildet].

fMRI-Experiment Tasks

- Reserialization
sentences

[_{NP} Wolken] [_{VP} haben sich [_{PP} über dem Atlantik] gebildet].

→ [_{PP} Über dem Atlantik] [_{VP} haben sich [_{NP} Wolken] gebildet].

fMRI-Experiment Tasks

- Reserialization
sentences

[_{NP} Wolken] [_{VP} haben sich [_{PP} über dem Atlantik] gebildet].

→ [_{PP} Über dem Atlantik] [_{VP} haben sich [_{NP} Wolken]
gebildet].

In der Matratze haben sich Wanzen eingeknistert.

fMRI-Experiment Tasks

- Reserialization
sentences

[_{NP} Wolken] [_{VP} haben sich [_{PP} über dem Atlantik] gebildet].

→ [_{PP} Über dem Atlantik] [_{VP} haben sich [_{NP} Wolken] gebildet].

[_{PP} In der Matratze] [_{VP} haben sich [_{NP} Wanzen] eingenistet].

fMRI-Experiment Tasks

- Reserialization
sentences

[_{NP} Wolken] [_{VP} haben sich [_{PP} über dem Atlantik] gebildet].

→ [_{PP} Über dem Atlantik] [_{VP} haben sich [_{NP} Wolken] gebildet].

[_{PP} In der Matratze] [_{VP} haben sich [_{NP} Wanzen] eingeknistet].

→ [_{NP} Wanzen] [_{VP} haben sich [_{PP} in der Matratze] eingeknistet].

fMRI-Experiment Tasks

- Reserialization
word lists

September Oktober November Dezember

fMRI-Experiment Tasks

- Reserialization
word lists

September Oktober **November** Dezember

fMRI-Experiment Tasks

- Reserialization

word lists

September Oktober **November** Dezember

→ **November** September Oktober Dezember

fMRI-Experiment Tasks

- Reserialization

word lists

September Oktober November Dezember

→ November September Oktober Dezember

Juli August Juni September

fMRI-Experiment Tasks

- Reserialization

word lists

September Oktober November Dezember

→ November September Oktober Dezember

Juli August **Juni** September

fMRI-Experiment Tasks

- Reserialization

word lists

September Oktober November Dezember

→ November September Oktober Dezember

Juli August **Juni** September

→ **Juni** Juli August September

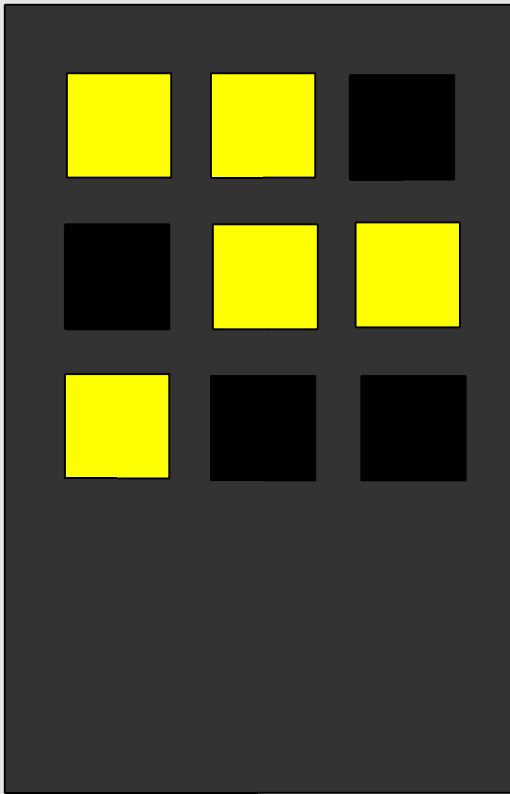
fMRI-Experiment Method

- 15 right-handed subjects
- event-related fMRI, randomized stimuli presentation
- fMRI-data obtained across the whole brain volume (28 slices, 4mm thickness, 1mm gap)
- magnetic field of 1.5 Tesla
- statistical analysis with SPM99

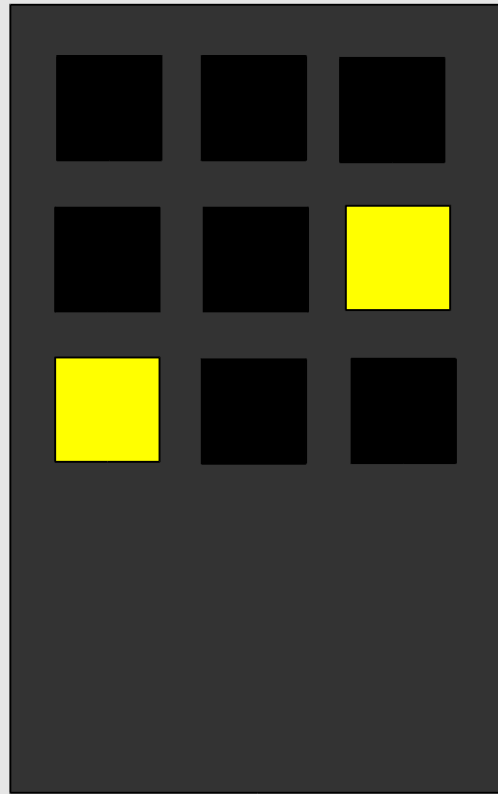
fMRI-Experiment Results

- subtraction design
 - two tasks which differ minimally
 - reorder sentences:
 - identification of an alternative syntactic constituent, presupposes a syntactic analysis
 - reorder lists:
 - identification of an alternative word/symbol
 - (Wildgruber et al. 1998)
 - reversal

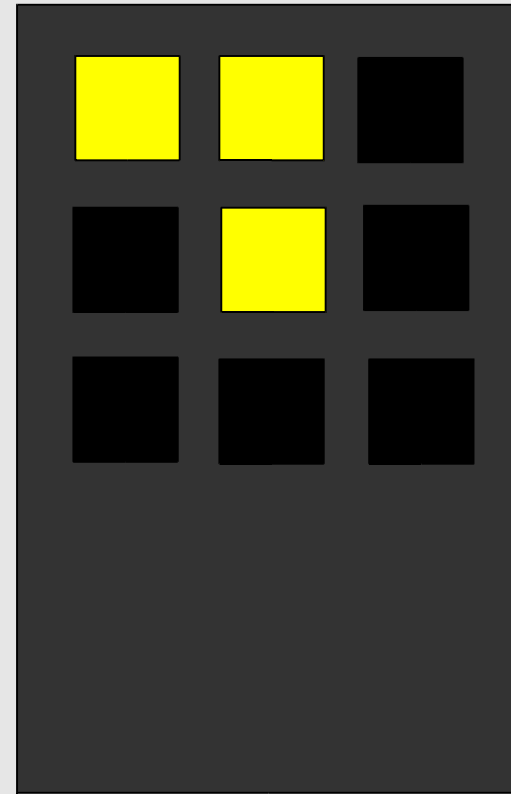
fMRI-Experiment



sentreord

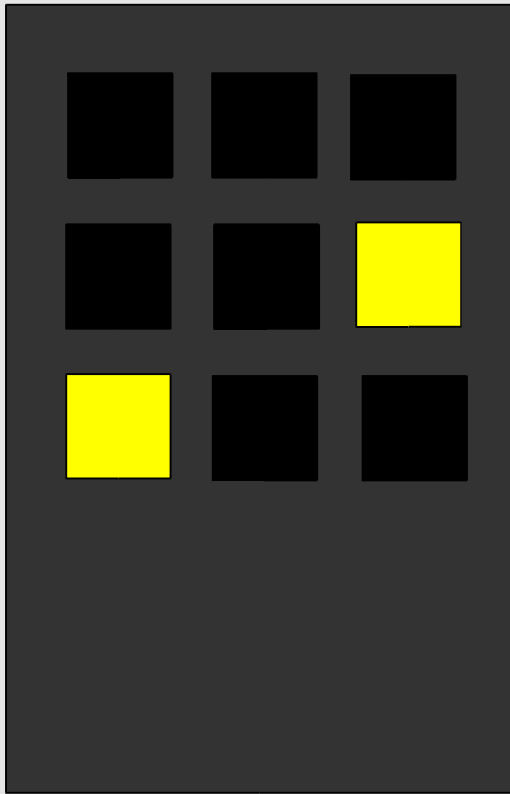


listreord

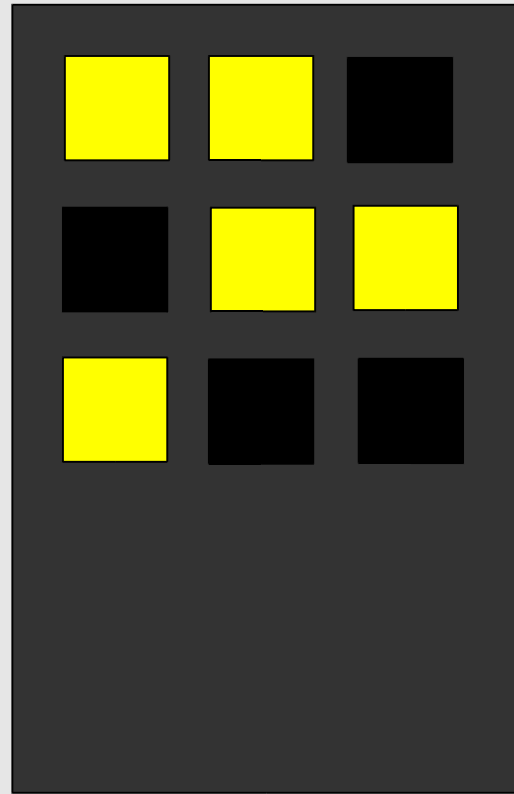


sentreord-listreord

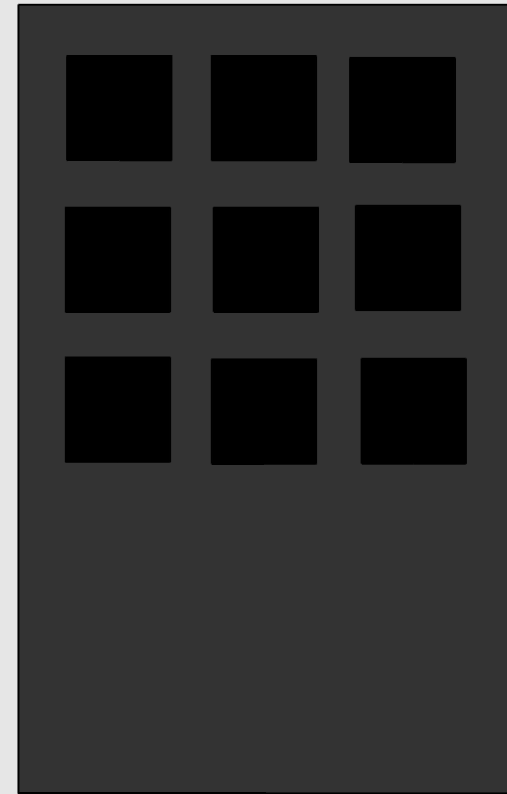
fMRI-Experiment



listreord



sentreord

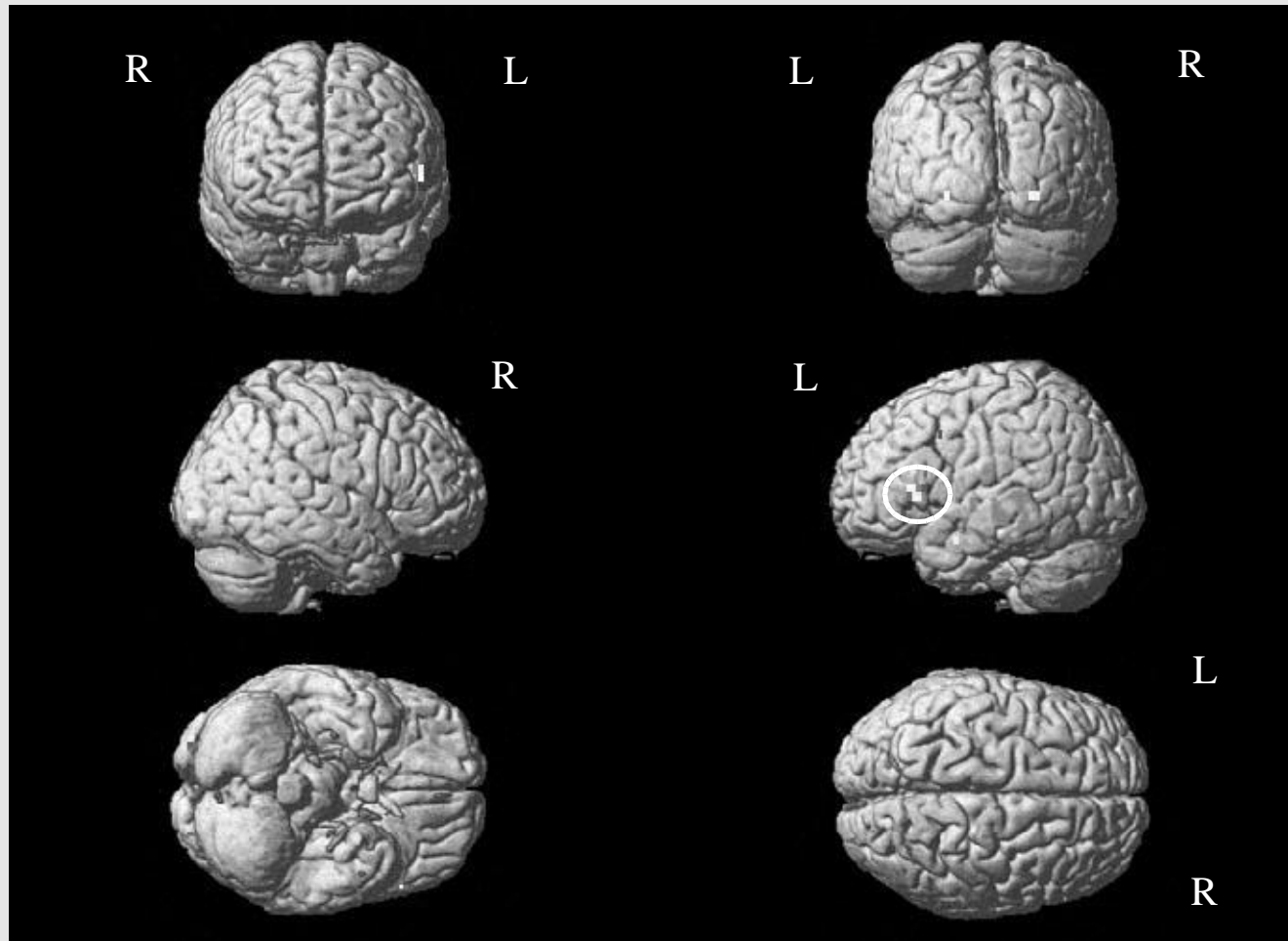


listreord-sentreord

fMRI-Experiment Results

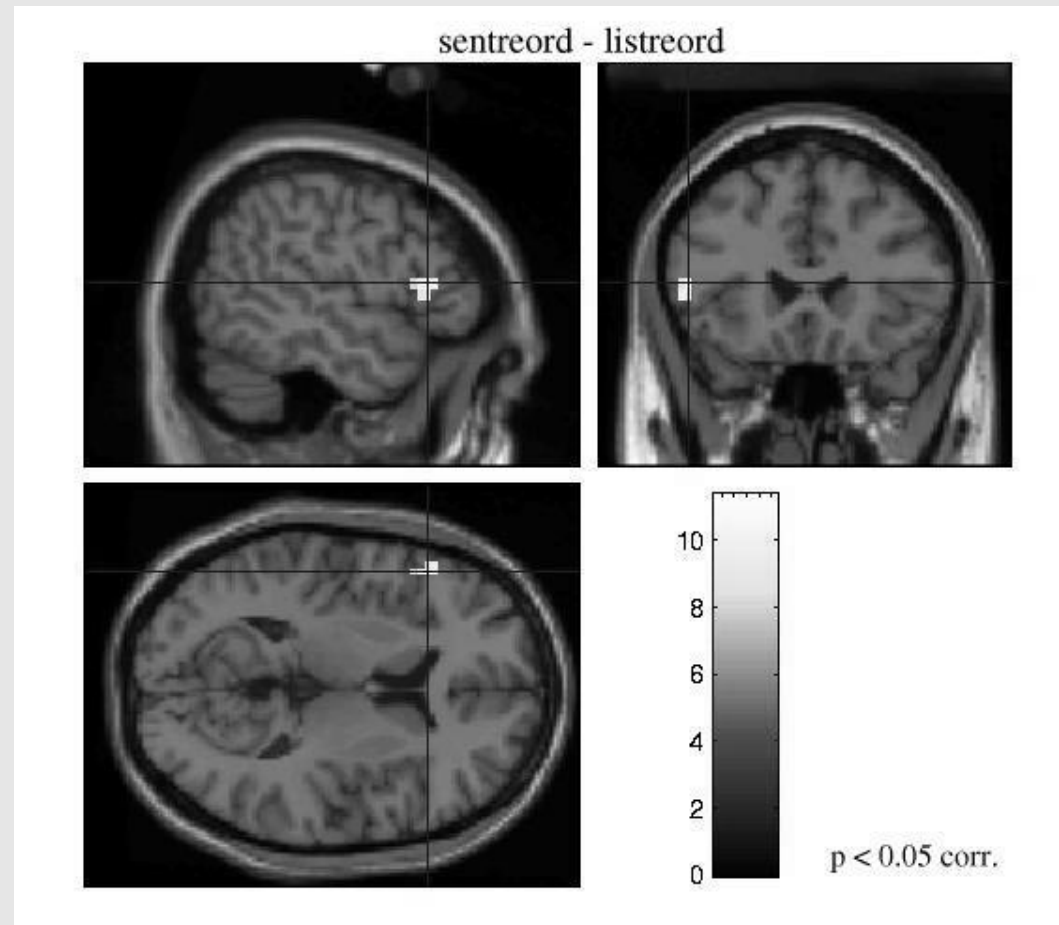
- contrasts
 - (1) sentreord-listreord
 - (2) sentread-listread
 - (3) listreord-listread
 - (4) sentreord-sentread

fMRI-Experiment Results



(1) sentreord - listreord, $p < 0.05$

fMRI-Experiment Results



fMRI-Experiment Results

<i>contrast</i>		<i>Z value</i>	<i>Talairach</i>			<i>BA</i>	<i>brain region</i>
			<i>x</i>	<i>y</i>	<i>z</i>		<i>(converted mni2tal)</i>
			<i>(unconverted)</i>				
(1) sentreord - listreord	L	5.62	-51	24	10	45	Gyrus frontalis inferior
	L	5.46	-36	6	40	9	Gyrus frontalis medior
	R	5.30	24	-96	-5	18	Occipitallobe
	L	5.11	-24	-96	-5	18	Occipitallobe
	L	4.98	-60	0	-20	21	Gyrus temporalis medior
	L	4.89	-3	12	55	6	Gyrus frontalis superior

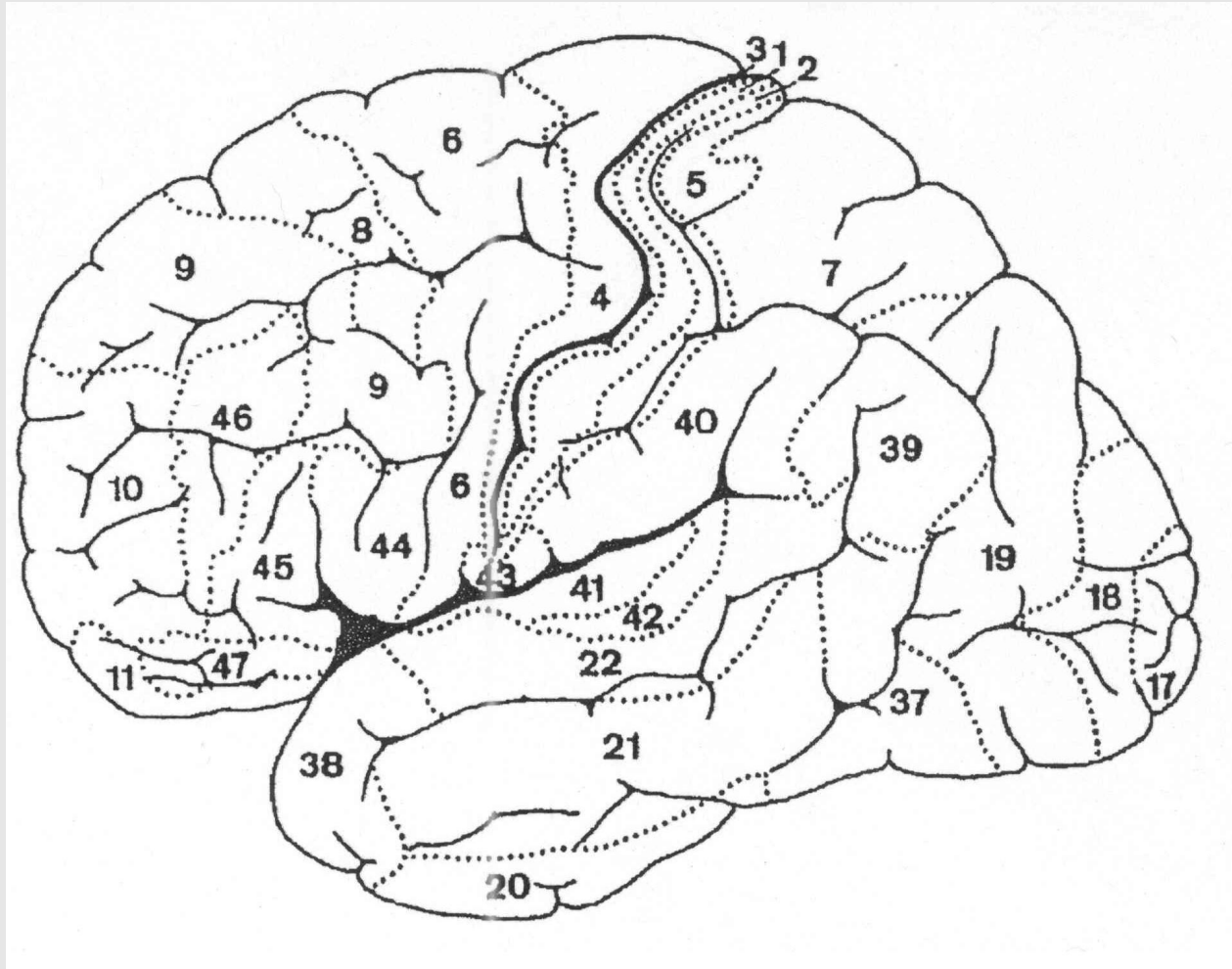
fMRI-Experiment

Discussion

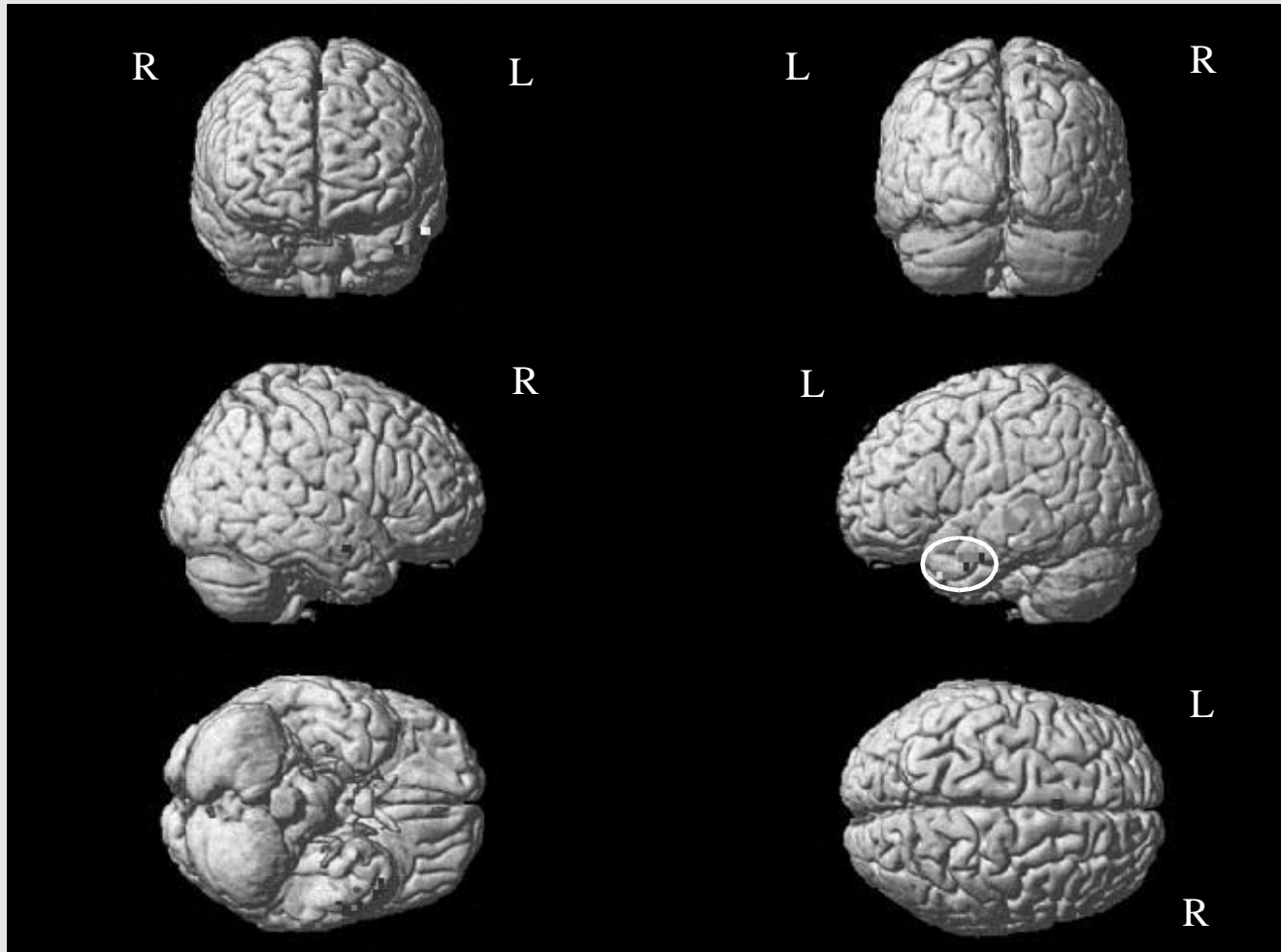
(1) sentreord - listreord

- BA 45 in accordance with many studies on syntactic processing (Caplan et al. 2000, Kang et al. 1999, Embick et al. 2000, Just et al. 1996)
- 2. BA 9 in accordance with Indefrey et al. (2001b)
- 3. BA 18 caused by visual processing
- 4. BA 21 in accordance with Just et al. (1996) and Kuperberg et al. (2000)
- 5. BA 6 in accordance with Newman et al. (2001)

fMRI-Experiment Results

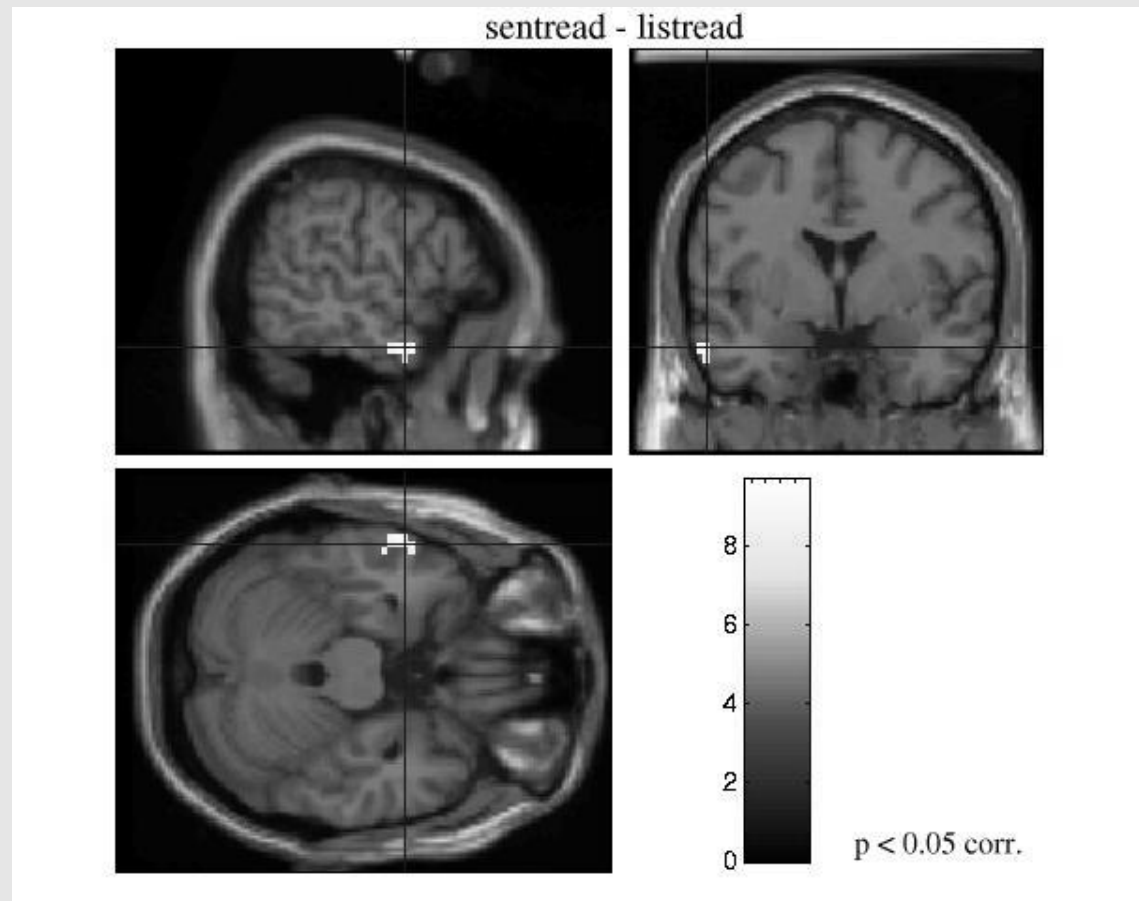


fMRI-Experiment Results



(2) sentread - listread, $p < 0.05$

fMRI-Experiment Results



fMRI-Experiment Results

<i>contrast</i>		<i>Z value</i>	<i>Talairach</i>			<i>BA</i>	<i>brain region</i>
			<i>x</i>	<i>y</i>	<i>z</i>		<i>(converted mni2tal)</i>
			<i>(unconverted)</i>				
(2) sentread - listread	L	5.25	-45	15	-35	38	Gyrus temporalis superior
	L	5.16	-57	0	-25	21	Gyrus temporalis medior
	R	4.97	51	-6	-20	21	Gyrus temporalis medior
	L	4.94	-3	15	55	8	Gyrus frontalis superior

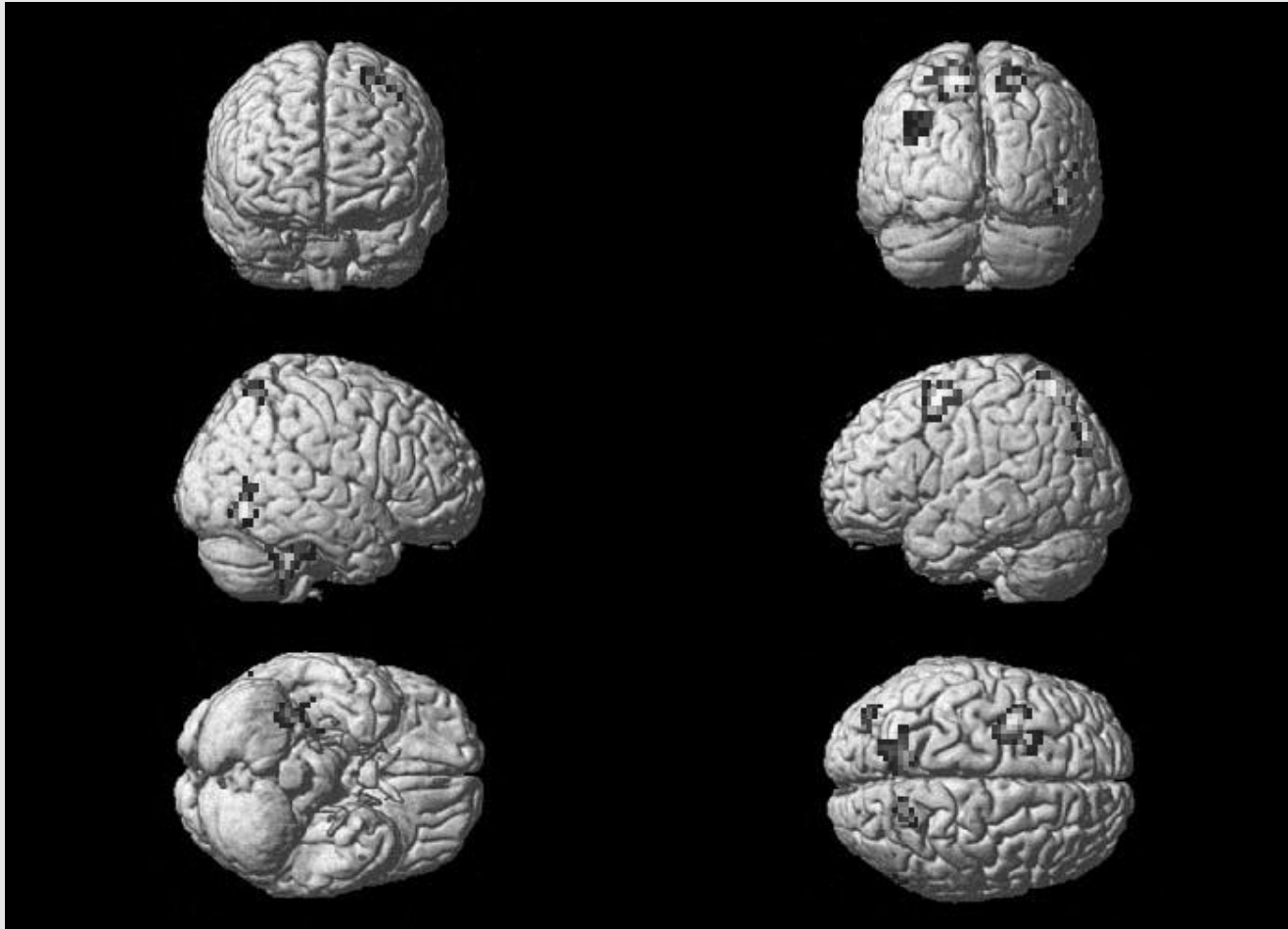
fMRI-Experiment

Discussion

(1) sentread - listread

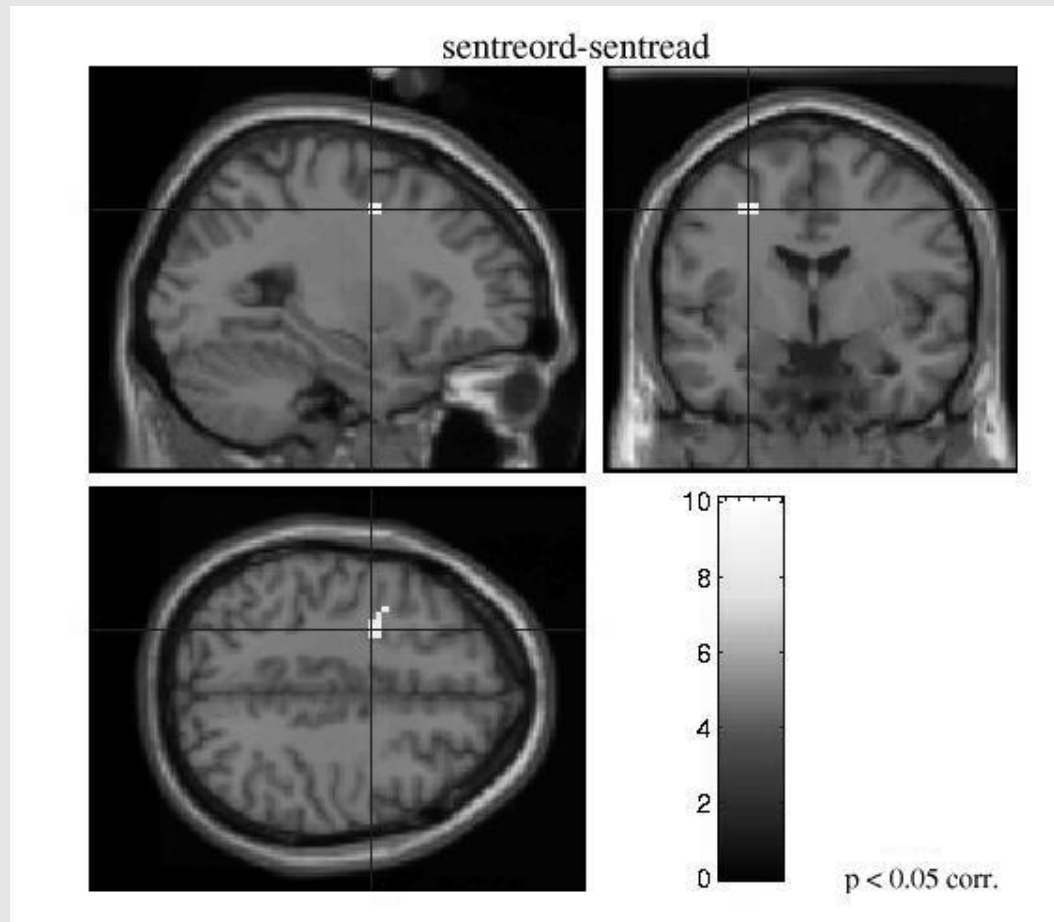
- BA 38 in accordance with Friederici et al. (2000a)
- 2. BA 21 bilaterally, in accordance to Kuperberg et al. (2000)
- 3. BA 8 dorsal prefrontal cortex, often involved in speech production, Dogil et al. (2002), Deacon (1992)

fMRI-Experiment Results



(3) listreord-listread, $p < 0.001$

fMRI-Experiment Results



(4) sentreord-sentread, $p < 0.05$

Conclusion

- the area with the coordinates -51 24 8 in the BA 45 of the left inferior frontal gyrus is involved in phrase structure generation
- difference between sentence processing and list processing might be the phrase structure generation, incremental structure building not word-by-word but phrase-by-phrase

Project

The Neuroanatomic Foundation of Language Production

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Michael Klein

Grzegorz Dogil

Jörg Mayer

Michael Erb

Axel Riecker

Wolfgang Grodd

Dietmar Röhm

Hubert Haider

Dirk Wildgruber

Hans Kamp

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