



S18 - Symposium Session 18

Wednesday, September 28, 15:30 - 17:30

Sala Falla

CURRENT TRENDS IN WORKING MEMORY RESEARCH: EVIDENCE FROM FUNCTIONAL NEUROIMAGING

Chair: Dr. Jochen Kaiser (Goethe University)

Co-chair: Christoph Bledowski (Institute of Medical Psychology, Goethe University, Frankfurt, Germany)

Speakers: Benjamin Rahm, Rhodri Cusack, Jöran Lepsien, Jarrod A Lewis-Peacock, Christoph Bledowski

Working memory (WM) refers to the ability to retain information active for further use and to do so in a highly flexible way. It has become one of the key concepts in cognitive neuroscience not least because it has turned out to strongly predict performance in complex cognitive activities such as reasoning and problem solving. Recent evidence has supported the view that WM emerges from the interaction of higher sensory, attentional and mnemonic components. The present symposium will cover different aspects of current neuroimaging research on WM. In the first talk Benjamin Rahm will show that recognition from WM activates regions distinct from those involved in the WM retention but previously implicated in recognition from long-term memory (LTM). Rhodri Cusack will then presents data from a meta-analysis showing that the dominant predictor of WM performance is the strategy for recoding sensory information, even when highly abstract stimuli were presented. Next, Jöran Lepsien will then demonstrate that the maintenance-related activity of WM representations can be significantly modulated by shifts of the focus of attention. Jarrod Lewis-Peacock will then present evidence supporting the view that WM retention is accomplished by the re-activation of long-term memories (LTM). For example re-focusing attention can restore the neural signature of a WM representation. Finally, Christoph Bledowski will review studies focusing on the “working” part of WM. He will introduce the term “basic operations” that refers to those functions that are essential for the functioning of visual WM and discuss their neuronal substrates.

ABSTRACTS

DISSOCIABLE NEURONAL BASES OF STORAGE AND RECOGNITION IN WORKING MEMORY

Authors: **Benjamin Rahm**¹

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Working memory (WM) is conceived as emerging from the interaction of attentional and mnemonic resources. The pivotal role of attention for short-term maintenance is thought to be reflected in the often observed pattern of activations in posterior parietal and frontal cortex. Theoretically, attention should in contrast play a minor role for recognition from WM, which may rather be dominated by mnemonic search, match and evaluation processes. Yet, there is no detailed empirical support for this assumption, and the neural basis of visual WM recognition is largely unknown. In the study



presented here, we used functional magnetic resonance imaging to investigate the separability of WM storage and recognition, and to characterize their neural correlates. Our results show that the often observed pattern of posterior parietal and frontal activation under higher memory load is evident at recognition. However, these activations did not vary in dependence of recognition demands, and comparing them with a condition where no recognition at all was necessary demonstrated that they are not recognition-related. In contrast, manipulating recognition demands by variation of sample-probe similarity gave rise to changes of activation in regions previously implicated in retrieval from long-term memory in inferior parietal cortex, posterior cingulate and superior frontal sulcus. Here, memory load too displayed effects, but only if recognition was required. Thus, two different variations of recognition demands, the number of to-be-evaluated items at WM and the sample-probe similarity, recruit almost completely overlapping brain regions. Thus, WM recognition may rely on a generalised neural basis, that is separable from those areas involved in the short-term storage of visual information.

INDIVIDUAL DIFFERENCES IN THE CAPACITY OF AUDITORY AND VISUAL SHORT-TERM MEMORY ARE DOMINATED BY RECODING STRATEGY

Authors: **Rhodri Cusack**¹

Affiliations: ¹MRC Cognition and Brain Sciences Unit (CBU), Cambridge, UK

There is good evidence for substantial recoding of auditory and visual information, even when highly abstract stimuli must be remembered for just a few seconds. Consistent with this, across a number of experiments, we have found that the dominant predictor of an individual's non-verbal short-term memory capacity is their strategy for recoding. In behavioural experiments, we find that simple manipulations that encourage different recoding strategies strongly influence performance on short-term memory tasks. A meta-analysis of a number of fMRI studies (N=112) found that the amount of activity during recoding predicts individual differences in activity but activity during maintenance did not. Furthermore, with an analysis method that can characterize form of neural representations at a much greater level of specificity than has previously been possible (multi-voxel pattern analysis) we show that in both auditory and visual short-term memory tasks, it is the precision of representations during recoding that predict subsequent memory performance across individuals, rather than the nature of the representation during maintenance.

ATTENTIONAL MODULATION OF WORKING-MEMORY REPRESENTATIONS

Authors: **Jöran Lepsieñ**

Affiliations: ¹Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

Many current models of working memory (WM) emphasize a close relationship between WM and attention, both at the level of cognitive processes and underlying neural networks. Recently, several studies have demonstrated that analogue to the perceptual domain, attention can be dynamically and voluntarily oriented to WM representations. Data from functional magnetic resonance imaging studies will be presented showing that the maintenance-related activity of those representations in the focus of attention is significantly modulated. In these studies, attentional allocation was manipulated by retro-cues presented during the retention period of a WM task, instructing participants to orient their attention to one or several representations held on-line in WM. Maintenance-related activity in



sensory cortices was modulated as an effect of attentional orienting towards the type of information represented in this area. In addition, parietal and prefrontal cortices exhibited a load-dependant interaction independent of the type of attended information. The activity in these brain areas reflected an effective reduction of WM load, i.e. the pattern of load-related activity after the retro-cue corresponded to the number of selected mnemonic representations in the focus of attention. In summary, the results shed further light on the functional role of attention for WM.

LONG-TERM MEMORY SUPPORTS THE RETENTION, PRESERVATION, AND PRIORITIZATION OF SHORT-TERM MEMORY

Authors: **Jarrod A Lewis-Peacock**¹

Affiliations: ¹Princeton University, USA

I will describe research that effected several empirical tests of the theoretical idea that the short-term retention of information (STM) is accomplished by the re-activation of long-term memory (LTM) representations. It leveraged a powerful new information-based analysis technique for neuroimaging data (pattern classification of fMRI) in a way that allowed for the precise tracking of actual information representations in the brain. First, I will establish the neural plausibility of the activated-LTM idea with data showing that a pattern classifier trained on category-specific brain activity from a LTM task was used to successfully decode brain activity from a subsequent STM task that required the short-term retention of the same stimuli. Second, I will describe recent data that suggest that delay-period activity may in fact reflect the focus of attention rather than the neural mechanism of short-term maintenance. Across two experiments we unconfounded attention and memory, either by causing an exogenous shift of attention to distracting information or by causing an endogenous shift to a subset of information held in memory. The neural representation of unattended information dropped to baseline, yet the information was remembered after a short delay. Whereas the loss of sustained activity has been thought to indicate a disruption of STM, our data also show that re-focusing attention can restore the neural signature and availability of a mental representation. Theoretically, these results call for rethinking the “activation” assumption in cognitive models describing STM as the temporary activation of LTM. Empirically, they suggest that many previous studies of short-term and working memory might usefully be reinterpreted as studies of sustained attention to information

BASIC OPERATIONS IN WORKING MEMORY: CONTRIBUTIONS FROM FUNCTIONAL IMAGING STUDIES

Authors: **Christoph Bledowski**¹

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In the neurosciences, much of the research on visual working memory (vWM) has concentrated on the storage function of vWM, however, its ‘working’ aspect still remains underspecified. Here we sought to isolate those operations that are “basic” for vWM functioning, i.e. that keep momentarily relevant information in a stable, yet flexibly accessible state. We introduce the term “basic” in order to keep the operations at a basic level, not implying more complex cognitive functions or the multiplicity of operations that may be performed on the contents of vWM. According to this definition we will summarize findings on five strands of research: (1) mnemonic selection of one item amongst others, (2) updating the focus of attention with the selected item, (3) updating the content of vWM with new



item(s), (4) rehearsal of visuospatial information and (5) coping with interference. We discuss the neuronal substrates underlying those basic operations obtained with functional magnetic resonance imaging and relate them to findings on “executive functions”. The presented data support the view that vWM emerges from interactions between higher sensory, attentional and mnemonic functions, with separable neural bases. However, the mediation of stability of WM in face of interference and the largely unspecified mechanisms of task set/rule representation and operation in WM may demand an extension of the attentional and mnemonic basis of vWM by executive control functions.