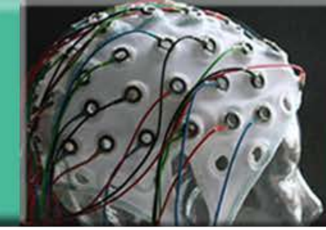
Kognitive Neuropsychologie

- 03.11. Geschichte der kognitiven Neurowissenschaft
- 10.11. Funktionelle Neuroanatomie
- 17.11. Methoden der kognitiven Neuropsychologie I
- 24.11. Methoden der kognitiven Neuropsychologie II
- 01.12. Visuelle Wahrnehmung
- 08.12. Objekterkennung
- 15.12. Auditive Wahrnehmung
- 05.01. Sprache
- 12.01. Aufmerksamkeit und Selektion
- **19.01. Kognitive Kontrolle**
- 26.01. Gedächtnis & Lernen
- 02.02. Kognitives Altern



CONTROL OF GOAL-DIRECTED AND STIMULUS-DRIVEN ATTENTION IN THE BRAIN

Maurizio Corbetta and Gordon L. Shulman

We review evidence for partially segregated networks of brain areas that carry out different attentional functions. One system, which includes parts of the intraparietal cortex and superior frontal cortex, is involved in preparing and applying goal-directed (top-down) selection for stimuli and responses. This system is also modulated by the detection of stimuli. The other system, which includes the temporoparietal cortex and inferior frontal cortex, and is largely lateralized to the right hemisphere, is not involved in top-down selection. Instead, this system is specialized for the detection of behaviourally relevant stimuli, particularly when they are salient or unexpected. This ventral frontoparietal network works as a 'circuit breaker' for the dorsal system, directing attention to salient events. Both attentional systems interact during normal vision, and both are disrupted in unilateral spatial neglect.

TOP-DOWN PROCESSING
The flow of information from 'higher' to 'lower' centres, conveying knowledge derived from previous experience rather than sensory stimulation.

BOTTOM-UP PROCESSING
Information processing that proceeds in a single direction from sensory input, through perceptual analysis, towards motor output, without involving feedback information flowing backwards from 'higher' centres to 'lower' centres.

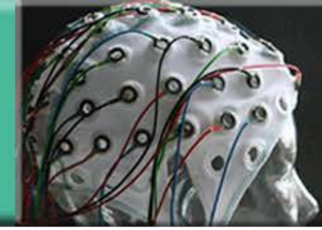
Departments of Neurology, Radiology, and Anatomy and Neurobiology, Washington University School of Medicine, St Louis, Missouri 63110, USA.
Correspondence to M.C.
e-mail: mau@npg.wustl.edu
DOI: 10.1038/nrn755

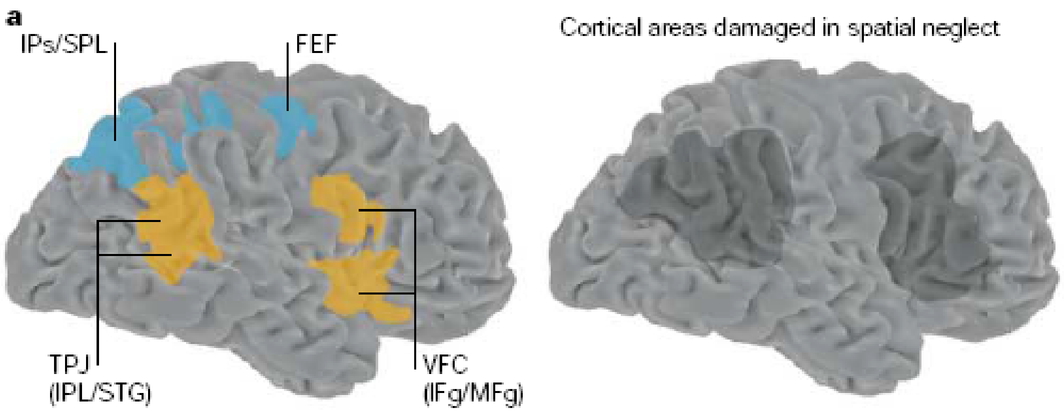
Picture yourself at the Museum El Prado in Madrid while a guide explains the painting *The Garden of Earthly Delights* by the fifteenth-century Flemish painter Hieronymous Bosch (FIG. 1). Bosch depicts a fantastic, surreal and satirical world, which is in stark contrast to anything else represented until that time. The guide's words cue us to attend to different aspects of the painting, such as its colour, spatial configuration or meaning. For example, if he notes "a small animal playing a musical instrument", we can use this information to spot the rabbit playing the horn near a black-and-white dice. Knowledge and expectations allow us to focus on elements, parts or details of a visual scene that we might otherwise have missed. Cognition aids vision by enabling the brain to create, maintain and change a representation of what is important while we scan a visual scene.

At the other extreme, visual perception can be dominated by external events. Initially, our eyes might have been drawn to the more salient objects in the painting, such as the large wooden musical instrument (a lute in construction) at the centre of the scene, rather than to more subtle aspects of the painting that are discussed by the guide. An event might even distract us from the painting altogether. If an alarm system started to ring and flash in a nearby room, everyone's attention would instantly be drawn towards the source of the alarm. Unexpected, novel, salient and potentially dangerous events take high priority in the brain, and are processed at the expense of ongoing behaviour and neural activity.

In everyday life, visual attention is controlled by both cognitive (TOP-DOWN) factors, such as knowledge, expectation and current goals, and BOTTOM-UP factors that reflect sensory stimulation. Other factors that affect attention, such as novelty and unexpectedness, reflect an interaction between cognitive and sensory influences. The dynamic interaction of these factors controls where, how and to what we pay attention in the visual environment. In this review, we propose that visual attention is controlled by two partially segregated neural systems. One system, which is centred on the dorsal posterior parietal and frontal cortex, is involved in the cognitive selection of sensory information and responses. The second system, which is largely lateralized to the right hemisphere and is centred on the temporoparietal and ventral frontal cortex, is recruited during the detection of behaviourally relevant sensory events, particularly when they

Ein neuroanatomisches Model attentionaler Kontrolle





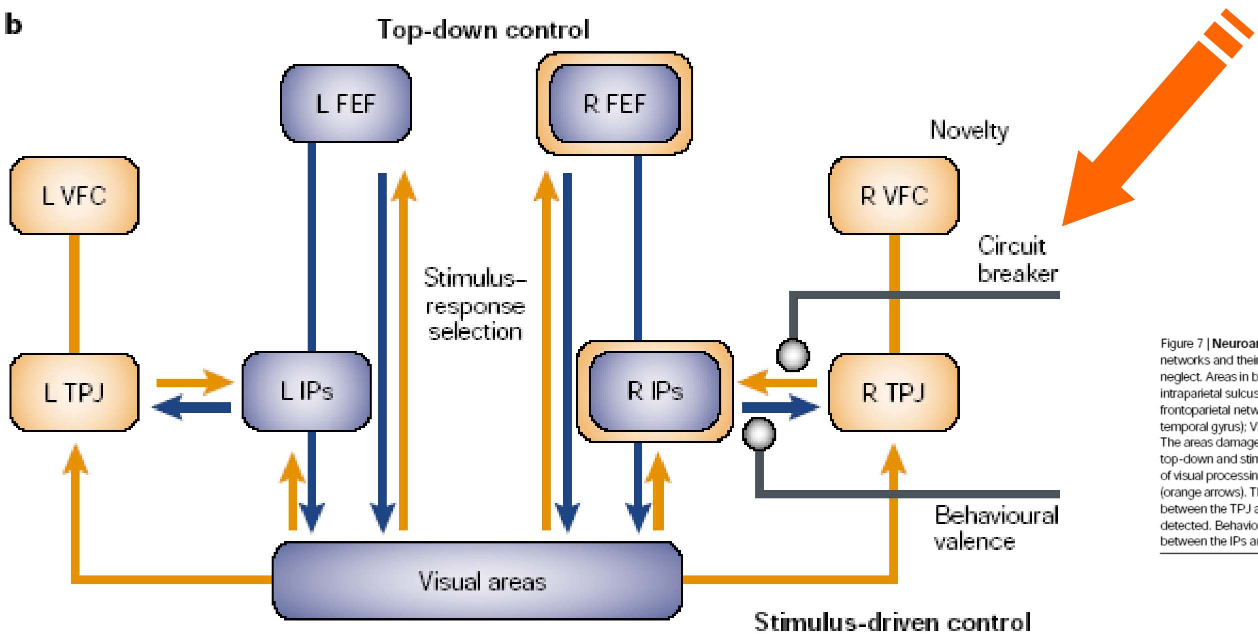


Figure 7 | **Neuroanatomical model of attentional control. a** | Dorsal and ventral frontoparietal networks and their anatomical relationship with regions of damage in patients with unilateral neglect. Areas in blue indicate the dorsal frontoparietal network. FEF, frontal eye field; IPs/SPL, intraparietal sulcus/superior parietal lobule. Areas in orange indicate the stimulus-driven ventral frontoparietal network. TPJ, temporoparietal junction (IPL/STG, inferior parietal lobule/superior temporal gyrus); VFC, ventral frontal cortex (IFg/MFg, inferior frontal gyrus/middle frontal gyrus). The areas damaged in neglect (right) better match the ventral network. **b** | Anatomical model of top-down and stimulus-driven control. The IPs–FEF network is involved in the top-down control of visual processing (blue arrows). The TPJ–VFC network is involved in stimulus-driven control (orange arrows). The IPs and FEF are also modulated by stimulus-driven control. Connections between the TPJ and IPs interrupt ongoing top-down control when unattended stimuli are detected. Behavioural relevance is mediated by direct or indirect (not shown) connections between the IPs and TPJ. The VFC might be involved in novelty detection. L, left; R, right.

Kognitive Kontrolle

1. Exekutive Funktionen
2. Präfrontaler Cortex

---

3. Arbeitsgedächtnis
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

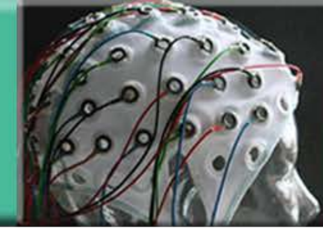
5. Selektion aufgabenrelevanter Information
6. Inhibitorische Kontrolle

---

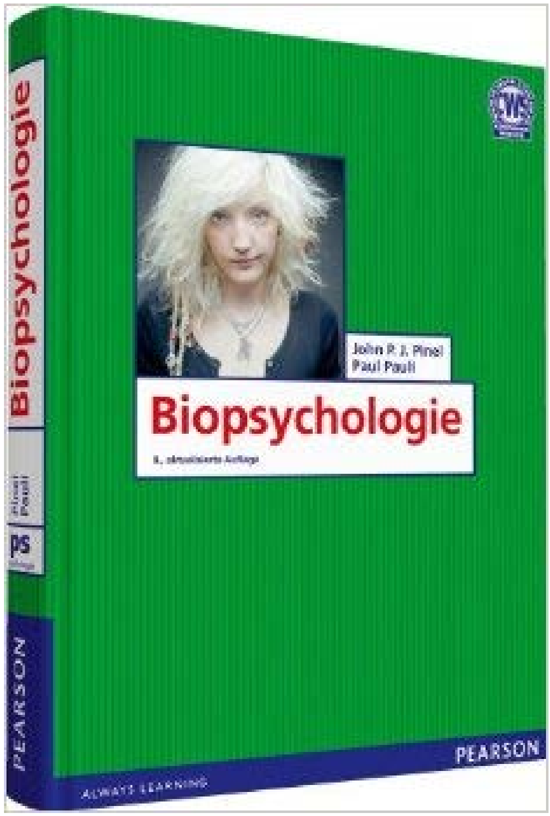
7. Task Switching

---

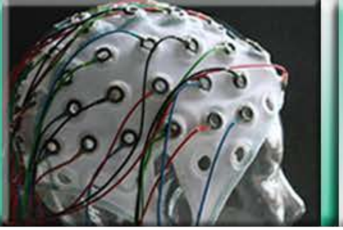
8. Handlungsselektion
9. Detektion von Konflikten
10. Zusammenfassung



Literatur



Gazzaniga, M.S., Ivry, R.B. & Mangun, G.R. (2009). Cognitive Neuroscience (3rd Edition). W.W. Norton & Company: NewYork (Kap. 13)

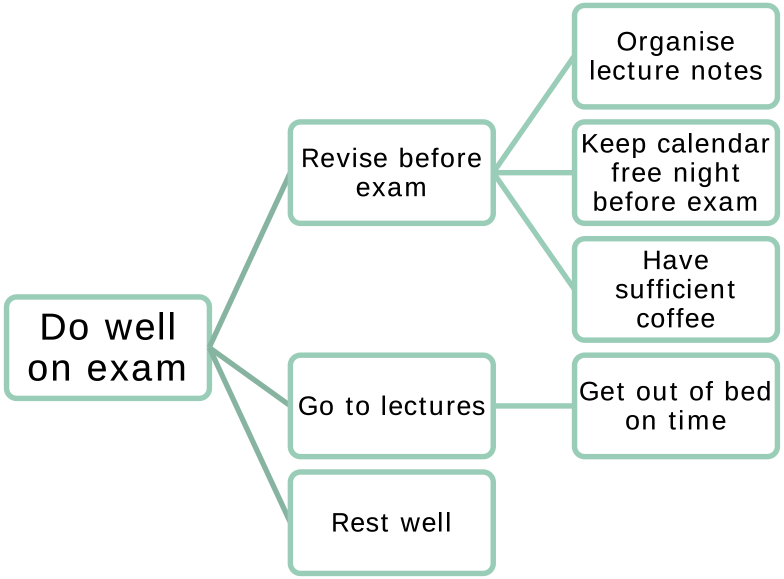


Kognitive Kontrolle

Exekutive Funktion

Attempts to define . . . executive function encounter . . . a . . . difficulty: no single exemplary task or even subset of tasks provides an adequate ostensive definition. It is often necessary to fall back on consensus definitions drawn from the common sense of the "man in the street" or poll the collective wisdom of "distinguished experts in the field" . . . these tend to be wide-ranging catalogues of examples of intelligent behavior and to avoid entirely discussions of underlying process (Rabbitt, 1997, p. 30).

Goal-Directed Behaviour




WWW.3BP.com
SHCO

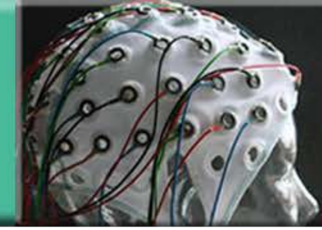
W.R. a typical young urban professional ...

... law school

... instructor in a tennis club (after 4 years)
... lost interests in romantic pursuits
... lost ego

... Astrocytoma invading the PFC
... no engagement in goal oriented behavior
... Actions without the context of an overriding goal

Subregionen des (prä)frontalen Cortex



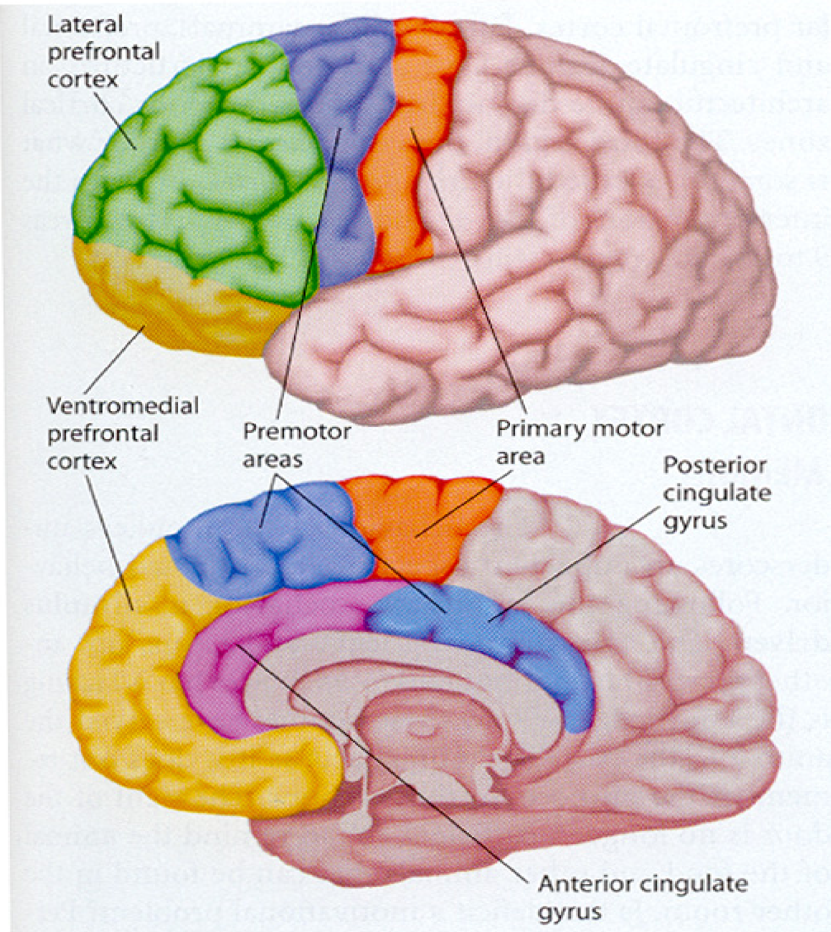
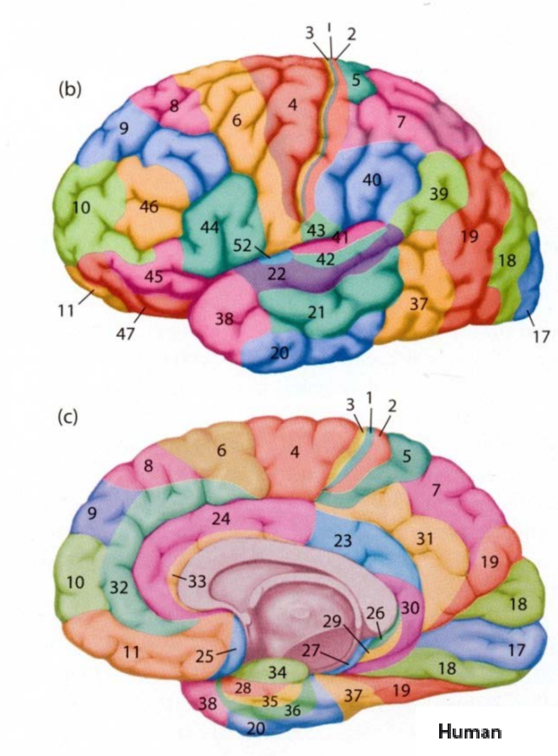
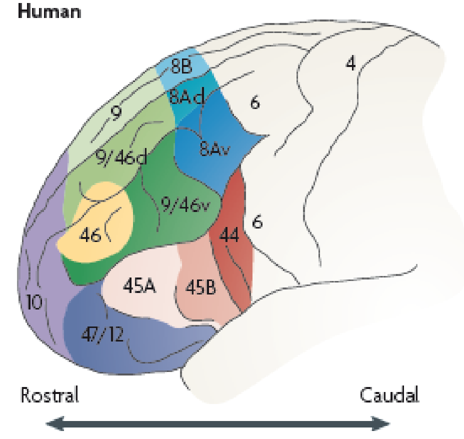


Figure 12.1 The areas of the frontal lobe. The prefrontal cortex includes all of the areas in front of the primary and secondary motor regions. The three major subdivisions of prefrontal cortex are the lateral prefrontal, ventromedial prefrontal, and the anterior cingulate cortex.





Subregionen des (prä)frontalen Cortex

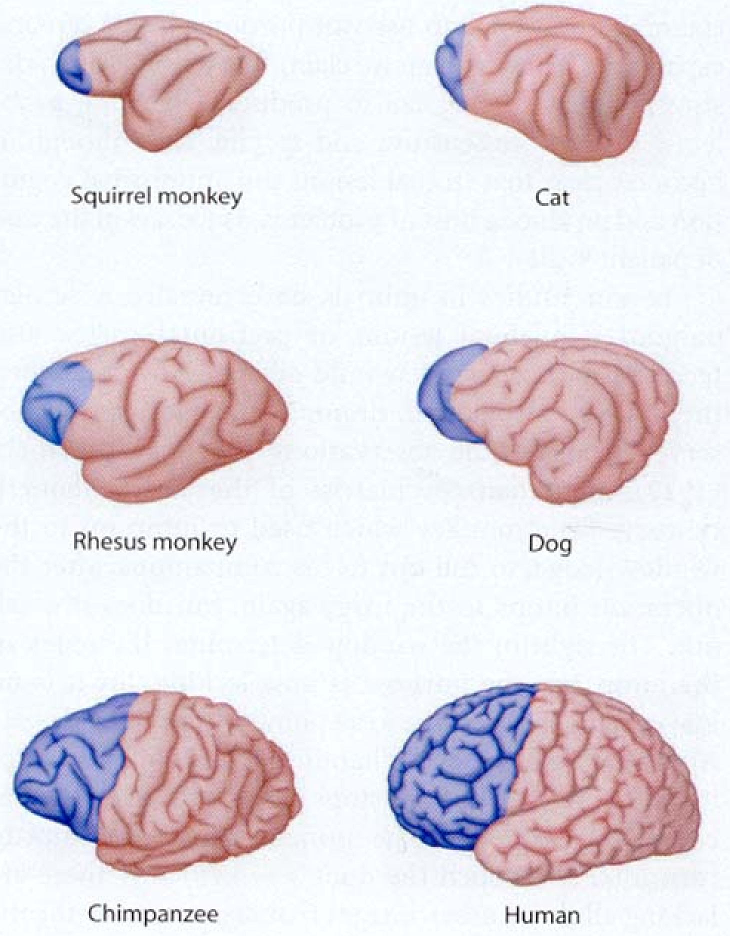


Figure 12.2 The shaded areas show the extent of prefrontal cortex in six species. Note how small this region is in the cat, dog, and squirrel monkey. It is greatly enlarged in humans. The brains are not drawn to scale. Adapted from Fuster (1989).

Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex

---

3. **Arbeitsgedächtnis**
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

5. Selektion aufgabenrelevanter Information
6. Inhibitorische Kontrolle

---

7. Task Switching

---

8. Handlungsselektion
9. Detektion von Konflikten
10. Zusammenfassung

PFC Läsionen

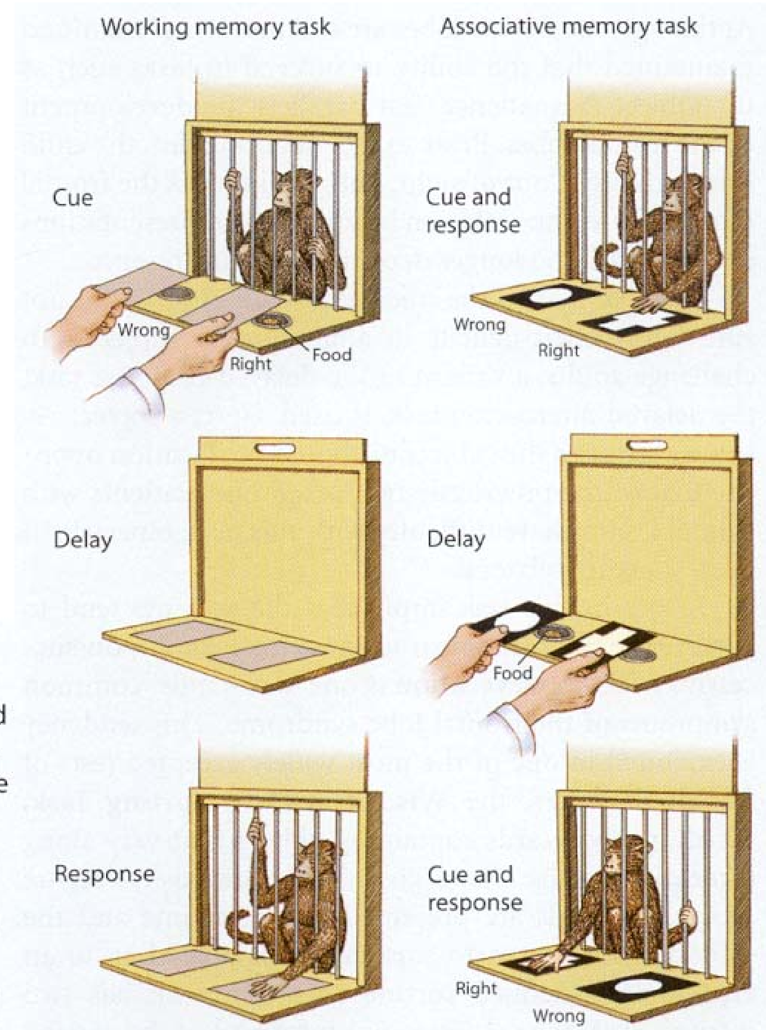
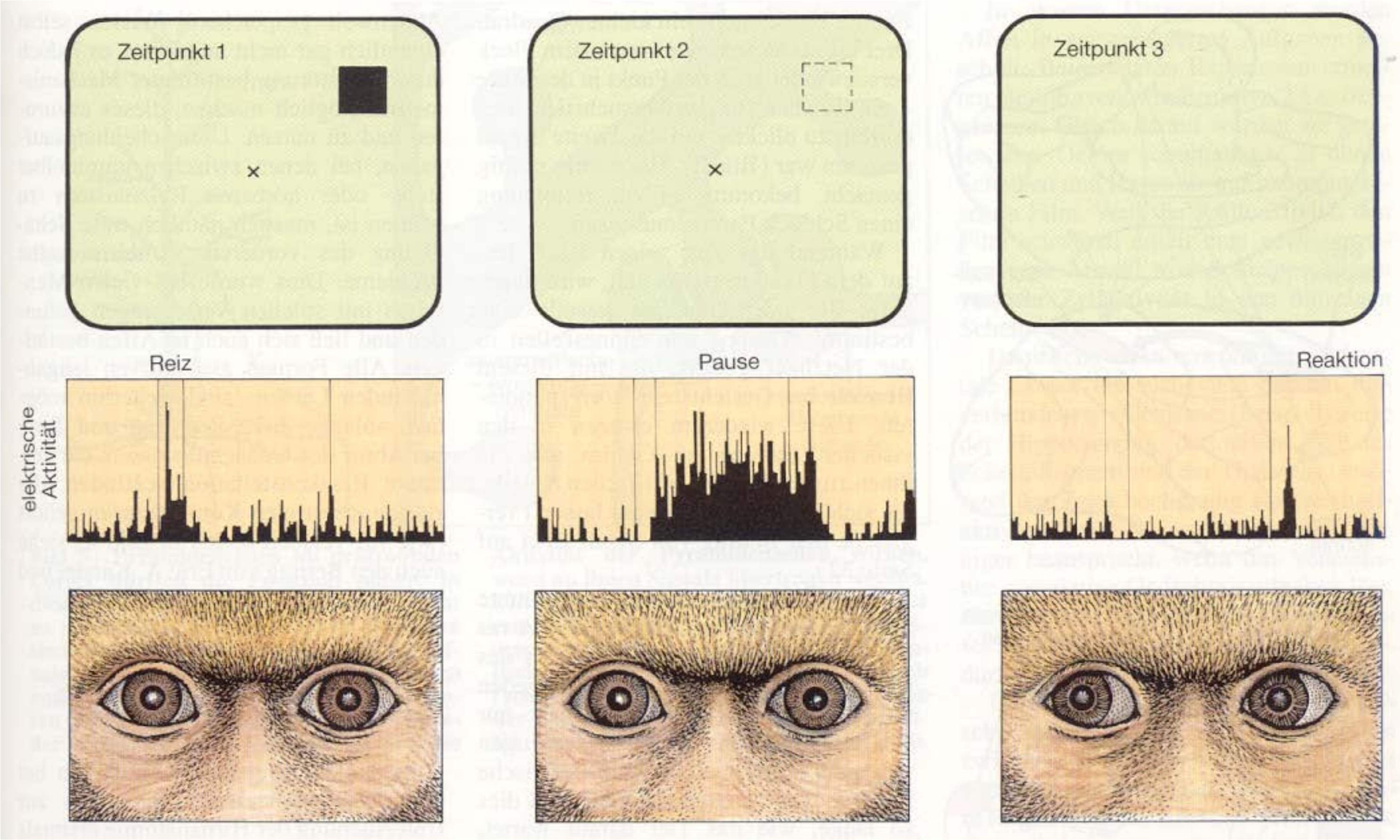


Figure 12.3 Monkeys with prefrontal lesions demonstrate selective impairment on the working memory delayed-response task. **(Left)** In the working memory task, the monkey sees one well baited with food. After a delay period, the animal retrieves the food. The location of the food is determined randomly. **(Right)** In the associative memory task, the food reward is always associated with one of the two visual cues. The location of the cues (and food) is determined randomly. Working memory is required in the first task because, at the time the animal responds, there are no external cues indicating the location of the food. Long-term memory is required in the second task since the animal must remember which visual cue is associated with the reward. Adapted from Goldman-Rakic (1992).

Arbeitsgedächtnisaufgaben mit oculomotorischer Antwort



Einzelzellaktivität bei delayed-response tasks

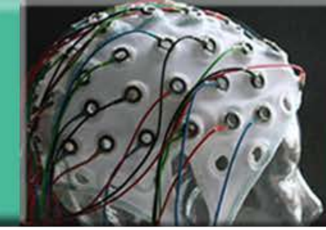
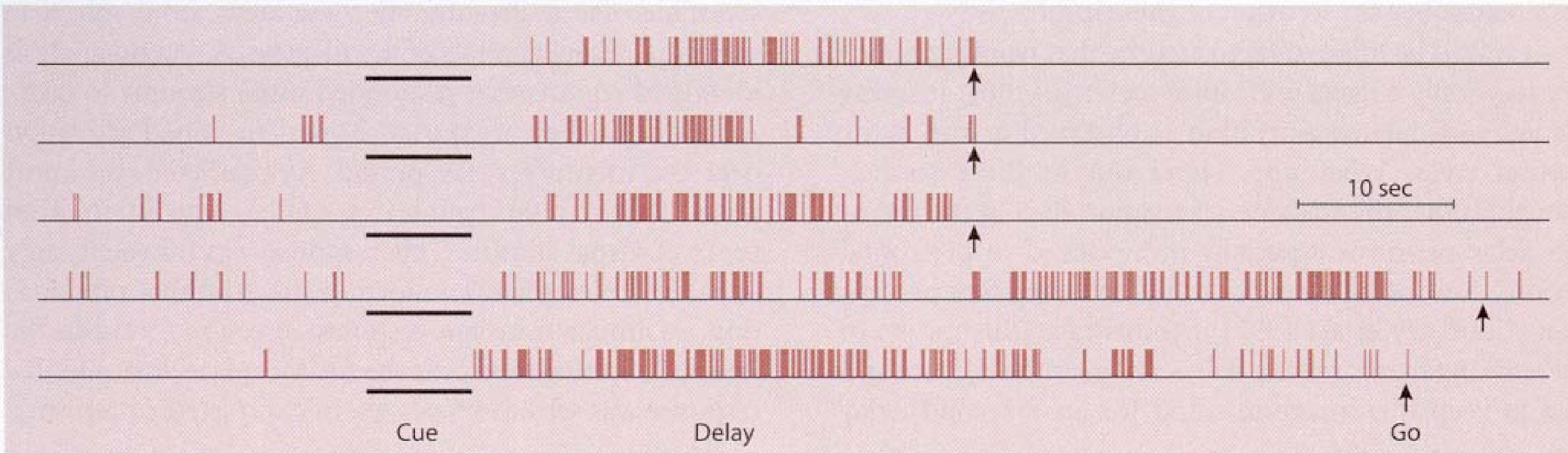
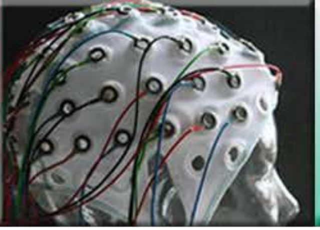


Figure 12.6 Prefrontal neurons can show sustained activity during delayed-response tasks. Each line represents a single trial. The cue indicated the location for a forthcoming response. The monkey was trained to withhold the response until a "Go" signal (arrows) appeared. Each vertical tick represents an action potential. This cell did not respond during the cue interval. Rather, its activity increased when the cue was turned off, and persisted until the response. Adapted from Fuster (1989).





Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex
3. Arbeitsgedächtnis
4. **Funktionale Spezialisierung im lateralen präfrontalen Cortex**
5. Selektion aufgabenrelevanter Information
6. Inhibitorische Kontrolle
7. Task Switching
8. Handlungsselektion
9. Detektion von Konflikten
10. Zusammenfassung

Einzelzellaktivität bei delayed-response tasks: Inhaltsspezifität!

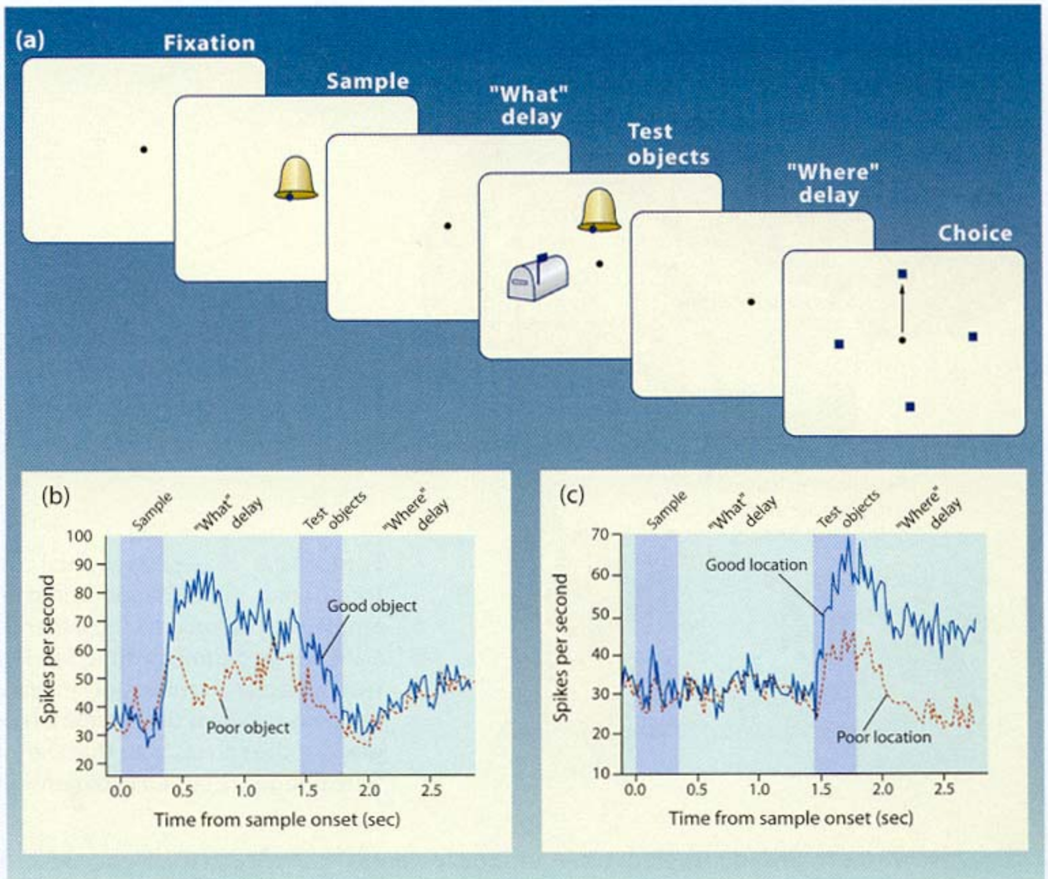
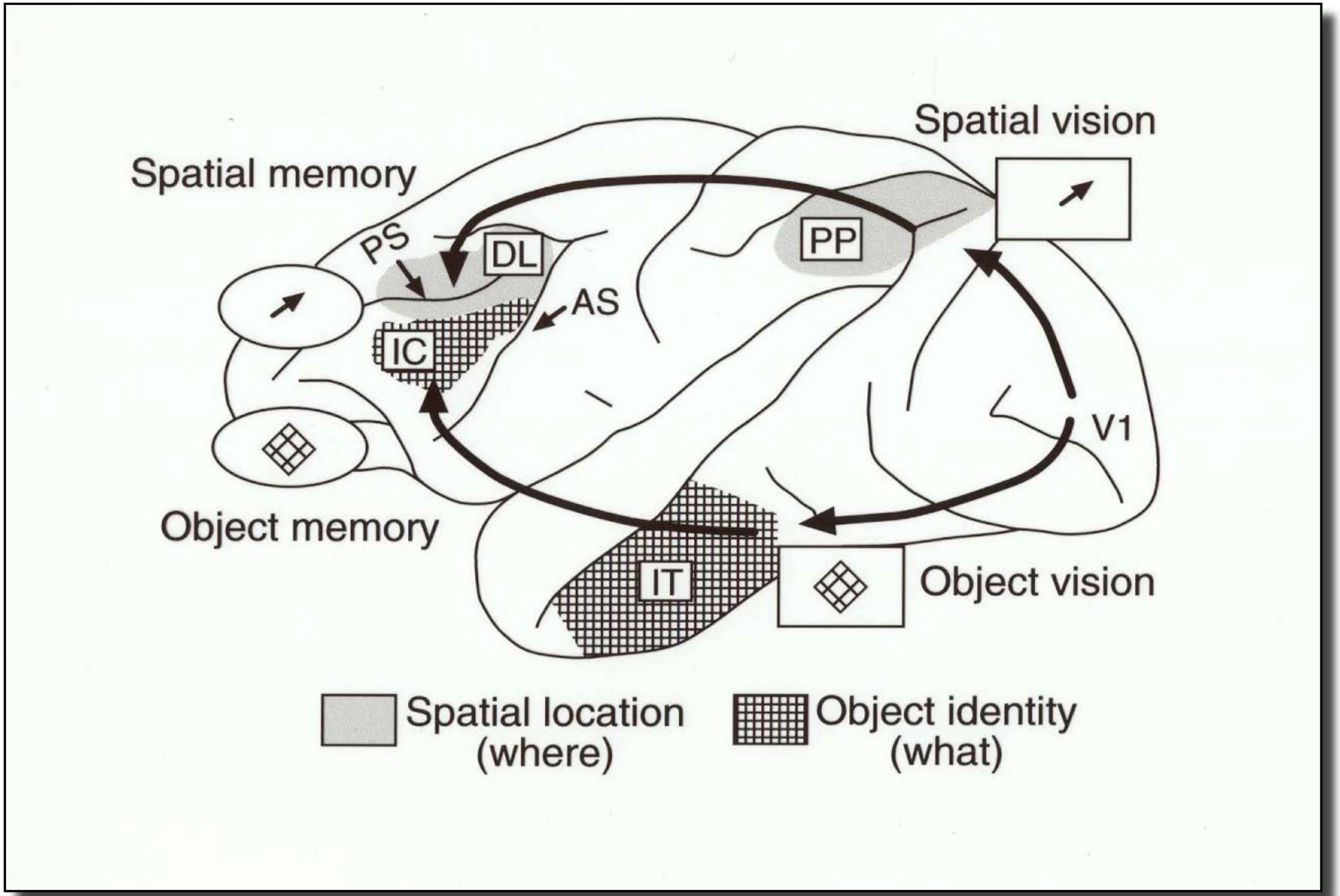


Figure 12.7 Coding of "what" and "where" information in single neurons of the prefrontal cortex in the macaque. **(a)** Sequence of events in a single trial. See text for details. **(b)** Firing profile of a neuron that shows a preference for one object over another during the "what" delay. The neural activity is low once the response location is cued. **(c)** Firing profile of a neuron that shows a preference for one location. This neuron was not activated during the "what" delay. Adapted from Rao et al. (1997).

Rao et al (1997),
Integration of what and where in the primate prefrontal cortex. *Science, 276, 821-824*

Einzelzellaktivität bei delayed-response tasks: Inhaltsspezifität!



PET & fMRI: Inhaltsspezifität!

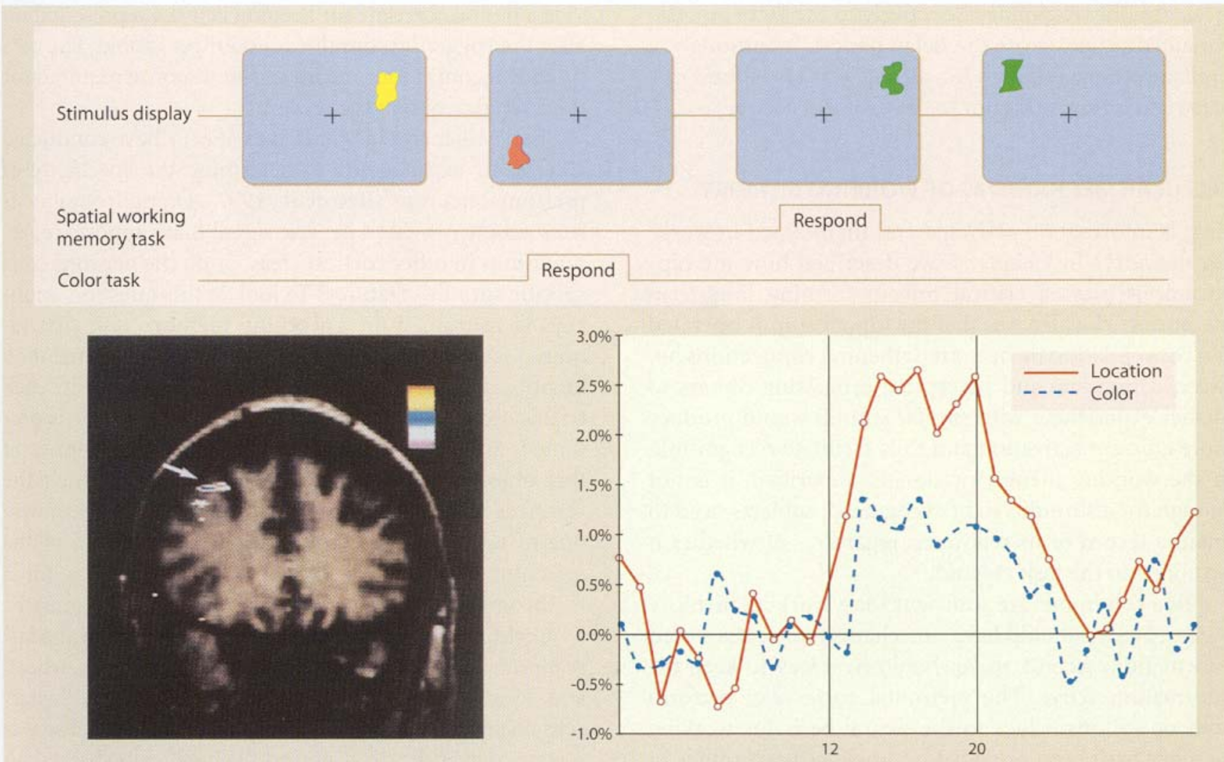


Figure 12.5 Lateral prefrontal activation revealed by functional magnetic resonance imaging (fMRI) in humans during a working memory task. **(Top)** Subjects viewed a series of colored, abstract shapes, appearing one at a time at various locations on the screen. In the spatial working memory condition, responses were required whenever a stimulus appeared at a location that had been used previously. In the control, color task, responses were required to all of the red objects. **(Bottom left)** During the spatial working memory task, there was a pronounced increase in activity in the lateral prefrontal cortex. This scan, obtained from a single subject, shows a prominent focus in the right prefrontal cortex (right hemisphere is on left). **(Bottom right)** The fMRI signal increased in the right prefrontal cortex during the 8-second stimulus period for both tasks. Most notable, the percentage increase in this area relative to the baseline was more pronounced during the spatial working memory task. Adapted from McCarthy et al. (1994).

McCarthy et al (1994),
fMRI of human prefrontal cortex activation during a spatial working memory task. *PNAS*, *91*, 8690-8694.

PET & fMRI: Inhaltsspezifität?
4 Jahre später

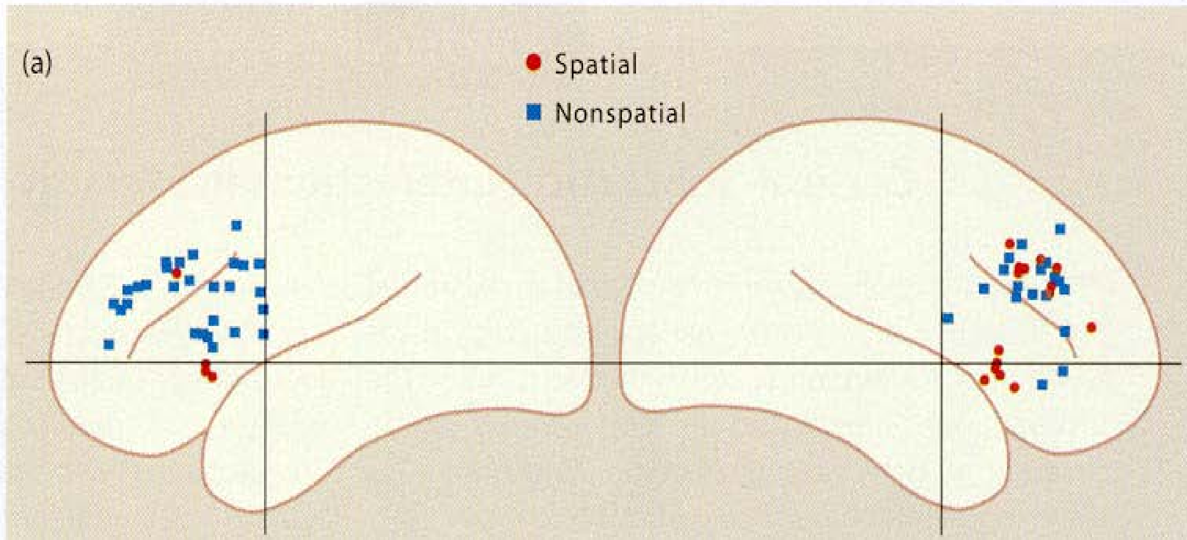
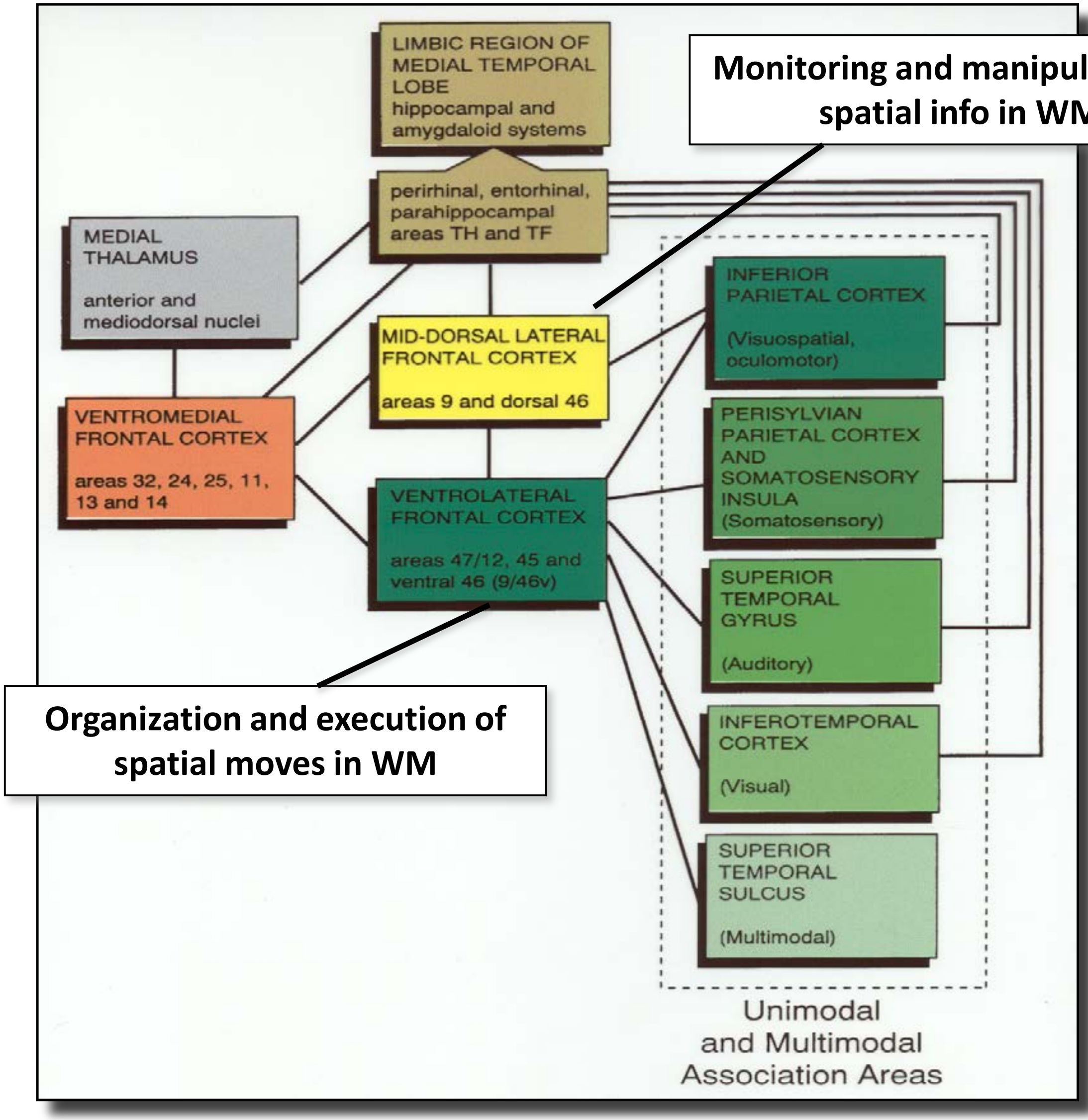


Figure 12.14 Functional organization within the lateral prefrontal cortex as revealed by meta-analysis of imaging studies. **(a)** Activation foci for tasks involving either spatial or nonspatial working memory.

D ʻEsposito et al (1998),
fMRI studies of spatial and nonspatial working memory. *Cog Brain Res*, *7*, 1-13.

Prozessspezifität des lateralen PFC ?



Owen et al (1996),
Evidence for a two-stage model of spatial working memory processing within the lateral frontal cortex: a positron emission tomography study. *Cer Cortex, 6, 31-38*

Prozessspezifität des lateralen PFC?
„Maintenance and Maintenance +"

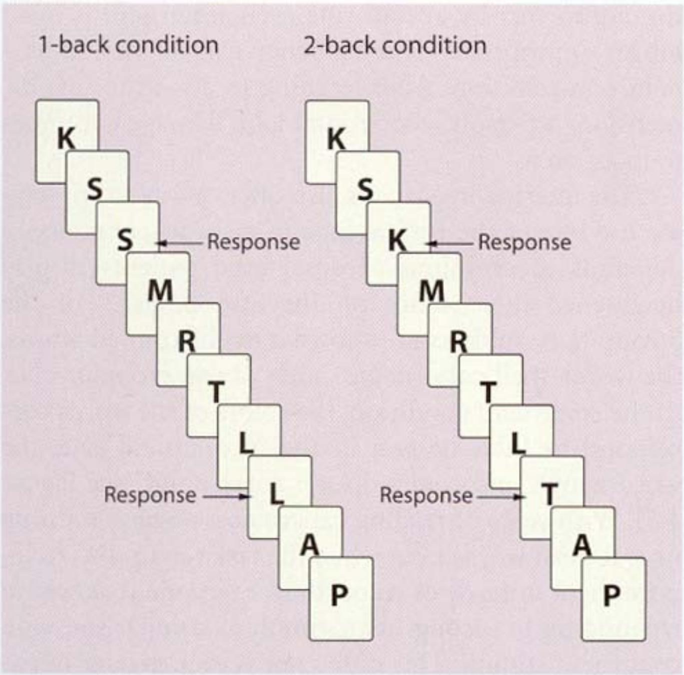
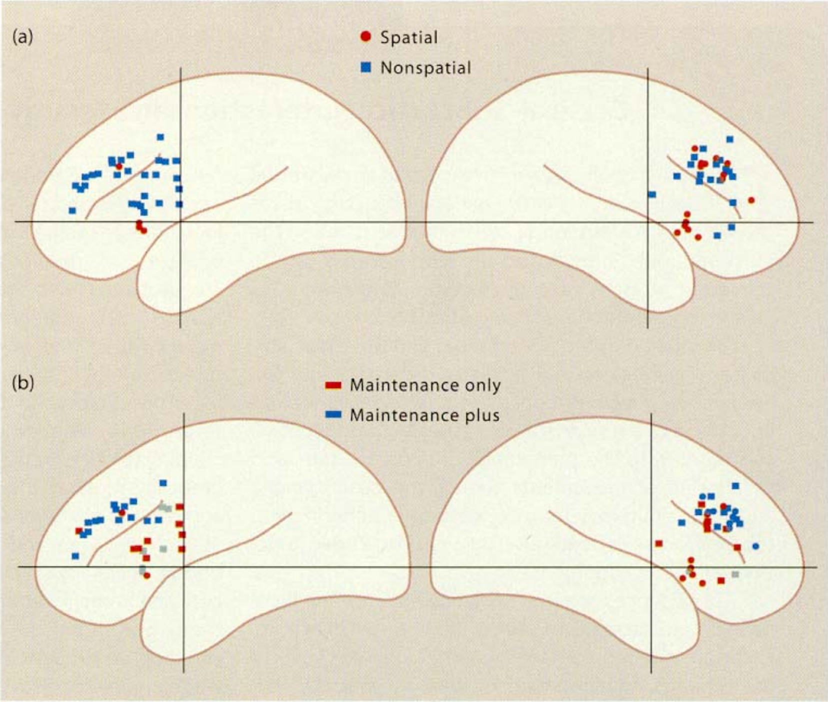
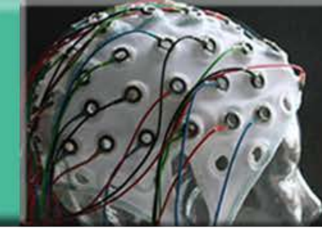


Figure 12.15 In *n*-back tasks, responses are required only when a stimulus matches one shown *n* trials before. The contents of working memory must be manipulated constantly as the target is updated on each trial.

Figure 12.14 Functional organization within the lateral prefrontal cortex as revealed by meta-analysis of imaging studies. **(a)** Activation foci for tasks involving either spatial or nonspatial working memory. **(b)** The same data, coded to discriminate between tasks that involved maintaining information and those that also involved manipulating the information. The maintenance-manipulation dichotomy provides a more parsimonious account of the results than the spatial-nonspatial one. Gray symbols indicate foci activated during maintenance plus tasks that also led to activation in a more dorsal prefrontal region. From D'Esposito et al. (1998).





Arbeitsgedächtnis

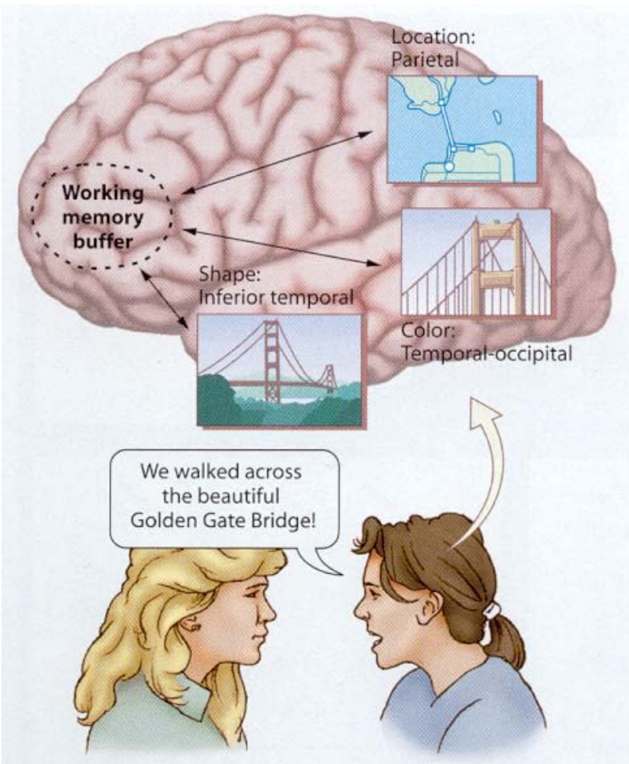
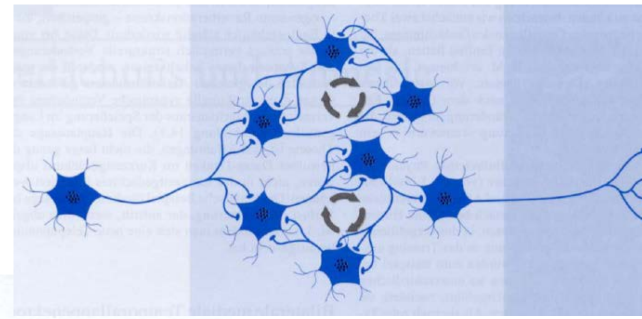


Figure 12.8 Lateral prefrontal cortex may provide a transient buffer for sustaining information stored in other cortical regions. In this example, the person is telling a friend about her walk across the Golden Gate Bridge during a visit to San Francisco. Long-term knowledge is reactivated and temporarily maintained through the reciprocal connections between the prefrontal cortex and the more posterior regions of the cortex. Note that the long-term memories of the Golden Gate Bridge are stored in dimensions-specific cortical regions.



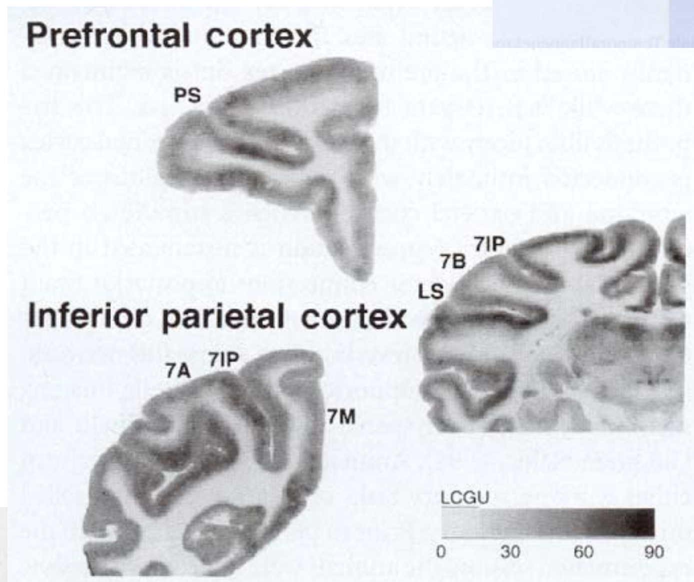
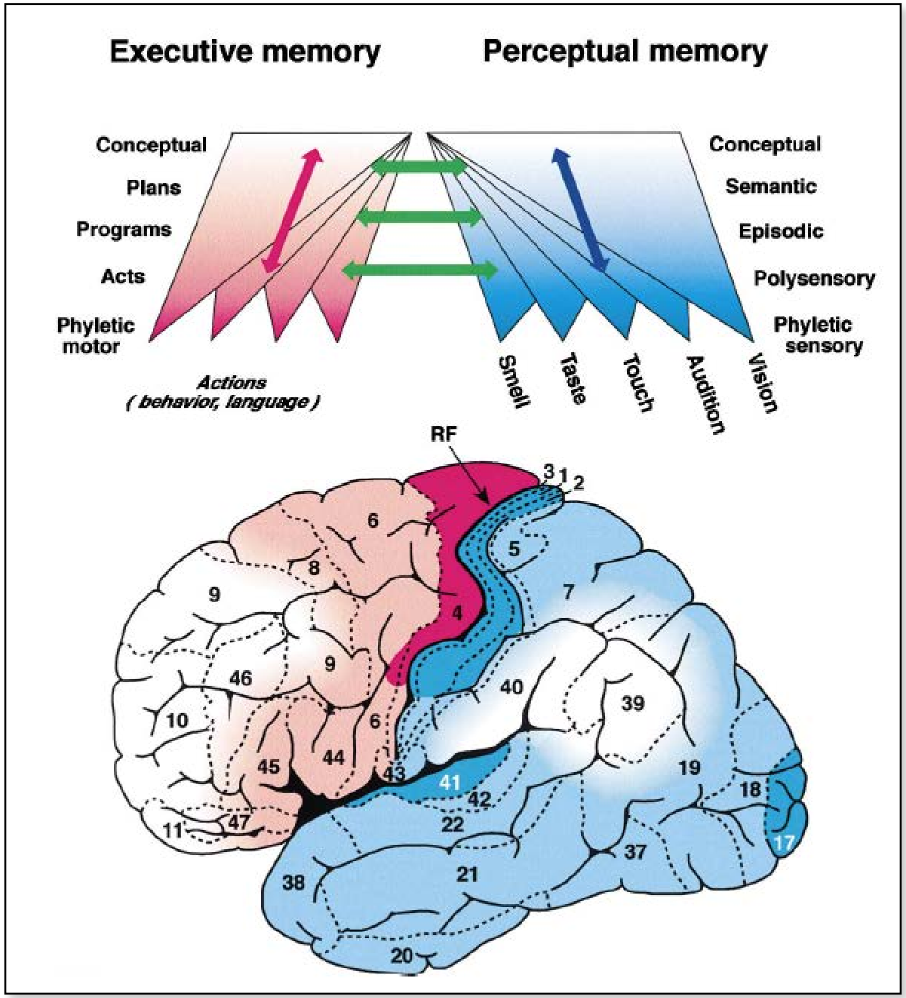


Figure 12.9 A radioactive tracer can reveal correlated activity in the prefrontal and inferior parietal cortex during a spatial working memory task. After being injected with the tracer, the animal performed the memory task. Upon completion, the animal was killed. Histological analysis revealed how the slow-decaying tracer was trapped in different brain regions. The results are coded on a gray scale in units of local cerebral glucose utilization (LCGU). PS in the top panel refers to the principal sulcus of the prefrontal cortex. The abbreviations with numeral 7 refer to area 7 regions of the parietal lobe. LS is the lateral sulcus, the division of parietal and temporal lobes. Embedded within this sulcus is the auditory cortex area measured for control purposes.

Arbeitsgedächtnis und cross-temporale Kontingenzen

In general terms, the entire PFC is dedicated to the memory, planning, or execution of actions.



Bridging of cross-temporal contingencies = adjusting actions to temporally distant objectives

JM Fuster (1985):

1. Working Memory
2. Preparatory Set
3. Control of Interference

Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex

---

3. Arbeitsgedächtnis
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

5. **Selektion aufgabenrelevanter Information**
6. Inhibitorische Kontrolle

---

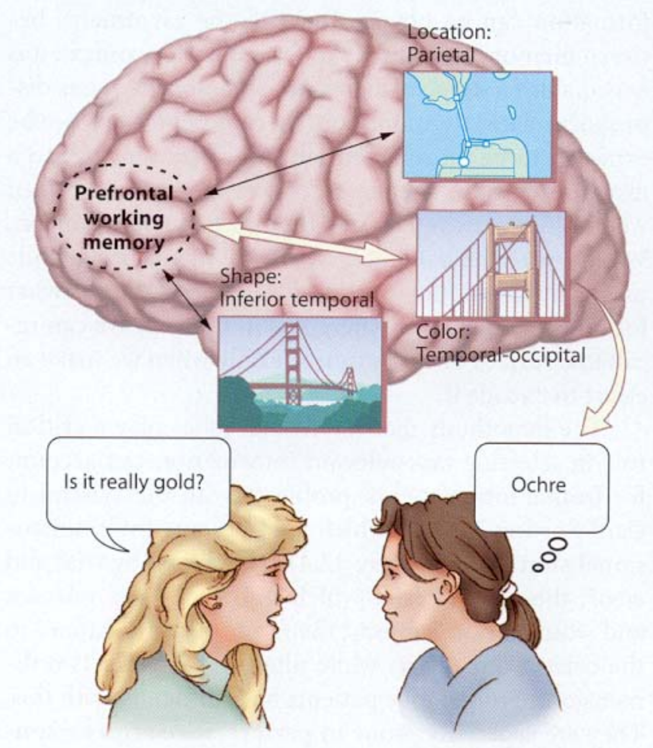
7. Task Switching

---

8. Handlungsselektion
9. Detektion von Konflikten
10. Zusammenfassung

Selektion aufgabenrelevanter Information: Bedside testing: The Wisconsin Card Sorting Test (WCST)

Figure 12.16 Prefrontal cortex not only provides a working memory buffer but also may use an inhibitory mechanism to highlight the information that is most relevant to the current task demands. When the subject is asked about the color of the Golden Gate Bridge, information regarding the location and shape of the bridge is inhibited.



Dynamic Filtering mechanism (Shimamura, 2000)
Psychobiology, 28, 207-218

Figure 12.4 Patients with damage in the lateral prefrontal cortex have difficulty on the Wisconsin Card Sorting Task. On each trial, the subjects place the top card of the deck under one of the four target cards. The experimenter indicates whether the response is correct or incorrect, allowing the subject to learn the sorting rule by trial and error. The sorting rule changes whenever the subject makes ten consecutive correct responses.

Selektion aufgabenrelevanter Information: Verb-Generierung

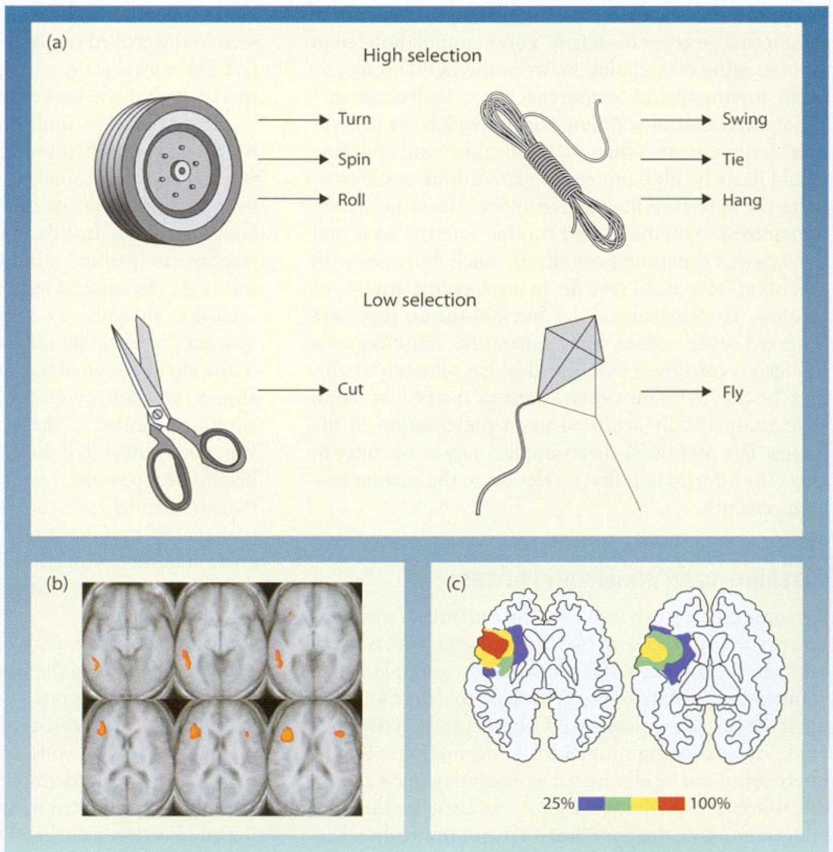
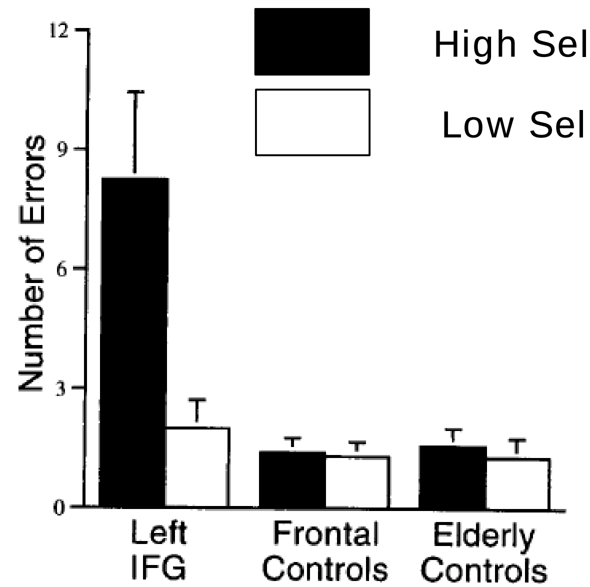


Figure 12.17 Involvement of inferior frontal cortex in response selection. **(a)** The verb generation task can be performed with nouns that are associated with many actions (high selection) or few actions (low selection). **(b)** Areas showing higher activity in the high-selection condition are shown in yellow. **(c)** Overlap in lesion location for patients who had difficulty in the high-selection condition. (b) From Thompson-Schill et al. (1997). (c) From Thompson-Schill et al. (1998).



Thompson-Schill et al (1998), Verb generation in patients with focal frontal lesions: a neuropsychological test of neuroimaging findings. *PNAS. 95*, 15855-15860

Selektion aufgabenrelevanter Information: Source Memory

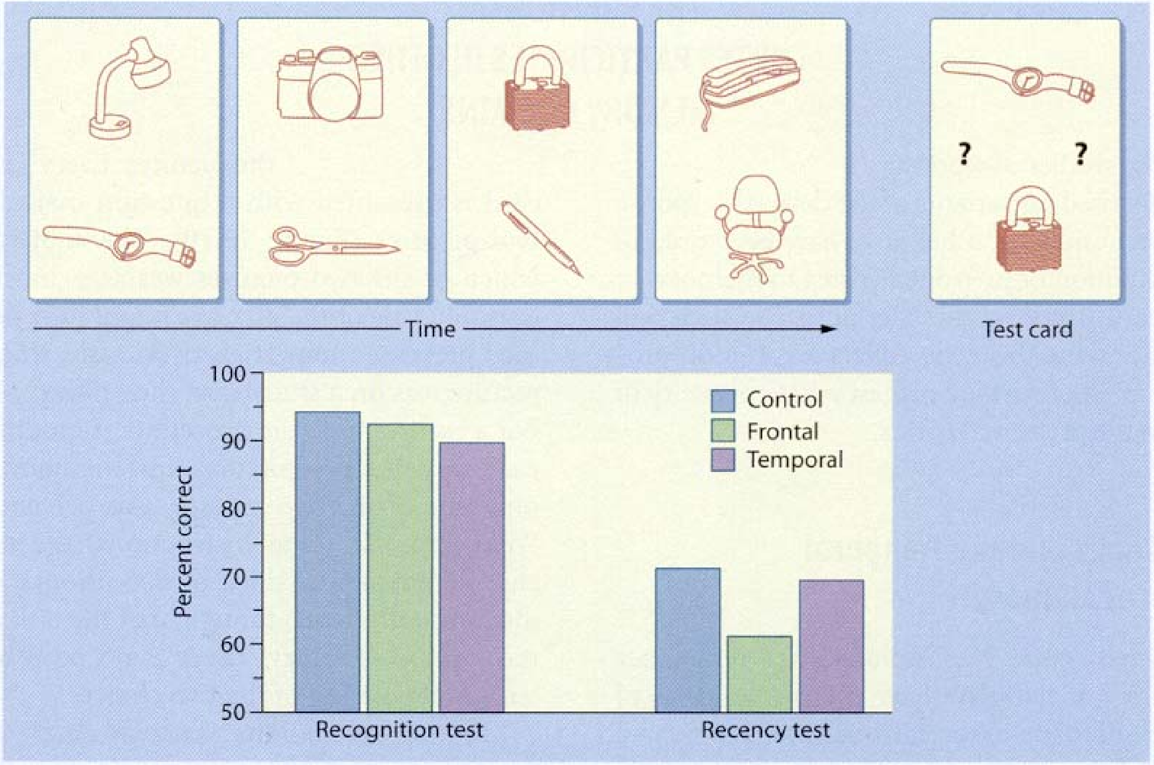
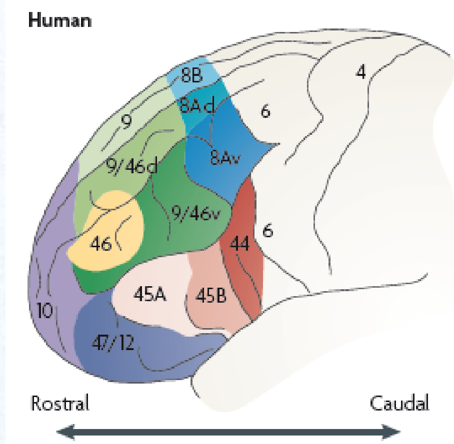


Figure 12.10 Recency memory is impaired in patients with prefrontal lesions. **(Top)** Subjects are presented with a series of cards, each one showing a pair of objects. On test cards, the objects are flanked by question marks, and the subject must indicate which object was seen most recently. In the recency test, both objects on the test cards had been seen previously. In the item recognition test, only one object had appeared previously. **(Bottom)** The results revealed a single dissociation. Patients who had had a frontal lobectomy performed more poorly on the recency task compared to both control subjects and patients who had had a temporal lobectomy. The frontal group was not impaired on the item recognition task. Adapted from Milner et al. (1991).



Selektion aufgabenrelevanter Information: Source Memory: Langsamer Aktivierungsabfall nach PFC Läsionen

Loss of inhibitory mechanisms

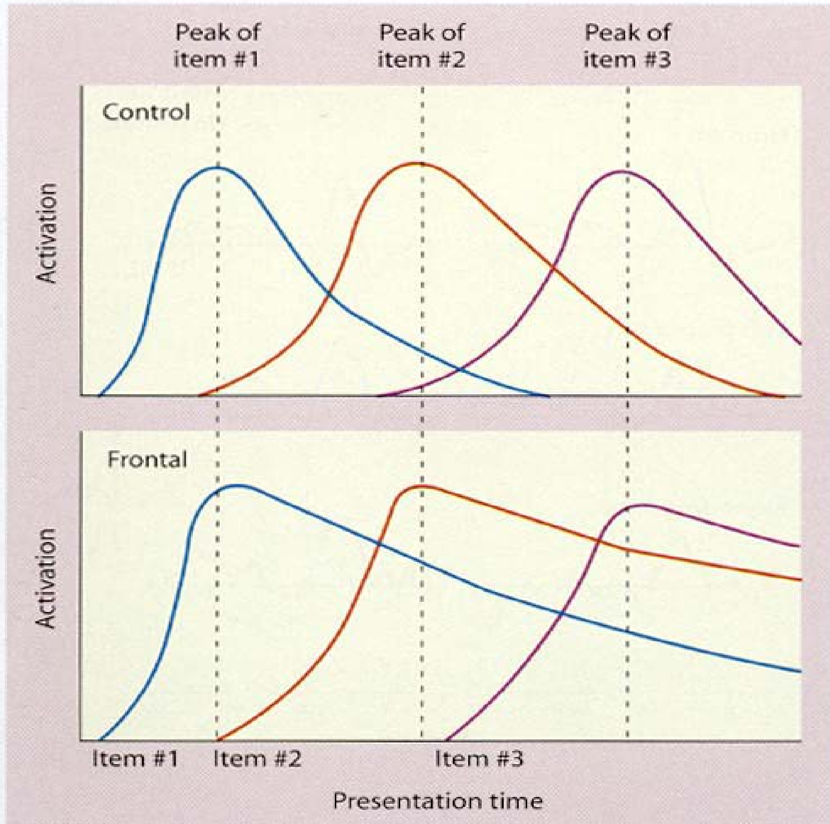
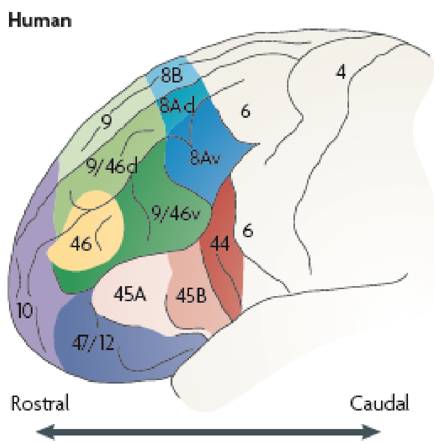
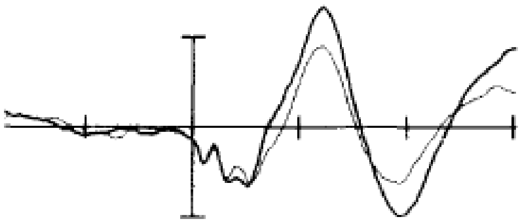


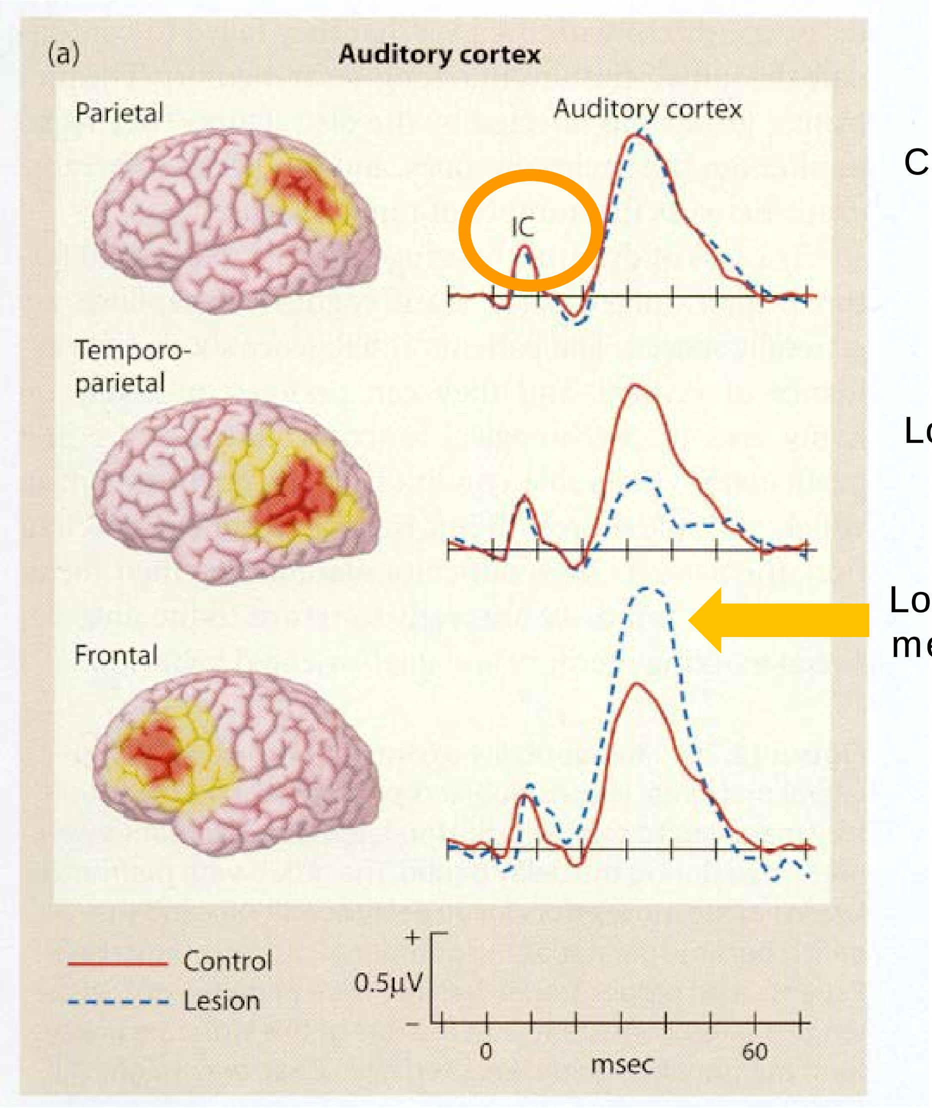
Figure 12.19 When a subject is presented with a series of items, activation for each item decays. A loss of inhibitory mechanisms following frontal lobe damage will lead to a slower decay process. Judgments on a recency memory task may be based on a comparison of the residual activation of the series of stimuli. In healthy people, the rapid decay of activation allows the temporal tag for each item to be distinct. In frontal lobe patients, the sustained activation leads to errors due to the similar activation states associated with successive items.



Selektion aufgabenrelevanter Information: Aufgaben-irrelevante auditorische Klicks

The P20-50 effect





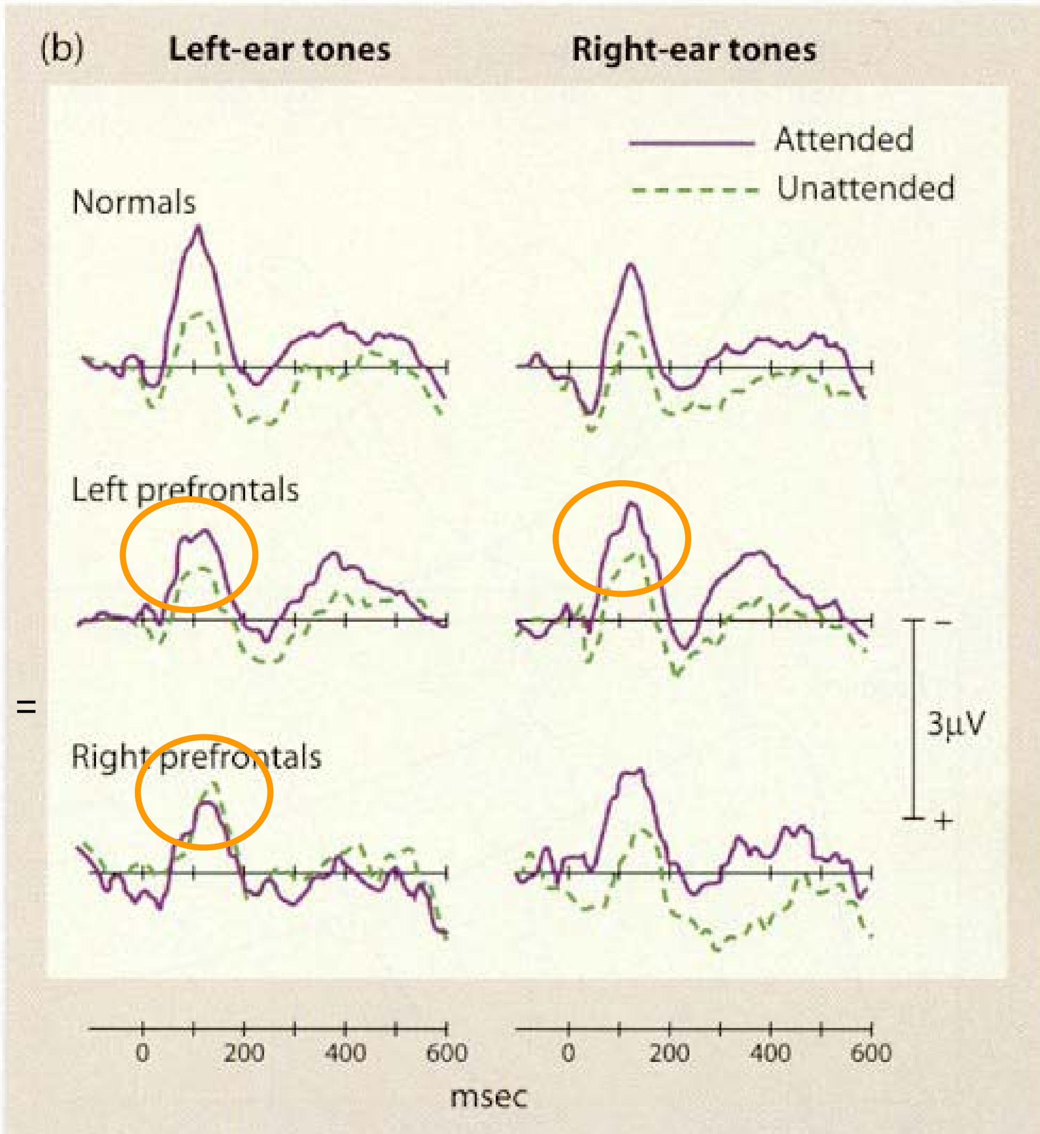
Control condition

Loss of neurons

Loss of inhibitory mechanisms

Knight & Grabowecky, 1995

Selektion aufgabenrelevanter Information: Effects of Attention



Loss of PFC neurons = Loss of inhibitory mechanisms ?

Knight & Grabowecky, 1995

Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex

---

3. Arbeitsgedächtnis
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

5. Selektion aufgabenrelevanter Information
6. **Inhibitorische Kontrolle**

---

7. Task Switching

---

8. Handlungsselektion
9. Detektion von Konflikten
10. Zusammenfassung

Selektion aufgabenrelevanter Information: Inhibitorische Kontrolle

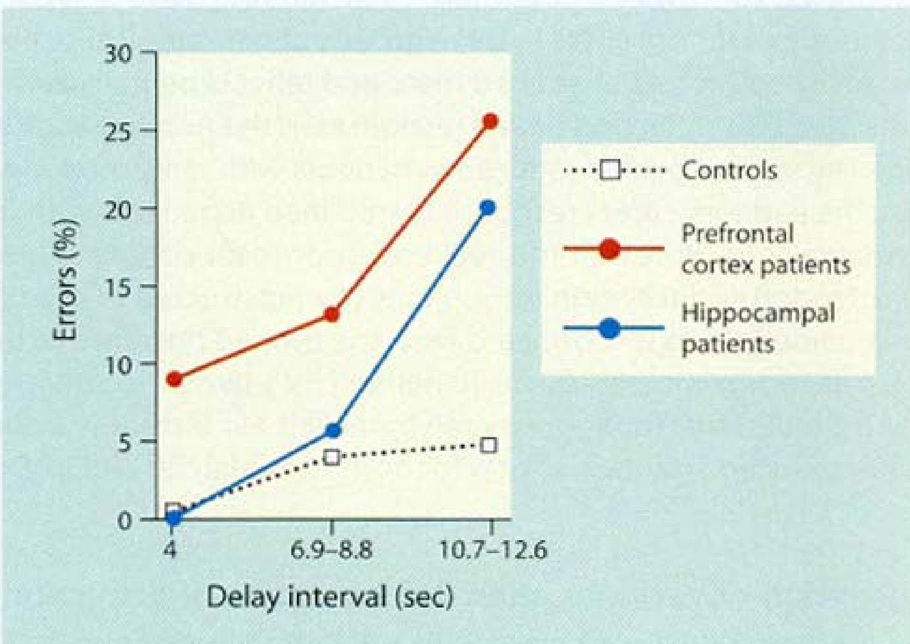
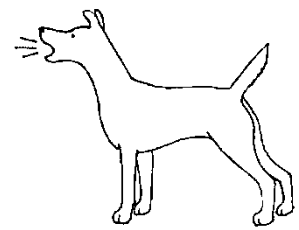
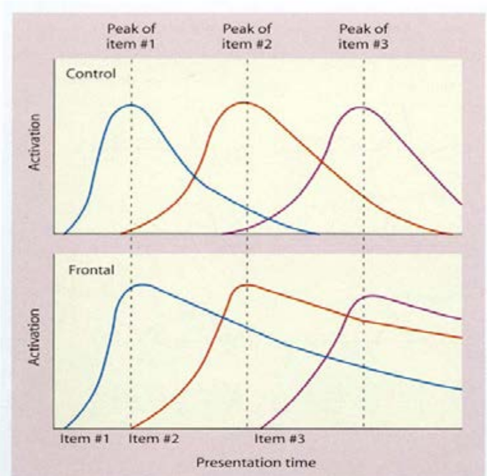


Figure 12.20 Susceptibility to distraction in patients with lateral prefrontal lesions. Subjects performed a delayed auditory matching to sample task. Unrelated distractor tones were presented during the delay period. The group with prefrontal lesions made more errors for all delay conditions, and the deficit became greater as the number of distractors increased. Patients with hippocampal damage were impaired only at the longest delay, consistent with the role of this structure in long-term memory formation. Adapted from Chao and Knight (1995).

Chao & Knight (1995),
Human prefrontal lesions increase distractability to irrelevant sensory inputs. *Neuroreport: Int. J. Rapid Commun. Res. Neurosci. 6,* 1605-1610



Auditory Delayed Response task



Arbeitsgedächtnis und selektive Aufmerksamkeit

The Role of Working Memory in Visual Selective Attention

Jan W. de Fockert,[1*] Geraint Rees,[2] Christopher D. Frith,[3] Nilli Lavie[1]

High Load Working Memory

Selective Attention (no distractor)

Selective Attention (distractor)

High Load Working Memory Test

Fig. 1. Example of a high working memory load trial with two attention displays. After a 500-ms fixation display, the memory set for that trial was presented for 1500 ms. Under low working memory load, the digits were always in the following order: 0, 1, 2, 3, 4. After the memory set, a fixation display was presented for 850 ms, followed by two, three, or four attention displays. The number of attention displays was varied in order to make the onset of the memory probe unpredictable, thus ensuring that the current memory set was actively rehearsed throughout the trial. Each attention display was presented for 500 ms and was followed by a 1250-ms blank response interval. After the final attention display, a memory probe was presented for 3000 ms. Participants were requested to report the digit that followed this probe in the memory set (to press "4" in this example). In order to ensure that all four responses (including "1" in low working memory load trials) were used, we presented a "0" before the four-digit memory set. Thus, the correct response to memory probe "0" would have been "3" in this example.

Arbeitsgedächtnis und selektive Aufmerksamkeit

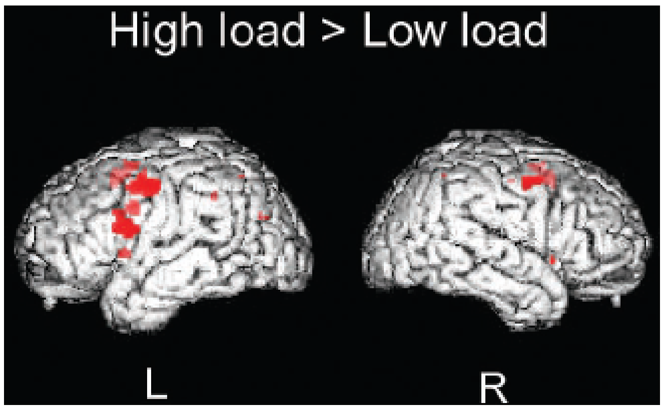


Fig. 2. Activity related to working memory load. Shown are left and right lateral views of a T1-weighted anatomical template image in Talairach space (27), on which are superimposed loci where activity was significantly greater ($P < 0.05$, corrected for multiple comparisons) during high working memory load than during low working memory load.

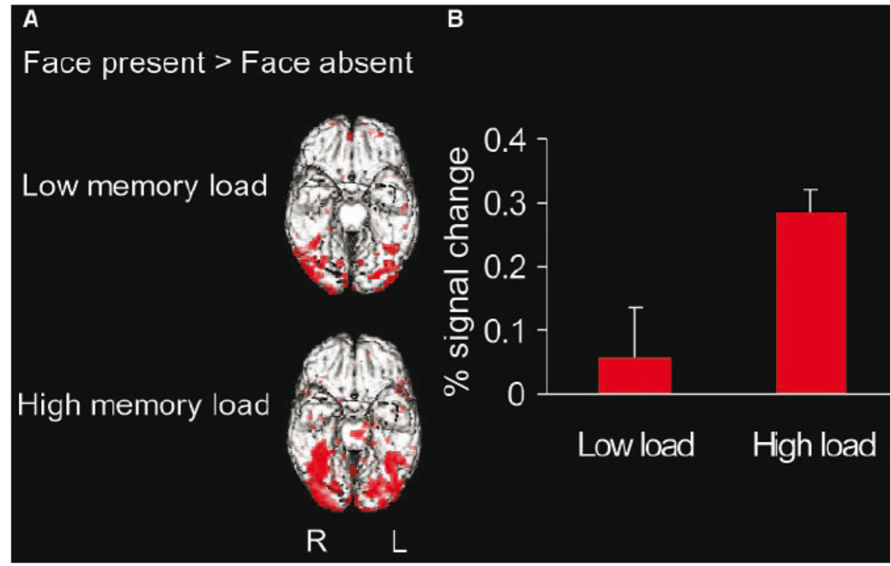
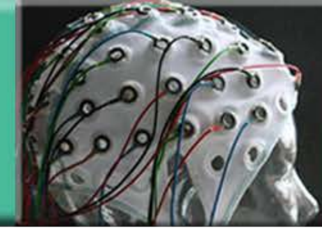
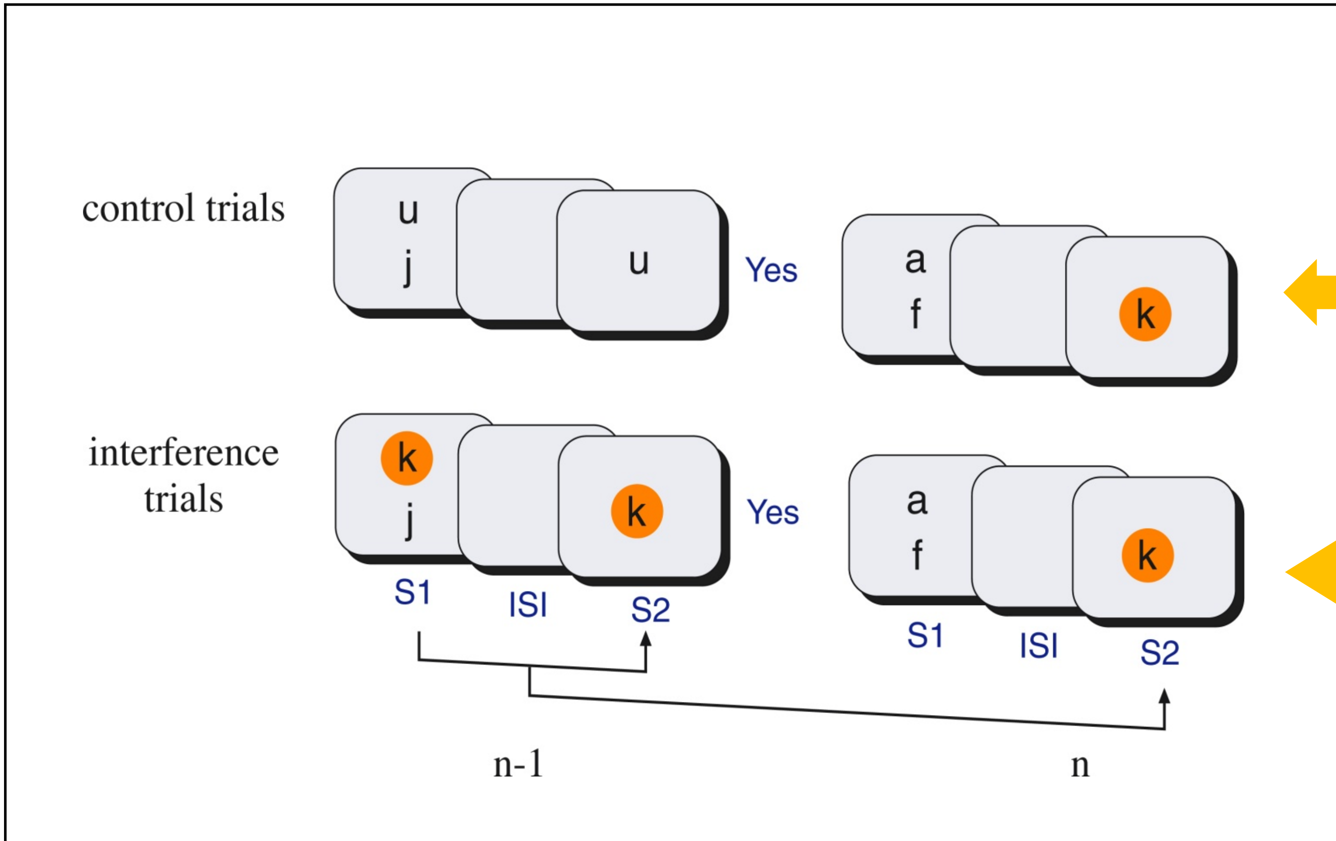


Fig. 3. Distractor-related activity in high versus low working memory. (**A**) Two views of the ventral surface of the template brain used in Fig. 2, on which are superimposed loci where activity was significantly greater in the presence than in the absence of distractor faces under conditions of low working memory load (top) and high working memory load (bottom). A threshold of $Z = 3.10$ (corresponding to $P < 0.001$, uncorrected) is used for display purposes. (**B**) Mean distractor-related activity (percent signal change for face presence minus face absence) for the maxima of the interaction in the right fusiform gyrus (36, −64, −16), plotted separately for low and high working memory load. Data are averaged across participants. Error bars represent interparticipant standard error.

(Fig. 3B). These findings imply that the processing of distractor faces, presented in the selective attention task, was more extensive under high working memory load than low working memory load in a concurrent memory task.

Inhibitorische Kontrolle: Die „Recent Negative Probe“ Technik



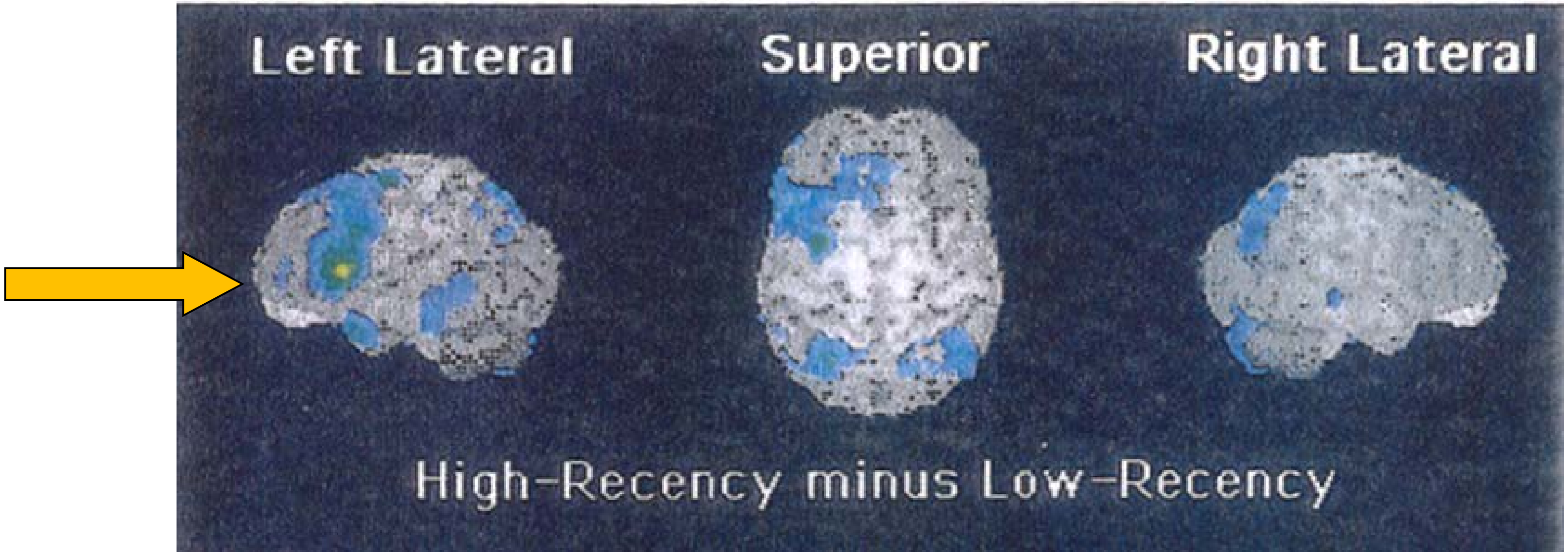


Low recency

High recency

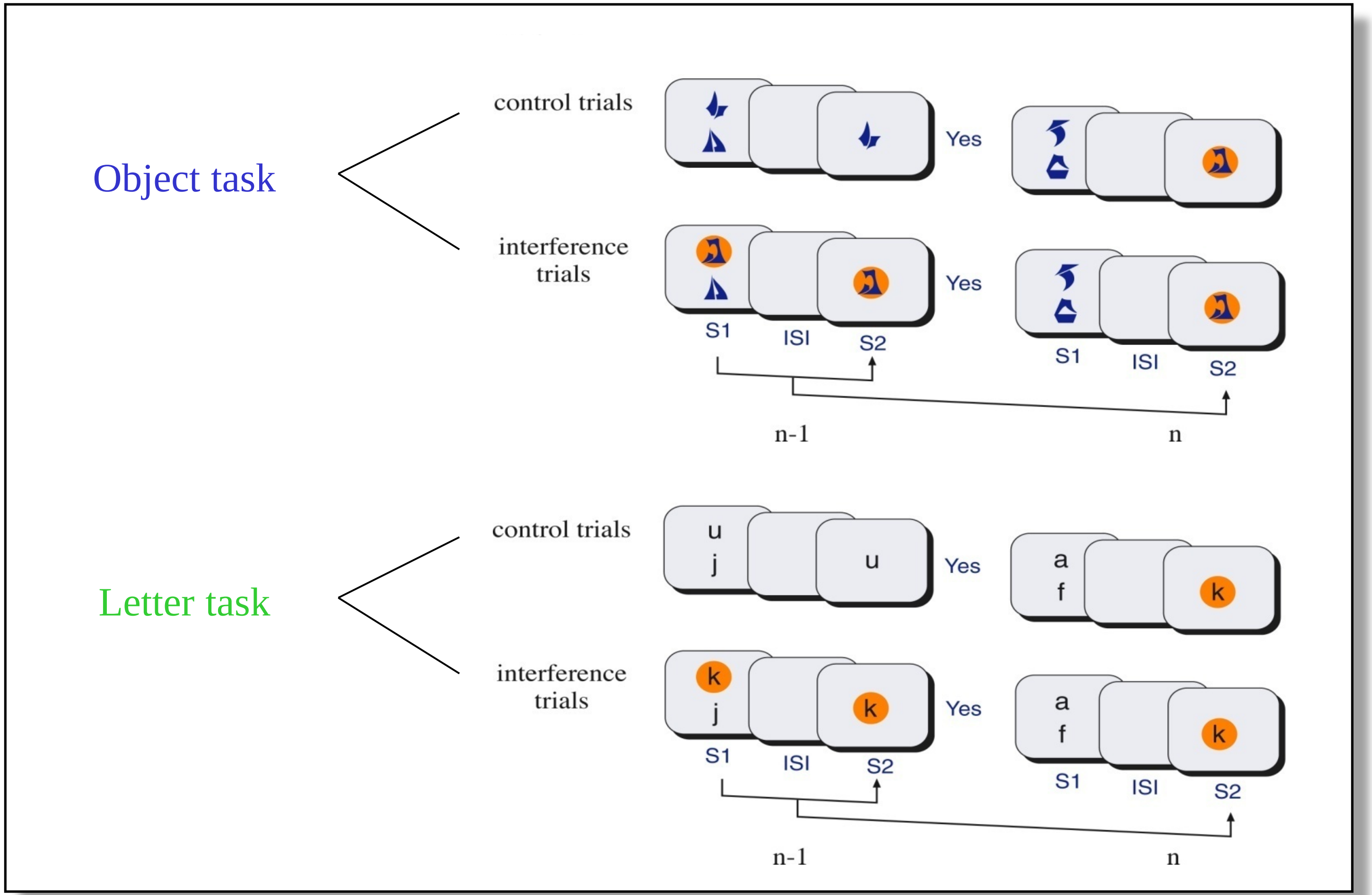
Mecklinger, Engle et al. (2003),
Dissociable brain mechanisms for inhibitory control: effects of interference content and working memory capacity. *Cognitive Brain Research, 18,* 26-38

Inhibitorische Kontrolle: Die „Recent Negative Probe“ Technik



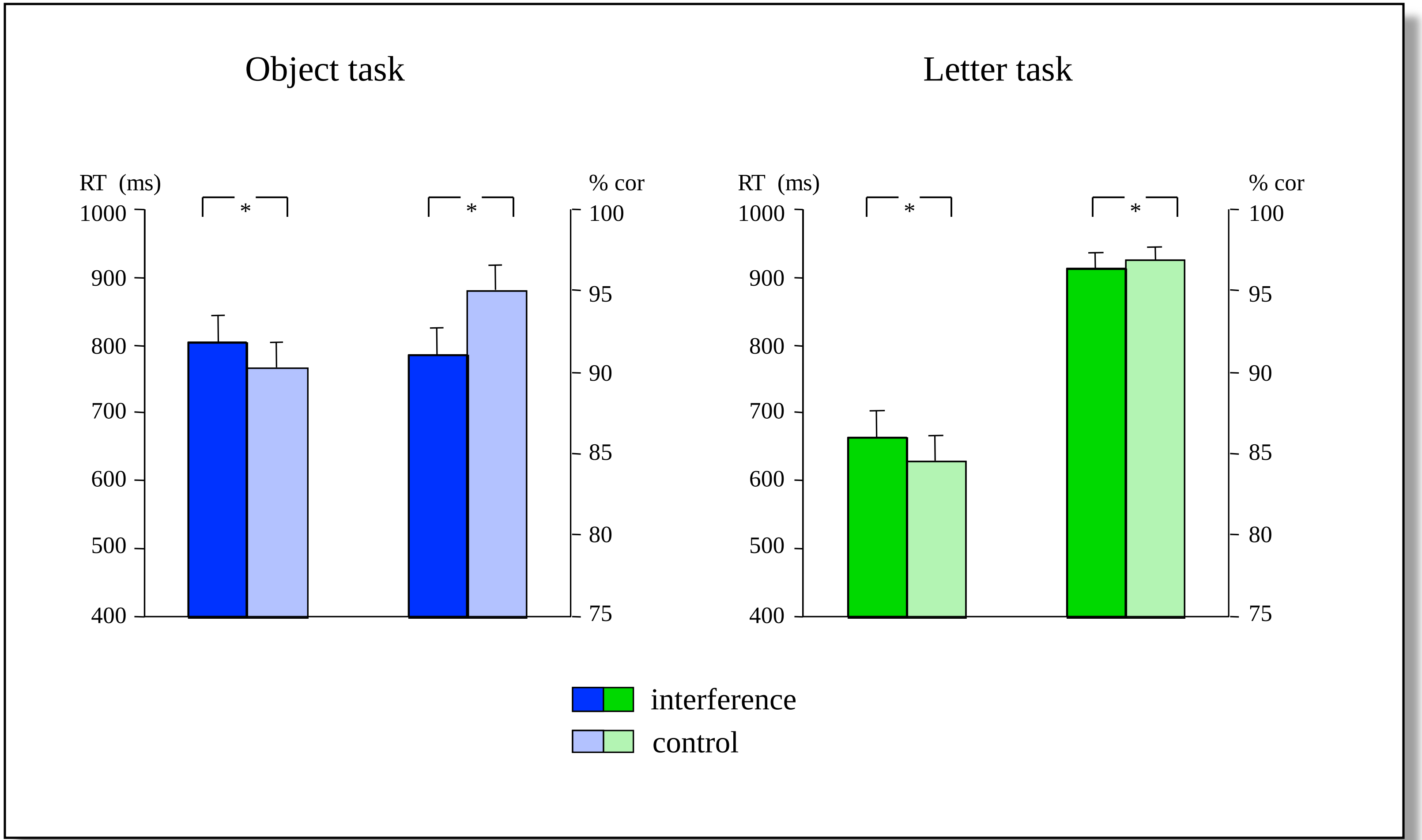
Jonides et al (1998),
Inhibition in verbal working memory revealed by brain activation. *PNAS, 95,* 8410-8413

Ist inhibitorische Kontrolle inhalts-spezifisch? Klingonen vs. Buchstaben



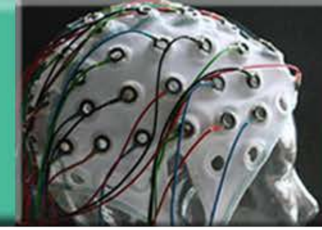
Mecklinger, Engle et al. (2003). Dissociable brain mechanisms for inhibitory control: effects of interference content and working memory capacity. *Cognitive Brain Research*, *18*, 26-38

Verhaltensdaten: Inhibitionskosten



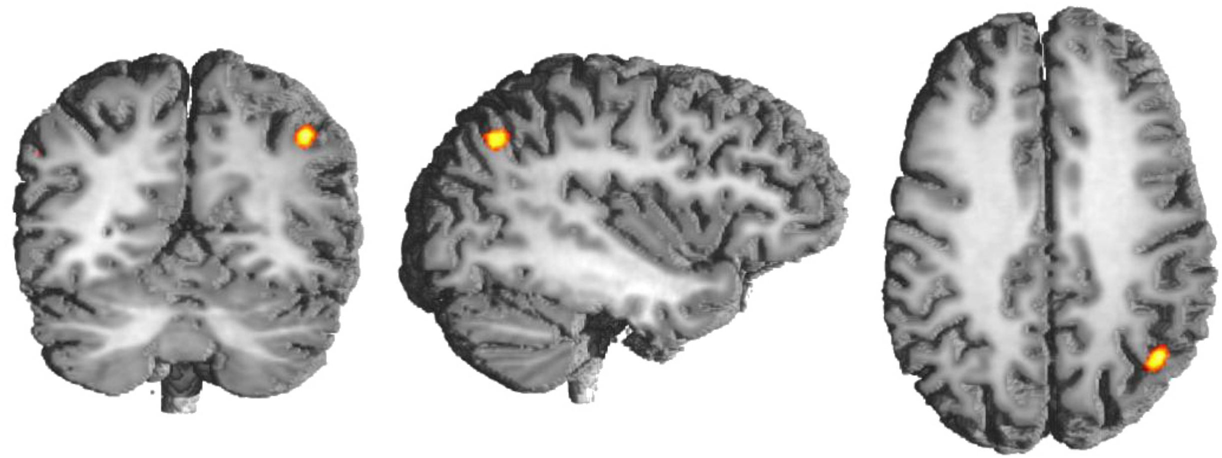
Mecklinger et al (2003)

FMRI Ergebnisse: Inhaltsspezifische Effekte

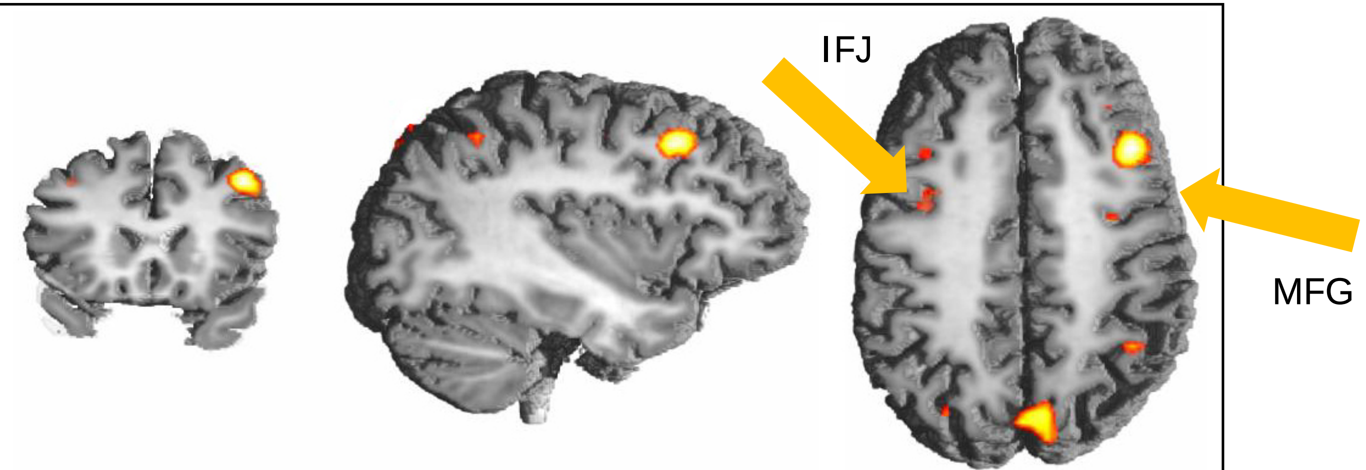


Interference > Control

Object task

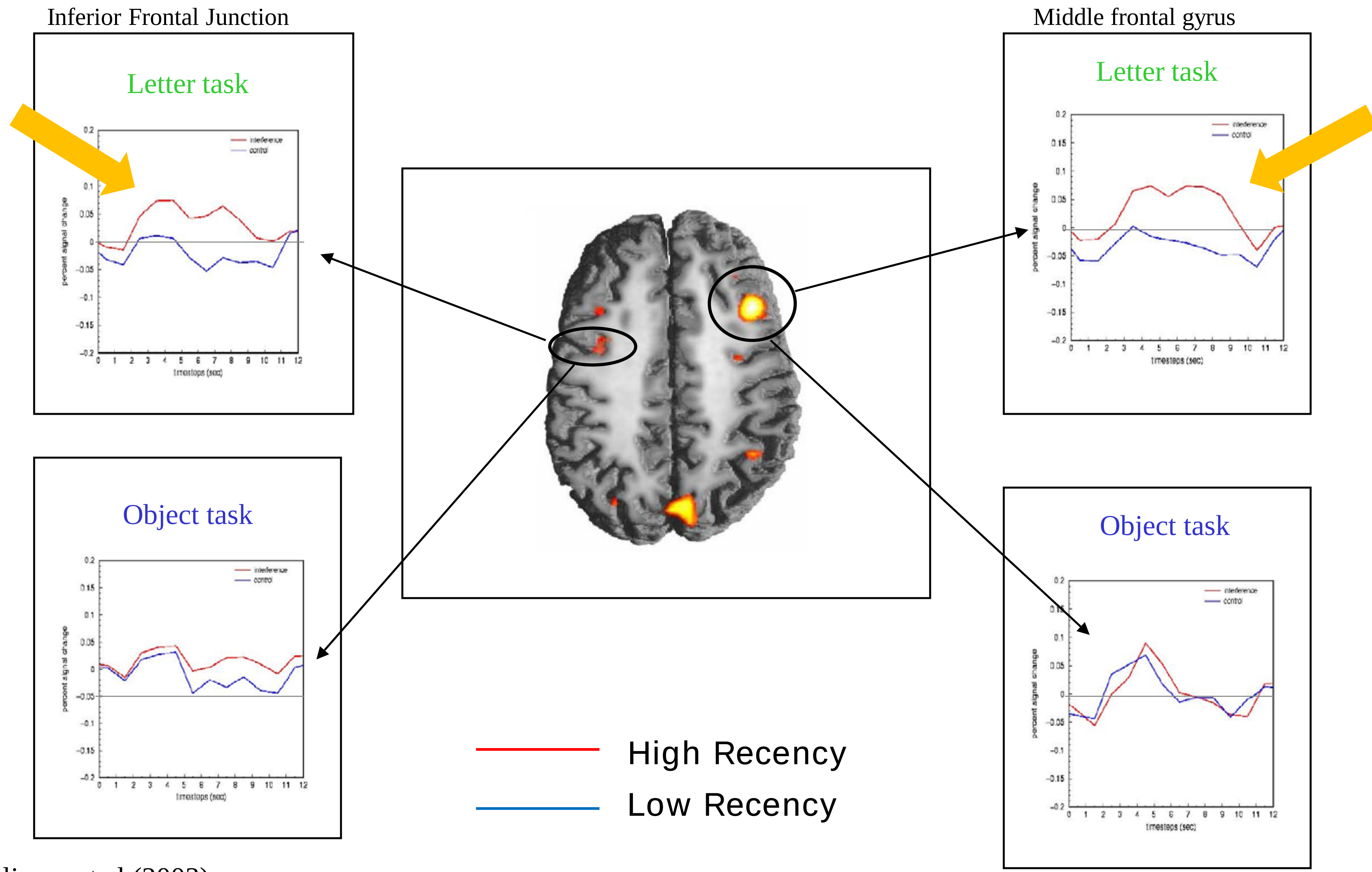


Letter task



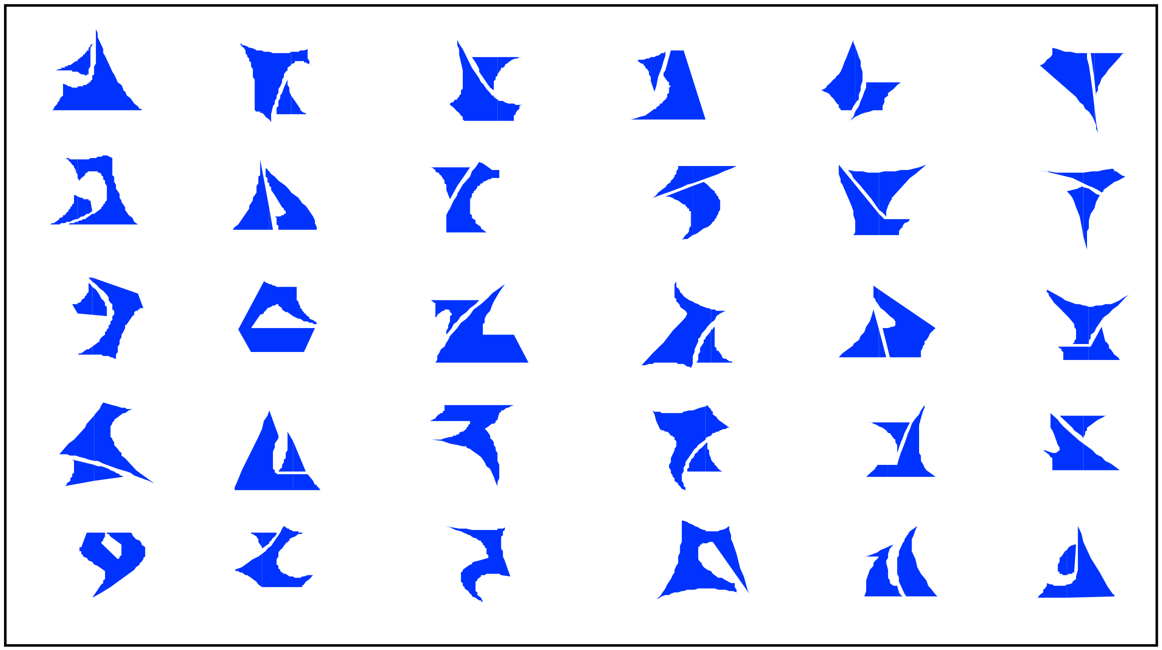
Mecklinger et al (2003)

FMRI Ergebnisse: Bedingungseffekte: IFG und MFG (high recency) Effekte nur bei hoch salienten Reizen (letters)



Mecklinger et al (2003)

Inhaltsspezifische Kontrollprozesse:



a b c d e f g h i j k l m n o p q r s t u v w y z ä ö ü ß

Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex

---

3. Arbeitsgedächtnis
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

5. Selektion aufgabenrelevanter Information
6. Inhibitorische Kontrolle

---

7. **Task Switching / Multitasking**

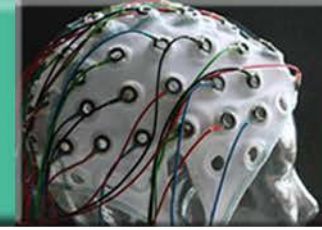
---

8. Handlungsselektion
9. Detektion von Konflikten
10. Zusammenfassung

PFC und „Multitasking“: Wechsel verschiedener Handlungsziele

Figure 12.4 Patients with damage in the lateral prefrontal cortex have difficulty on the Wisconsin Card Sorting Task. On each trial, the subjects place the top card of the deck under one of the four target cards. The experimenter indicates whether the response is correct or incorrect, allowing the subject to learn the sorting rule by trial and error. The sorting rule changes whenever the subject makes ten consecutive correct responses.

PFC und „Multitasking“: Wechsel verschiedener Handlungsziele



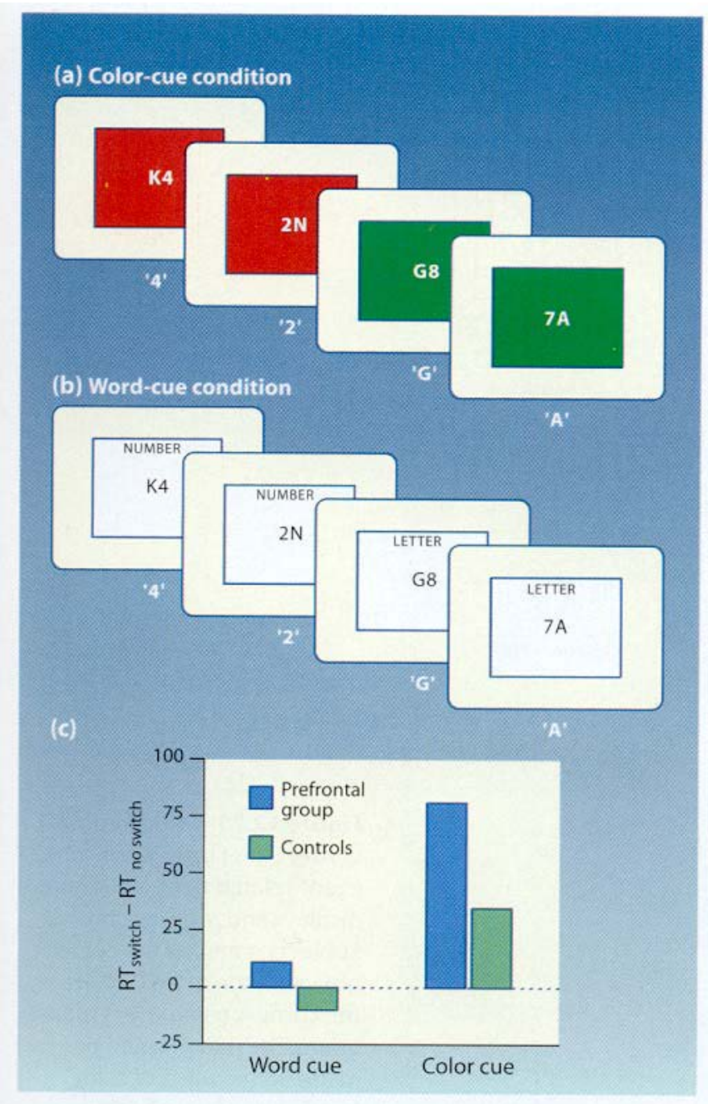
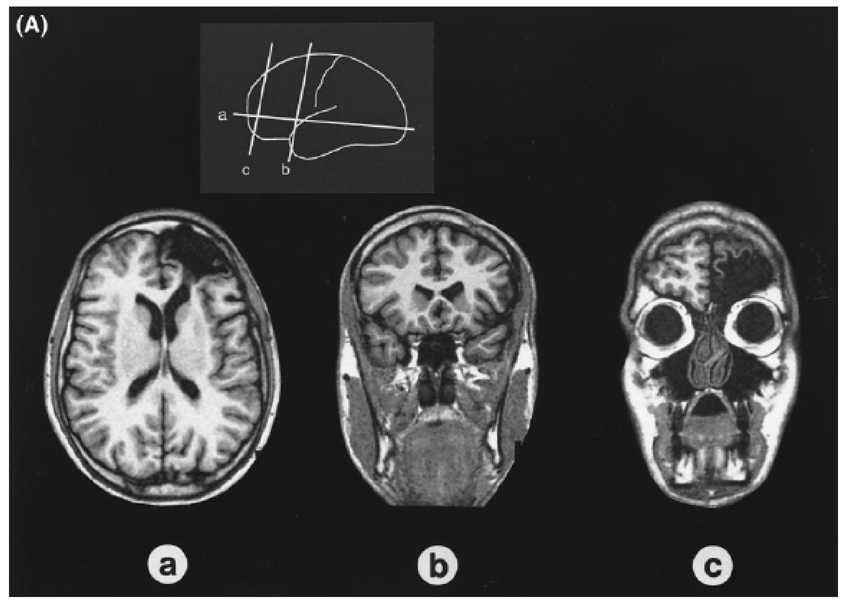
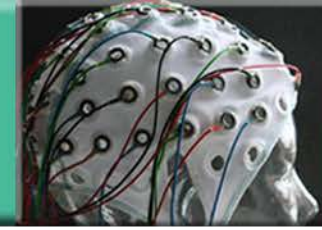


Figure 12.22 Task-switching experiment, with the task cued by either **(a)** a color or **(b)** a word. **(c)** Switching cost, the time required to switch from one task to the other (e.g., from naming the digit to naming the letter), is measured as the difference in reaction time on switch trials and no-switch trials. Patients with prefrontal lesions showed impairment only on the color cue condition. (a), (b) From Rogers et al. (1998).



Rogers et al (1998). Dissociating executive mechanisms of task control following frontal lobe damage and Parkinson ‘s disease. *Brain*, *121*, 815-842

PFC Aktivität beim Aufgabenwechsel: bilaterale Gyrus Frontalis Inferior Aktivität bei hohen Selektionsanforderungen



Konishi et al (1998). Transient activation of inferior prefrontal cortex during cognitive set shifting. *Nat Neuro, 1,* 80-84

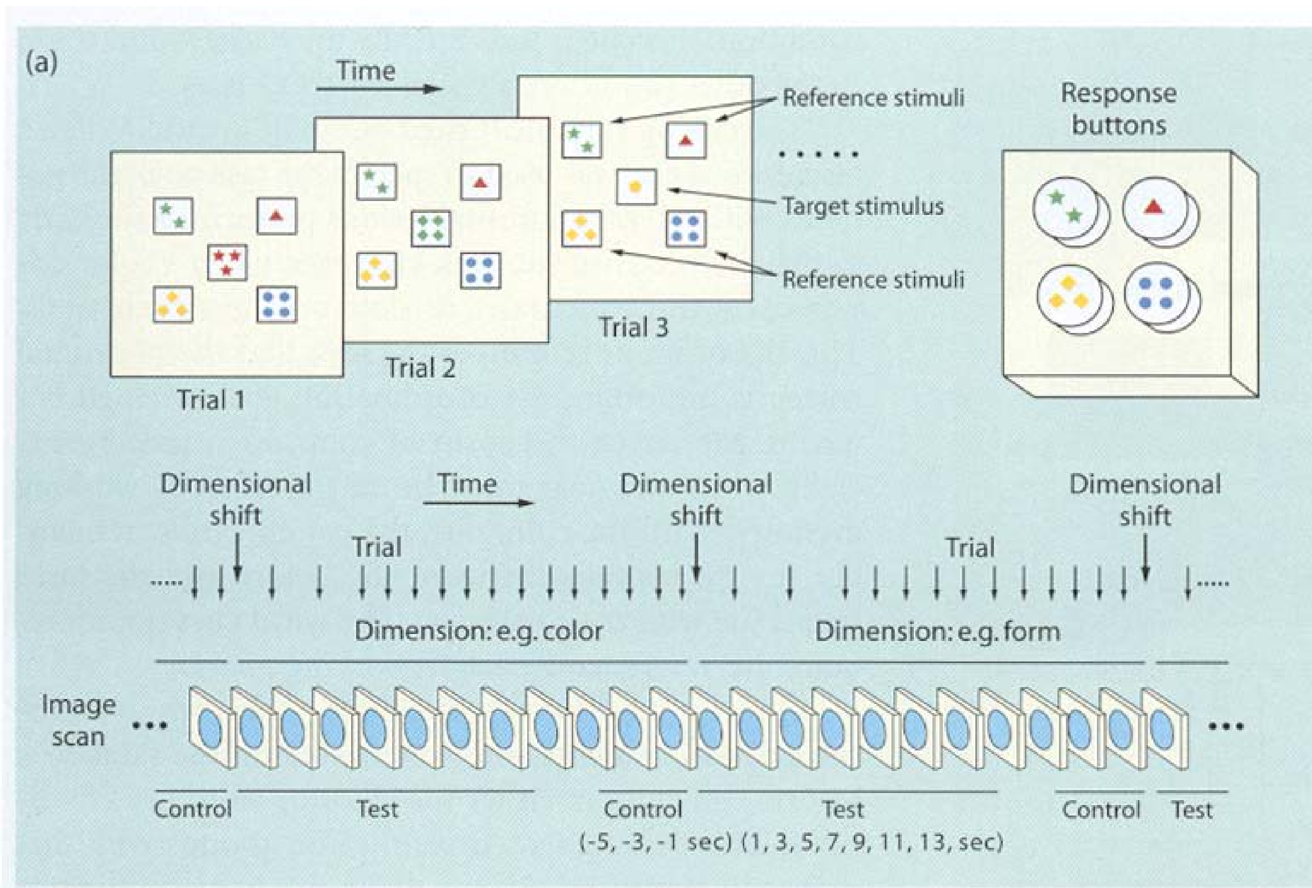


Figure 12.23 Modified Wisconsin Card Sorting Task for event-related fMRI. **(a)** Stimulus displays and response board. Subjects matched the center object to one of four objects in the corners, using the response board. The match could be made on the basis of color, form, or number. After ten correct responses, the matching rule would change, indicating a dimensional shift. **(b)** Increased activation was observed bilaterally in the inferior frontal cortex following the signal to shift dimensions. Note that the hemodynamic response peaks about 7 seconds after the shift. From Konishi et al. (1998).

PFC Aktivität beim Aufgabenwechsel: bilaterale Gyrus Frontalis Inferior Aktivität bei hohen Selektionsanforderungen

Konishi et al (1998),
Transient activation of inferior prefrontal cortex during cognitive set shifting. *Nat Neuro, 1,* 80-84

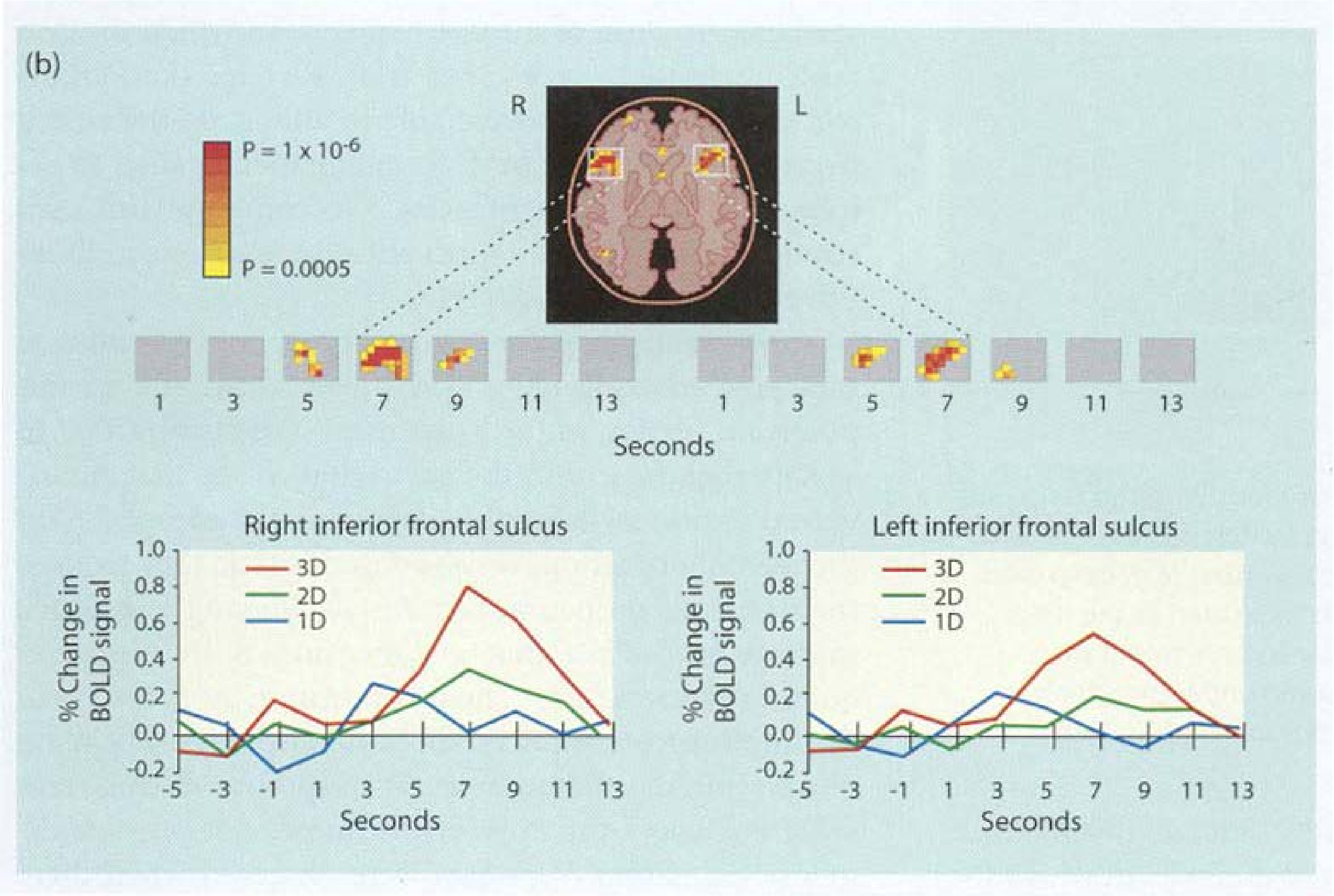


Figure 12.23 Modified Wisconsin Card Sorting Task for event-related fMRI. **(a)** Stimulus displays and response board. Subjects matched the center object to one of four objects in the corners, using the response board. The match could be made on the basis of color, form, or number. After ten correct responses, the matching rule would change, indicating a dimensional shift. **(b)** Increased activation was observed bilaterally in the inferior frontal cortex following the signal to shift dimensions. Note that the hemodynamic response peaks about 7 seconds after the shift. From Konishi et al. (1998).

Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex

---

3. Arbeitsgedächtnis
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

5. Selektion aufgabenrelevanter Information
6. Inhibitorische Kontrolle

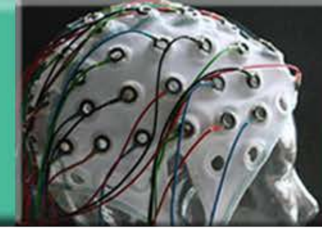
---

7. Task Switching

---

8. **Handlungsselektion**
9. Detektion von Konflikten
10. Zusammenfassung

Handlungsselektion: Selection of action



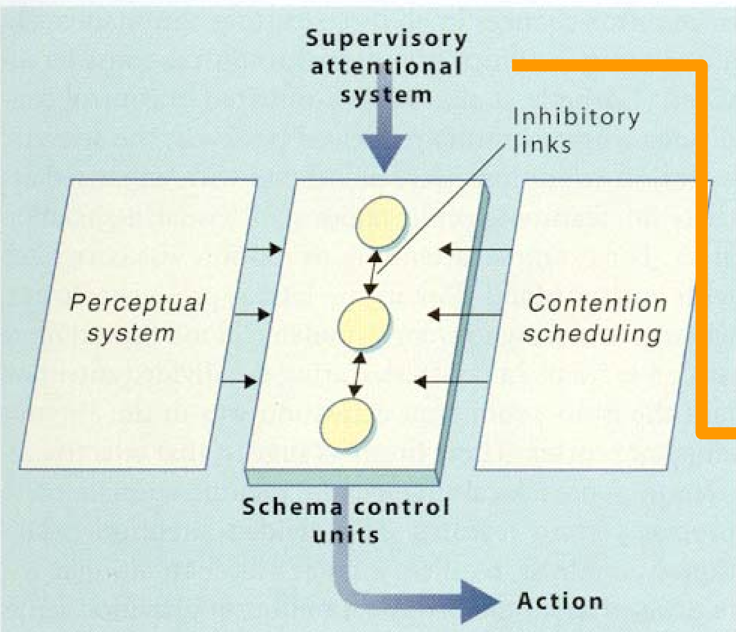
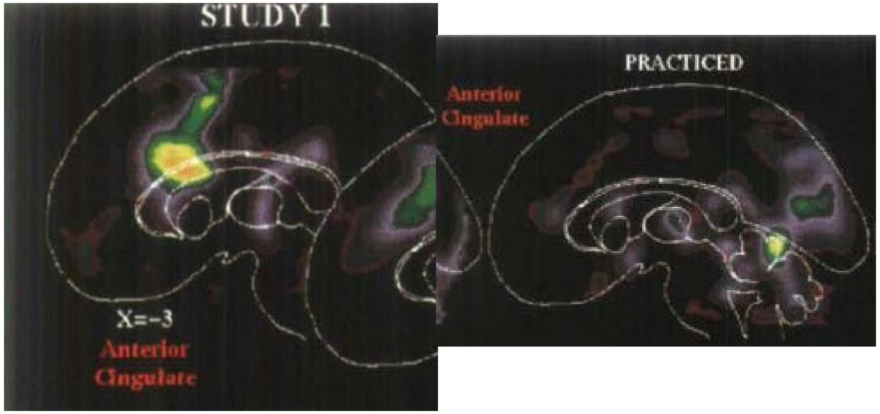


Figure 12.24 Norman and Shallice's model of response selection. Actions are linked to schema control units. The perceptual system produces input to these control units. However, selection of these units can be biased by the contention scheduling units and the supervisory attentional system (SAS). The SAS provides flexibility in the response selection system. Adapted from Shallice et al. (1989).

Two means for selection: CS & SAS

1. When situation requires planning
2. When links between inputs and schema are not well learnt
3. When situation requires overcoming a strong, habitual response
4. When the situation requires error correction or trouble shooting
5. When the situation is difficult

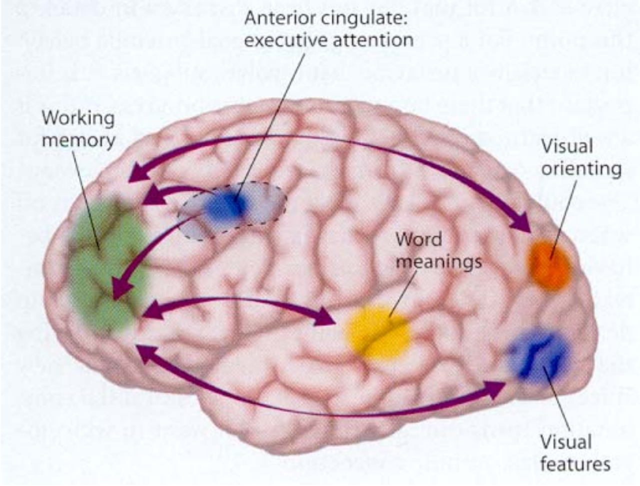
Supervisory Attentional System (SAS) und der anteriore Gyrus Cinguli



Raichle et al (1994),
Practice-related changes in human brain functional anatomy during nonmotor learning. *Cer Cortex, 4,* 8-26

1. When situation requires planning
2. When links between inputs and schema are not well learnt
3. When situation requires overcoming a strong, habitual response
4. When the situation requires error correction or trouble shooting
5. When the situation is difficult

Figure 12.25 The anterior cingulate has been hypothesized to operate as an executive attention system. This system serves to ensure that processing in other brain regions is most efficient given the current task demands. Interactions with the prefrontal cortex may select working memory buffers; interactions with the posterior cortex can serve to amplify activity in one perceptual module over others. The interactions with the posterior cortex may be direct or they may be mediated by connections with the prefrontal cortex. Adapted from Posner and Raichle (1994).



Kognitive Kontrolle

1. Exekutive Funktion
2. Präfrontaler Cortex

---

3. Arbeitsgedächtnis
4. Funktionale Spezialisierung im lateralen präfrontalen Cortex

---

5. Selektion aufgabenrelevanter Information
6. Inhibitorische Kontrolle

---

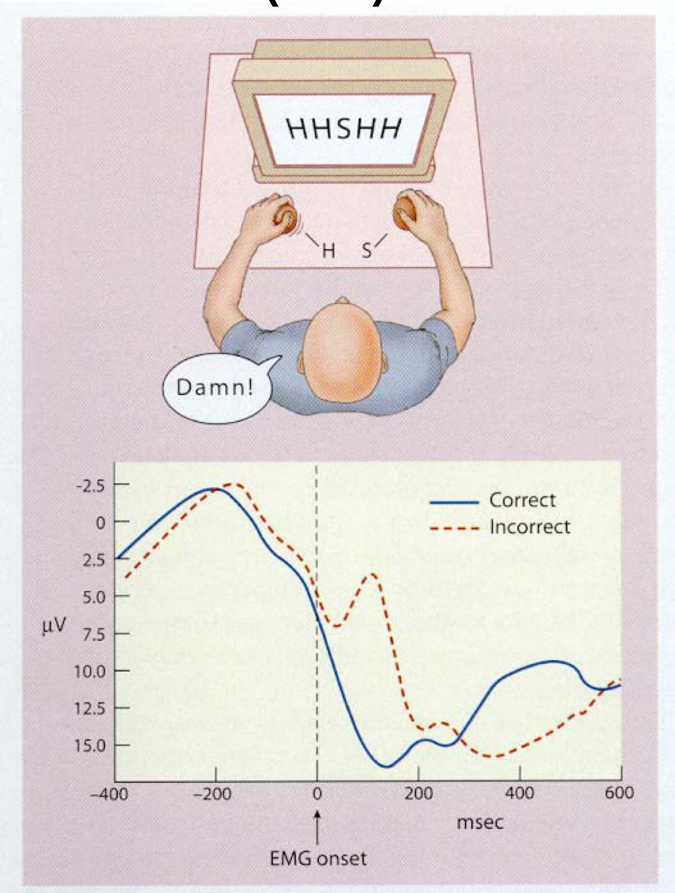
7. Task Switching

---

8. Handlungsselektion
9. **Detektion von Konflikten**
10. Zusammenfassung

Der anteriore Gyrus Cinguli: Monitoring und Detektion von Konflikten und die ERN

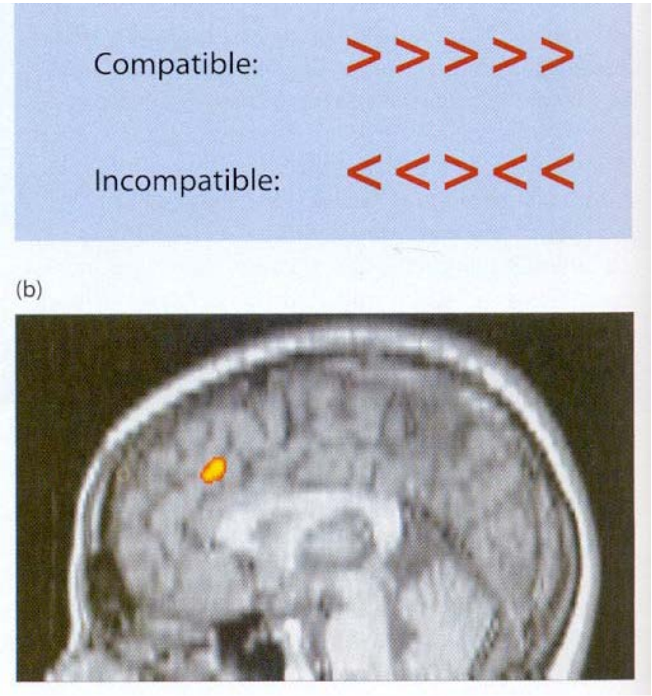
Error-related negativity (ERN)



Gehring et al (1993),
A neural system for error detection and compensation. *Psych Sci*, *4*, 385-390

4. When the situation requires error correction or trouble shooting

Response Conflict



Die ERN
Fehlerdetektion und Kompensation

PSYCHOLOGICAL SCIENCE

Research Report

A NEURAL SYSTEM FOR ERROR DETECTION AND COMPENSATION

William J. Gehring,[1] Brian Goss,[1] Michael G.H. Coles,[1] David E. Meyer,[2] and Emanuel Donchin[1]

[1]University of Illinois and [2]University of Michigan

Abstract—*Humans can monitor actions and compensate for errors. Analysis of the human event-related brain potentials (ERPs) accompanying errors provides evidence for a neural process whose activity is specifically associated with monitoring and compensating for erroneous behavior. This error-related activity is enhanced when subjects strive for accurate performance but is diminished when response speed is emphasized at the expense of accuracy. The activity is also related to attempts to compensate for the erroneous behavior.*

A fundamental characteristic of human cognition is its fallibility. People rarely perform tasks perfectly, even though the costs of imperfection can be devastating (Norman, 1988; Reason, 1990). It is plausible to assume that the prevalence of errors, and their high cost, has led to the evolution of mechanisms that monitor the accuracy of actions and attempt to correct, or compensate for, errors. That such mechanisms exist is, indeed, assumed explicitly or implicitly in many theories of cognition. For example, concepts of error monitoring are included in theories of action (MacKay, 1987), learning (Adams, 1971; Rumelhart, Hinton, & Williams, 1986), speaking (Levelt, 1989), and consciousness (Kosslyn & Koenig, 1992). Monitoring mechanisms are also implied by theories of executive or supervisory cognitive control systems (Logan, 1985; Shallice, 1988; Stuss & Benson, 1986).

Given the frequency with which the concept of error monitoring is invoked, it is remarkable that there is little direct neurophysiological evidence for the existence of error-detection and -compensation systems (but see Gemba, Sasaki, & Brooks, 1986, for an exception). Much of the work investigating the issue has inferred the existence of a monitoring and compensation apparatus from behavior that appears to be compensatory, as when subjects execute an error and then quickly execute the correct response (Rabbitt, 1966, 1968) or slow down subsequent to errors (Laming, 1968; Rabbitt, 1966). These phenomena, while consistent with the existence of an error-monitoring system, are not conclusive, however, because they could occur without the presence of an error-detection system: The apparent correction could simply be a correct response produced in parallel with, but more slowly than, the error. Furthermore, a response on a trial after an error could be slow because of a persistence of the processing problem that caused the error.

More direct evidence for an error-monitoring mechanism comes from descriptions of an event-related brain process that appears to be evoked contemporaneously with the commission of erroneous responses. We (Gehring, Coles, Meyer, & Donchin, 1990) have reported that an error-related negativity (ERN) appears selectively on error trials in choice reaction time experiments. The ERN takes the form of a sharp, negative-going deflection of up to 10 µV in amplitude and is largest at electrodes placed over the front and middle of the scalp. Its onset is shortly after the onset of electromyographic (EMG) activity detected in the limb that is about to make an error, and it peaks about 100 ms following its onset. A similar observation was made, independently, by Falkenstein, Hohnsbein, Hoormann, and Blanke (1990).

In this report, we present evidence that the ERN is a manifestation of the activity of a system associated with monitoring the accuracy of the response system and with compensating for errors. Our test is predicated on the assumption that if the ERN manifests the activity of such a system, it will be more active when response accuracy is important to the subject. We predicted that the amplitude of the ERN will vary with the relative weight the subject's task assigns to accuracy and speed. Furthermore, if the ERN is a manifestation of an error-compensation mechanism, there ought to be a relationship between its amplitude and the dynamics of the erroneous

Address correspondence to William J. Gehring, who is now at the Center for Neuroscience, University of California, Davis, Davis, CA 95616.

VOL. 4, NO. 6, NOVEMBER 1993

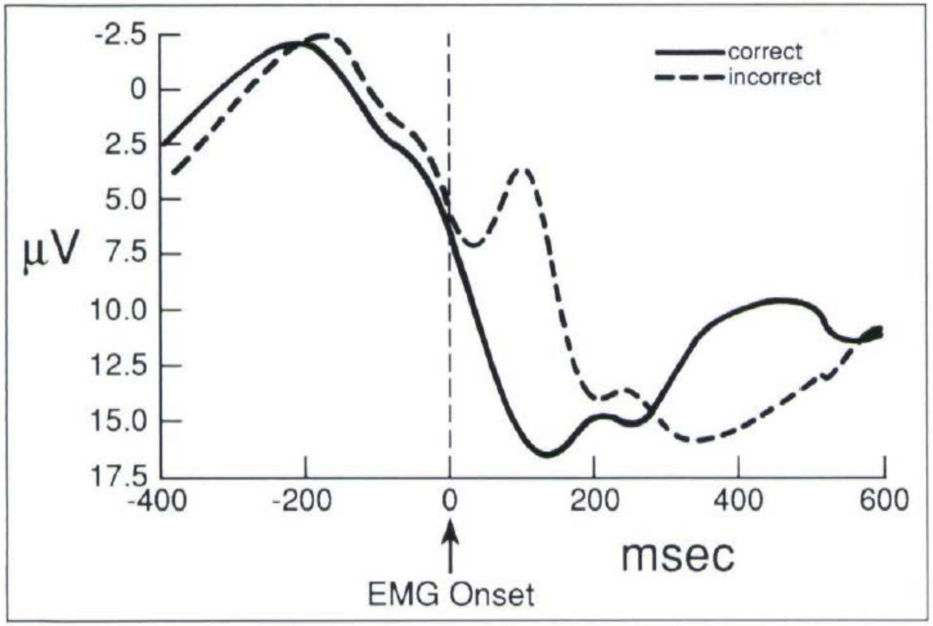
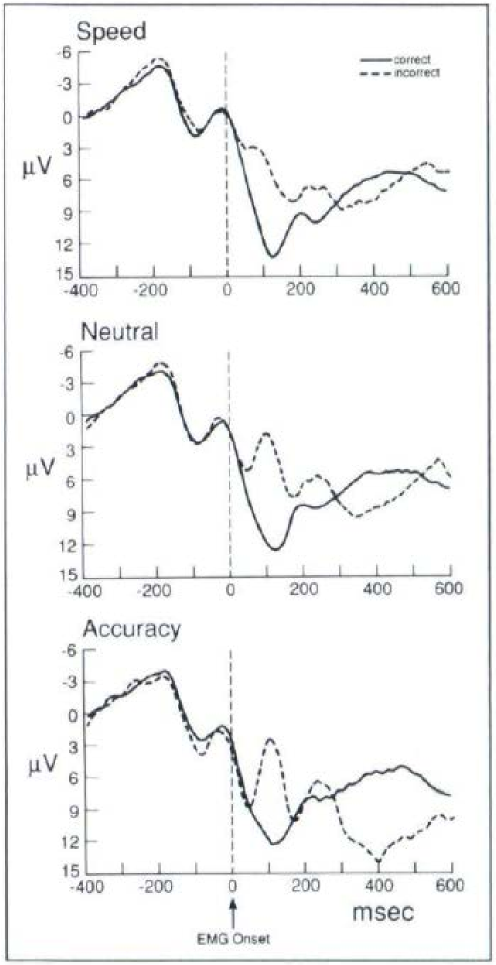


Fig. 1. Comparison of response-locked event-related potential activity, recorded at the C_z electrode, for correct and incorrect trials.



Die ERN
Fehlerdetektion und Kompensation

PSYCHOLOGICAL SCIENCE

Research Report

A NEURAL SYSTEM FOR ERROR DETECTION AND COMPENSATION

William J. Gehring,[1] Brian Goss,[1] Michael G.H. Coles,[1] David E. Meyer,[2] and Emanuel Donchin[1]

[1]University of Illinois and [2]University of Michigan

Abstract—*Humans can monitor actions and compensate for errors. Analysis of the human event-related brain potentials (ERPs) accompanying errors provides evidence for a neural process whose activity is specifically associated with monitoring and compensating for erroneous behavior. This error-related activity is enhanced when subjects strive for accurate performance but is diminished when response speed is emphasized at the expense of accuracy. The activity is also related to attempts to compensate for the erroneous behavior.*

A fundamental characteristic of human cognition is its fallibility. People rarely perform tasks perfectly, even though the costs of imperfection can be devastating (Norman, 1988; Reason, 1990). It is plausible to assume that the prevalence of errors, and their high cost, has led to the evolution of mechanisms that monitor the accuracy of actions and attempt to correct, or compensate for, errors. That such mechanisms exist is, indeed, assumed explicitly or implicitly in many theories of cognition. For example, concepts of error monitoring are included in theories of action (MacKay, 1987), learning (Adams, 1971; Rumelhart, Hinton, & Williams, 1986), speaking (Levelt, 1989), and consciousness (Kosslyn & Koenig, 1992). Monitoring mechanisms are also implied by theories of executive or supervisory cognitive control systems (Logan, 1985; Shallice, 1988; Stuss & Benson, 1986).

Given the frequency with which the concept of error monitoring is invoked, it is remarkable that there is little direct neurophysiological evidence for the existence of error-detection and -compensation systems (but see Gemba, Sasaki, & Brooks, 1986, for an exception). Much of the work investigating the issue has inferred the existence of a monitoring and compensation apparatus from behavior that appears to be compensatory, as when subjects execute an error and then quickly execute the correct response (Rabbitt, 1966, 1968) or slow down subsequent to errors (Laming, 1968; Rabbitt, 1966). These phenomena, while consistent with the existence of an error-monitoring system, are not conclusive, however, because they could occur without the presence of an error-detection system: The apparent correction could simply be a correct response produced in parallel with, but more slowly than, the error. Furthermore, a response on a trial after an error could be slow because of a persistence of the processing problem that caused the error.

More direct evidence for an error-monitoring mechanism comes from descriptions of an event-related brain process that appears to be evoked contemporaneously with the commission of erroneous responses. We (Gehring, Coles, Meyer, & Donchin, 1990) have reported that an error-related negativity (ERN) appears selectively on error trials in choice reaction time experiments. The ERN takes the form of a sharp, negative-going deflection of up to 10 µV in amplitude and is largest at electrodes placed over the front and middle of the scalp. Its onset is shortly after the onset of electromyographic (EMG) activity detected in the limb that is about to make an error, and it peaks about 100 ms following its onset. A similar observation was made, independently, by Falkenstein, Hohnsbein, Hoormann, and Blanke (1990).

In this report, we present evidence that the ERN is a manifestation of the activity of a system associated with monitoring the accuracy of the response system and with compensating for errors. Our test is predicated on the assumption that if the ERN manifests the activity of such a system, it will be more active when response accuracy is important to the subject. We predicted that the amplitude of the ERN will vary with the relative weight the subject's task assigns to accuracy and speed. Furthermore, if the ERN is a manifestation of an error-compensation mechanism, there ought to be a relationship between its amplitude and the dynamics of the erroneous responses. We varied, therefore, the speed and accuracy requirements placed upon the subject, and we measured several performance parameters that may reflect compensatory activity, including the force with which the subject executes a response, the probability of correcting the error, and the speed of responses following the error. We embedded these manipulations and measures in a task known from previous research to produce erroneous response activation (see Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988).

METHOD

Subjects

Six University of Illinois students (4 men and 2 women) between the ages of 18 and 26 served as subjects. All were right-handed and had normal or corrected-to-normal vision. They received $3.50 per hour plus bonuses for participation.

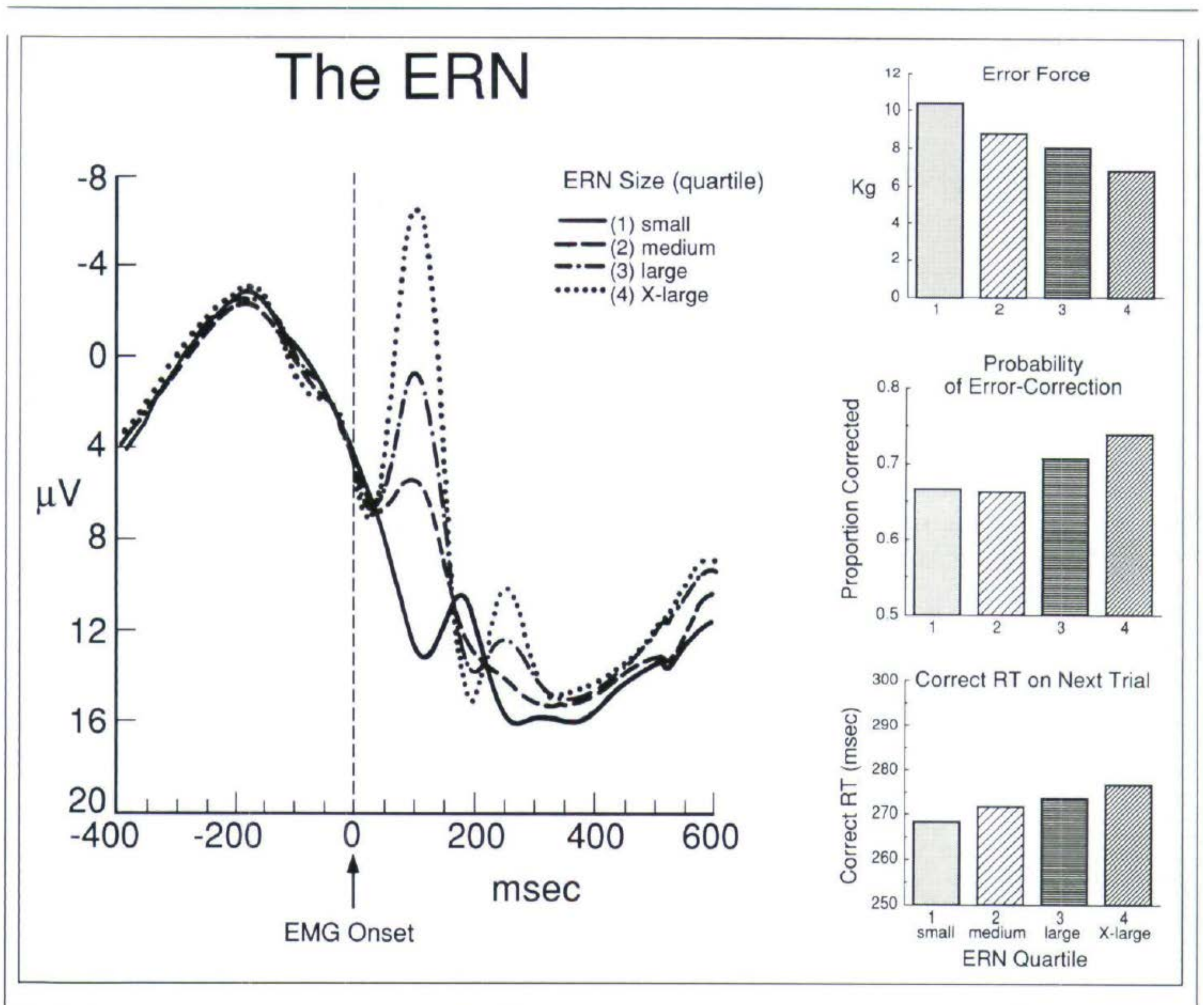
Stimuli

Stimuli were presented on a Hewlett-Packard computer display (#1310A). Subjects sat 1 m from the screen, such that each letter subtended approximately 0.5° of visual angle. One of four arrays occurred on each trial: The two compatible arrays were HHHHH and SSSSS, and the two incompatible arrays were SSHSS and HHSHH. The probability of each of these arrays was .25. A fixation

Address correspondence to William J. Gehring, who is now at the Center for Neuroscience, University of California, Davis, Davis, CA 95616.

VOL. 4, NO. 6, NOVEMBER 1993

Copyright © 1993 American Psychological Society 385



Zusammenfassung

Präfrontaler Cortex und Arbeitsgedächtnis

Funktionale Spezialisierung im lateralen PFC

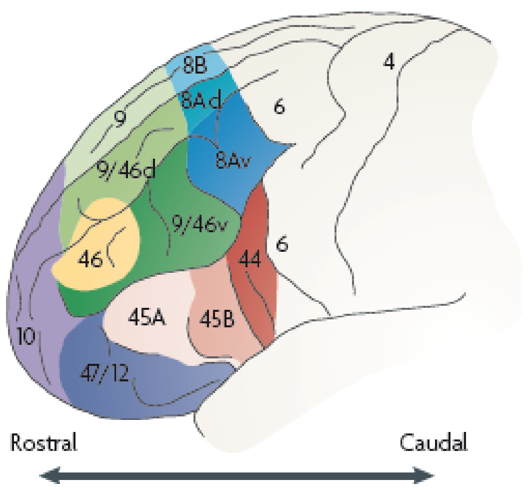
- Lateralität/Inhalt/Prozess

Lateraler PFC und:

- Selektion aufgabenrelevanter Information
- Inhibitorische Kontrolle
- Multitasking/Task Switching

Anteriore Gyrus Cinguli und:

- Handlungsselektion
- Detektion von Konflikten



The Cingulate Cortex Does Everything

by Gregory J. Gage†, Hirak Parikh†, Timothy C. Marzullo††

Annals of Improbable Research | May–June 2008 | vol. 14, no. 3 | 13

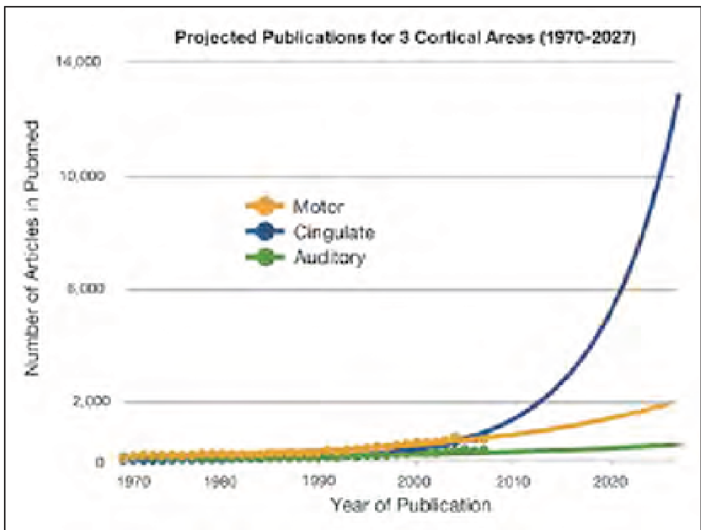
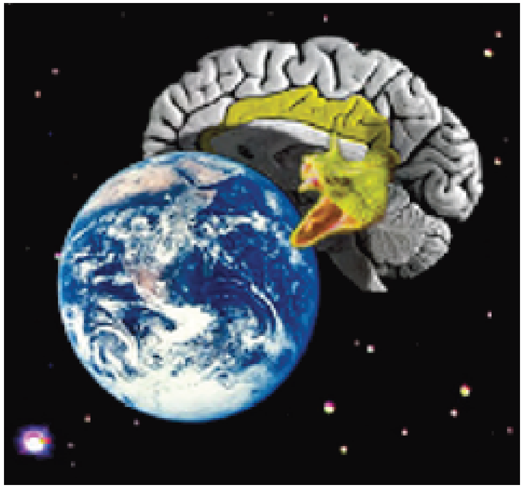


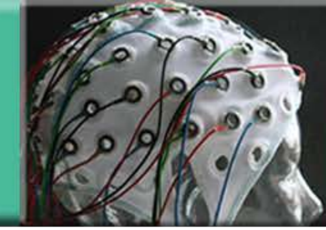
Figure 2. Projected publications for three cortical areas (1970-2027). Using our exponential model, we predict that the number of citations for the cingulate cortex in the year 2027 will be on the order of 13,500! That is a 15-fold increase in publications from the 900 in 2007, whereas the motor and auditory cortices will have a more reasonable and sustainable number of publications.

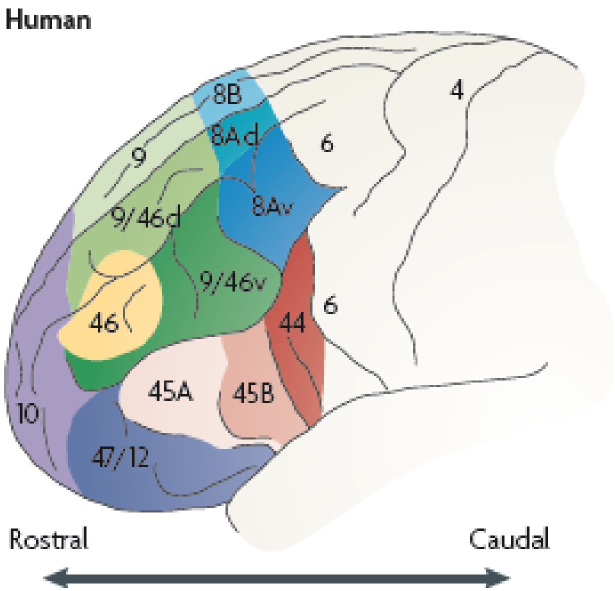
The Cingularity

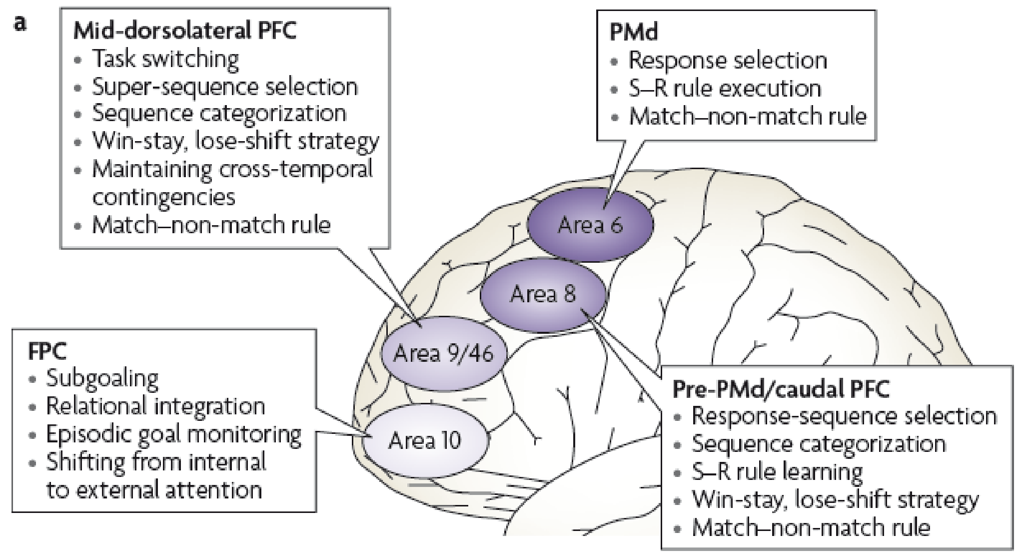
We predict that between 2050 and 2100, there will be more cingulate publications than there are cells in the cingulate cortex itself. At this point, we fear that the "Cingularity" will be reached, and the cingulate cortex will become self-aware.

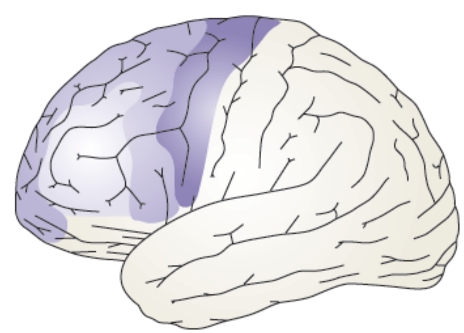


Weitere PFC Strukturen:
Der rostral PFC









Different rates of maturation

Badre & D'Esposito (2009). Is the rostro-caudal axis of the frontal lobes hierarchical? *Nat Rev Neuro, 10,* 659-669


Danke für Ihre
Aufmerksamkeit!