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LFG Neuropsychologie,
Medizinische Fakultät,
RWTH Aachen

# Funktionelle Neuroanatomie von Aufmerksamkeitsstörungen im Kindes- und Jugendalter und ihre Bedeutung in der neuropsychologischen Diagnostik

Bruno Fimm

Universitätsklinikum Aachen
Lehr- und Forschungsgebiet Neuropsychologie

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## Components of attention (Posner & Rafal, 1987)

| | |
|---|---|
| Alertness | |
| Tonische Alertness | Fluktuation von Wachheit und Leistung im Tagesverlauf |
| Phasische Alertness | Durch ein Warnsignal ausgelöster allgemeiner Leistungsanstieg |
| Selektive Aufmerksamkeit | |
| Vorbewusst | • Vorbereitung für selektive Informationsaufnahme<br>• parallele Verarbeitung multipler Reize<br>• simultane Aktivierung von Bahnen |
| Bewusst | • willentliche gesteuerte Aufmerksamkeitszuwendung<br>• sequentielle Verarbeitung<br>• beschränkte Kapazität |
| Vigilanz oder Dauer-aufmerksamkeit | Umfang an bewusster Anstrengung, die in eine gegebene Handlung investiert wird |

Posner, M.I. & Rafal, R.D. (1987). Cognitive theories of attention and the rehabilitation of attentional deficits. In Meier, R.J.; Benton, A.C. & Diller, L (eds.) Neuropsychological Rehabilitation. Edinburgh: Churchill Livingstone.

# Attention - Domains and Paradigms

| Dimension | Domain of attention | Paradigms or tasks |
|---|---|---|
| Intensity | Alertness (intrinsic, tonic, phasic) | Simple reaction time tasks without (intrinsic, tonic; top-down) or with warning signal (phasic; bottom-up) |
| | Sustained attention | Long lasting tasks, high critical event rate, detection of small changes |
| | Vigilance | Long lasting tasks, low critical event rate, |
| Selectivity | Selective oder focused attention | Choice reaction time tasks, Distractor tasks |
| | Visuo-spatial attention, Shift of attentional focus | Tasks requiring overt or covert spatial shifts of attention |
| | Divided attention | Tasks requiring attention to be shared or divided between two or more information channels (e.g. dual task paradigms) |

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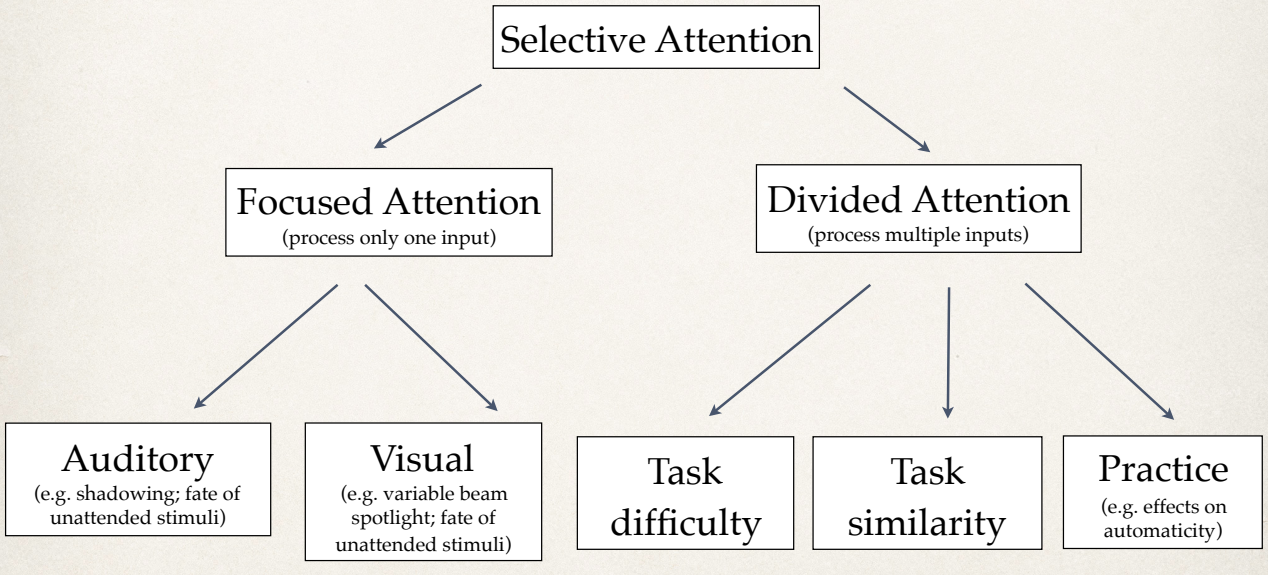
# Selective Attention

## Focused vs. Divided Attention

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# Aufmerksamkeit Funktionelle Neuroanatomie

| Dimension | Bereich | Netzwerk |
|---|---|---|
| Intensität | Aufmerksamkeitsaktivierung (Alertness)<br><br>Daueraufmerksamkeit Vigilanz | Hirnstammanteil der formatio reticularis, besonders noradrenerge Kerngebiete; dorsolateraler präfrontaler und inferiorer parietaler Kortex der rechten Hemisphäre, intralaminare und retikuläre Thalamuskerne, anteriorer Anteil Gyrus cinguli |
| Selektivität | Selektive oder fokussierte Aufmerksamkeit | Inferiorer frontaler Kortex, v.a. der linken Hemipshäre; fronto-thalamische Verbindungen zum Nucleus reticularis des Thalamus; anteriorer Gyrus cinguli? |
| | Visuell-räumliche selektive Aufmerksamkeit, Wechsel des Aufmerksamkeitsfokus | Inferiorer parietaler Kortex (disengage), colliculi superiores (shift), posterior-lateraler Thalamus, v.a. Pulvinar (engage) |
| | Geteilte Aufmerksamkeit | Präfrontaler Kortex (bilateral), vordere Abschnitte des Gyrus cinguli |





# Neuronale Netzwerke der Aufmerksamkeit (Posner & Raichle, 1994)

- Alertness
- Orientierung
- Exekutive Aufmerksamkeit

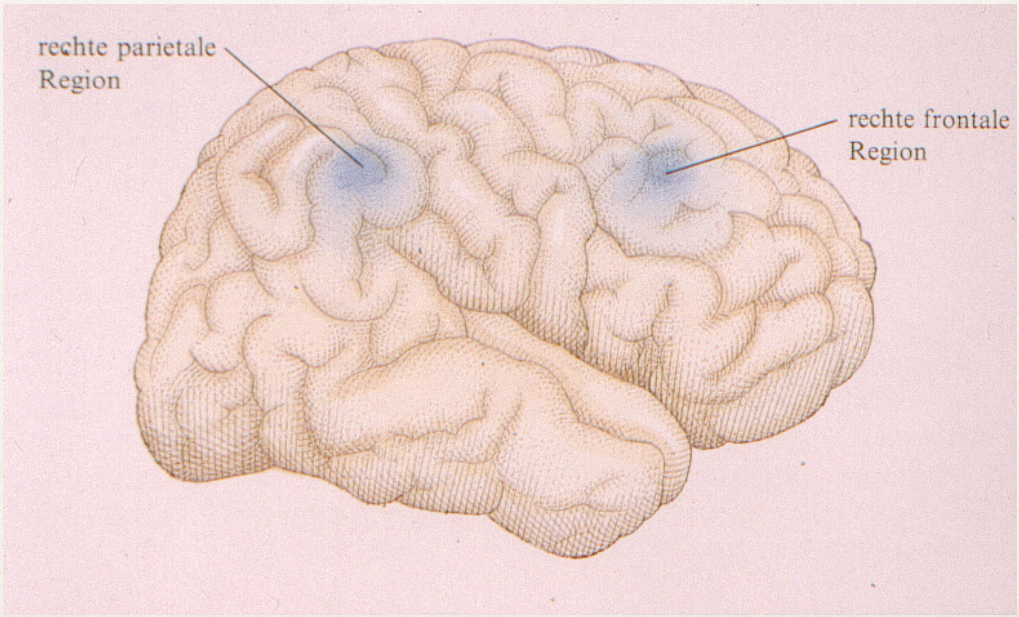
→ stimulierte umfangreiche Forschung zur funktionellen Neuroanatomie der Aufmerksamkeit

# Intrinsic alertness (Top-down, voluntary control of arousal)



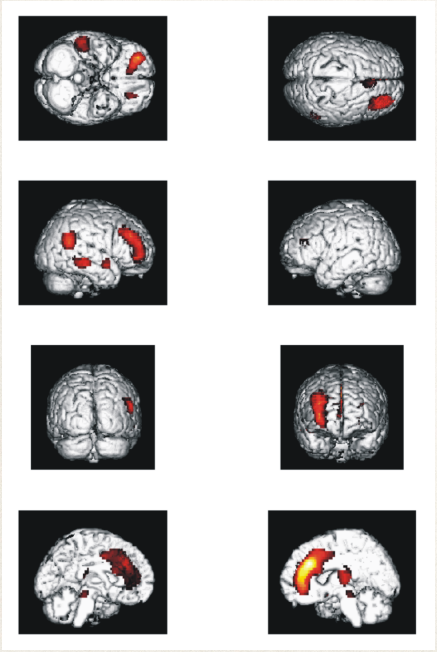


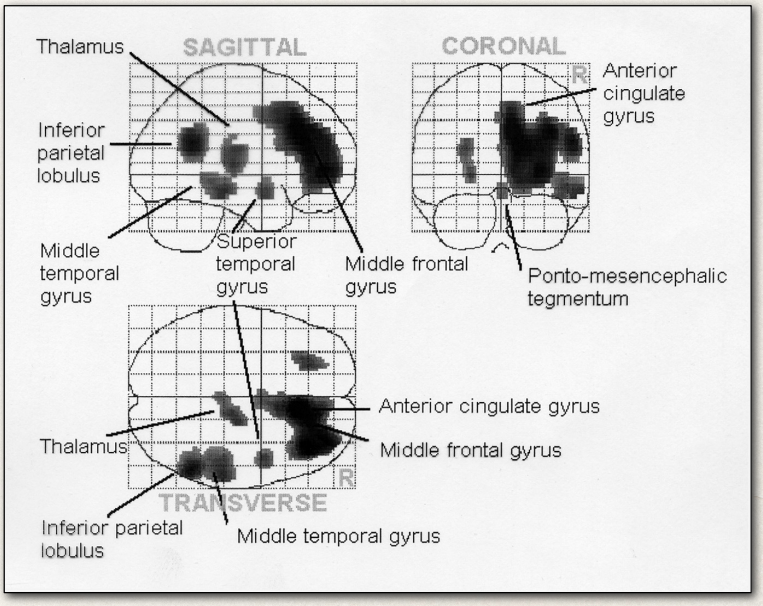
# „Sustained attention“ network (early PET findings)




Posner, M.I. & Raichle, M.E. (1996). Bilder des Geistes. Spektrum: Heidelberg

# Neuroanatomy of intrinsic alertness (visual stimulation)








Ref.: Sturm, W. & Willmes, K. (2001) On the functional neuroanatomy of intrinsic and phasic alertness. Neuroimage, 14, 76-84.



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# Mechanisms of LC activation

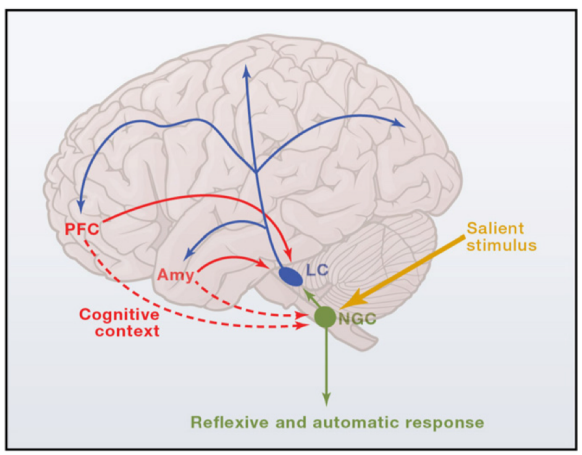


**Figure 4. Schematic Overview of the Proposed Mechanisms Underlying LC Activation and Its Function**

When a salient or behaviorally significant stimulus occurs (orange arrow), it elicits an activation of LC neurons in parallel with autonomic reflex responses, presumably from a common input, the NGC (green). The intensity of this activation is modulated as a function of the cognitive context, by descending influences from the amygdala and the prefrontal cortex (red). This descending influence could be exerted directly on the LC (full line) or indirectly via the NGC and other brainstem autonomic nuclei (dotted lines). Activation of LC neurons will induce release of noradrenaline in its numerous target regions (blue arrows), including cerebral cortices, limbic structures, thalamus, cerebellum, brainstem, and spinal cord. This surge of NA would facilitate sensory and motor processing and, more generally speaking, the reorganization of distributed functional networks, thereby promoting behavioral adaptation. Activation of LC by the salient context and its functional consequences of facilitation of cortical processing might be considered as an updated version of the "Truncated Conditioned Reflex" proposed by Kupalov at the beginning of the previous century (see text).

NGC: Nucleus gigantis cellularis
LC: Locus coeruleus
Amy: Amygdala
PFC: Prefrontal cortex

Aston-Jones, G. & Cohen, J.D. (2005): An integrative theory of Locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. Ann. Rev. Neurosci., 28, 403-450

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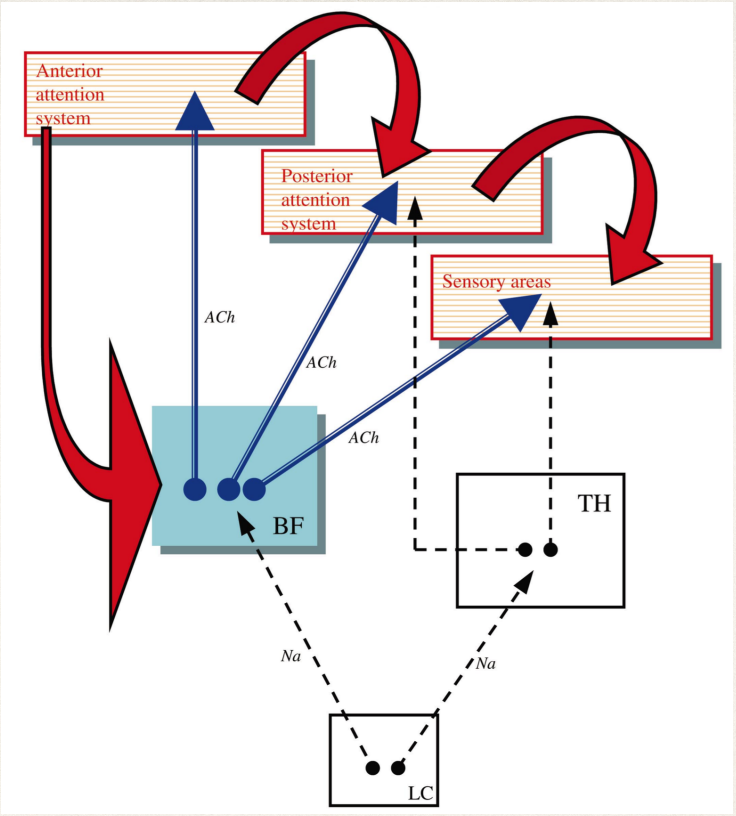
| | |
|---|---|
| BF | Basal forebrain |
| TH | Thalamus |
| LC | Locus coeruleus |
| ACh | Acetylcholine |
| Na | Noradrenaline |

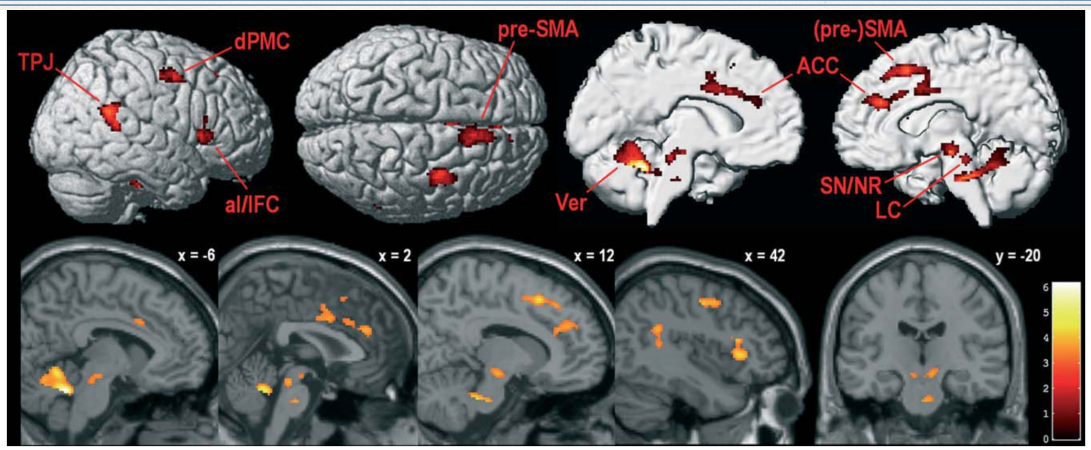



Sarter, M., Givens, B. & Bruno, J.P. (2001). The cognitive neuroscience of sustained attention: where top-down meets bottom-up. Brain Research Reviews, 35, 146-160.





# Supramodal activity while expecting auditory, tactile or visual targets




Supramodal alertness-related brain activity (averaged unimodal alertness conditions vs. averaged control conditions, masked to only include voxels that showed stronger activity during each unimodal alertness condition than during resting baseline and the respective control condition). TPJ, temporo-parietal junction; dPMC, dorsal premotor cortex; al/IFC, anterior insula/inferior frontal cortex; pre-SMA, pre-supplementary motor area; Ver, cerebellar vermis; ACC, anterior cingulate cortex; SN/NR, substantia nigra/nucleus ruber; LC, locus coeruleus. Parasagittal slices show activity overlaid over the SPM5 single-subject template brain; coordinates refer to MNI space; color codes *t* values; voxel-wise $P < 0.001$ and FWE-corrected cluster-level $P < 0.05$.

Langner, R., Kellermann, Eickhoff, S.B., Boers, F., Chatterjee, A., Willmes, K. & Sturm, W. (2012). Staying responsive to the world: Modality-specific and -nonspecific contributions to speeded auditory, tactile, and visual stimulus detection. Human Brain Mapping, 33, 398-418.

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Research Report

# Alerting deficits in children with attention deficit/hyperactivity disorder: Event-related fMRI evidence

*Qingjiu Cao[a], Yufeng Zang[b], Chaozhe Zhu[b], Xiaohua Cao[a], Li Sun[a], Xiaolin Zhou[c,*], Yufeng Wang[a,*]*

[a]Institute of Mental Health, Peking University, Beijing 100083, China
[b]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China
[c]Department of Psychology, Peking University, Beijing 100871, China

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ABSTRACT

Attention deficit/hyperactivity disorder (ADHD) is one of the most common but poorly understood developmental disorders in childhood. Although neuropsychological studies demonstrate that children with ADHD have attentional alerting deficits, the neurobiological bases of such deficits have not been examined extensively. In this study, by using functional magnetic resonance imaging (fMRI), we explored the neural correlates of intrinsic alertness and phasic alertness deficits in ADHD by comparing twelve boys with ADHD (13.4±1.7 years) with 13 age-matched normal controls (13.2±1.2 years) in a cued target detection task. Behaviorally, compared with the controls, the ADHD group showed a higher overall error rate and a larger reaction time variability in performing the task. At the neural level, children with ADHD showed less activation than the controls in frontal (middle and superior frontal gyrus), parietal (inferior parietal lobe, precuneus) and putamen regions. These results demonstrate that children with ADHD have deficits in alerting functions and these deficits are related to the abnormal activities in frontal and parietal regions subserving top-down attention control processes.



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**Table 1 – Demographic and clinical characteristics of the ADHD and the control groups**

| Variables/group | ADHD ($n$=12) | Controls ($n$=13) |
|---|---|---|
| Age | 13.4 (1.7) | 13.2 (1.2) |
| Full scale IQ | 102.7 (9.0) | 112.7 (13.8)[a] |
| ADHD RS-IV | | |
| Total scores | 44.9 (11.6) | 25.5 (6.8)[b] |
| Inattention | 24.4 (4.8) | 14.0 (5.4)[b] |
| Hyperactivity/impulsivity | 20.5 (7.9) | 11.5 (2.1)[b] |
| CPRS | | |
| Total scores | 36.2 (15.6) | 6.5 (7.3)[b] |
| Cognitive problems/inattention | 6.2 (2.4) | 1.2 (2.2)[b] |

Note: ADHD RS-IV = ADHD rating scale-IV; CPRS = Conners' parents rating scales.
[a] $p<0.05$.
[b] $p<0.001$.

**Table 2 – Task performance in children with ADHD and in the normal controls**

| Variable/group | ADHD ($n$=12) | Controls ($n$=13) |
|---|---|---|
| Target-only trials | | |
| Mean RT (ms) | 487 (55) | 458 (91) |
| RT variability | 97 (24) | 86 (27) |
| Cue-plus-target trials | | |
| Mean RT (ms) | 423 (60) | 389 (64) |
| RT variability | 116 (41) | 80 (26) |
| Alerting effect (ms) | 64 (44) | 69 (58) |
| Overall error (%) | 11.93 (8.33) | 5.19 (4.21) |
| Commission for the catch trial (%) | 7.55 (6.73) | 2.47 (3.21) |
| Omission for target (%) | 12.07 (10.41) | 6.11 (5.56) |

Numbers in parentheses represent standard deviations.

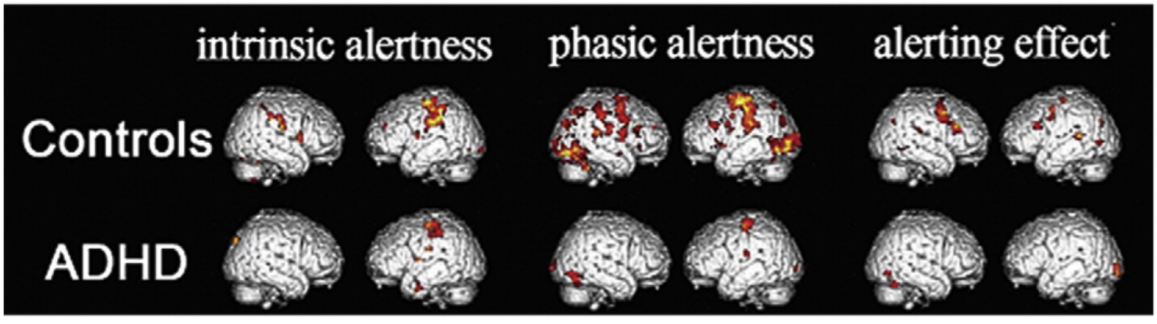


**Fig. 1 – Brain activations for the three within-group contrasts in the two participant groups.**



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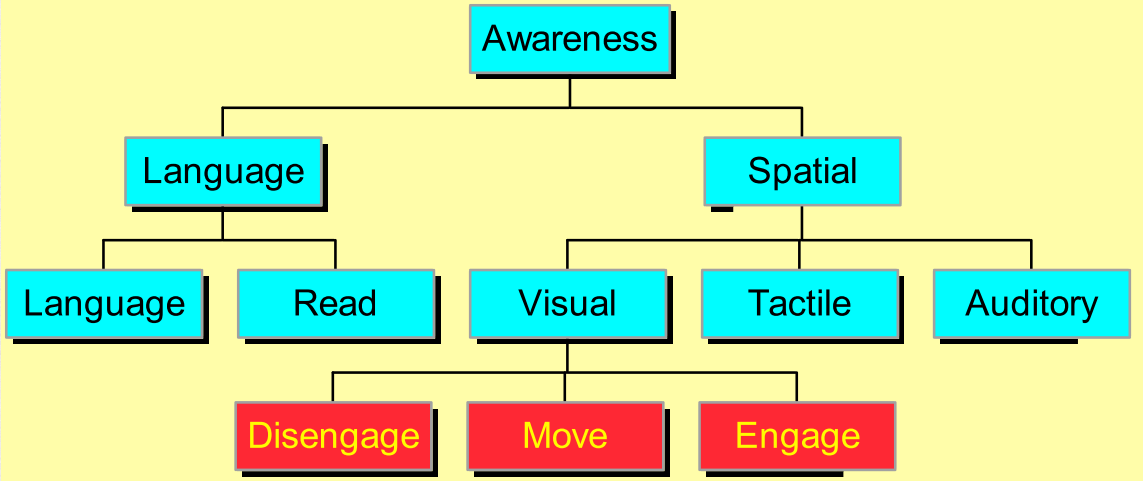
# Orienting of attention





# Hierarchical model of selective attention (Posner, 1987)

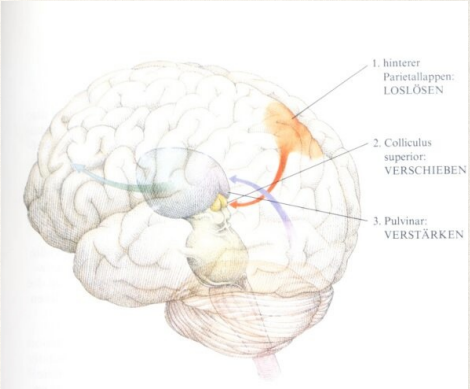


# Covert Attention – Network of visual orienting

disengage: Disengaging attention at a certain location ---> posterior parietal lobe?

move: Moving attention to another location ---> Colliculus Superior (midbrain)?

engage: Engaging/Fixing attention to a certain location
---> Pulvinar nucleus (Thalamus)?



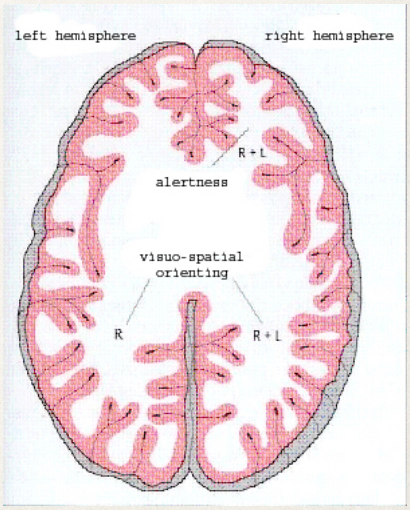

Lit.: Posner MI, Raichle ME (1994) Images of mind. New York: WH Freeman.





# Anatomical relations of the networks of attention

- The alertness network and the network of visuo-spatial attention significantly overlap in the right parietal cortex
- Neglect patients normally exhibit a low level of general alertness
- Training of alertness or general phasic alerting can lead to significant improvements in performance of visuo-spatial attention in neglect patients (Thimm et al., 2006; Robertson et al., 1998).
- Experiments with healthy subjects also prove an influence of the level of alertness on visuo-spatial attention (Fimm et al., 2006, Manly et al., 2005).



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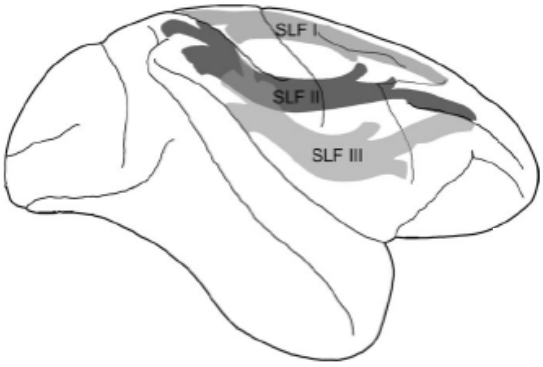
# Overlapping (Diffusion Tensor Imaging DTI) subcortikal lesions in Neglect:
# Dark blue: Fasciculus Arcuatus, Blue: Superior longitudinal Fasciculus (SLF) II; Orange: SLF III




From: Bartolomeo, P.

Cerebral Cortex, 17, 2007

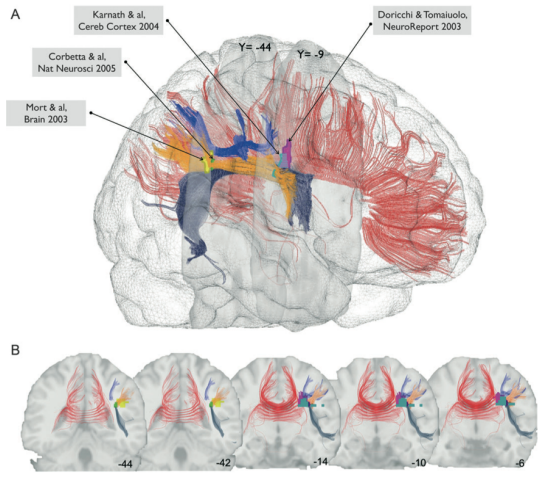



**Figure 2.** Lateral view (*A*) and coronal sections (*B*) of a normalized brain showing a 3-dimensional reconstruction of white matter pathways (red, corpus callosum; dark blue, AF; orange, SLF III; blue, SLF II) and the maximum overlap of neglect patients' subcortical lesions from 4 studies (pink, Doricchi and Tomaiuolo 2003; yellow, Mort et al. 2003; light blue,

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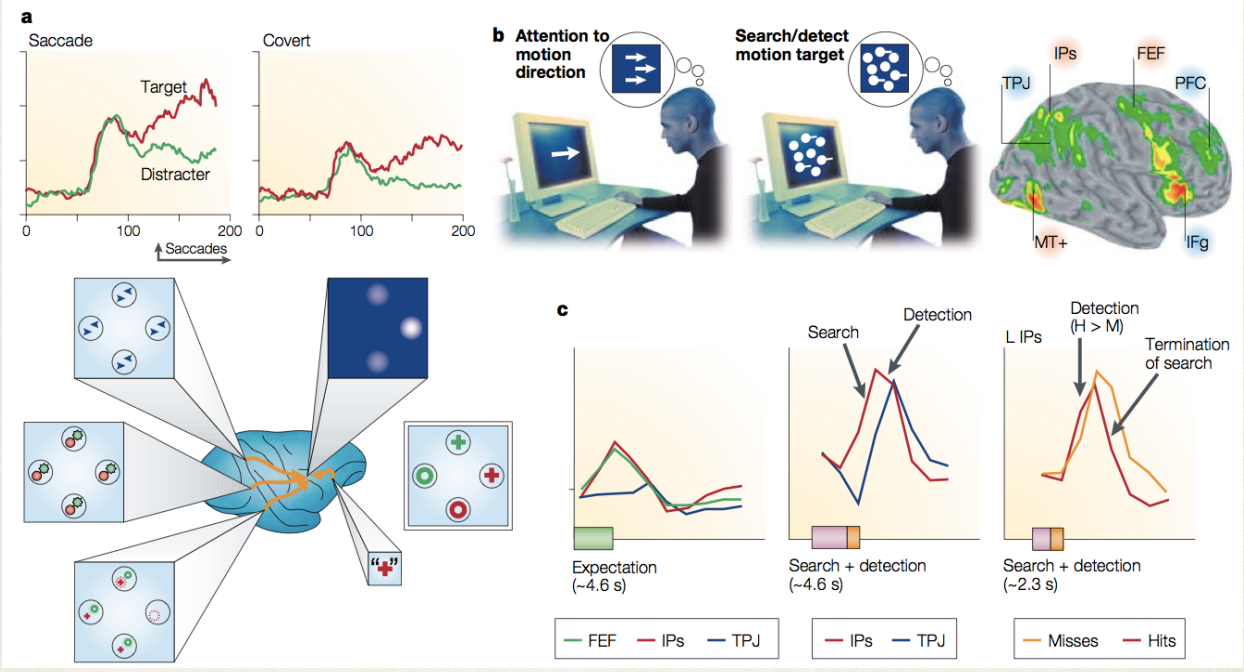
# Dorsal fronto-parietal network (top-down; orienting to attended stimuli)




Corbetta, M. & G.L. Shulman (2002). Control of goal-directed and stimulus-driven attention in the brain. Nat Rev Neurosci, 3, 201-215.
Shulman, G.L. & Corbetta, M. (2012). Two attentional networks. Identification and function within a larger cognitive architecture. In: M.I. Posner (ed.) Cognitive Neuroscience of attention. Second edition. (pp. 113-128). New York: Guilford Press

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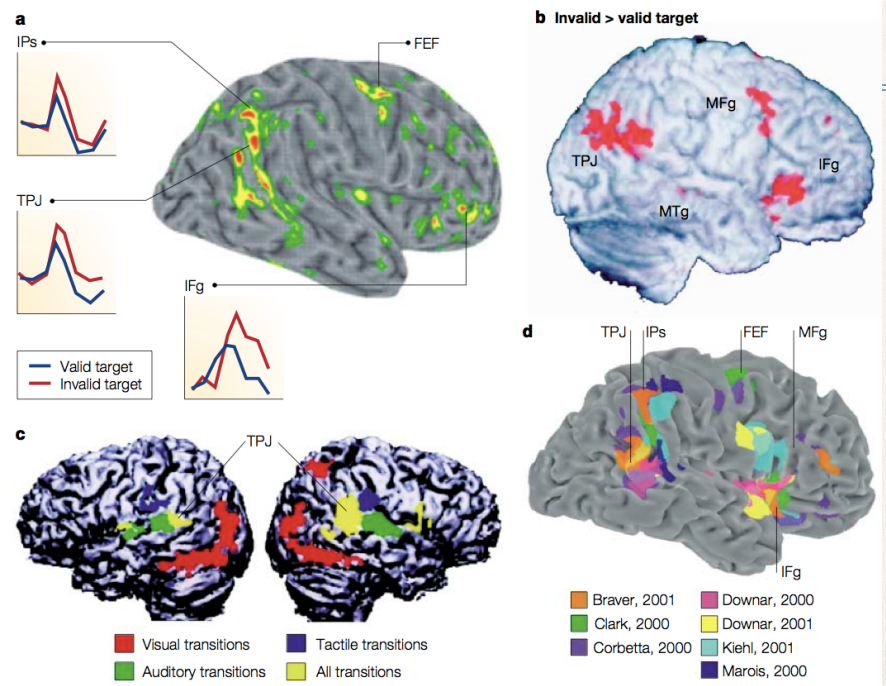
# Ventral fronto-parietal network (stimulus-driven; reorienting to unattended stimuli)

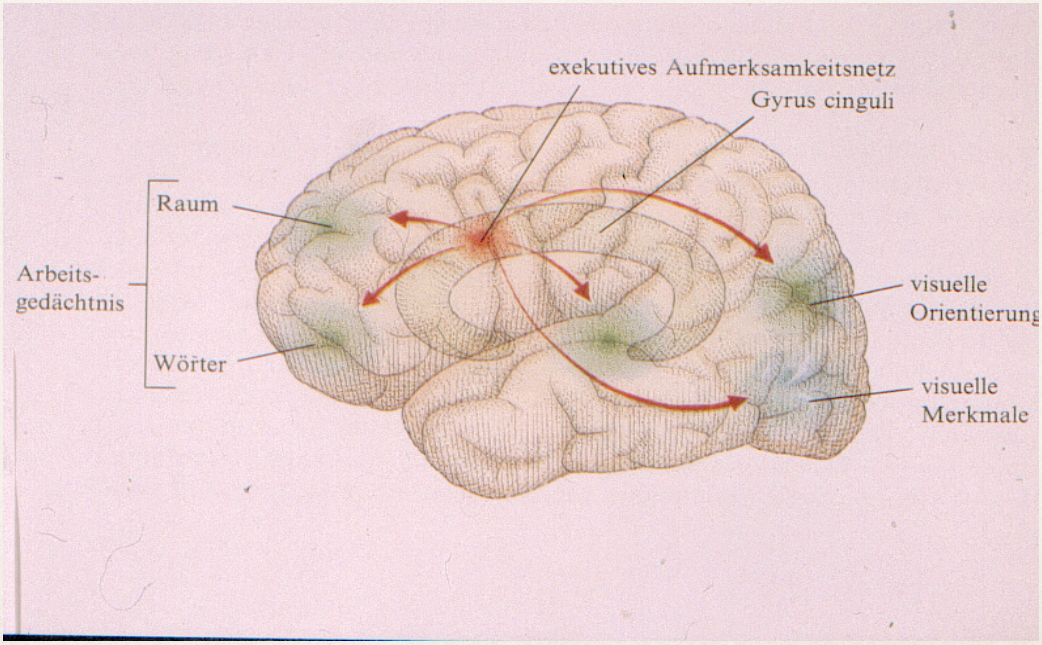



Corbetta, M. & G.L. Shulman (2002). Control of goal-directed and stimulus-driven attention in the brain. Nat Rev Neurosci, 3, 201-215.
Shulman, G.L. & Corbetta, M. (2012). Two attentional networks. Identification and function within a larger cognitive architecture. In: M.I. Posner (ed.) Cognitive Neuroscience of attention. Second edition. (pp. 113-128). New York: Guilford Press





# Exekutives Aufmerksamkeitsnetzwerk



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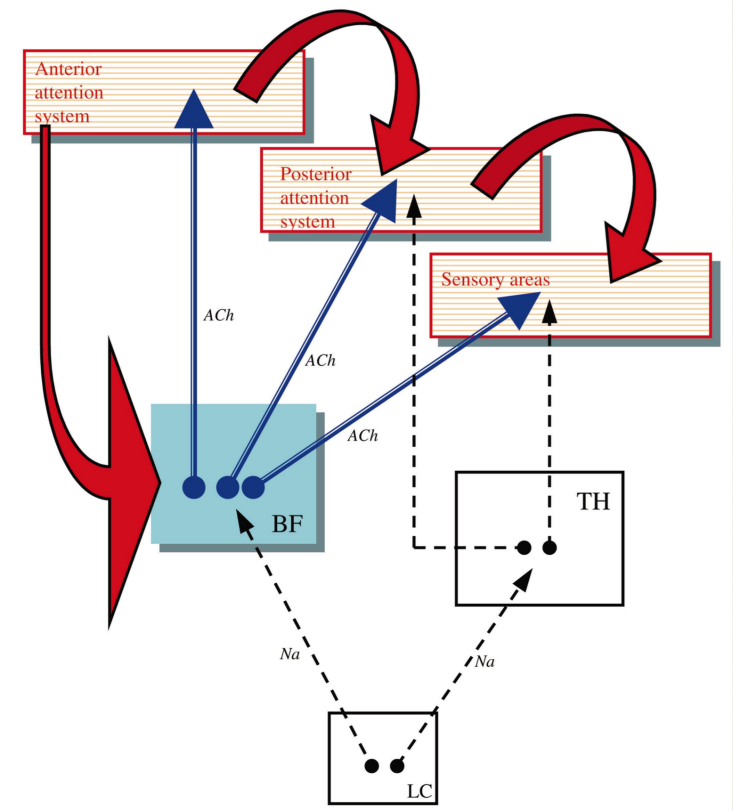
| | |
|---|---|
| BF | Basal forebrain |
| TH | Thalamus |
| LC | Locus coeruleus |
| ACh | Acetylcholine |
| Na | Noradrenaline |




Sarter, M., Givens, B. & Bruno, J.P. (2001). The cognitive neuroscience of sustained attention: where top-down meets bottom-up. Brain Research Reviews, 35, 146-160.





# fMRI: Attentional networks (Beispiel 1)

## Dysfunctional Attentional Networks in Children with Attention Deficit/Hyperactivity Disorder: Evidence from an Event-Related Functional Magnetic Resonance Imaging Study

Kerstin Konrad, Susanne Neufang, Charlotte Hanisch, Gereon R. Fink, and Beate Herpertz-Dahlmann

***Background:*** *Although there is evidence for attentional dysfunction in children with attention deficit/hyperactivity disorder (ADHD), the neural basis of these deficits remains poorly understood.*
***Methods:*** *We used event-related functional magnetic resonance imaging (fMRI) to investigate brain activations related to three particular aspects of attention: alerting, reorienting, and executive control. Sixteen medication-naive boys with ADHD and 16 healthy boys, aged 8 to 12 years, were studied.*
***Results:*** *Behaviorally, children with ADHD showed a significant impairment only in their executive control system compared to healthy subjects. Neurally, children with ADHD (relative to controls) recruited deviant brain regions for all three attentional networks: less right-sided activation in the anterior cingulate gyrus during alerting, more fronto-striatal-insular activation during reorienting, and less fronto-striatal activation for executive control. ADHD symptom severity was associated with dysregulation of the blood oxygen level dependent (BOLD) signal within the putamen during reorienting and executive control.*
***Conclusions:*** *Our results demonstrated altered brain mechanism in ADHD associated with all three attentional networks investigated. For alerting and executive attention, our data indicate a deviant mechanism of cortical control, while ADHD children may have adopted altered strategies for reorienting of attention. Our results also stress the etiological role of functional abnormalities in the putamen in medication-naive ADHD.*

BIOL PSYCHIATRY 2006;59:643–651

**Table 1.** Characteristics of the Patient and Control Groups

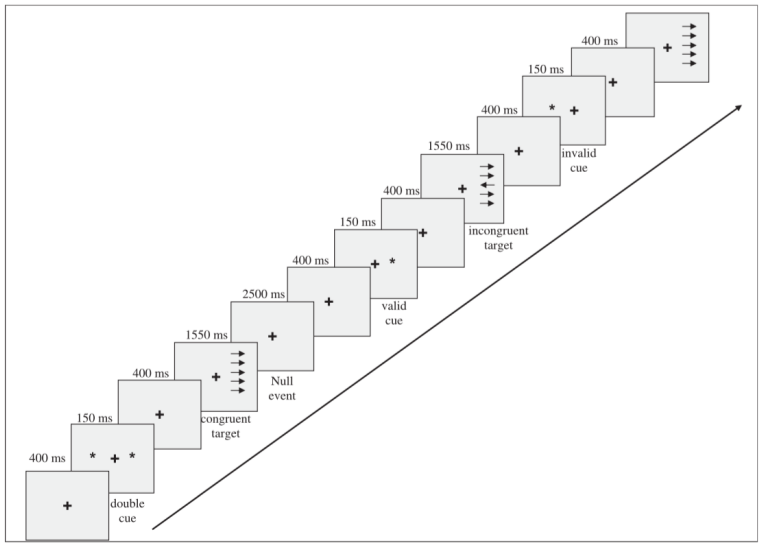
| | Healthy Children M (SD) | ADHD Children M (SD) | p |
|---|---|---|---|
| Age | 10.1 (1.3) | 10.2 (1.9) | .9[a] |
| Full-Scale IQ (WISC-III) | 105 (10) | 103 (12) | .8[a] |
| FBB-HKS (total score of symptom severity) | 6.3 (2.1) | 32.1 (8.7) | <.001 |
| | *n* | *n* | *p* |
| Handedness | 16 R | 16 R | >.99[b] |
| DSM IV Diagnoses of ADHD | 0 | 16 | <.001[b] |
| ADHD Combined | 0 | 9 | |
| ADHD Inattentive Subtype | 0 | 6 | |
| ADHD Hyperactive/Impulsive Subtype | 0 | 1 | |
| ODD | 2 | 5 | .45[b] |
| Anxiety Disorders | 3 | 3 | >.99[b] |

WISC-III, Wechsler Intelligence Scale for Children-III edition; FBB-HKS, German Parental and Teacher Report on ADHD symptoms; R, right-handed; ODD, Oppositional Defiant Disorder; ADHD, attention deficit hyperactivity disorder.
[a]*P* values are for 2-tailed *t* tests.
[b]*P* values are for $\chi^2$.

**Table 2.** Task Performance Separately for Children with ADHD and for Healthy Children

| | Healthy Children (*n* = 16) M (SE) | ADHD Children (*n* = 16) M (SE) | *t* | *p* |
|---|---|---|---|---|
| Alerting [msec] | 30 (17) | 55 (21) | −.9 | .38 |
| Reorienting [msec] | 93 (18) | 138 (20) | −2.1 | .08 |
| Conflict [msec] | 80 (9) | 122 (13) | −2.9 | .01 |
| MRT [msec] | 822 (26) | 868 (48) | .84 | .40 |
| Total error [%] | 4.45 (0.6) | 8.44 (1.4) | −2.7 | .02 |

MRT, Mean Reaction Time; ADHD, attention deficit hyperactivity disorder.




Konrad et al. (2006)

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# Alerting network (Konrad et al., 2006)

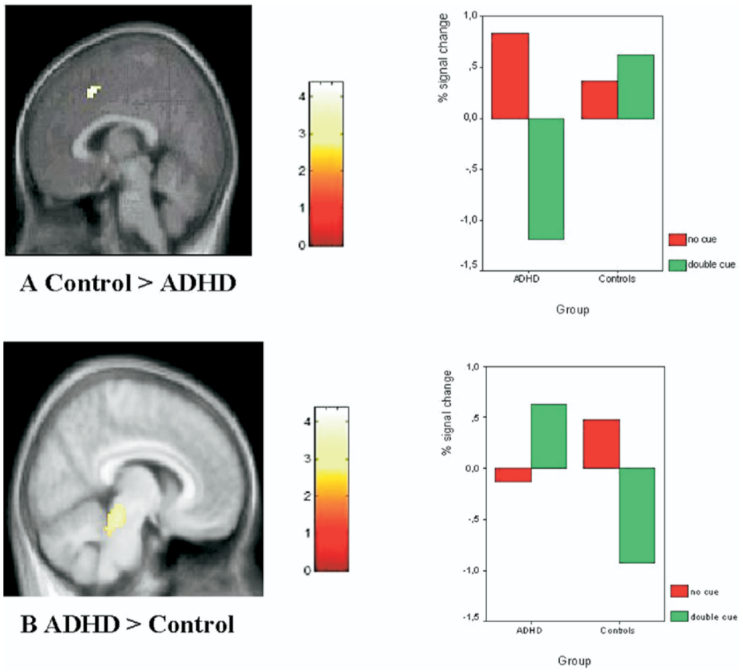


**Figure 2.** Differential activation of attention deficit hyperactivity disorder (ADHD) and healthy participants as identified in a two-sample-*t*-test for the alerting condition (thresholded at $p < .001$, uncorrected, extend threshold 10 voxel, shown on an averaged group T1 image). **(A)** Increased activation in the right anterior cingulate gyrus in healthy children compared to ADHD children. **(B)** Increased activation of the brainstem in children with ADHD compared to healthy children. Plots of the percentage blood oxygen level dependent (BOLD) signal change are shown separately for both groups as a function of trial type (pooled over congruent and incongruent targets) for the respective activation maximum.

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# Executive network (Konrad et al., 2006)

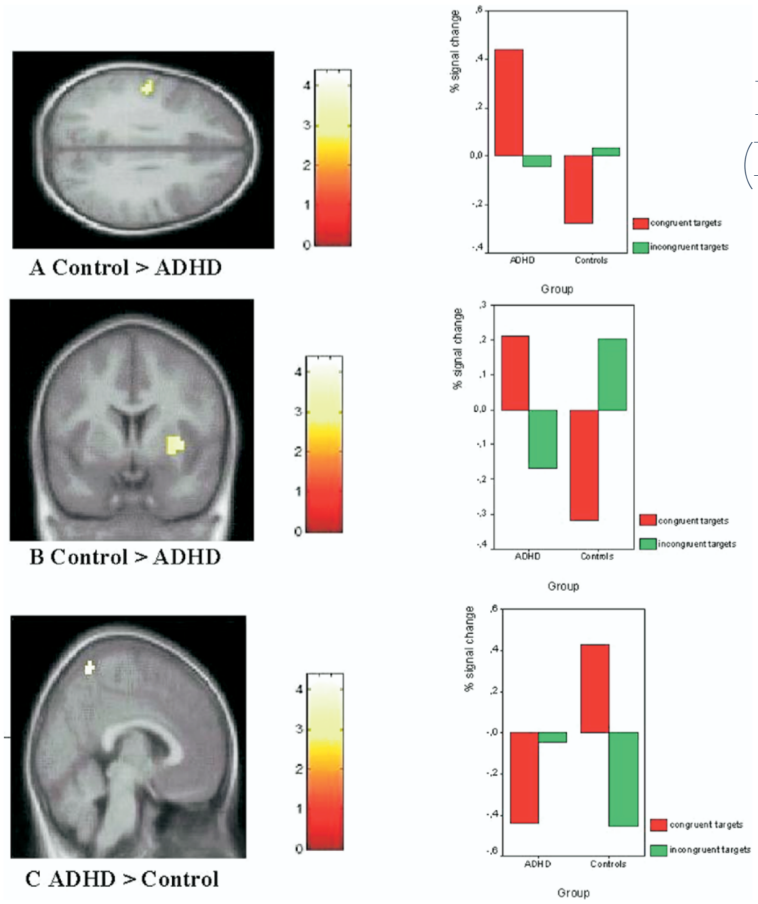


**Figure 4.** Differential activation of attention deficit hyperactivity disorder (ADHD) and healthy subjects as identified in a two-sample-*t*-test for the conflict condition (thresholded at $p < .001$, uncorrected, extend threshold 10 voxel, shown on an averaged group T1 image). **(A)** Increased activation in the left medial frontal gyrus in healthy children compared to ADHD children. **(B)** Increased activation in the right putamen in healthy children compared to ADHD children, and **(C)** increased activation in the left superior parietal cortex (BA 7) in children with ADHD compared to healthy children. Plots of the percentage blood oxygen level dependent (BOLD) signal change are shown separately for both groups as a function of target type (pooled over cueing conditions) for the activation maximum.

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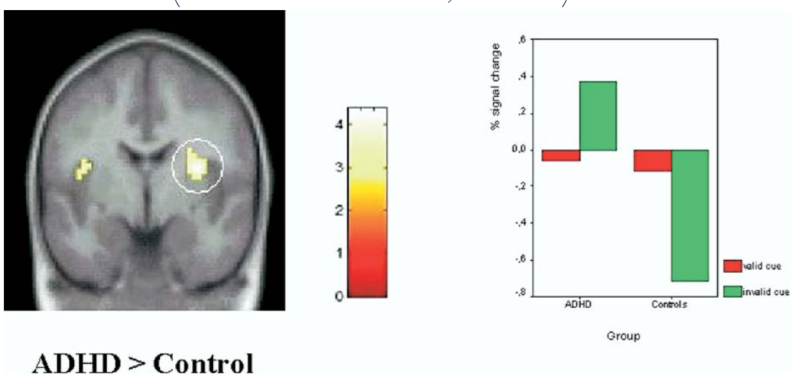
# Orienting network (Konrad et al., 2006)

**Figure 3.** Differential activation of attention deficit hyperactivity disorder (ADHD) and healthy participants as identified in a two-sample-*t*-test for the reorienting condition (thresholded at $p < .001$, uncorrected, extend threshold 10 voxel, shown on an averaged group T1 image) showing increased activation in the putamen, inferior frontal gyrus and insula in children with ADHD compared to healthy children. Plots of the percentage blood oxygen level dependent (BOLD) signal change are shown separately for both groups as a function of trial type (pooled over congruent and incongruent targets) for the activation maximum in the putamen.



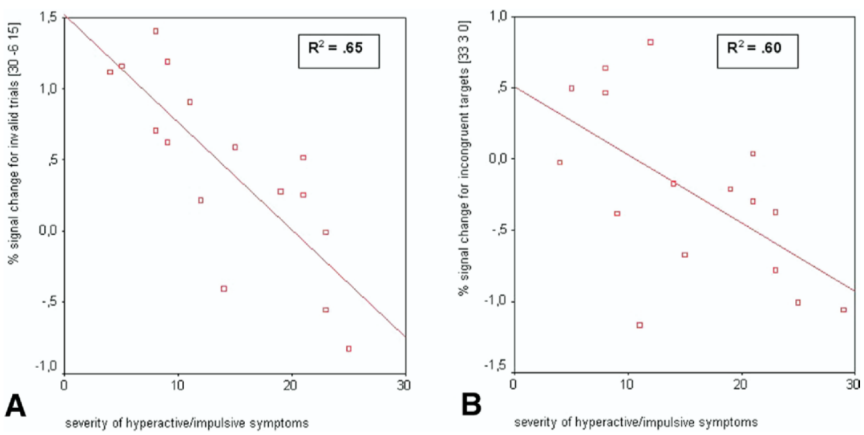




**Figure 5.** Scatterplots for the percentage blood oxygen level dependent (BOLD) signal change in the putamen and the severity of hyperactive/impulsive symptoms within the attention deficit hyperactivity disorder (ADHD) group: **(A)** for the maximally activated voxel found in the two-sample-*t*-test for the reorienting condition **(B)** for the maximally activated voxel found in the two-sample-*t*-test in the conflict condition.

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# fMRI: Attentional networks (Beispiel 2)

## Age-related differences in attentional networks of alerting and executive control in young, middle-aged, and older Chinese adults

Shan-shan Zhou [a], Jin Fan [b], Tatia M.C. Lee [c], Chang-qing Wang [a], Kai Wang [a,*]

[a] Laboratory of Neuropsychology, Department of Neurology, The First Hospital of Anhui Medical University, Hefei, Anhui Province, China
[b] Laboratory of Neuroimaging, Department of Psychiatry, Mount Sinai School of Medicine, One Gustave L. Levy Place, Box 1230, New York, NY 10029, USA
[c] Institute of Clinical Neuropsychology and Neuropsychology Laboratory, The University of Hong Kong, Hong Kong

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ABSTRACT

Previous studies suggest that aging is associated with impairment of attention. However, it is not known whether this represents a global attentional deficit or relates to a specific attentional network. We used the attention network test to examine three groups of younger, middle-aged, and older participants with respect to the efficiency of three anatomically defined attentional networks: alerting network, orienting network, and executive control network. Age-related change was found to have the greatest effect on the executive network and the least effect on the alerting network as well as on overall mean response time. Impairment of the orienting network was found to be insignificant. Age-related deterioration of the prefrontal lobe, the dopaminergic system, and function of specific genes may explain the age-related changes in executive attention, which occur after the fourth decade of life.



Brain and Cognition 75 (2011) 205–210



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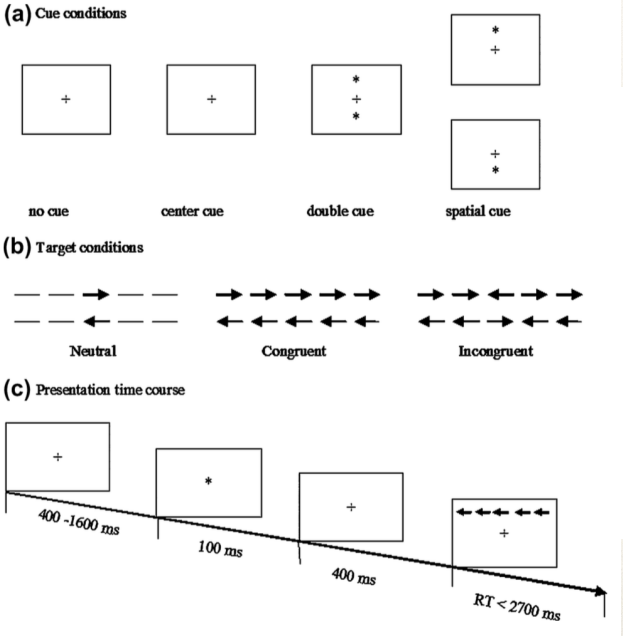
# fMRI: Attentional networks (Beispiel 2)




*2.2.2. Calculation of attention network efficiencies*

The ANT uses differences in reaction times (RT) derived from the different experimental conditions to measure the alerting, orienting, and executive control networks (Fan et al., 2002).

*2.2.3. Alerting network*

The alerting effect was calculated by subtracting the mean RTs of the conditions with double cues from the mean RTs of the conditions with no cue.

*2.2.4. Orienting network*

The orienting effect was calculated by subtracting the mean RTs of the conditions with spatial cues from the mean RTs of the conditions with center cues.

*2.2.5. Executive control network*

The executive effect was calculated by subtracting the mean RTs of the conditions with congruent flankers from the mean RTs of the conditions with incongruent flankers. For details of the ANT, see Fan et al. (2002).



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# Developing Attention: Behavioral and Brain Mechanisms

**Michael I. Posner**[1], **Mary K. Rothbart**[1], **Brad E. Sheese**[2], and **Pascale Voelker**[1]

[1]University of Oregon, Eugene, OR 97403, USA

[2]Illinois Wesleyan University, Bloomington, IL 61701, USA

## Abstract

Brain networks underlying attention are present even during infancy and are critical for the developing ability of children to control their emotions and thoughts. For adults, individual differences in the efficiency of attentional networks have been related to neuromodulators and to genetic variations. We have examined the development of attentional networks and child temperament in a longitudinal study from infancy (7 months) to middle childhood (7 years). Early temperamental differences among infants, including smiling and laughter and vocal reactivity, are related to self-regulation abilities at 7 years. However, genetic variations related to adult executive attention, while present in childhood, are poor predictors of later control, in part because individual genetic variationmay have many small effects and in part because their influence occurs in interaction with caregiver behavior and other environmental influences. While brain areas involved in attention are present during infancy, their connectivity changes and leads to improvement in control of behavior. It is also possible to influence control mechanisms through training later in life. The relation between maturation and learning may allow advances in our understanding of human brain development.





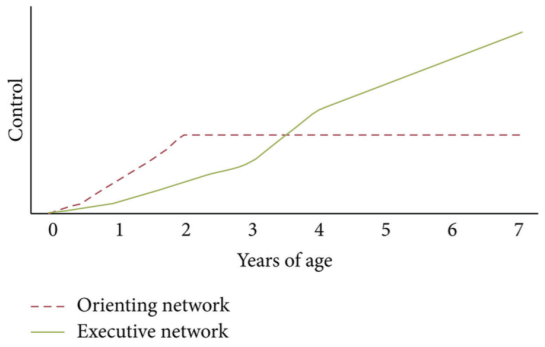



**Figure 1.**
Hypothesized relation between brain attention networks and dominance of control between birth and adulthood.

Correlations between temperament measures at 7 months and ANT scores at 7 years.

| IBQ | ANT at age 7 | | | | | |
|---|---|---|---|---|---|---|
| | Alerting | | Orienting | | Conflict | |
| | r | P | r | P | r | P |
| Perceptual sensitivity | .56* | .02 | .18 | .51 | −.07 | .79 |
| Duration of orienting | .55* | .03 | .01 | .96 | .03 | .91 |
| Approach | .29 | .27 | .76* | .001 | −.28 | .29 |
| Soothability | .13 | .63 | .56* | .024 | −.24 | .37 |
| Smiling and laughter | .17 | .53 | .06 | .84 | −.60* | .015 |
| Vocal reactivity | .24 | .37 | .20 | .47 | −.64* | .007 |
| Cuddliness | −.04 | .88 | .08 | .77 | −.64* | .008 |
| Positive Affect (higher order) | .43 | .10 | .38 | .15 | −.58* | .019 |

*denotes $P < .05$.

Relating attention networks to dominant modulators and relevant genes.

| Network | Modulator | Genes |
|---|---|---|
| Alerting | Norepinephrine | ADRA2A NET |
| Orienting | Acetylcholine | CHRNA4 APOE |
| Executive | Dopamine | DRD4, DAT1, and COMT MAOA, DBH |
| | Serotonin | TPH2, 5HTT |

This table is adapted from Green et al., 2008 [28].

# Differenziertere Betrachtung des exekutiven Netzwerks

## Differentiating Frontostriatal and Fronto-Cerebellar Circuits in Attention-Deficit/Hyperactivity Disorder

Sarah Durston, Janna van Belle, and Patrick de Zeeuw

Attention-deficit/hyperactivity disorder (ADHD) has long been conceptualized as a neurobiological disorder of the prefrontal cortex and its connections. Circuits with the prefrontal cortex relevant to ADHD include dorsal frontostriatal, orbitofronto-striatal, and fronto-cerebellar circuits. Dorsal frontostriatal circuitry has been linked to cognitive control, whereas orbitofronto-striatal loops have been related to reward processing. Fronto-cerebellar circuits have been implicated in timing. Neurobiological dysfunction in any of these circuits could lead to symptoms of ADHD, as behavioral control could be disturbed by: 1) deficits in the prefrontal cortex itself; or 2) problems in the circuits relaying information to the prefrontal cortex, leading to reduced signaling for control. This article suggests a model for differentiating between interlinked reciprocal circuits with the prefrontal cortex in ADHD. If such a differentiation can be achieved, it might permit a neurobiological subtyping of ADHD, perhaps by defining "dorsal fronto-striatal," "orbitofronto-striatal," or "fronto-cerebellar" subtypes of ADHD. This could be useful as a template for investigating the neurobiology of ADHD and, ultimately, clinically.

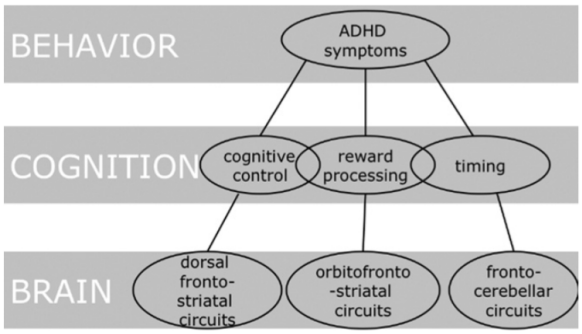



**Figure 1.** Model showing how distinct neurobiological pathways might lead to overlapping but separable cognitive profiles and similar behavioral patterns. ADHD, attention-deficit/hyperactivity disorder.

BIOL PSYCHIATRY 2011;69:1178–1184





# Differenziertere Betrachtung des exekutiven Netzwerks

## Cingulate, Frontal, and Parietal Cortical Dysfunction in Attention-Deficit/Hyperactivity Disorder

George Bush

Functional and structural neuroimaging have identified abnormalities of the brain that are likely to contribute to the neuropathophysiology of attention-deficit/hyperactivity disorder (ADHD). In particular, hypofunction of the brain regions comprising the cingulo-frontal-parietal cognitive-attention network have been consistently observed across studies. These are major components of neural systems that are relevant to ADHD, including cognitive/attention networks, motor systems, and reward/feedback-based processing systems. Moreover, these areas interact with other brain circuits that have been implicated in ADHD, such as the "default mode" resting state network. The ADHD imaging data related to cingulo-frontal-parietal network dysfunction will be selectively highlighted here to help facilitate its integration with the other information presented in this special issue. Together, these reviews will help shed light on the neurobiology of ADHD.

BIOL PSYCHIATRY 2011;69:1160–1167

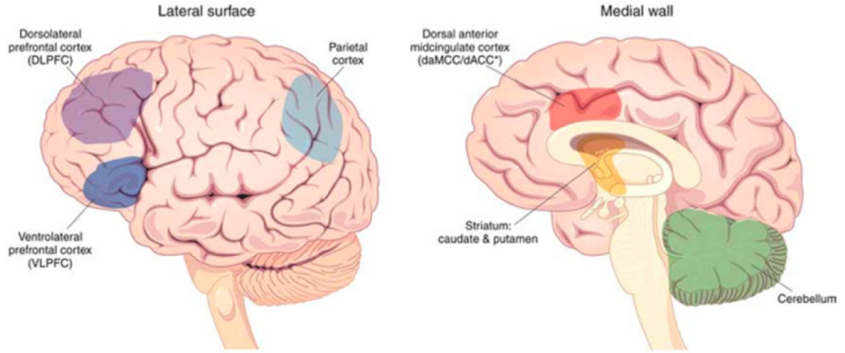
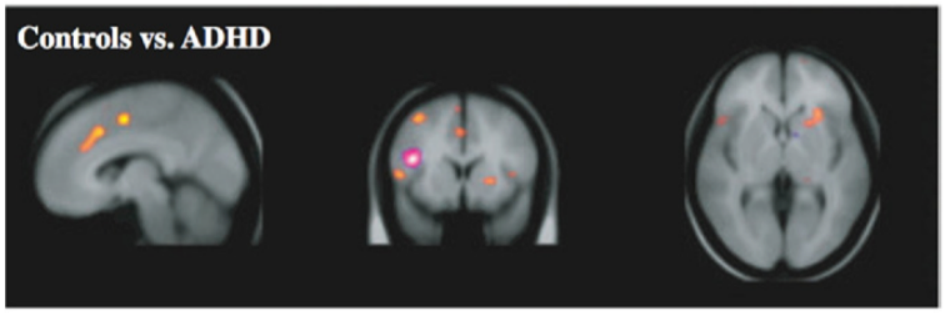



**Figure 1.** The cingulo-frontal-parietal (CFP) cognitive/attention network. The daMCC, DLPFC, VLPFC, and parietal cortex comprise the CFP network (8). These regions work in concert with each other and other regions such as striatum and cerebellum to support normal cognition, attention, and motor control processes. All of these brain regions have been found to display functional and structural abnormalities in attention-deficit/hyperactivity disorder. Reprinted with permission from (8).

# CFP- und MCC-Hypoaktivierung bei ADHS




Controls > ADHD  ADHD > Controls

**Figure 4.** Meta-analysis shows daMCC and CFP dysfunction in ADHD. Dickstein *et al.* (40), via an activation likelihood meta-analysis, found daMCC to be among a limited number of brain regions that were hypoactive in ADHD relative to healthy control subjects (figure reprinted with permission from John Wiley and Sons). The CFP network abnormalities were also reported. Abbreviations as in Figures 1 and 2.

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# Kortikale Veränderungen der grauen Substanz

## Dynamic mapping of human cortical development during childhood through early adulthood

Nitin Gogtay*†, Jay N. Giedd*, Leslie Lusk*, Kiralee M. Hayashi‡, Deanna Greenstein*, A. Catherine Vaituzis*, Tom F. Nugent III*, David H. Herman*, Liv S. Clasen*, Arthur W. Toga‡, Judith L. Rapoport*, and Paul M. Thompson‡

*Child Psychiatry Branch, National Institutes of Mental Health, National Institutes of Health, Bethesda, MD 20892; and ‡Laboratory of Neuro Imaging, Department of Neurology, University of California School of Medicine, Los Angeles, CA 90095-1769

Communicated by Leslie G. Ungerleider, National Institutes of Health, Bethesda, MD, April 15, 2004 (received for review January 7, 2004)

**We report the dynamic anatomical sequence of human cortical gray matter development between the age of 4–21 years using quantitative four-dimensional maps and time-lapse sequences. Thirteen healthy children for whom anatomic brain MRI scans were obtained every 2 years, for 8–10 years, were studied. By using models of the cortical surface and sulcal landmarks and a statistical model for gray matter density, human cortical development could be visualized across the age range in a spatiotemporally detailed time-lapse sequence. The resulting time-lapse "movies" reveal that (*i*) higher-order association cortices mature only after lower-order somatosensory and visual cortices, the functions of which they integrate, are developed, and (*ii*) phylogenetically older brain areas mature earlier than newer ones. Direct comparison with normal cortical development may help understanding of some neurodevelopmental disorders such as childhood-onset schizophrenia or autism.**



temporal cortex, which contains association areas that integrate

**Table 1. Demographics of the study sample**

| | |
|---|---|
| No. of subjects | 13 |
| Gender (no. of male:female) | 6:7 |
| Total no. of scans | 52 |
| Average age (±SD) at | |
| Scan 1 | 9.8 ± 3.8 years |
| Scan 2 | 11.7 ± 4.1 years |
| Scan 3 | 13.8 ± 4.4 years |
| Scan 4 | 16.7 ± 4.3 years |
| Average age for all scans | 13.0 ± 4.8 years |
| Average IQ (±SD) | 125.8 ± 12.7 |
| Handedness (no. of right:left) | 12:1 |

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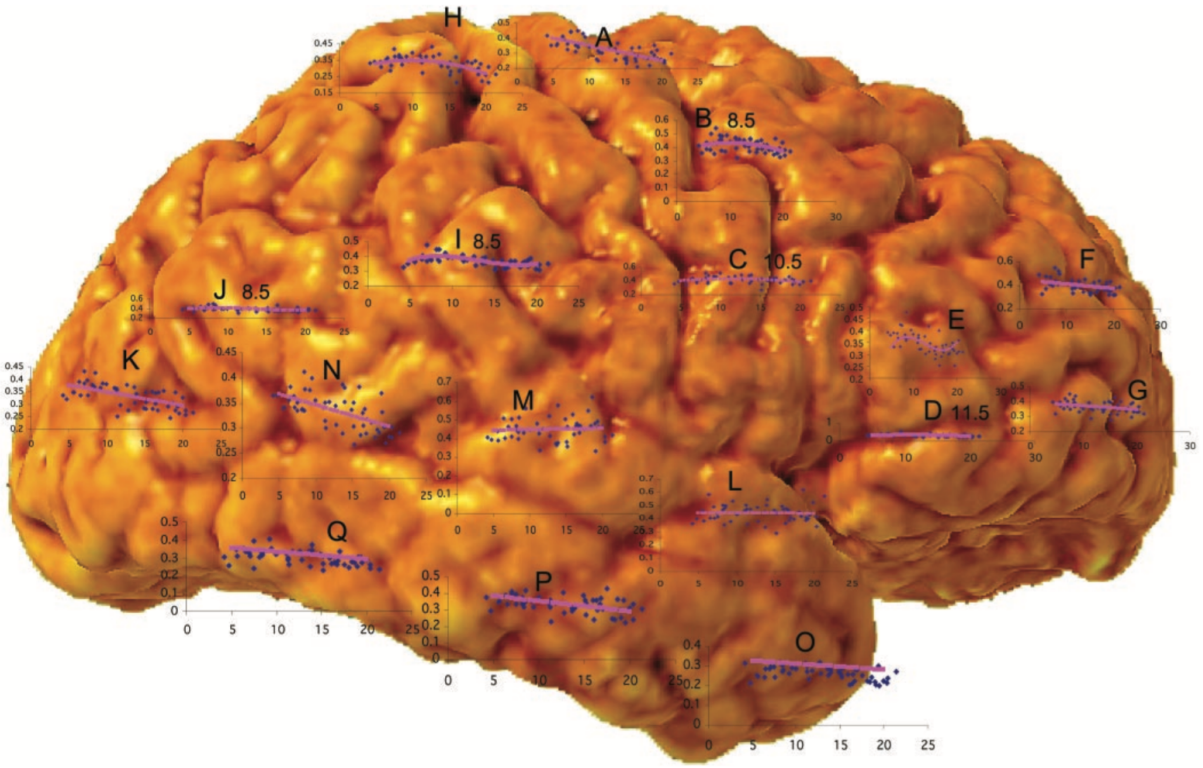


**Fig. 1.** Mixed-model regression plots at regions of interest over the cortical surface. The following regions were selected for analyses in each hemisphere: A, precentral gyrus and primary motor cortex; B, superior frontal gyrus, posterior end near central sulcus; C, inferior frontal gyrus, posterior end; D, inferior frontal sulcus, anterior end in the ventrolateral prefrontal cortex; E, inferior frontal sulcus in the dorsolateral prefrontal cortex; F, anterior limit of superior frontal sulcus; G, frontal pole; H, primary sensory cortex in postcentral gyrus; I, supramarginal gyrus (area 40); J, angular gyrus (area 39); K, occipital pole; L–N, anterior, middle, and posterior portions of STG; O–Q, anterior, middle, and posterior points along the inferior temporal gyrus anterior end. All quadratic, cubic, or linear terms were significant with $P < 0.05$. Age of peak GM is shown for B–D, I, and J. *x*-axis values are ages in years, and *y*-axis values show GM volumes. 37

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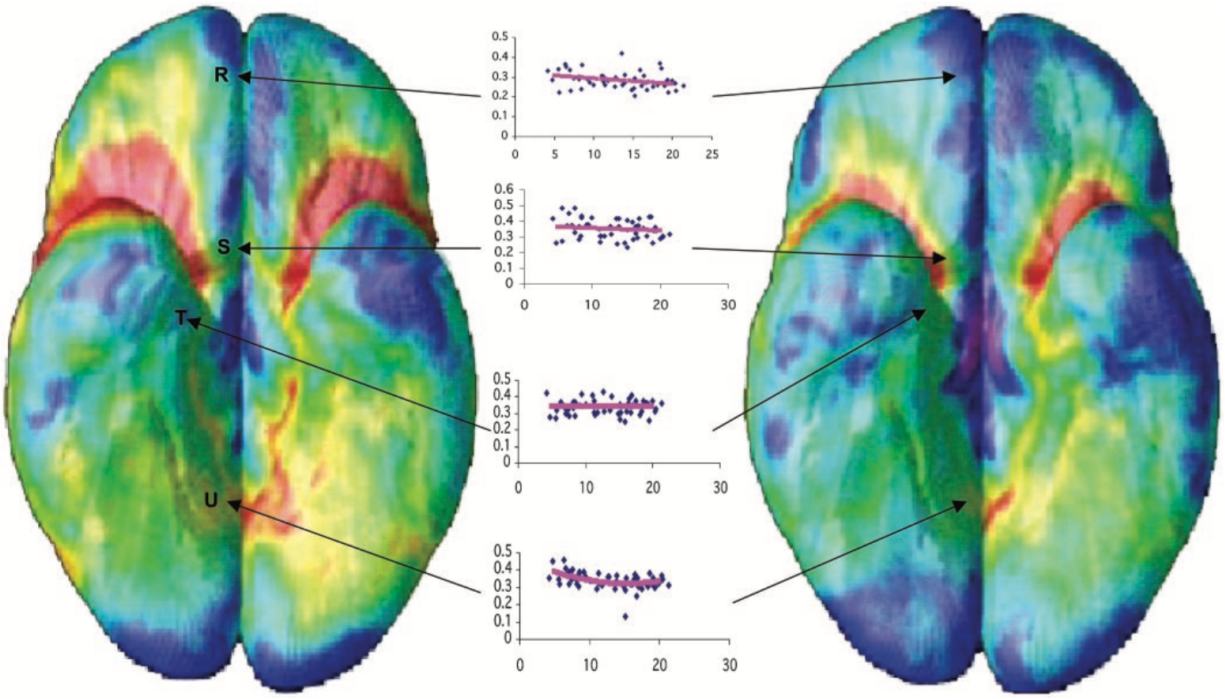


**Fig. 2.** Bottom view of the brain showing early and late time-lapse images. Points correspond to anterior and posterior ends of the olfactory sulcus (R and S) and collateral sulcus (T and U), and mixed-model graphs corresponding to the regions of interest on the right hemisphere are shown in the middle. *x*-axis values show ages in years, and *y*-axis values show GM volumes.

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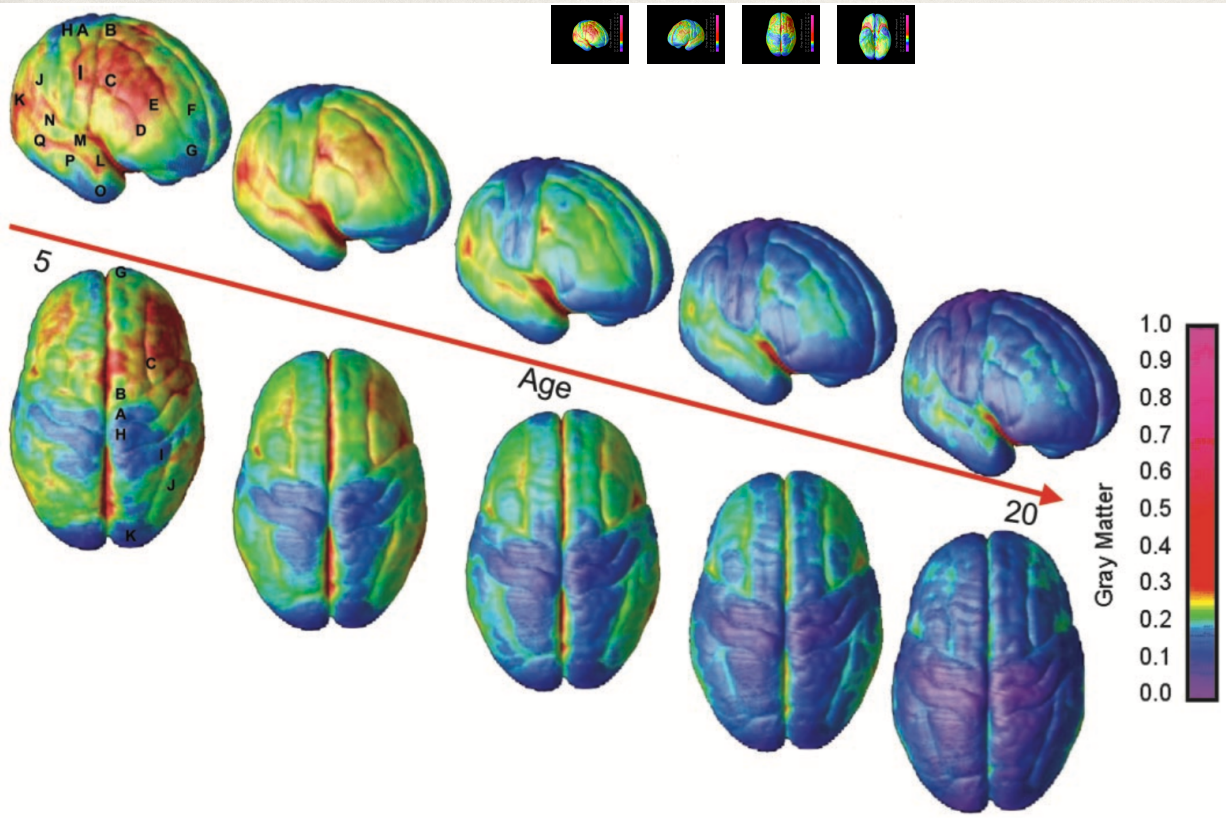


**Fig. 3.** Right lateral and top views of the dynamic sequence of GM maturation over the cortical surface. The side bar shows a color representation in units of GM volume. The initial frames depict regions of interest in the cortex as described for Fig. 1. This sequence is available in Movies 1–4 in the supporting information.

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# Kortikale Veränderungen der grauen Substanz

- Overall, the total GM volume was found to increase at earlier ages, followed by sustained loss starting around puberty
- Frontal-lobe maturation progressed in a back-to-front direction, beginning in the primary motor cortex (the precentral gyrus) and spreading anteriorly over the superior and inferior frontal gyri, with the prefrontal cortex developing last.
- The process of GM loss (maturation) begins first in dorsal parietal cortices, particularly the primary sensorimotor areas near the interhemispheric margin, and then spreads rostrally over the frontal cortex and caudally and laterally over the parietal, occipital, and finally the temporal cortex.
- Frontal and occipital poles lose GM early, and in the frontal lobe, the GM maturation ultimately involves the dorsolateral prefrontal cortex, which loses GM only at the end of adolescence

Gogtay et al. (2004)

40

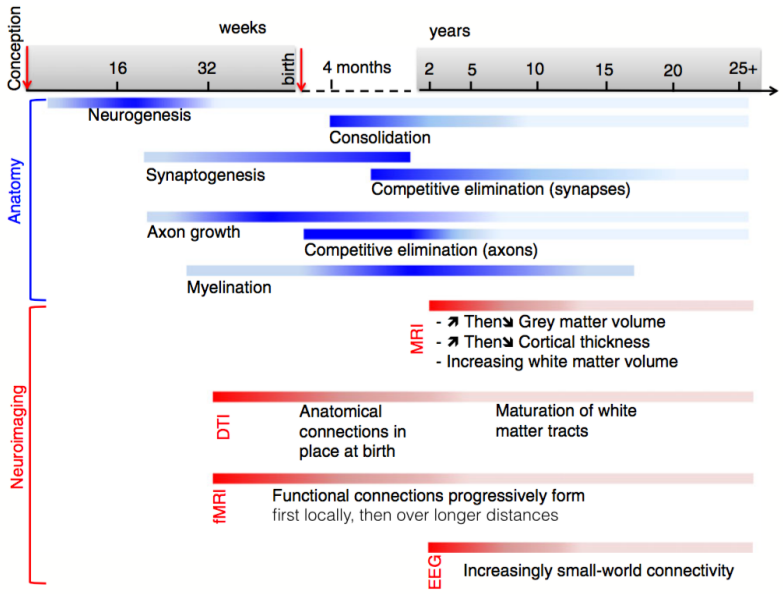


**Figure 2** Gantt chart of the sequence of events in brain maturation (blue) and related neuroimaging observations (red) (Collin & van den Heuvel, 2013; Giedd & Rapoport, 2010). The intensity of colour in each bar corresponds to the intensity of developmental changes observed

JOURNAL OF CHILD PSYCHOLOGY AND PSYCHIATRY
*Journal of Child Psychology and Psychiatry* 56:3 (2015), pp 299–320 doi:10.1111/jcpp.12365

**Annual Research Review: Growth connectomics – the organization and reorganization of brain networks during normal and abnormal development**

**Petra E. Vértes,[1,2] and Edward T. Bullmore[1,2,3]**
[1]Behavioural and Clinical Neuroscience Institute, Department of Psychiatry, University of Cambridge, Cambridge, UK; [2]Cambridgeshire and Peterborough NHS Foundation Trust, Cambridge, UK; [3]ImmunoPsychiatry, Alternative Discovery and Development, GlaxoSmithKline, Cambridge, UK

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# Classification of TAP-Tests based on taxonomies of Van Zomeren und Brouwer (1994) and Posner & Raichle (1994)

| | Alertness | Orienting | Executive attention |
|---|---|---|---|
| Intensity | Alertness (tonic / intrinsic / phasic) | | |
| | Vigilance | | |
| | Sustained Attention | | |
| Selectivity | | Visuo-spatial attention | Focused attention |
| | | | |
| no eye movements → | | Covert Orienting of Attention | Go/Nogo |
| | | Neglect (extinction phenomenon) | |
| | | etc. | Distractibility |
| | | | |
| | | overt orienting of attention | Divided Attention |
| eye movements → | | Pro- and Antisaccades | Flexibility |
| | | Visual Search etc. | Working Memory (n-back) |
| Supervisory Attentional Control (SAC) | | | Strategy |
| Central Executive | | | Flexibility |

decreasing relevance of the SAC

**Fimm, B.** (2007). Aufmerksamkeit. In: L. Kaufmann, H.-C. Nuerk, K. Konrad, K. Willmes (Hrsg.). *Kognitive Entwicklungsneuropsychologie*. (S. 153-176). Hogrefe: Göttingen

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