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POSTER ABSTRACTS

Session I

1. Does working memory training have to be adaptive?

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This study tested the common assumption that, in order to be most effective, working memory (WM) training should be adaptive (i.e., task difficulty is adjusted automatically to individual performance). Indirect evidence for this assumption stems from studies comparing adaptive training to a condition in which tasks are practiced on the easiest level of difficulty only (cf. Klingberg, 2010), thereby, however, confounding adaptivity and exposure to varying task difficulty. For a more direct test of this hypothesis, we therefore randomly assigned 132 participants to one of three training procedures (adaptive, randomized, or self-chosen task difficulty) or to an active control group. In comparison to the control, all three experimental groups showed increased performance in the trained tasks which, to some degree, transferred to non-trained, structurally different WM tasks. However, there was no transfer to reasoning in any of the groups. Surprisingly, neither training nor transfer effects were modulated by training procedure, indicating that the role of adaptivity might have been overestimated in previous training research.

2. **Evidence that people use available time to mentally refresh information to be remembered**

Evie Vergauwe, Emily Roemer, & Nelson Cowan
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Evidence is accumulating for domain-general reactivation of working memory (WM). The specific mechanism is often referred to as refreshing and the basic idea is that people use available time to briefly rethink of the information to be remembered. This process is assumed to reactivate WM representations which, in turn will lead to less forgetting. In line with this idea, it has been shown that increasing the time available to refresh information results in better immediate recall (Barrouillet & Camos, 2012) and delayed recall (McCabe, 2008). In the current study, we aimed at pinpointing the operation and the time course of refreshing more directly. We varied the time available to refresh information and, rather than studying the distant outcome (recall performance), we studied the status of memory items locally, i.e., during the available time. Therefore, we probed the content of WM during the available time by showing a probe item for which participants had to decide whether it is a member of the current memory set or not. These probes were presented at different delays. By examining response latency patterns, we were able to demonstrate that the status of different memory items is locally modulated as a function of the time available for refreshing before a probe is presented. Increasing the available time from 200ms to 800ms showed a change in response latencies that is consistent with the idea that individuals first encode the current item and then use the remaining time to refresh all items in the to-be-remembered list.

3. Storage of multi-feature visual objects in working memory

Kyle Hardman and Nelson Cowan
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This study examined how visual objects and their features are stored in working memory. It addresses a longstanding debate in the literature about whether storage limits in visual working memory include a limit to the complexity of discrete visual objects. We examined the issue with a number of change-detection experiments that used complex stimuli which possessed multiple features per stimulus item. The stimuli were rectangular bars which possessed a color, orientation, length, and the presence or absence of a black "gap" in the middle of the bar (Luck and Vogel, 1997). We manipulated the number of relevant features of the stimulus objects (i.e. which feature or features could change at test) in order to vary feature load. Simultaneously, object load was manipulated by varying the number of task-relevant stimulus items. In all of our experiments, we found that increased feature load led to a reduction in change-detection accuracy. However, we found that feature load alone could not account for the results, but that a consideration of the number of relevant objects was also required. An additional finding was that a constant number of objects were stored, regardless of feature load, which helps to generalize the findings of a constant object capacity to objects with multiple features. This study supports limits to both feature and object storage in visual working memory.

4. Role of perceptual organisation in short-term memory: Split-span serial recall reinterpreted

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We report two experiments suggesting that the cost for auditory-verbal serial recall of presenting items alternately to the two ears is a by-product of the adaptive process of organizing the auditory scene into coherent streams and not, as classically thought, structural limitations of short-term storage. Experiment 1 showed that inducing an auditory illusion whereby ear-alternating items are more likely to be assigned to a single stream—without altering the putative requirement for switching between different 'channels' into a limited-capacity short-term store—markedly reduces the ear-alternation effect. Conversely, promoting the segregation of ear-alternating items by pre-exposing participants to the alternating pattern before the onset of the to-be-remembered list increases the cost of alternation. The results provide further evidence for the centrality of the apparently peripheral process of perception in short-term memory performance.

5. Executive function processes mediate the impact of working memory impairment on intelligence in schizophrenia

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Objective: The study investigated working memory, executive functions (conceptualized as response inhibition, updating, and response inhibition), and intelligence in schizophrenia, using structural equation modelling to determine the relationship between working memory and intelligence, testing whether specific executive functions act as a mediator for the association.
Method: 125 individuals diagnosed with schizophrenia and 64 healthy participants were included in the study, tested using measures of working memory, intelligence and executive functioning. Structural equation modelling (SEM) was used to estimate direct and indirect associations between main measures.
Results: The schizophrenia group had significantly lower working memory, executive function and intelligence than the healthy group. The relationship between working memory and intelligence was significantly mediated by inhibition, updating and shifting functions.
Conclusion: The study indicates a mediating role of executive functions in determining intellectual function in schizophrenia. It is further proposed that in people with schizophrenia, cognitive remediation approaches targeting executive functioning contributions to working memory may in turn improve intellectual function generally.

6. The influence of input and output modalities on following instructions in working memory

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Following instructions is an important component of learning and has been shown to rely on working memory. This study examined the ability to follow instructions within working memory under varying input and output modalities. Participants heard, read, or viewed demonstration of short sequences of instructions, and recalled either by repetition or enactment. Both input modality and recall type had significant effects on span performance. Recall was superior when instructions were demonstrated relative to spoken or written presentation, with the latter conditions yielding similar span scores. Enacted recall was superior to oral repetition, but this advantage varied with the type of input modality. The effect size was large following spoken instruction, medium for written instruction, and negligible after demonstration. Crucially, the benefit of demonstration relative to spoken instruction was larger for repetition than for enactment. These findings suggest non-additive effects of input and output modalities on the ability to

remember and follow instructions in working memory, with implications for theory and pedagogic practice.

7. Visuospatial Boostrapping in older and younger adults

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Background: Recent studies on verbal immediate serial recall (Darling & Havelka, 2010; Darling et al., 2012) show evidence of the integration of information from verbal and visuospatial short term memory (STM) with long term memory (LTM) representations. This so-called 'visuospatial bootstrapping' pattern, in which verbal serial recall is improved when the information is arranged in a familiar spatially distributed pattern, such as a telephone keypad, is consistent with the existence within working memory (WM) of an episodic buffer (EB; Baddeley, 2000).
Objective: The present study investigated how visuospatial systems support verbal WM using the visuospatial bootstrapping paradigm across older and younger adult samples, an issue that has not yet been researched.
Materials and Methods: Two different samples were recruited: younger adults (18-35 years) and older adults (55-75 years). Each participant was assessed with a brief neuropsychological battery of tests and the assessments of bootstrapping. The latter tasks compared immediate serial recall performance across three visual display conditions: single digit presentations, standard (familiar) keypad arrays and random (unfamiliar) keypad arrays without suggestion as to what memory strategy to use.
Results: 64 subjects were tested (N = 32 younger adults, N = 32 older adults). The results indicate the presence of a bootstrapping effect in the group of young people and a substantial main effect suggestive of bootstrapping across the two groups.
Conclusions: Visuo-spatial Bootstrapping is investigated for the first time in a group of older adults. Preliminary analysis indicates a significant improvement in memory in the standard keypad condition across young and older adults.

8. Neural correlates of working memory under the second order false belief task: An event-related fMRI study based on theory of mind

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Theory of Mind (ToM) allows us to attribute empathies, desires, and intentions to others to predict or explain their actions and to posit their intentions (mindreading). ToM testify an ability to make inferences about others' mental state and allows us to understand what we believe to be true and what is true may be different (Perner, 1991). Children under the age of four, along with most autistic children of older ages likely fail to perform first order False Belief Task (FBT). We assumed one of the causes of the failure would due to insufficient executive function of working memory in dorsolateral prefrontal cortex (DLPFC). Thus, we

investigated neural correlates of working memory in the social brain under the second order FBT which is assumed the more sophisticated mindreading task to normal adults using event-related fMRI. We expected the second order meta-representations based on working memory are prerequisite to solve the task. Results showed brain activations both in the cortical midline structures including bilateral MPFC, precuneus and in the dorsal working memory network involving bilateral DLPFC and PPC under the second order FBT.

9. Common principles underlying visual, auditory and tactile working memory resources

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A prevalent view of working memory (WM) considers it to be capacity-limited, fixed to a set number of items. However, recent shared resource models of WM have challenged this 'quantized' account using measures of recall precision. Although this conceptual framework can account for several features of visual WM, it remains to be established whether it applies to other sensory modalities.
We tested whether the resource model can be extended to auditory and tactile WM. For the audition, recall precision was measured for pitch and speech sounds. With respect to touch, we measured precision for vibrotactile frequencies. Novel matching tasks were designed to probe participants' memory for each stimulus feature. In each experiment, after the presentation of a sequence of stimuli, a probe stimulus appeared which had to be adjusted to match a selected target. This continuous, analog response method allowed us to measure recall precision for the respective stimulus feature. Crucially, this provides an index of the variability of a memory representation around its true value, rather than a binary "yes/no" recall measure typically used in change detection paradigms.
Our findings support key predictions made by the resource model: We show a monotonous decline in memory precision with an increase in memory load, suggesting no discrete item limit, for audition and touch. The results show that there is no fixed upper limit to the number of stimuli that can be stored in WM, a principle that obtains across sensory modalities. Instead, the resource model, previously shown to account for visual WM processes, can be extended to auditory and tactile WM. A unified mechanism – the resource model – provides a biologically plausible description for WM mechanisms across the senses.

10. The role of the phonological loop in the acquisition of new words in adults.

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The maintenance of verbal information in the phonological loop has been considered an important step for the acquisition of new vocabulary. In this experiment the impact of retaining a series of six digits during the encoding of Spanish pseudowords was studied in a sample of 24 university students. Both implicit and explicit memory for the pseudowords was assessed by means of perceptual priming and a cued recall tests, respectively. The results showed no effect of the memory load of digits in the priming task, suggesting that implicit memory for new words does not rely on phonological loop resources. By contrast, loading the phonological loop at encoding caused a significant disruptive effect on the explicit memory test for new words.

11. Subliminally Presented Stimuli Do Not Influence Working Memory Contents

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Given the strict capacity limitations on the contents of our conscious awareness an important question pertains to the fate of information left out of conscious experience. Relatively high-level processing of visual input can occur without stimuli ever reaching awareness, and subliminally presented stimuli can modulate conscious perception of other stimuli. It is unclear, however, to what extent unconscious information can affect more than just immediate perception; for example the retention of information held in working memory (WM). Here we examined how information that is not consciously perceived may influence WM representations. Twenty participants completed two tasks. In a WM task they remembered one of two sequentially presented orientation stimuli. The presentation duration of the other, distracting, orientation stimulus was varied so that this stimulus was either consciously perceived or not consciously perceived. Conscious perception of the distracter stimulus was assessed throughout the experimental task in a prime identification task. Participants performed a forced-choice discrimination task and rated the perceptual clarity of the prime stimulus. Our results show that precision of recall for the target orientation is reduced only when the distracting stimulus is consciously perceived. Similarly, orientation reports are biased by a visible distracter stimulus but not by an invisible distracter. Thus, while subliminal information has an influence on perceptual representations and processing, this may not be the case for WM operations.

12. Orienting and habituation to irrelevant speech effects - according to Dr Turing and the Reverend Bayes.

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According to his statistical assistant at Bletchley Park, Alan Turing developed a quantifiable "factor in favour of a hypothesis" during WWII without direct reference to earlier work by Thomas Bayes (1763) and others (Good, 1979). These factors, now known as "Bayes Factors", give the weight of evidence in favour of a particular hypothesis when compared to an alternative. As such, they represent a coherent approach to statistical inference when the results of orthodox hypothesis tests are non-significant (Dienes, 2008; 2011; submitted). The irrelevant speech effect on immediate recall (ISE), which has contributed greatly to discussions about the construct of working memory (e.g., Baddeley, 1986, 2000, 2007; Jones, Macken & Nicholls, 2004; Jones & Tremblay, 2000; Neath, 2000), has a history of inference based upon such null effects (e.g., non-significant effects of repeated, or continuous sounds) or effects that have proven difficult to replicate (e.g., phonological similarity between irrelevant speech and to-be-recalled material). To determine the weight of evidence in favour of a particular theory of irrelevant speech effects, Bayes factors were derived for published studies on the ISE and combined into a meta-analysis, focusing upon the evidence in support of the idea of the orienting response as the basis for the ISE, and the subsequent habituation supposed by Cowan's (1998) embedded-processes model of working memory. The results of Bayesian meta-analyses of two different ways of examining habituation (pre-exposure to the irrelevant speech and increased orienting via a larger irrelevant speech/sound "token set size") are contrasted.

13. Effects of ageing on working memory precision and binding

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Visual working memory (VWM) performance declines as people get older, but the nature of this decline is not well understood. Studies examining change detection performance have identified two components of age-related decline in VWM – memory for single features and memory for associations between features (binding).
We tested 139 healthy subjects between 19 and 83 years on a recently established object-location VWM task. In each trial, participants were asked to remember the identity and location of 1 or 3 objects. Following a delay, participants were firstly required to identify a previously seen object and then report its location using a touch sensitive screen. Unlike most previous studies on location memory we used an analogue measure of report that has been shown to be sensitive to quality of location memory and object-location binding.

Our results show an age-related decrease in object identification and precision of memory for location. For localization performance this deficit is apparent even when only one item has to be remembered and worsens disproportionately with increasing memory load. However, we did not find evidence for a decrease in binding performance with increasing age. Thus, whilst precision for single features declines in the elderly, object-location binding ability seems to remain unimpaired. Interestingly, as it has been reported that VWM binding impairments are the first cognitive signs of early Alzheimer's dementia (AD), our results support the possible implementation of VWM binding in the early diagnosis of AD.

14. List length and output order effects in the immediate free recall of verbal and visuo-spatial stimuli

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A recent finding reported by Ward, Tan and Grenfell-Essam (2010) is that participants perform immediate free recall (IFR) of short lists of words in a similar manner to how they perform immediate serial recall (ISR). In the current research, we were interested in whether this finding was underpinned by a language-specific mechanism, (such as a speech input/output buffer or verbal short-term memory mechanism). To this end, the IFR of lists of between 1 and 15 words was contrasted with the IFR of lists of between 1 and 15 visuo-spatial dots. We found that participants tended to initiate recall of short lists of both words and dots with the first item for short lists (resulting in more "ISR-like" recall), but tended to initiate recall of longer lists of both words and dots with one of the last four presented items with longer lists (resulting in greater recency and reduced primacy). The findings extend the growing literature suggesting that similar mechanisms underpin verbal and visuo-spatial immediate memory, and specifically rules out language-specific explanations of the finding.

Ward, G., Tan, L., & Grenfell-Essam, R. (2010). Examining the relationship between free recall and immediate serial recall: the effects of list length and output order. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 36*,1207-1241.

15. Examining the relationship between immediate serial and free recall: Similar effects of phonological similarity and articulatory suppression.

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This poster reports the work of Spurgeon, Ward and Matthews. Recent research has appealed for an integrated account of immediate serial recall (ISR) and immediate free recall (IFR). However one outstanding potential obstacle for unification is the apparent opposing effects of (phonological) similarity in both tasks: increased similarity between list items appears to benefit IFR with free recall (FR) scoring, but impairs ISR with serial recall (SR) scoring. Two experiments examined the effects of phonological similarity in lists of visually-presented words

drawn from large stimulus sets. Performance was examined over a range of list lengths with and without articulatory suppression (AS) using both SR and FR scoring. The methodology of the two experiments was identical with the exception that Experiment 1 examined ISR and Experiment 2 examined IFR. We found that *in both tasks*: (1) AS reduced recall, (2) participants recalled short lists from the start of the list, (3) phonological similarity impaired performance using SR scoring, (4) but these phonological similarity effects we were reduced by FR scoring and eliminated with AS, (5) and AS but not phonological similarity affected the tendency to recall short lists from the start of the list. Therefore, previous opposing effects of phonological similarity in ISR and IFR appear to be due to differences in the list lengths and scoring systems used and differences in the operationalization of phonological similarity. Using equivalent methodology, both tasks are similarly affected by phonological similarity and AS, supporting the plausibility for theoretical unification of both tasks.

Spurgeon, J., Ward, G., & Matthews, W. J. (accepted subject to minor revisions). Examining the relationship between immediate serial recall and immediate free recall: Common effects of Phonological Loop variables, but only limited evidence for the Phonological Loop. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

16. Working memory in children: Tracing age differences and special educational needs to parameters of a formal model

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Parameters of a formal working-memory model were estimated for verbal and spatial memory updating of children. The model proposes interference though feature overwriting and through confusion of whole elements as the primary cause of working-memory capacity-limits. We tested two age groups containing each one group of normal intelligence and one deficit group. For young children the deficit was developmental dyslexia; for older it was a general learning difficulty. The interference model predicts less interference through overwriting but more through confusion of whole elements for the dyslexic children than for their age-matched controls. Older children exhibited less interference through confusion of whole elements and a higher processing rate than young children, but general learning difficulty was associated with slower processing than in the age-matched control group. Furthermore, the difference between verbal and spatial updating mapped onto several meaningful dissociations of model parameters.

17. Comparison of visual working memory maintenance and associative memory retrieval in ageing and synaesthesia

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Our ability to maintain, manipulate and recall information is critical for normal cognitive function. In this study we compare three groups of participants during the performance of a visual associative memory task and a visual working memory task, using black and white fractal stimuli in an fMRI study. The first group of volunteers are young (n=19, mean age: 24.3), the second are older (n=19, mean age: 66.2), and the third are young synaesthetes (n=19, mean age: 23.0). During the working memory task, we find a main effect of group in the inferior occipital gyrus, the superior parietal lobule (SPL), and dorsolateral prefrontal cortex. In all three areas, the synaesthetes show less signal change, compared to young and older adults, indicating a more efficient use of relevant neural networks. The older participants show higher levels of activity in the SPL compared to the other two groups, indicating increased use of relevant resources to achieve a similar level of performance. This finding supports the compensation-related utilization of neural circuits hypothesis (CRUNCH). During the delay period of the associative memory task, we also find a main effect of group in the SPL, the inferior temporal cortex, and the anterior prefrontal cortex. Additionally, we find a main effect in the middle temporal gyrus and the perirhinal cortex, an area known to support higher-order conceptual associations. The prefrontal activations (BA10), consistent with monitoring and verification of retrieved information, were significantly lower in the synaesthetes compared to young and older adults. Our data are consistent with the view that visual representations are activated both during sensory stimulation and maintenance of visual information. Despite functioning at similar performance levels, synaesthetes and older adults show higher and lower neural efficiency, reflected in reduced or enhanced activations respectively within the same brain networks.

18. Healthy body, healthy mind: the effect of varying dual task demand

Amy Cadden, under the supervision of Prof Robert Logie.
University of Edinburgh.

The current study investigated whether exercise acted as a facilitating factor for dual task performance in the healthy adult population. Two groups of participants, elite athletes (n=20) and sedentary controls (n=20), were compared on digit recall and visuospatial tracking tasks. Tasks were performed at varying demand levels ranging from low to high, both separately and concurrently where the demand of one task was fixed at an individually titrated level while the other was varied through three demand levels. The results demonstrated a significant yet minimal dual task cost across all participants. Both groups exhibited similar performance reductions in response to increasing demand, however, there was some suggestion

of a beneficial effect of exercise participation in high demand digit recall conditions. The results provided further support for the existence of a specific dual task coordination mechanism within a multi-component working memory system, however, the ability of high levels of physical activity to aid dual tasking performance in the healthy population was not conclusively supported.

19. Neural basis of object-based shifting of attention in working memory

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Working memory (WM) enables the retention of limited number of items and the prioritization of a subset of items for processing by focusing attention on them. In vision, shifts of attention between spatial positions within one object are performed faster than shifts between positions located on different objects. This within-object benefit can be explained by an automatic spread of attention within perceived object boundaries in visual cortex.
Hypothesizing the same attentional mechanisms in WM as in perception, we tested whether the within-object benefit can be observed, both on the behavioral and neural level, when subjects focus attention on spatial positions in WM. Subjects were presented two objects each containing two highlighted spatial positions and memorized all four spatial positions. Attentional shifts in WM were faster for spatial positions located on the same object compared with equidistant positions on separate objects as observed in a perceptual version of the same task. Analysis of visual cortex using pattern classifiers revealed that the automatic spread of attention within object boundaries was present also for information held in WM. Specifically, when attention was shifted to a memorized position, activity in early visual areas was enhanced at the retinotopic location corresponding to the second position co-located on the same object. These results extend the hypothesized shared mechanisms of spatial attention in perception and WM by demonstrating this notion for object-based attention. They also suggest activation of the complete object by attentional selection when object-like representations are held in WM, thus accounting for the within-object benefit.

20. Cross-modal binding in children and young adults: developmental trajectory and relationship with reading development

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How does the capacity to bind information in working memory from different sensory modalities (specifically, visual patterns and novel phonological word forms) develop with age, and how might this relate to reading ability? This study examined the performance of Grade 2 (8 yrs old) and Grade 3 (9 yrs old) children and young adults on novel tasks measuring memory for visual shapes, auditory-verbal nonwords, and the cross-modal associations between these features. Clear developmental trajectories were observed, with improvements in the ability to hold cross-modal bindings in working memory between Grades 2 and 3, and between

the children and adult groups, that were independent from memory for the individual elements. Furthermore, cross-modal binding accuracy significantly correlated with word recognition ability and predicted unique variance on this measure when controlling for age, feature memory, and other possible predictors of reading development. These findings suggest that the capacity to temporarily bind novel auditory-verbal information to visual form in working memory improves through childhood, and may be an important factor in driving reading development.

21. Does spatial orientation information of working memory deploy selective attention in the visual search?

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There is a lot of evidence that working memory could automatically or strategically deploy selective attention in the visual search (Soto, Heinke, Humphreys, & Blanco, 2005; Soto, Hodsoll, Rotshtein & Humphreys, 2008; Olivers, 2009). Usually the contents of visual working memory are represented by colour, shape or object. However, there are few studies which concern spatial orientation information. Considering the functional dissociation between visual-object and visual-spatial information processing in the visuo-spatial sketchpad, we investigated the deployment of spatial orientation to selective attention. Experiment 1 used three arrows from an origin which divided the plane into three 120° segments to indicate the orientation. Participants were told to memorize one of three orientations or the colour then completed a search task and memory task. Experiment 2 used the same stimulus and procedure, except for the change of angles among different orientations which was non-centrosymmetric. Both the experiments, regardless of whether they utilised regular orientation (Exp 1) or irregular orientation (Exp 2), showed that when orientation was held in working memory, both the orientation-matched and colour-matched item could automatically capture attention strongly. However, when colour was kept in working memory, the orientation-matched item didn't affect the search task, while the colour-matched item still captured attention robustly. These results suggested that colour in the working memory undoubtedly deploys attention by capturing automatically, but orientation in working memory could lead to a weaker effect. It appears that maintaining orientation information in the visuo-spatial sketchpad is a controlled process.

22. Adult mathematicians have superior working memory storage capacity in the spatial domain

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Previous research has demonstrated the importance of the limited-capacity working memory system in performing mathematics. However, there has been much debate over whether resources within this system are general or domain-

specific. This two-experiment study used a working memory span task, incorporating a face matching task as a neutral processing element, to discover whether adult mathematicians have superior working memory capacity to adult non-mathematicians in general, or whether they have superior capacity for the storage of numerical, spatial or verbal information. The results of Experiment 1 indicated that, whilst there was no difference between mathematicians and non-mathematicians in the verbal domain, mathematicians had superior capacity for information in the spatial domain. As performance of both groups was around ceiling for numerical stimuli, Experiment 2 used larger span set sizes in the numerical condition and an exact replica of the spatial condition. Results replicated the findings of Experiment 1. The findings of this study indicate that mathematicians have superior capacity for the storage of spatial information and support the separability of spatial and verbal resources within the multi-component model of working memory. Results also suggest the importance of spatial working memory in particular, for performance in advanced mathematics.

23. Visual buffer and retrieval of visual information from working memory.

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Irrelevant visual input interferes with the generation of visual mental images at encoding and retrieval, however, little is known about its effect on visual memory tasks. In this study, we used a retroactive spatial cue (retro-cue) to investigate retrieval of visual information from working memory. Participants viewed an array with four geometrical shapes, briefly presented around a fixation point, and were later requested to decide if a probe stimulus was presented or not in the array (50% probability). An informative retro-cue, presented 2500 ms after the offset of shapes, pointed to the location where the probe was presented with 75% validity. In Experiment 1, we manipulated the retro-cue to probe stimulus interval (RSI) used to estimate the time needed to retrieve visual information from working memory. Both accuracy and reaction time showed that the facilitatory retro-cue effect is greater for RSI between 250-750 ms than for 50-150 ms; thus, we suggest that 250 ms is the minimum time needed to recover visual representation from working memory. In Experiment 2, the RSI was fixed at 700 ms and filled with DVN in half of the trial. The performance, accuracy, and reaction time are enhanced by the informative retro-cue; however, this effect is eliminated in the presence of DVN. The results support the conclusion that visual representation is recovered from working memory to a visual buffer and liable to the interference of DVN, similarly to what occurs in visual imagery tasks.

24. The neural correlates of the phonological loop: Direct cortical stimulation during awake surgery

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Neuropsychological reports, activation studies and transcranial magnetic stimulation have suggested that the neural correlates of phonological short-term memory are located in the left hemisphere with BA 40 being responsible for short-term storage [1]. However, a review of the literature on the role of this area showed equivocal data. We investigated this issue by testing phonological STM during awake surgery by direct stimulation of cortical sites.
Ten patients with a left hemisphere low-grade glioma were submitted to a neuropsychological evaluation including language and verbal memory tasks. They showed no deficits. Since digit span had to be evaluated during awake surgery, we used a "conservative" criterion and we selected a sequence length at which each patient was able to correctly repeat three sequences out of three.
In the intra-operative phase, patients performed counting, digit span, phonological judgments and naming tasks during electrical stimulation of BA 40 or other different cortical sites, namely Broca's region, the middle frontal gyrus, the anterior part of the superior and middle temporal gyrus, the superior parietal cortex. We found that 26 out of 27 stimulations over BA 40 disrupted digit span, with a significant number of order errors. No effect on naming was found. Stimulation over Broca's area produced item errors in 20 out of 27 stimulations. Stimulation of other sites never disrupted the digit span. After surgery, digit span returned normal. These results suggest a specific role of BA 40 in the maintenance of serial order.

Romero, Walsh, Papagno (2006) J. Cogn. Neurosci, 18, 1147-1155.

25. Oculomotor preparation as a rehearsal mechanism in spatial working memory

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There is little consensus regarding the specific processes responsible for encoding, maintenance, and retrieval of information in visuo-spatial working memory (VSWM). One influential theory is that VSWM may involve activation of the eye-movement (oculomotor) system. In this study we experimentally prevented healthy participants from planning or executing saccadic eye-movements during the encoding, maintenance, and retrieval stages of visual and spatial working memory tasks. Participants experienced a significant reduction in spatial memory span only when oculomotor preparation was prevented during encoding or maintenance. In contrast there was no reduction when oculomotor preparation was prevented only during retrieval. These results show that (a) involvement of the

oculomotor system is necessary for optimal encoding and maintenance of directly-indicated locations in spatial working memory and (b) oculomotor preparation is not necessary during retrieval from spatial working memory. We propose that this study is the first to unambiguously demonstrate that the oculomotor system contributes to the maintenance of spatial locations in working memory independently from the involvement of covert attention.

26. Effects of interference and cognitive load on working memory in normal and pathological aging

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Decline in working memory (WM) performance has been largely described in normal and pathological aging but the causes of forgetting remain discussed. In young adults, an interference-based account (Farrell & Lewandowsky, 2002) assumes that forgetting depends on interference produced by encoding of distractors (novelty). Meanwhile, a time-based account (Barrouillet, Portrat & Camos, 2011) assumes that forgetting depends rather on the temporal decay of memory traces, forgetting being a function of the proportion of time during which attention is captured by processing (cognitive load). The present study investigates in young adults, healthy older adults and patients with Alzheimer disease the impact of novelty and cognitive load on WM performance. We used a computer-paced complex span task in which participants had to maintain images for further recall while reading distractors. The pace of the distractors and their level of novelty were manipulated. The results revealed a strong effect of population indicating that patients recalled much less items compared to healthy older adults, themselves having impaired recall compared to young adults. In addition, an effect of pace was observed in young and older adults but not in patients. Finally, the effect of novelty did not appear ever. Consequently, the decline of WM performance in aging can be hardly explained by a higher sensibility to interference while time-based factors seems to be crucial. Computational simulations based on the TBRS* model (Oberauer & Lewandosky, 2011) gave more support for such interpretation.

27. The nature of the stored representations in working memory depends on the task characteristics and maintenance strategies

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Using a novel paradigm, this project investigated the effectiveness of semantic and phonological cues during immediate recall from a complex span task in order to elucidate the underlying encoding mechanisms that support WM maintenance and recall. If a memorandum was forgotten during the recall phase of the administered complex span task, participants could ask for a cue word that was either semantically related or rhymed with the memorandum. In Experiment 1 participants were assigned to either a standard complex span task or a task that allowed 300 msec of extra time after each processing decision. In Experiment 2 participants were instructed to use either a rehearsal-based or refreshing-based maintenance strategy. Both experiments revealed that use of the cues was similar between cue types, but the semantic cues were more effective for recall than phonological cues when participants were given extra time after the processing decisions (Experiment 1) and when instructed to use refreshing to maintain the memoranda (Experiment 2). This extends current research showing that rehearsal and refreshing are distinguishable maintenance mechanisms that affect the nature of the stored representations. Specifically, WM tasks that promote the use of refreshing, either by affording a brief pause or by deliberate instruction to refresh, also promote the semantic characteristics of the memoranda.

28. Explaining the repetition-based bonus in visual working memory

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Repeated information in a visual scene has been shown to boost working memory capacity for elements of the scene (Quinlan & Cohen, 2012). This could occur because repetitions provoke a more efficient perceptual organization of the display that affords binding between objects, or because of strategic allocation of attention toward the repeated colors. These two explanations provide unique predictions about estimated capacity: efficient organization should boost capacity for all elements of the array, whereas allocating attention selectively towards the repeated items would boost capacity only for tests of the selectively attended items. We manipulated the occurrence of repetitions in an array, and also whether a repeated item or a singleton was probed. Half of the participants engaged in articulatory suppression and half counted backwards by threes. Although capacity estimates were lower across the board in the counting group, tests of duplicate colors nonetheless resulted in decidedly boosted capacity, as in the suppression group. With undivided attention, singleton tests from displays with repetitions resulted in higher capacities than tests from displays including all unique colors, but this bonus was less pronounced in the backwards-counting group. Analyses of gazes showed that with full attention, participants tended to glance earlier at repeated colors during the stimulus presentation, but prioritize rehearsal of singletons during the retention interval. This pattern of results suggests that the

repetition-based bonus occurs because efficient perceptual organization of the display is enhanced by strategic attention allocation when attention is available.

29. Chunking in working memory: a time-based process?

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The present study investigated the chunking process in working memory. Chunking is considered as a maintenance mechanism that consists on grouping together several pieces of information in order to constitute a unique significant unit. The purpose was to test if the advantageous effect of chunking on recall performance is affected by the temporal characteristics of a concurrent processing task.
Adult participants had to perform a computer-paced complex span task in which they had to maintained series of 7 letters while concurrently performing a location judgement task interleaved after each letter. The pace of the processing activity (fast and slow) and the presence of 3-letters acronyms –i.e., chunks- within the memoranda (absent, present in 1st, 3rd and 5th position) were orthogonally manipulated in a within subjects design. As expected, results showed that the mean number of letters correctly recalled was enhanced when the memoranda contained acronyms. However, a counter-intuitive interaction has been observed. Indeed, this positive "chunk effect" was much more pronounced when the concurrent processing task was performed at fast-pace compared to slow-pace. Hence, time pressure seems beneficial to chunking in working memory. Computational simulations proposed an implementation of the time course of the chunking process within the framework of the Time-based Resource Sharing model (Barrouillet, Portrat & Camos, 2011; Oberauer & Lewandowsky, 2011) and gave more insight concerning the mechanisms underlying this counter-intuitive effect. While chunking as well as refreshing are both beneficial to working memory performance, they are nonetheless competing processes in this framework.

30. Working memory as a predictor of linguistic giftedness

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The present study investigated the role of working memory (WM) and short-term memory (STM) as predictors of FL aptitude in 126 foreign language learners. The subjects of the study were 44 accomplished multilinguals and 82 mainstream English philology students. The accomplished multilinguals group consisted of 44 students who were identified as gifted based on proficiency scores, the number of languages they had learned, language learning history, and the *Modern Language Aptitude Test* (*MLAT*, Carroll & Sapon, 2002) score. Three instruments were used in the study: the *Polish Reading Span – PRSPAN* (Biedroń & Szczepaniak 2012), designed by the present author, the *Wechsler Adult Intelligence Scale – WAIS-R (PL)* (*Memory and Resistance to Distraction index* which includes: *Arithmetic, Digit-Span, Digit-Symbol Coding*) – an adaptation for use with the Polish

population by Brzezinski et al. (1996), and the MLAT. The independent variables in regression analysis were the WAIS-R (PL) *Memory and Resistance to Distraction* index and the PRSPAN scores. The dependent variables were the MLAT scales. It emerges that working memory (the *Memory and Resistance to Distraction index* and the *PRSPAN*) is a predictor of the MLAT score. Moreover, significant differences between the two samples were observed, especially in the memory tests based on verbal material, with those of the gifted L2 learners being higher. The conclusion is that gifted learners who score high on WM capacity tests, like the PRSPAN, are more able to notice and select relevant information and to inhibit irrelevant information, which can make them more capable of noticing of corrective feedback (cf. Mackey et al., 2002, Robinson, 2002).

31. Is feature binding in visual working memory age invariant?

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Visual working memory (VWM) exhibits pronounced decline across the adult lifespan (Johnson et al., 2010). It has been proposed that increasing age may impair the ability to bind the different features of an object (e.g. shape and colour) into a coherent object-file (Brockmole et al., 2008). The majority of studies assessing this question have found little evidence that feature binding is more age-sensitive than VWM for individual features. However, feature binding may not be entirely age invariant as there may be certain conditions under which older adults struggle to bind features in VWM (Brown & Brockmole, 2010; Cowan et al., 2006). The present experiments aimed to test such conditions. For example the study of Brown and Brockmole (2010) has suggested that increasing the duration that memory objects are presented for may impair older adults' ability to bind shape and colour in VWM. To further address this we manipulated the amount of time younger and older adults were given to study objects for a change detection task. Overall change detection performance was lower in the older group relative to the younger group. However, the effect of age was no more pronounced for feature bindings compared to individual features, regardless of presentation time. Therefore, increasing study time does not appear to affect the age invariance of feature binding.

Session II

1. Neural systems underlying distractor inhibition in verbal working memory and their contribution to individual differences in working memory capacity

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Recent work has shown that ventrolateral prefrontal cortex (VLPFC) is involved in shielding the contents of working memory (WM) against distraction. While it has been suggested that the individual ability to inhibit distractors critically contributes to individual differences in WM capacity, an association between inhibition-related brain activity and WM capacity was observed in dorsolateral prefrontal cortex (DLPFC) but not in VLPFC. These insights rely primarily on studies of visual and visuo-spatial WM. We used functional magnetic resonance imaging to investigate the neural bases underlying distractor inhibition in verbal WM and their contribution to individual differences in WM capacity. In a sample of 52 participants, we observed robust activity in VLPFC and DLPFC, elicited by distractor letters during the delay period of a letter WM task, but suppressed activation in occipital cortex. Functional coupling of VLPFC and DLPFC with visual regions was increased during distractor inhibition, and multiple prefrontal seed regions showed convergent functional coupling with the occipital areas that exhibit distractor-related suppression of BOLD signals. Individual WM capacity was negatively correlated with the strength of functional coupling between right VLPFC and higher visual areas. These results provide evidence for fronto-posterior top-down guided suppression of perceptual processing as a mechanism underlying the shielding of working memory against distraction. Importantly, our data lend strong support to the hypothesis that the capacity of WM is determined – at least partly – by the degree to which VLPFC can implement top-down control over visual areas when task-irrelevant information must be ignored.

2. Recall interferes with both local and global, while time to recall affects only local, spatial representations in working memory

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Spatial recall is influenced by global factors, namely the number of objects held in memory and their configuration, and local factors, namely the target location, suggesting the presence of variable resolution, multiple reference frames-based representations in spatial working memory. Can these spatial working memory representations, reliant on global and local factors, be dissociated behaviorally? To this end, we examined the effect of recall on the accuracy and precision of spatial working memory using a whole report procedure. The sample array consisted of

three coloured discs displayed at five canonical locations. Target position at each location was slightly jittered, trial-by-trial, by adding normally distributed position noise. Recall precision decreased with recall order. Moreover, a decrease in the ability to report canonical positions, as well as the ability to report deviations of the targets from their canonical positions, was seen with increasing recall order. In a control partial report task, in which only one target was reported and the time to recall was matched to that in the whole report procedure, recall precision diminished with increasing delays. However, the ability to report deviations of the targets from their canonical position and the canonical position themselves was preserved. We conclude that local memory representations are liable to the effects of recall and delay interval, while global representations, though affected by recall, are robust in the face of increasing time delays. This dissociation provides further evidence for the presence of multiple, local and global level, representations in spatial working memory.

3. Using reinforcement learning to solve working memory tasks

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Working memory (WM) is necessary for many daily life tasks such as problem solving, reading and communicating with others. These activities require us to selectively maintain some information in WM while replacing old and irrelevant information with new and relevant one.
Reinforcement learning (RL) has been proposed as a plausible framework for how people learn to use their WM. Several recent models consider WM as a collection of past observations and use RL to learn when to update or maintain WM contents. These RL models have been shown to learn how to solve WM tasks such as the n-back task (O'Reilly & Frank, 2006; Todd et al., 2009).
We competitively tested a number of RL models of WM on a battery of standard tasks used to evaluate WM-based RL models, including the 12-AX, n-back and the SIR-2 tasks. Our simulations show that these models perform very well in WM tasks, but that part of the explanation for such good performance is that these tasks are not particularly diagnostic of the involvement of WM. In addition, learning in these models is very slow, especially when the task requires more than one WM state, raising questions about whether WM could reasonably be learned purely from experience. Nonetheless, one interesting implication of these models is that a larger WM can slow learning by increasing the amount of learning required, potentially explaining why we have a limited working memory capacity. Finally, we propose several ways to increase the performance and learning speed of these models. Hence, we can start testing and comparing learning performance given by these models with human data.

O'Reilly, R. C. and Frank, M. J. (2006). Making working memory work: A computational model of learning in the prefrontal cortex and basal ganglia. *Neural Computation*, 18:283-328.
Todd, M. T., Niv, Y., and Cohen, J. D. (2009). Learning to use working memory in partially observable environments through dopaminergic reinforcement. *Neural Inform Process Syst*, 21:1689-1696.

4. An exploratory approach to understanding working memory and classroom achievement in young children.

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Working memory and complex span tasks are predictive of academic performance and classroom behaviour, and in themselves, complex span tasks are likely to reflect a large number of skills and processes. In this study, we sought to determine the relative contribution of a wide ranging set of skills and abilities to both complex span performance and academic and behavioural measures. 218 children in Years 2 and 3 of mainstream primary school (aged 6-8) completed reading and mathematics tests, and teacher reports of classroom behaviour were provided for each child. A battery of tests designed to estimate primary and secondary memory, verbal and visuo-spatial processing speed, rehearsal rate, and forgetting rate, alongside traditional and novel complex working memory tasks were also completed by each child. Two measures of each construct were tested in order to provide construct reliability for exploratory factor analysis and structural equation modelling. The associations between each construct and their relative contribution to complex span performance and classroom measures will be discussed, with an aim to understanding how the large set of skills which go towards working memory capacity interplay in our understanding of children's achievement.

5. Benefits of a working memory training program for inattention in daily life: a systematic review and meta-analysis

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Background. Many common disorders across the lifespan feature impaired working memory (WM). Reported benefits of a WM training program include improving inattention in daily life, but this has not been evaluated in a meta--analysis. This study aimed to evaluate whether one WM training method has benefits for inattention in daily life by conducting a systematic review and meta--analysis.
Methods. We searched Medline and PsycINFO for studies with an intervention and control group reporting post--training estimates of inattention in daily life. To reduce the influence of different WM training methods on the findings, the review was restricted to trials evaluating the Cogmed method. A meta--analysis calculated the pooled standardised difference in means (SDM) between intervention and control groups.
Results. A total of 561 studies were identified and 9 studies with 10 group comparisons met inclusion criteria and were included in analyses. The meta--analysis showed a moderate and significant training effect on inattention in daily life, SDM=--0.55, 95% CI --0.77, --0.33, p<.00001. Subgroup analyses showed

this effect was observed regardless of methodological and participant characteristics examined. Five studies reported follow--up assessment and a meta--analysis showed persisting training benefits for inattention in daily life, SDM=--0.37, 95% CI --0.64 --0.09, p=0.008. An additional meta--analysis confirmed improvements on non--trained WM tasks after training, SDM=0.87, 95% CI 0.46, 1.29, p<0.0001.
Conclusions. Benefits of a WM training program generalise to improvements in everyday functioning. We show that a working memory training method has significant benefits for inattention in daily life with a clinically relevant effect size.

6. Circadian and homeostatic effects on different subsystems of the multiple component working memory model and fractionated executive functions

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We investigated circadian and homeostatic sleep pressure effects on performance of tests that tap different subsystems of multicomponent model of working memory (WM), including measures of executive updating, shifting, and inhibition of prepotent responses during 36 hours of continuous wakefulness (08:00h-20:00h the following day). We also assessed how they related to attentional changes (simple attention, arousal, vigilance, wakefulness), mood, and metacognition. Participants were 21 young, healthy males of indifferent chronotype. The only WM measures not to show circadian rhythmicity related to spatial storage in WM an executive shifting. All others displayed singular rhythms that did not parallel attentional circadian effects, except for phonological and visual storage. Only inhibition and working memory capacity measures were sensitive to sleep pressure, performance having been worse in the morning after sleep deprivation, thus differing from the attentional impairment which became evident from the sleep deprivation night. Only positive mood was decreased. Changes in mood, perceived time constraints and reported cognitive effort involved in the tasks could not explain the patterns of circadian rhythms, nor of sleep deprivation-induced impairment. Overall we found most WM subsystems and executive domains exhibit different circadian rhythmicity, that few are susceptible to sleep deprivation, and that these patterns of effects were not similar to those of changes in attention (simple attention/arousal/vigilance/wakefulness), nor of subjective ratings of mood. These results may serve as a guide for the selection of optimum times off day to evaluate WM and executive functions and have implications for situations in which acute sleep deprivation is involved.

7. The executive function of updating information in working memory for the serial order of visual and spatial events

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We sought to investigate the involvement of the executive function of updating information in memory for the order of visual and spatial events. The participants performed visual and spatial primary memory tasks under interference of secondary executive tasks of choice reaction time (CRT) and tasks of updating information (one-back choice reaction time – CRT-1). The similarities between visual and spatial serial memory results were: primacy and recency in serial position curves; frequent errors of transposition in one item; detrimental effect of increasing the size of the sequence; performance impaired by the interference in the executive resources, especially those designed to support the executive function of updating information. The differences between the two types of serial representation were: smaller capacity and precision in the representation of visual items as compared to the spatial characteristics; the vulnerability of visual memory to the increasing the amount of items is bigger than in spatial memory; and for visual memory there is not a clear differentiation between the effects of two types of executive interference (CRT and CRT-1) as could be determined for the spatial task. We conclude that executive resources of updating information are part of the mechanisms involved in the registration of the serial order of visual and spatial events. The visual memory has a mechanism for registration of serial order similar to spatial memory, and the differences between the two patterns of performance are attributed to the maintenance of identity of the items, and not the maintenance of serial order.

8. Investigating the irrelevant speech effect with visual statistical learning: A test of the object-oriented episodic record model and the distraction hypothesis

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The irrelevant speech effect (ISE) is the phenomenon where serial recall performance is impaired when irrelevant auditory material is concurrently presented with the target visual stimuli. Using a task of visual statistical learning, the current study aimed to test two accounts of the ISE – the object-oriented episodic record model (O-OER) and the distraction hypothesis. The questions of interest were whether familiarity of language and a change in the irrelevant speech stream would affect performance, as predicted by the distraction hypothesis but not the O-OER. Sixty-nine undergraduates watched a sequence made up of 219 geometric shapes under one of five sound conditions (silence, English steady-state, English changing-state, Mandarin steady-state, Mandarin changing-state) and were tested on their learning of the statistical regularities in the sequence. Contrary to the literature, no ISE was found in the current study; performance in the silent condition was no better than the irrelevant speech conditions, and performance with steady-state irrelevant speech showed no advantage over that with changing-state irrelevant speech. No difference in performance between the English and

Mandarin conditions was observed, and there was also no drop in performance when irrelevant speech was changed. However, it is noted that accuracy rates were low in general and there was a substantial proportion of chance-level performance, making it difficult to determine the effects of the experimental manipulations. Further studies incorporating the suggestion for an additional task to help boost performance levels could help to clarify the nature of the ISE, and whether explicit and implicit tasks both involving the retention of serial order information are affected differentially by it.

9. Working memory in first and second language: Towards an integrated model

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The present paper draws on nomothetic theories of WM in cognitive psychology and research findings in psycholinguistics and second language acquisition (SLA) to propose a theoretical framework for conceptualizing and measuring WM in first and second language research. The central tenet of this integrated WM-Language framework lies in its postulation that the phonological component of working memory (PSTM; embracing a phonological short-term store and an articulatory rehearsal process) plays an instrumental role in the *acquisition* and *developmental* aspects of first and second language domains such as vocabulary, formula/chunks and grammar. The executive component of working memory (EWM; subsuming such executive functions as attentional regulating, task-switching, inhibitory control), on the other hand, is most evident in some *post-interpretive language processes* and real-time *performance* aspects in such areas of listening, speaking, reading, writing, and interpreting.
Couched within this dichotomy of the Phonological/Executive WM distinction (i.e. the P/E Model; Wen, 2012, 2013, 2014) are also some general guidelines as well as more specific stipulations for implementing measurement procedures. For example, the P/E model proposes to adopt a simple memory span task (i.e., the nonword repetition span task) to measure PSTM and a complex memory span task (e.g., the reading span task, the operation span task) to measure EWM. The P/E model also proposes a hierarchical view on implementing WM measures according to participants' *age* (in WM-L1 studies) and L2 proficiency (in WM-SLA studies). Overall, it is argued here that, when the two most directly implicated WM components (i.e., PSTM and EWM) are thus pinned down and their associated functions/mechanisms further aligned with specific first and second language domains and activities, we can proceed to formulate *novel, specific* and *testable* hypotheses regarding their intricate relationships.

10. Working memory and the ability to follow spoken instructions

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The aims of this study were to investigate the role of working memory in carrying out sequences of commands and to identify the optimal method for presenting multi-step instructions to children. To this purpose a modified version of Gathercole et al.'s (2008) following instructions paradigm was used in which the modalities of presentation and recall were manipulated. At encoding, instruction sequences were either spoken aloud by the experimenter, or spoken by the experimenter and performed by the participants. At recall, participants were asked either to repeat the instructions, or to perform the actions in sequence. Children's performance was enhanced by both the enactment of instructions at encoding and executing actions at recall. The absence of an interaction between presentation and recall suggests separate mechanisms are involved in encoding and retrieving sequences of instructions. The ability to verbally recall spoken instruction sequences was associated with verbal aspects of working memory, but there was no association between the enactment or action recall of instruction sequences and working memory. It is speculated that an as yet unspecified component of working memory may be responsible for the temporary storage of spatial-motoric representations.

Gathercole, S. E., Durling, E., Evans, M., Jeffcock, S., & Stone, S. (2008). Working memory abilities and children's performance in laboratory analogues of classroom activities. *Applied Cognitive Psychology*, *22*, 1019-1037.

11. White Matter Structural Network Connectivity of Prefrontal Cortex Predicts Individual Differences in Working Memory Capacity

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Recent studies have found that inter---individual differences in working memory capacity (WMC) can be partly attributed to differences in attentional processes that are involved in filtering of irrelevant information (1---3). Irrelevant information consumes unnecessary WMC and the extent to which only relevant information is stored, may form a basis for WMC (2, 4). It has been argued that a network of prefrontal cortex (PFC), basal ganglia (BG), and thalamus (Th) might exert attentional control over working memory storage in parietal cortex (PPC), and filter unnecessary information (2, 4). While this account is supported by studies using functional imaging it remains unknown whether this filtering mechanism is also reflected in the anatomical structure of white matter networks.

Here, we investigate the contribution of large---scale, white matter connectivity networks to individual WMC differences (N=70). Using graph---theoretical analysis of probabilistic diffusion tractography, we found that network centrality of the ventro---lateral PFC is positively correlated with individual WMC ($r = .42$, $P < .0001$). Individuals with higher WMC show greater PFC connectivity within a network of subcortical regions, than individuals with lower WMC. While we found no overall differences in PFC---PPC connectivity, a 'simulated lesion analysis (disrupting white matter tracts through BG and Th), revealed that individuals with higher WMC have more indirect PFC---PPC connections that pass through these subcortical regions. These results are in line with the attentional filtering account and show that more efficient filtering processes in individuals with higher WMC are also reflected in the underlying anatomical network organization.

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McNab F & Klingberg T (2008) Prefrontal cortex and basal ganglia control access to working memory. Nat Neurosci 11:103---107. 3. Vogel EK & Machizawa MG (2004) Neural activity predicts individual differences in visual working memory capacity. Nature 428:748---751. 4. Vogel EK, McCollough AW, & Machizawa MG (2005) Neural measures reveal individual differences in controlling access to working memory. Nature 438:500--- 503.

12. Decoding Mental States and the Distributed Account of Working Memory Storage

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The storage buffers retaining working memory contents were originally postulated to reside in prefrontal cortex, but a dissenting view has evolved that assumes the distributed storage of sensory input in more sensory-driven brain regions. Importantly, storage of memory content in a given area can only be demonstrated by directly showing that neural activity specifically represents the contents held in working memory. Recently, our group (amongst others) has performed a series of experiments investigating the content-specificity of ongoing activity across the whole human brain using multivariate Decoding methods applied to fMRI data. We found evidence for storage of visual contents in occipital and parietal areas, but not prefrontal cortex.
Here, using meta-analytic techniques we revisited our results. We show evidence for a distributed network engaged in retaining visual contents. We compared the information a given brain areas holds across studies using different forms of content (color, motion and shape) to reveal common and unique storage systems across occipital, temporal and parietal cortex. In addition, we investigated the role

of prefrontal brain areas employing conjunction analyses across studies and found evidence for a role in both working memory storage and control.
This evidence can be combined with data from other groups using hemodynamic and electrophysiological signals in both humans and monkeys. In summary, the data currently available can be interpreted as evidence for a distributed representation of working memory contents that does not critically depend on storage in prefrontal cortex but might be heavily influenced by prefrontal control circuits.

13. The focus of attention in working memory and perceptual attention: Spatial priority is shared, but representations are distinct.

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Recent work has highlighted the processes of selection and priority as a point at which the mechanisms underlying WM and perception interact: a) a single-item 'search template' can bias perceptual input in visual search (Olivers & Eimer, 2011); and b) a common neurophysiological component is associated with the selection of an item in both WM and in a perceptual scene (Kuo, Rao, Lepsien & Nobre, 2009). Here, we examine whether holding an item in priority in spatial WM is dependent upon perceptual attention. Participants updated the locations of two objects in a grid through a sequence of updating operations, each mentally shifting one object to a new location according to an arrow cue. In Experiments 1 and 2, the arrows were presented in a randomly selected cell of the grid. Reaction times were faster when updating the same object in two successive steps compared to switching between objects, reflecting a cost of shifting attention in WM. This switch cost was independent of where the arrows were presented, though faster RTs were observed when the location of the arrow cue coincided with the object being updated. Experiments 3 and 4 revealed that the switch cost is not reduced when multiple arrow cues must be discriminated in peripheral locations. Together these results imply that the focus of attention in WM can be dissociated from perceptual selection. We account for these data with a framework in which perceptual attention and WM are separate mechanisms but interact through a shared spatial priority map.

14. Neural correlates of working memory capacity for features and conjunctions

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Previous work has shown differences in evoked and induced neural activity during visual working memory (WM) for object compared to spatial information, and

during integration of stimulus features in visual WM. Other work has shown that the neural mechanisms underlying WM are influenced by WM capacity. However, it is not clear how WM capacity affects the ability to integrate different types of information in WM. This study used magnetoencephalography (MEG) to examine the neural correlates of visual WM capacity for features and conjunctions. Participants had to memorise either the colour, the orientation, or both the colour and orientation (conjunction task) of 2 or 4 coloured shapes. Then, after a short delay, a single shape appeared and participants had to indicate whether this shape matched the colour, orientation, or both colour and orientation of one of the previous shapes. Accuracy decreased as the number of shapes in the encoding array increased, however performance on the conjunction task was equivalent to performance on the single feature tasks at both levels of WM load, consistent with parallel processing of object and spatial WM representations. Beamformer source analysis of the MEG data showed specific spatiotemporal profiles of neural activity during WM for different stimulus features, and this neural activity was modulated by WM load. Of most interest, WM load appeared to have a greater effect on the neural processes underlying WM for conjunctions, suggesting an increased demand on cognitive resources for feature integration as WM nears capacity limits.

15. School effects on working memory and academic test in children

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The aim of this research was to compare Working Memory (WM) and academic test performance considering kind of school (public and private) in Salvador-Brazil. Two-hundred and seven children (7-12 years old) took part is this study being 153 from private and 54 from public schools. A questionnaire was applied to check development factors and only children with typical development were included. Another questionnaire checked children socioeconomic status (SES). To evaluated WM, Digit Span (forward and backward) and Corsi Block (forward and backward) were used. To assess academic abilities (reading, writing and arithmetic) a Brazilian standardized instrument, the test of academic performance (TDE, in Portuguese) was used. All assessments occurred in schools in Salvador-Brazil. We made descriptive and inferential statistic data analysis using SPSS package. Children studying in private schools were from high SES level families (income/month: $2850.00 to $4760.00) with high parental educational level and children from public schools were from low SES level (income/month: $ 286.00 to $ 571.00) with low parental educational level. The results showed significant differences between public and private schools ($p \leq 0,01$) in all measures of WM and academic tests. Another analysis showed WM as a good predictor of the academic tests scores. Together, these results indicate that kind of school influences the capacity of WM and consequently, children learning capacity. This study points out that the kind of school may interfere on the ability of WM and cognitive function and may have an effect on learning capacity on writing, reading and arithmetic.

16. Music and Working Memory

Catherine Jordan
University of Edinburgh

Exploring short-term memory through the multicomponent model of working memory (Baddeley, 2000; Baddeley & Hitch, 1974) presents the opportunity to discover the influence of music training and practice on the processing and maintenance of information within such a system. The present study compared musician's performance on melody recognition tasks to non-musicians. In experiment 1A, an auditory recognition task was presented to both musicians and non-musicians, under three conditions: control, humming and singing suppression. Singing suppression had greatest impact to non-musicians performance of the task. A second experiment examined musician's ability to encode a visual melody, transform the visual melody into an auditory melody, after a retention interval of 10 seconds perform a recognition task. Across the three conditions as per experiment 1A, singing suppression showed greatest interference during the visual task. These preliminary results suggest a difference between musicians and non-musicians working memory system. It is possible the phonological loop may be enhanced due to music training, hence musicians superior performance on such tasks, compared to non-musicians. However, to further explore these results, a follow up experiment will incorporate a similar experimental design, under three conditions, control, singing suppression and articulatory suppression with the view to further explore musicians superiority on tests of working memory and also, discover the possible existence of a tonal loop within a musicians working memory system.

17. A training study to enhance verbal short-term memory performance in individuals with Down syndrome, using phonological and semantic associations.

Liz Smith and Chris Jarrold
University of Bristol

Individuals with Down syndrome (DS) tend to experience specific difficulty in the verbal short-term memory (vSTM) domain, this study aimed to enhance vSTM performance, via teaching memory strategies using a memory aid. 20 individuals with DS (age 5-30 years) participated in this study, half were in an active control condition, subsequently participating in the training condition, while half participated only in the training condition. Participants' memory span was recorded once weekly for 3 weeks pre-training and 3 weeks post-training. During training, participants were presented with a story board depicting a path running through a park. Along the path were 3/4 pictures each representing a serial position, in part of a story. In two training stages, a. Phonological, and b. Semantic, participants were presented with auditory lists of items to remember. In stage 1 each item was associated phonologically to the picture of corresponding serial position on the story board, thus, item 1 rhymed with picture 1, item 2 rhymed with picture 2. In stage 2 each item was associated semantically to the item of corresponding serial position on the story board. Participants were taught and encouraged to use these associations. An identical procedure was used in the active control condition,

however participants were shown irrelevant abstract pictures on the story board; with no strategies encouraged. The ability of individuals with DS to benefit from a conceptual aid for ordered recall and to develop associative links involving either phonology or semantic knowledge during vSTM tasks will be discussed.

18. The effect of periodic auditory alerts on the multitasking performance of older adults

Dr Anna Law,
Liverpool John Moores University

Multitasking refers to the ability to switch attention between multiple tasks within a limited time frame. It is important in activities such as cooking and shopping, which can become challenging for older adults experiencing declines in working memory and executive function. The present study tested a potential intervention to improve the multitasking performance of older adults. Thirty-six adults aged 61-79 years (M = 68.9, SD = 5.59) performed a test of multitasking that involved switching between four simple sub-tasks while following a set of rules. The experimental group were presented periodically with 'content-free' cues (auditory tones) during the execution of a multitasking test. This intervention has previously been shown to improve the performance of dysexecutive patients on a similar test (Manly et al., 2002). Relative to a control group, the presence of the alerts led to a small increase in switching between sub-tasks, but there was no evidence of significantly greater multitasking efficiency, where efficiency was measured by the proportion of completed items that were coloured red. (Participants were instructed to collect red items in each sub-task, as these attracted a higher score.) Verbal working memory capacity was positively related to participants' initial learning of the rules, and to the frequency with which they switched sub-tasks, but not to efficiency. Further research is needed to test interventions that may facilitate efficient multitasking, particularly for older adults and other groups who may struggle with this important type of everyday activity.

Manly, T., Hawkins, K., Evans, J., Woldt, K., & Robertson, I. H. (2002). Rehabilitation of executive function: Facilitation of effective goal management on complex tasks using periodic auditory alerts. *Neuropsychologia, 40*(3), 271-281.

19. Hemispheric remapping in VWM across changes in attention and eye position.

Brittany J. Dungan & Edward K. Vogel
University of Oregon

We perceive a stable world despite frequent shifts in eye position and attentional focus that cause objects to be translated between visual fields. This study investigated how such translational shifts in eye position affect which cerebral hemisphere represents attended objects. Specifically, we tested two alternative remapping hypotheses that (1) items are immediately remapped to the new hemisphere or (2) items linger in the initial encoding hemisphere. We examined hemispheric remapping following changes in both eye position and attentional

focus by monitoring a sustained working memory component (Contralateral Delay Activity; CDA) of the event-related potential while subjects performed a change detection task where items remained visible throughout the trial. In eye movement blocks, subjects either maintained central fixation throughout the retention period, or were cued to refixate a new position 7 degrees to the left or right of central fixation **(**bringing the objects into a new visual field). In attention movement blocks subjects maintained central fixation and either attended an initially cued set of items in one hemifield throughout the trial, or were cued to shift their attention to items in the opposite visual hemifield during the middle of the retention period. The eye movement blocks showed a sustained CDA persisting in the original contralateral hemisphere even after the subjects refixated. However, the attention movement condition showed a rapid flip in CDA polarity upon a shift to a new visual field. These results support an immediate remapping for inter-hemispheric attentional shifts but a delayed remapping for eye movement shifts.

20. Working Memory Profiles and Use in Rural and Urban Poverty

Michele Tine, Ph.D.
Dartmouth College

A study was designed to investigate if children living in rural and urban poverty 1) exhibit different working memory profiles and 2) utilize verbal and visuospatial working memory in different ways when completing mathematics and reading tasks. Verbal and visuospatial working memory tasks and reading and mathematic tasks were administered to children living in lowincome rural, low-income urban, high-income rural, and high-income urban developmental contexts.

Both low-income rural and low-income urban children showed working memory deficits, but their deficits were distinct. See Figure 1. Low-income urban children exhibited symmetrical verbal and visuospatial working memory deficits compared to their high-income urban counterparts. Meanwhile, low-income rural children exhibited asymmetrical deficits when compared to their high-income rural counterparts, with more extreme visuospatial working memory deficits than verbal working memory deficits.

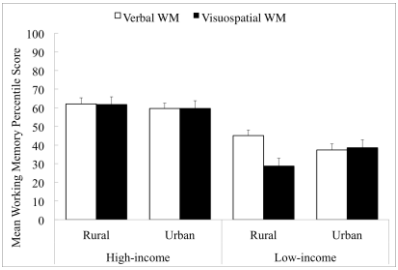


Figure 1. Mean Verbal and Visuospatial Working Memory Percentile Scores as a Function of Developmental Context

Preliminary results also suggest that children living in rural and urban poverty differ in the ways they utilize their working memory. Specifically, children living in rural poverty showed a stronger relationship between verbal working memory and mathematics than between visuospaital working memory and mathematics. However, children living in urban poverty showed the opposite pattern.

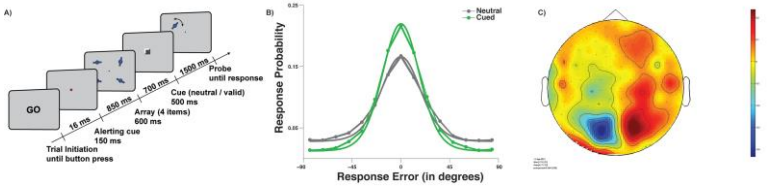
The findings suggest that different types of poverty are associated with different working memory abilities and utilization patterns. The findings also lend credence to Baddeley and Hitch's model of working memory; even though verbal and visuospatial working memory did not differentiate in the low-income urban sample, the fact that they can differentiate, as evidenced in the low-income rural sample, supports that they are related, but distinct cognitive processes.

21. Control of Working Memory in Ageing.

Robert M. Mok[12], Nicholas E. Myers[12], Anna C. Nobre[12]
University of Oxford

Working memory (WM) abilities decline as we age. Studies in younger adults have shown that top-down attention can improve WM performance. However, the ability to control attention in WM has not previously been studied in older adults. Preserved attentional mechanisms operating within WM may provide vehicles for the development of interventions to counteract cognitive decline. To study the neural mechanisms of WM in ageing, a large sample (N=75) of older adults (60 years+) performed a precision WM task with or without an attention-guiding cue whilst undergoing a magnetoencephalography (MEG) scan. Cues presented in the maintenance period of the trial (retro-cues) conferred a significant advantage for WM performance, suggesting preserved attentional mechanisms in older adults. A model based analysis revealed that retro-cues i)increased the probability that one could report a probed item, ii)decreased the probability to mis-report the non-target items (mis-binding), and iii)decreased the guess rate. Retro-cues did not significantly affect precision of the remembered item.

Preliminary results in the MEG data show that alpha oscillations (8-14Hz) after a retro-cue or a neutral cue indexed attentional orienting to the cued item location. These preliminary data suggest that relatively intact WM control mechanisms may correspond to similar attentional mechanisms in younger adults.



22. Working memory training: Is it strategic?

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Adaptive computerised training has been associated with significant enhancements in working memory, but the nature of the cognitive changes that underpin these improvements are not yet fully understood. In two studies we investigate the possibility that training stimulates the development of strategies. In Study 1, 20 participants completed four tests of working memory before and after 10 sessions of working memory training. Open-ended interviews about strategy use were conducted after each working memory task at both pre- and post-training. Following training, there were significant improvements in all four working memory tasks, and a significant increase in the number of participants using chunking post-training. Study 2 was a randomised controlled trial, with participants receiving either adaptive working memory training, non-adaptive working memory training with low memory loads, or no training. Adaptive training was associated with selective improvements in untrained tests of working memory accompanied by a significant increase in the use of chunking reported for verbal and visuo-spatial short-term memory and verbal working memory tasks. These results indicate that training related improvements in working memory may be, in part, mediated by implicit and spontaneous changes in the use of chunking strategies.

23. Whole-report procedures reveal trial-by-trial variability in capacity and precision of visual working memory

Kirsten C. S. Adam , Irida Mance, Edward Awh, & Edward K. Vogel
University of Oregon

Most estimates of visual working memory (WM) capacity have relied on partial---report procedures in which an observer is tested on a single item from a multi---item array. Whole---report procedures (testing all items) could provide richer information about within and between---trial variability in WM performance, but concerns about output interference have mostly precluded the use of these tasks. Here, we measured memory performance with a whole---report procedure to directly test whether or not output interference is a major concern. Using responses from all items in the multi---item array, we examined variations in memory quality for items within set---size arrays (Set Sizes 1,2,3,4, and 6). All items were presented simultaneously, but they were reported sequentially. The order of response was either (1) randomly chosen by the computer or (2) freely chosen by the participant. Participants reported features on a continuous scale (360 degrees of color or orientation space), and distributions of errors were fit with a mixture model distribution to estimate both probability of storage and precision. Critically, no reliable effects of response order were observed with random recall order, indicating that output interference alone does not alter representational quality in this task. Free recall responses, on the other hand, revealed systematic variability in representational quality. A bimodal pattern of high--- and low---precision representations was directly related to individual estimates of capacity

and to subjects' confidence of item memory. Together, these results provide support for a model that includes both discretely remembered items and variability in mnemonic precision among remembered items.

24. Examining the neural signatures of trial-by-trial variability in task performance using a whole report procedure.

Irida Mance, Keisuke Fukuda, & Edward K. Vogel
University of Oregon

Individual differences in visual working memory (VWM) capacity are an important predictor of higher order cognitive functioning. Consequently, research has focused primarily on how inter-individual differences are related to task performance, with little work examining how intra-individual differences may also be contributing to performance. One reason for this may be that trial-by-trial variations in performance have been difficult to quantify using partial report tasks such as change detection or cued recall, in which only a single item is probed. Here we examined within-subject variability using a whole report task, in which subjects reported the identity of each item following a brief memory delay. Behavioral results indicated that while the modal number of three items was correctly recalled, there was a substantial proportion of trials in which subjects recalled fewer or greater items than this mode. Additionally, we recorded EEG from subjects to examine whether this within-subject variability in performance reflected trial-by-trial variation in neural activity during the maintenance period. Time-frequency analyses indicated that power in the 8-12Hz frequency band decreased as a function of number of items subjects were asked to remember. We used a linear classifier on the bandpassed individual trial EEG and found it could reliably distinguish between the number of items subjects were asked to recall. Our results suggest that memory capacity is not fixed across trials and that trial-by-trial variability is partially driven by variations in the sustained 8-12Hz desynchronization during memory maintenance.

25. Visuospatial Bootstrapping: links between verbal and spatial memory during digit recall

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Baddeley and Hitch's working memory model proposed segregation between modality specific slave systems. Subsequently, it has become clear that some tasks require the co-ordination of information across segregated stores. 'Visuospatial Bootstrapping' (Darling et al, 2012), is a simple test of verbal immediate serial recall which compares performance between two visual presentation conditions. Memory is better when digits are presented using a familiar, spatially distributed array like a telephone keypad. This pattern has been taken to be supportive of the existence of channels that link long term and short term visual representations with verbal memory.

This poster describes three experiments further exploring visuospatial bootstrapping. Experiment 1 showed that spatial interference (tapping) removed the beneficial memory effect of presenting information in a keypad array, whilst Experiment 2 demonstrated that verbal interference (articulatory suppression) did not.
Experiment 3 investigated the effect of presenting spatial interference during retrieval, but not during encoding. Initial results suggest that tapping at retrieval did *not* eliminate the bootstrapping effect. Consequently, given the results of Experiment 1, it is likely that links between visuospatial and verbal representations were established either at encoding or during maintenance.
This pattern of results indicates communication between memory systems during encoding and maintenance, whilst effects of verbal and spatial interference are most easily interpreted within a model that incorporates multiple modality specific subsystems. Overall these data support recent models describing the role of the episodic buffer in working memory (Baddeley, et al, 2011).

Baddeley, A.D., Allen, R.J., & Hitch, G.J. (2011). Binding in visual working memory: The role of the episodic buffer. *Neuropsychologia, 49*, 1393-1400]
Darling, S., Allen, R.J., Havelka, J., Campbell, A., & Rattray, E. (2012). Visuospatial Bootstrapping: Long Term Memory Representations are Necessary for Implicit Binding of Verbal and Visuospatial Working Memory. *Psychonomic Bulletin & Review, 19*, 258-263.

26. Mathematical ability in children with agenesis of the corpus callosum: the unique contribution of working memory

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[2] University of Melbourne, Melbourne, Australia
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[4] The Royal Children's Hospital, Melbourne, Australia
[5] University of Birmingham, Birmingham, United Kingdom
[6] Swinburne University of Technology, Melbourne, Australia

Background: Mathematical ability is underpinned by a network of interacting left and right brain regions in typically developing children. The corpus callosum is the largest commissure connecting the two hemispheres and crucial for transfer and integration of information across the brain. Developmental absence (agenesis) of the corpus callosum (AgCC) is a congenital brain malformation resulting from disruption of corpus callosum formation. This study aimed to: 1) describe mathematical ability and 2) examine the role of cognitive abilities (working memory (WM), nonverbal reasoning, processing speed) and status of cerebral commissures (corpus callosum, anterior, hippocampal commissures) for understanding mathematical ability in children with AgCC. Methods: Eighteen children with AgCC (partial AgCC n=9, complete n=9) 8 to 15 years were recruited from the Royal Children's Hospital, Melbourne. Cognitive and mathematical abilities were estimated using standardised tests. Brain MRI was reviewed qualitatively. Results: Preliminary analyses showed that children with AgCC performed 1.7 SD

below the test mean for mathematical ability (p<.001). Regression analyses revealed that WM (p=.002) and nonverbal reasoning (p=.04) predicted mathematical ability, but the contributions of processing speed and status of cerebral commissures were nonsignificant. The significance of the WM prediction persisted after accounting for nonverbal reasoning (p=.024), and in this model the contribution of nonverbal reasoning reduced to nonsignificant. Conclusion: Mathematical ability is impaired in children with AgCC. WM is a unique and significant predictor of mathematical ability in children with AgCC, possibly reflecting an overlap in brain networks underpinning these abilities. Status of cerebral commissures do not predict mathematical ability.

27. The contribution of specific working memory components to academic achievement of Chinese and English learning in Chinese 2ed to 4th graders

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[2] Nanjing University, Nanjing, China

The contribution of the three components of working memory to the academic achievement of Chinese and English learning in Chinese primary school students was explored this study. 170 children grade 2, 3 and 4 were assessed using working memory measurements. and Chinese (native language) and English (second language) Academic achievements were assessed with school exam scores. For 2ed graders, phonological loop and visuospatinal pad components predicted English achievement and phonological and central executive components predicted Chinese achievement. For 3rd graders, visualspatial pad predicted English achievement and phonological loop predicted Chinese achievement. For 4th graders, central executive component became only predictor for both Chinese and English. The results suggests with increasing of grade, the the working memory components contributing to academic achievement of Chinese native language and English as second language learning changed from domain specific storage to domain general central executive. Implications for teaching and learning are discussed.

28. Shape and spatial working memory have separate storage resources

Motoyuki Sanada, Koki Ikeda, and Toshikazu Hasegawa
The University of Tokyo

Whether visual working memory shares a common storage resource or consists of multiple subsystems has been a controversial issue. Logie (1995) suggested that it can be divided into visual (for color, shape, object, etc.) and spatial working memory (for location). However, a recent study reported evidence against this hypothesis. Using a dual task paradigm, Wood (2011) showed interference between shape and spatial working memory capacities, suggesting that they share a common resource limitation. However, the spatial working memory task adopted in this study contained a critical methodological concern. Since multiple white dots appeared simultaneously on the screen to indicate the locations to remember,

participants might have encoded them as a shape formed by these white dots rather than separate spatial points. If this was the case, the observed interference might have simply occurred between two shape working memory tasks. To critically examine this factor, we replicated the study of Wood (2011) with one crucial change in the way to present the location information. White dots were shown sequentially, not simultaneously, to prevent shape imagery formation, and the shape-location interference was tested again. Contrary to the previous report, no interference between the two tasks was found, and this finding was replicated across two experiments. These results indicate that the capacity resources of spatial and shape working memory systems are independent from each other, providing strong support for the theory of Logie (1995).

29. A componential analysis of working memory and different mathematical abilities in children

Erica Bottacin[a], MSc; Prerna Menon, MSc[b]; Meesha Warmington, PhD[c]; Graham Hitch[c]

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[b] University of Oxford
[c] University of York

Although the role of the multi-component working memory (WM) construct in relation to mathematics has been examined in a number of studies, the specific contribution of each WM sub-component still remains unclear. One issue is that most studies have used mathematical achievement tests that encompass different mathematical skills and processes, thus potentially tapping onto different cognitive systems. Such an approach is uninformative for clarifying the relationship between WM and mathematics. In the present study we addressed this issue by investigating children's ability to perform single-digit arithmetic, arithmetic word-problems and algorithmic computations and assessing the different components of WM together with reading and IQ as predictors of these abilities. One hundred and fourteen 7-10 year-olds were assessed on the three mathematical skills and on measures of verbal WM, phonological loop, visuo-spatial sketchpad (VSSP), reading and IQ. Path analysis models suggested an incremental structure of mathematical abilities, with contributions from arithmetic to word problems and algorithmic computation. The model that provided the best fit to the data showed that each mathematical skill was predicted by a different composition of cognitive measures: reading and verbal WM accounted for 29% of the variance in simple arithmetic; reading, IQ and arithmetic explained 38% of the variance in word problem solving; reading, IQ, VSSP, and arithmetic accounted for 55% of the variance in algorithmic computation. The results illustrate the importance of treating mathematics as a collection of skills and competences each requiring a different ensemble of cognitive mechanisms in place in order to reach age-appropriate levels.

30. The language modality specificity of working memory

Mary Rudner & Jerker Rönnberg
Linköping University, Sweden.

Working memory is fundamental for communication. Although most hearing individuals prefer speech communication, sign language may be the natural communication choice for many deaf people. Both auditory deprivation and preferred language modality influence cognitive development. The functional structure of working memory and its neural representation have been studied extensively in relation to speech-based languages and a smaller body of work has investigated working memory for sign language. Signed languages are natural languages whose structure can be described in the same linguistic terms that can be applied to speech-based languages. For example, phonology can be generally described as the sublexical structure of language. In speech-based language this refers to the patterning of speech sounds but in signed language it refers to the form, position and movement of the signing hands. Despite these apparent surface differences, there is evidence of supramodal representation and processing of phonology as well as a "phonological loop" for sign language. It is sometimes assumed that iconicity of signs makes them more semantically available than words. Although research has shown that this does not seem to be the case for sign language users, some phonological elements of signs may bear semantic information. For example, signs located at the head may refer to cognition. Although the capacity of working memory and its neural representation is generally similar across language modalities, there are modality-specific differences relating to both phonological and semantic processing. These may be partly explained by the close link between phonology and semantics in sign language.

Session III

1. Exploring the symmetry and temporal dynamics of verbal-spatial bindings in working memory

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[2] University of the Balearic Islands, Spain

Verbal-spatial bindings are integral to routine cognitive operations (e.g., reading), yet relatively little is understood about the processes supporting them in working memory (WM). We recently reported on data suggesting the obligatory binding of letters to locations when participants were directed to remember the letters in an array of letters in locations, but no binding of locations to letters when participants were instructed to remember only the filled locations; an effect referred to as binding *asymmetry* (Campo et al., 2010). The present study contrasted two explanations for the binding asymmetry effect. First, it may result from an obligatory dependence on "where" information during the representation of "what" information in WM, while "where" information may be held independently of its contents (the *strong asymmetry* hypothesis). Second, it may constitute a snapshot of a dynamic binding process that had only partially completed by test. Indeed, Logie et al. (2011) suggested that bindings flexibly change over time through a gradual feature inhibition process – one that took longer for "where" features than "what" features (the *asymmetrical inhibition* hypothesis). Using a modified change detection paradigm (Campo et al., 2010) with a variable retention interval between display and test, we presented participants with four consonants in distinct locations and contrasted performance between "remember letters" and "remember locations" instructions. Our data supported the *strong asymmetry* hypothesis through demonstrating binding in the 'remember letters' task, but not in the 'remember locations' task. Critically, when present, verbal-spatial bindings were remarkably stable, enduring in WM for at least 15 seconds.

2. Differential effects of task-irrelevant emotions on the precision of working memory representation

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It has been suggested that the precision of the encoded representation in visual working memory varies across trials and conditions depending on random fluctuations of alertness and attention. We hypothesized that task-irrelevant emotional stimuli modulate the precision of working memory representations by tuning the deployment of resources for the task. Using a delayed-estimation task (N = 17) where task-irrelevant emotional vocalizations were presented during the maintenance period, we observed that positive stimuli (vs neutral) reliably

increase response precision ($p < 0.05$). Interestingly, emotions did not affect the guessing rate and interacted with the task only when the load condition reached and exceeded individual working memory capacity. As follow up, we sought to identify the impact of affectively laden stimuli on the quality of the representation when task-irrelevant emotions are presented during different phases of the working memory task, i.e., encoding, maintenance or retrieval. The results suggest that emotional stimuli of positive valence reduce the noise of the encoded information as compared to negative and neutral stimuli when presented during both encoding and maintenance, but they have a detrimental effect when presented during the retrieval phase of the task. Our observations support the predictions of the variable-precision model and indicate the importance of investigating different working memory sub-processes for thoroughly characterizing emotion-cognition interaction.

3. Multivoxel coding of rules for working memory manipulation in parietal cortex

C.M. Dodds and C.J.A. Morgan
University of Exeter

Neuroimaging studies have consistently demonstrated that frontoparietal cortex is activated more strongly during the manipulation, relative to the simple maintenance, of information in working memory (WM). However, it is unclear precisely what information is represented in these regions during task performance. In the present study, we tested the hypothesis that the currently implemented rule is encoded in the distributed pattern of activation across frontal and parietal regions activated during WM manipulation. Twenty healthy volunteers performed a WM task in the MRI scanner requiring, on each trial, maintenance of a string of four letters over a short delay, reordering of the letter string according to one of two rules, and a subsequent forced choice (match/mismatch) decision to a probe. Subjects were scanned over ten blocks in an event-related design in which rule order was randomised within blocks. Multivoxel pattern analysis was carried out using an N-minus-one (leave-one-block-out) cross-validation procedure, implemented in the Princeton MVPA toolbox. Results showed that in the absence of any univariate difference between conditions, the identity of the currently implemented rule could be decoded from the voxelwise pattern of activation across parietal cortex. Despite observing activation in prefrontal cortex during task performance, rule identity could not be decoded from the pattern of activation in this region. These results suggest that, in situations where rules apply to the manipulation of information in WM, rule representation may be achieved via distributed population codes in the parietal cortex.

4. Age-related differences on presentation order effects: Evidence from the visual patterns task

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[1] University of Edinburgh
[2]University of Strathclyde

Research suggests that individuals approach working memory tasks differently with age (Johnson, Logie and Brockmole, 2010).
Brown, Forbes, and McConnell (2006) developed a modified visual patterns task (VPT) with easy to name (ETN) and hard to name (HTN) pattern sets.
A series of studies using these pattern sets has shown that younger and older adults demonstrate different patterns of performance depending on the presentation method of these pattern sets. Simultaneous presentation leads to higher performance in ETN compared to HTN sets in both younger and older adults. Sequential *random* presentation removes this difference in both groups. Sequential *ordered* presentation leads to an ETN benefit in older, but not younger adults (Horne, Brown, and Logie - in prep).
Further analysis of this data suggests that the pattern set first presented to participants affects younger and older adults' performance differently. We present the results of a series of studies looking at presentation order effects. Using either simultaneous or sequential *ordered* presentation, younger (18-25) and older (60-75) participants were presented with either ETN or HTN patterns, followed by two neutral pattern sets, then the remaining HTN/ETN pattern set.
Results suggest that older adults display higher maximum spans in the simultaneous task when presented with ETN patterns first. This effect is not seen in the sequential task.

Brown, L.A., Forbes, D. & McConnell, J. (2006) Limiting the use of verbal coding in the Visual Patterns Test. *Quarterly Journal of Experimental Psychology*, 59 (7), 1169-1176.
Johnson, W., Logie, R. H., & Brockmole, J. R. (2010). Working memory tasks differ in factor structure across age cohorts: Implications for dedifferentiation. *Intelligence 38* 513-528.

5. Executive function training improves preschool working memory

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Executive functions (EFs) allow us to maintain and update information (working memory), flexibly adjust our attention (cognitive flexibility), and suppress irrelevant responses (inhibition). Recent research has reported improvements in various EFs after cognitive training during infancy (Wass *et al*., 2011), middle childhood (Dunning *et al*., 2013), and adulthood (Jaeggi *et al*., 2008). However, there is still debate over the extent to which training transfers to structurally different tasks, and how long improvements last for (Shipstead *et al.,* 2012). Furthermore, few training studies have targeted the preschool years, when there are dramatic improvements in EFs (Zelazo *et al*., 2003). The current study sought to address these issues. Thirty-five 4-year-olds were randomly assigned to either a

working memory and inhibition training group, or an active control group. Both groups completed computerised tasks in four sessions over one month. Transfer was assessed by administering non-trained and non-computerised measures of working memory (backward word span), inhibition (peg tapping), cognitive flexibility (SwIFT), and processing speed one week before training, one week after training, and four months after training. The training group significantly improved their working memory from pre-training relative to the control group (p= 0.031). This effect was maintained at a 4-month follow-up (p= 0.041). Children with the poorest working memory at baseline were more likely to maintain this improvement (p= 0.005). These results suggest that working memory may be particularly sensitive to training, and support the suggestion that children with poorer working memory are most likely to benefit from training (Dunning et al., 2013).

6. Benefits of auditory and working memory training to improve cognition, speech perception and self-reported hearing abilities for adults with hearing loss

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One in ten older adults (55-74 years) has a significant hearing impairment, yet just one in three who would benefit from hearing aids (HAs) has them. Auditory training (AT) is an intervention designed to improve listening abilities and alleviate the difficulties associated with hearing loss. For training interventions to benefit people with hearing loss (PHL), any task-specific learning needs to generalise to functional benefits in real-world listening.

A randomised controlled trial (RCT) of n=44 adults (50-74 years) with mild sensorineural hearing loss showed significant on-task learning for a phonemic-discrimination training task ($p<.001$), and generalisation to improvements in self-reported hearing ($p<.05$), working memory ($p<.05$) and divided attention ($p<.01$). No improvements were shown for speech-in-noise perception. A second study identified appropriate and sensitive outcome measures to assess training-related benefits. Participants (n=33, 50-74 year old HA users) trained on a phonemic-discrimination-in-noise task. Significant on-task learning ($p<.001$) generalised to improvements in a cognitively-demanding competing-speech task ($p<.05$) and a dual-task of listening and memory ($p<.01$), with the greatest improvements shown for challenging listening conditions. Results suggest that the real-world benefits of phonemic-discrimination training are governed by the development of cognitive skills.

A double-blind randomised active-controlled trial (RCT) assessed whether directly training cognition could result in increased patient-benefit. Participants (n=64, 50-74 year old HA users) used either Cogmed RM (adaptive) working memory training or Cogmed RM (non-adaptive) training. Real-world benefit was assessed using optimal measures of cognition, speech perception and self-reported hearing. Findings are presented together with implications for the cognitive-based rehabilitation of PHL.

7. Individual Differences in Primary and Secondary Memory: Which One Predicts Working Memory Capacity?

Hannah Roome and Dr. John Towse
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Unsworth and Engle (2007) proposed an important and exciting account of working memory capacity within the adult literature that draws on a dual-memory framework (ie the differential use of primary memory (PM) and secondary memory (SM) on working memory tasks). They suggested SM as the main driving force behind complex span performance based on the theory that storage items are displaced from PM as attention is switched to the processing element of the complex span task. We describe two experiments in adults and children (6-10 year olds) that derive estimates of PM and SM from immediate free recall and used these to predict listening span performance. Both free recall experiments showed PM predominates over SM in children's recall, whilst for adults both systems support recall. Intriguingly, despite the very low usage of SM in children in absolute terms, it was this memory system that uniquely and significantly explained working memory performance. Adults span performance was in contrast better explained by PM. The evidence implies that PM may support recall for many children equally, but it is the variance in the more limited SM processes that are relevant to understanding complex span. There may then be a developmental shift towards the relevance of PM processes in adulthood. We conclude that the dual memory framework offers an important perspective on the components of memory that sustain individual differences in complex span, and that these components are not developmentally fixed.

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: active maintenance in primary memory and controlled search from secondary memory. *Psychological Review, 114* (1), 104-132.

8. Relationships between working memory, cognitive processes, and executive functions in early childhood children: An exploratory study

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The purpose of the study was to explore the relationships among certain cognitive, executive, and working memory (WM) measures in a group of Greek nursery school children. Sixty participants (mean age 70.8 months) were administered the Cognitive Assessment System (CAS, Naglieri & Das, 1997) and the Working Memory Test Battery for Children (WMTB-C, Pickering & Gathercole, 2001). Language–based tasks were translated in Greek and appropriately adapted in both batteries. The CAS consists of four sub-scales, evaluating Planning, Attention, Simultaneous, and Successive processes (PASS Theory of Intelligence; Das, Naglieri, & Kirby, 1994). Planning assesses the capacity to formulate and monitor a strategy. Attention evaluates selective attention. Simultaneous processing assesses the capacity to survey and integrate elements, in order to form a conceptual whole. Finally, the successive scale evaluates the capacity to process information in a serial fashion. Analyses revealed good internal consistency for

both batteries. Pearson's correlation coefficient indicated a strong correlation between verbal WM, verbal STM, and successive processing tasks. Moderate to strong correlations were also obtained between verbal WM and planning tasks, as well as between verbal WM and attention tasks. Findings are discussed in relation to different theories attempting to explain the interplay among WM, cognitive processes, and executive operations.

9. Perceptual binding processes in schizophrenia: A study on the recall of visuospatial symmetrical and asymmetrical patterns

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The present study investigated perceptual binding in 20 schizophrenic (SC) patients and 20 age-matched healthy controls by measuring their performance in the recall of symmetrical (vertical, horizontal and diagonal) and asymmetrical patterns. The retrieval of symmetrical patterns requires the use of perceptual binding processes i.e. the ability to bind long term information about symmetry with the content of visuospatial working memory. A classical span procedure was used: for all types of configurations, testing started with the presentation of 2-square patterns and continued in ascending order of difficulty until 9-square patterns. Overall, results showed that, although SC patients were less accurate than controls in all conditions, both groups recalled symmetrical patterns better than asymmetrical ones. The impairment of SC patients was magnified with supra-span symmetrical arrays, and they were more likely to reproduce symmetrical patterns as asymmetrical, particularly at medium and high length levels. It is proposed that schizophrenia may be associated with a specific deficit in the formation and retrieval of the global visual images of studied patterns and in the use of the on-line information about the type of symmetry being tested to guide retrieval processes.

10. In competition for the attentional template: Can multiple items within visual working memory guide attention?

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Recent studies have revealed that the deployment of attention can be biased by the content of visual working memory (VWM), but that stored memories do not always interact with attention. This has led to a model which proposes a division within VWM between a single active template that interacts with perception and multiple accessory representations that do not. The present study was designed to study whether multiple memory representations are able to bias attention. Participants performed a visual search task while maintaining a variable number of

colors in VWM. Consistent with earlier findings, we observed increased attentional capture by memory-related distractors when VWM was filled with a single item. However, memory-related capture was no longer present for memory loads beyond a single item. The absence of memory-related capture at higher VWM loads was independent of individual VWM capacity, nor was it attributable to weaker encoding, forgetting, or reduced precision of memory representations. When analyses were limited to those trials in which participants had a relatively precise memory, there was still no sign of attentional guidance at higher loads. However, when observers were cued towards a specific memory item after encoding, interference with search returned. These results are consistent with a distinction within VWM between representations that interact with perception and those that do not, and show that only a single VWM representation at a time can interact with visual attention.

11. Greater than the sum of its parts? Complex span and its association with storage, processing speed, forgetting, and academic performance in childhood

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Processing speed and short-term memory measures are correlates of performance on complex span tasks, and independently predict variance in academic performance. Complex span tasks themselves typically consist of both a memory load and a processing element, however, there is residual variance within complex span which is itself predictive of academic performance. In this study, Year 1 (N=62, age 5-6) and Year 3 (N=48, age 7-8) children in mainstream school were tested on measures to further pinpoint the foundation of this residual variance. A simple digit span task was used to estimate memory capacity, and two tasks were used to estimate the speed of verbal and visuo-spatial processing. These processing tasks were also used in two complex span tasks which required either verbal or visuo-spatial processing, with digits as memoranda. The rate at which information was forgotten was estimated using Brown-Peterson type tasks, and articulation rate was measured as an indicator of rehearsal speed. Forgetting rate was correlated with the residual variance in complex span performance. Reading and mathematical ability were correlated with simple span and complex span task performance, and there were associations between reading, forgetting rate, and the residual variance in complex span performance. These associations suggest that the rate at which information is forgotten may be an important predictor of academic performance; however, complex span itself remains the greatest predictor of performance.

12. The role of encoding processes in temporary visual feature binding in younger and older adults.

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This project was aimed at establishing the extent to which an age-related deficit exists for associating surface visual features (colours and shapes) in working memory, and to determine the potential role of encoding processes in any deficits observed. Despite an overall age-related decline in visual working memory performance, and supporting previous conclusions in the literature, three of the four experiments showed that healthy older adults are able to create and maintain temporary surface visual feature bindings. Importantly, these experiments also showed that extending the encoding time, presenting the memory array sequentially rather than simultaneously, and presenting to-be-ignored stimuli during encoding, did not bring about any binding deficits in older compared with younger adults. Finally, the research demonstrated theoretically interesting limitations in how older adults encode information in visual working memory. Specifically, when testing memory for items that appeared in the middle of the to-be-remembered array of three visual objects, older adults performed at chance level. In contrast, the first and last items were much less affected by ageing. Furthermore, the research highlighted that older adults are less able than younger adults to inhibit distracting items. These latter findings may indicate age-related deficits in attentional and/or storage capacity.
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13. Estimating Visual Working Memory Capacity (K) Using the Multiple Change Detection Approach

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Incorrect responses during a working memory (WM) task may be due limitations in capacity, or a lapse of attention that results in no items being stored in working memory. Thus, typical measures of K are potentially confounded with attentional lapses. Recent attempts to dissociate working memory capacity and attentional lapses have used multiple set sizes and new analysis techniques (Morey, 2011; Rouder, Morey, Cowan, Zwilling, Morey, & Pratte, 2008). However, there is evidence that trials with a larger array size might receive reduced effort, leading to a decreased estimate of K (Rouder, et al., 2008). In this research, we evaluate the *Multiple Change Detection* (MCD) approach, which provides concurrent measures of attentional lapses and K while eliminating differential effort allocation across set sizes (Gibson, Wasserman, & Luck, 2011). This method keeps set size constant and varies the number of items that change, removing the possibility of

effort allocation differences seen in previous studies. The number of changes is not known in advance, so observers cannot strategically vary their level of effort. Monte Carlo simulations showed MCD was less distorted by attentional lapses and traditional methods for estimating K. Research contrasting the MCD approach with another measure of K, change localization, showed that both the capacity and attentional lapse parameters from MCD were significant predictors of change localization K in a regression model. This work suggests that MCD might provide a more accurate measure of working memory capacity than traditional measures.

14. A developmental investigation of lexical composition effects in immediate serial recall of words and nonwords.

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University of Bristol

Influence of lexical knowledge on children's immediate serial recall (ISR) has long been argued to arise from redintegration into a phonological code (Gathercole et al. 2001; Thomson et al., 2005). Children's 'lexicalised' responses to nonword fragments has provided a source of empirical support for a redintegration account (Thomson et al., 2005), although these error patterns are confounded by children's natural tendency to recombine phonemes during ISR. An alternative 'semantic binding' account assumes the co-activation of stored phonological and semantic knowledge during encoding (Patterson et al. 1994). Empirical support for this latter account largely derives from ISR of typical adults and patients with disordered semantic cognition using a 'mixed list' methodology (Jefferies et al., 2006). The present study also adopts a mixed-list methodology and reports a comprehensive evaluation of error patterns within ISR of 4-item lists of words and nonwords in children from aged five to ten years. The findings show that phoneme identity errors are more prevalent than migration errors within words and nonwords; but migrations are more prevalent within nonword items, even in 5-6 year olds. Generally, intra-item stability of phonemes is more robust within complete 'word' items, but children present multiple fragments of nonword recombinations as the ratio of words: nonwords drops across lists, approximating towards the spoken input. Overall, these findings are consistent with a lexical-semantic binding account of phoneme stability in children's ISR.

15. Contrasting the role of attentional resources during surface-feature binding and location binding in working memory.

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Presenting Author: Simon Ferneyhough (PhD candidate).

The question of whether feature binding in working memory (WM) draws on general attentional resources has generated a great deal of empirical research over the last decade. While the general consensus is that the binding of surface-features (e.g., between colour & shape) proceeds relatively automatically (Allen et al., 2011), it remains possible that other classes of binding may rely on the

availability of attention. In particular, object identity (provided by *surface-feature binding*) remains relatively stable while the relationship between an object and its spatial position (provided by *location binding*) is more transient. Furthermore, surface-feature binding and location binding appear to undergo different developmental trajectories (e.g., Oakes et al., 2006) and patterns of cognitive decline (c.f., Brockmole et al., 2008; Kessels et al., 2007) giving rise to the possibility that they may further diverge in their reliance on attentional resources. Indeed, Elsley and Parmentier (2009) demonstrated disruption to verbal-spatial bindings under conditions of concurrent cognitive load. Accordingly, in a modified version of Allen et al.'s (2006) paradigm we compared memory for arrays of colours, shapes or locations with memory for bound binary combinations of these features in the presence or absence of a concurrent load task. Our results indicated a detrimental impact of load across all conditions, with the effect no greater in the combination conditions relative to the feature conditions suggesting that both surface-feature binding and location binding proceed relatively automatically in WM. Findings are discussed in terms of the episodic buffer and paradigm differences between existing studies of binding.

16. Shared resource effects in a multiple component working memory system: A Bayesian analysis

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Some recent investigations into the functional limits of working memory have focused on trade-offs between concurrent tasks (e.g. Barrouillet, Portrat, & Camos, 2011; Portrat, Barrouillet, & Camos, 2008). This approach assumes that a single, modality independent resource is shared amongst concurrent tasks during dual-tasking, with increases in the demand of either subtask affecting contra-task performance. These findings appear incompatible with the multiple component model of working memory (Baddeley, 2012; Baddeley & Hitch, 1974; Baddeley & Logie, 1999; Logie, 2011), which assumes separate, domain-specific components. Whilst contemporary research has argued for the separation of storage and processing components of the working memory system (e.g. Borst et al., 2012; Duff and Logie, 1999, 2001; Logie and Duff, 2007), difficulties arise from how small effects are interpreted and from reliance on null effects. Here we present two experiments investigating the effect of titrated memory and processing load on dual-task performance. Utilising a Bayesian approach to data analysis, we report no effect of processing load on dual-task memory performance when the processing task is set equal to or below participants' single-task ability. An effect of processing load on memory performance only occurs once the processing component of the dual-task is set above participants' ability, although this effect is considerably smaller than that of memory load. These data fit with the Multiple Component Model and the separation of processing and storage systems, whilst supporting Logie's (2011) hypothesis that shared resource effects may occur in a multiple component system once individual components' capacities are exceeded.

17. Bottom-up and top-down influences during encoding in VWM

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As we perceive visual information, perceptual representations need to be stabilized into visual working memory (VWM) representations to prevent interference from subsequent visual input. Previous work has shown that when visual masks are presented soon after the offset of the memory array, VWM accuracy is impaired, especially with larger set sizes (Gegenfurtner & Sperling, 1993; Jolicoeur & Dell' Acqua, 1998; Vogel et al., 2006). Vogel and colleagues (2006) argued visual masks overwrite memory items when they have not been fully consolidated, suggesting a bottom-up process for interference. Recent work, however, has suggested that top-down filtering mechanisms are involved in preventing interference from visual masking (Blalock, 2013; Ueno et al., 2010, 2011). This top-down view is also consistent with controlled attention models of working memory (Engle & Kane, 2004). The current study contrasts these views by examining how VWM encoding (also referred to as short-term consolidation) is affected by the similarity of subsequent visual masks in a color change detection task. Masks were either the same colored squares as the to-be-remembered items (similar masks), or they were colored squares outside of the memory set (dissimilar masks). Masks were shown at varying intervals following the memory array, providing insights into the time-course of encoding in VWM and how it may differ between similar and dissimilar masks. Set size was also manipulated, with participants viewing either one or four squares. Results suggest top-down influences on VWM encoding: accuracy with dissimilar masks was higher at short mask intervals particularly at large set sizes.

18. A neurobiological basis for heritable forms of specific language impairment

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Specific language impairment (SLI) is a highly heritable disorder, where typically in addition to language deficits affected children are also typically characterised by deficits in verbal working memory (VWM). Since there is also a higher prevalence VWM deficits in the parents and siblings of these children compared with those of typically developing children, it has been suggested that poor VWM represents a heritable risk factor for the SLI. We used fMRI to tease apart the neural basis for the poorer VWM of parents of children with SLI. We included 10 parents of children with SLI (Par-SLI) and 12 of typically-developing children (Par-TD). Participants were simultaneously presented with verbal stimuli in both the auditory and visual modalities (encoding phase) and were required to subvocally rehearse either the seen or the heard stimuli for an extended period of time before performing a recognition task. We predicted similar cortical responses in both groups during the encoding phase of the task, with differences in activations emerging later, during the rehearsal and recognition phases and being localised to the inferior frontal gyrus, and the Sylvian-parieto-temporal and supramarginal areas. Preliminary

results largely confirm these predictions. Notably, however, little evidence was found for deviant information-processing in the parents of children with SLI, instead group differences reflect considerably reduced levels of activation particularly across the frontal lobes in these adults.

19. Visuospatial WM processing in developmental dyslexia: ERP and behavioural evidence.

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Impaired Working memory (WM) processing in dyslexia has traditionally been associated with the phonological loop. Emerging research (e.g., Wang, & Gathercole, 2013), has demonstrated a visuospatial WM deficit, implicating the central executive (CE). The current experiments aimed to explore the extent to which adults with developmental dyslexia show impairment when maintaining information of different set sizes (Experiment 1), or when required to maintain versus manipulate information online (Experiment 2). For Experiment 1, participants were presented with 1, 3, 5, or 7 dots, followed by a fixed delay and probe. For Experiment 2, participants were presented with a pre-cue, which instructed them to remember the location of dots presented around a horizontal line (maintain), or to mentally rotate the information (manipulation). ERPs were measured during the target display (encoding), and during the probe (retrieval). For Exp1, set size increased the N2 and decreased the P300. Individuals with dyslexia were unimpaired in maintaining visual spatial information in WM, even as set size increased. Accuracy, reaction times, sensitivity, and the amplitude of the N2 and P300 component did not differ between groups. For experiment 2, The N2 and P300 increased for conditions requiring manipulation, indicating a greater amount of attentional control, and increased updating in WM respectively. However, while individuals with dyslexia had comparable accuracy and ERP responses to non-dyslexic participants, they were slower when required to manipulate information. The results suggest that adults with dyslexia are not impaired for passive maintenance but are impaired for tasks loading highly on the CE.

20. Investigating the relationship between speech tests and measures of hearing and cognition

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As part of a study into benefits of phoneme discrimination training for improving speech perception in listeners with mild sensorineural hearing loss, we investigated the relationship between speech tests and measures of hearing and cognition. Speech tests were phoneme discrimination in quiet, digit triplet (DT) perception in steady-state noise, and sentence intelligibility in 8Hz modulated noise. Adaptive signal-to-noise ratios were achieved either by fixing the noise level and varying the

speech level: sentence test, DT (fixed noise); or by fixing the speech level and varying the noise level: DT (fixed speech). In addition, measures of hearing sensitivity, fluid intelligence (nonverbal IQ), divided attention (Test of Everyday Attention) and working memory (digit span and visual monitoring task) were collected. For the speech tests, correlational analyses (bivariate and partial) suggested that phoneme identification was correlated with DT (fixed noise), which in turn was correlated with sentence perception. DT (fixed speech) was only related to the DT (fixed noise) but not to phoneme or sentence perception. Hearing threshold level was most strongly correlated with the DT measures. All speech measures, except DT (fixed speech), showed some correlation with attention and working memory, but not fluid intelligence. Over 50% of performance variance was accounted for by hearing sensitivity alone for DT (fixed speech), and by hearing and attention combined for DT (fixed noise). Considerably less variance was explained for sentence (40%) and phoneme (30%) perception by the collected measures. Thus, contribution of hearing and cognition varies between speech tests and testing situations.

21. The influence of working memory load and task domain on the time course of the Simon effect

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Objectives: To investigate the interface between working memory and attention by examining the time course of the Simon effect over the distribution of response times under varying working memory load conditions.
Summary: Like the Stroop and flanker effects, the Simon effect is thought to result from the conflict between the irrelevant response tendency and the intended response. Since attentional control has been linked to conflict resolution, the Stroop, flanker, and Simon tasks have been proffered as a possible tools for measuring the efficacy of executive control mechanisms. These executive control mechanisms are also involved in working memory processes, and are thought to be responsible for the maintenance of information in the presence of continued processing or distraction.
The Simon effect refers to the relatively longer response times and larger error rates when responding to targets that appear in a task-irrelevant spatial location that is incongruent with the location of the correct response key, compared to targets that appear in spatially congruent locations. We examined the Simon effect under conditions of varying working memory loads and working memory task domains. Participants completed verbal 0-back, spatial 0-back, verbal 2-back, and spatial 2-back tasks. The results show that the Simon effect is diminished in the high working memory load tasks compared to the low load tasks, and that the Simon effect interacts with the spatial task domain such that the effect persists across the distribution of response times.
In contrast, the Simon effect peaks and then decays in verbal tasks. The results demonstrate that the Simon effect interacts with working memory load, and with task domain, suggesting that the effect is more modifiable than expected, and support a complex interface between working memory and attentional control.

22. Dual and single suffix effects in visual short-term memory: Further evidence for a visual-verbal distinction.

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Japan Society for the Promotion of Science

The stimulus suffix effect has proved valuable in the analysis of verbal short-term memory with variables such as perceptual similarity and suffix length casting light on the underlying processes. A striking feature of the auditory suffix effect is that two suffixes are less disruptive than one. We investigated this in the visual domain using arrays of three or four objects each comprising a coloured shape. Retention was tested either by a single-item recognition probe or by probed recall. In the former case, participants were required to decide whether the probe (a bound combination of colour and shape) had been contained within the memory stimuli. In the latter case, the colour or shape of one of the to-be-remembered objects was given as a cue for recall of its shape or colour. We compared performance when zero, one or two suffixes were interposed between presentation and at test. In line with our earlier work, we found that potentially relevant suffixes, taken from the overall set of possible stimuli, disrupted performance much more dramatically than visual suffixes from outside that set. In the case of such suffixes, a double suffix had a reliably greater impact than a single suffix, in clear contrast to the situation with auditory STM. We discuss the implications of our results for underlying memory mechanisms in visual and auditory memory.

23. Order learning for tactile sSequences: Further cross-modal equivalence in sequence learning

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Hurlstone, Hitch, and Baddeley (2013) have argued that cross-modal similarities in serial order memory (e.g. Ward, Avons, & Melling, 2005) can be accommodated within a modular conceptualisation of working memory (Baddeley & Hitch, 1974) via utilisation of a competitive queuing mechanism. The present study examines sequence learning for tactile stimuli in order to investigate cross-modal similarity beyond the established visual and verbal working memory slave systems. Four experiments examined both serial position effects and the Hebb Repetition Effect (Hebb, 1961) for tactile sequences. In Experiment 1, blindfolded participants received tactile stimulations to six fingers and were required to reconstruct the order of presentation through movement of the fingers. Every third trial, the same sequence was surreptitiously repeated. The canonical serial position function of strong primacy and moderate recency found with serial order reconstruction (e.g. Ward et al., 2005) was observed, and, in addition, gradual improvement for the repeated sequence was reported. These effects were qualitatively unchanged following articulatory suppression (Experiment 2). In Experiments 3 and 4, blindfolded participants received a sequence of tactile stimulations to the forearm. At test, participants pointed to the areas of tactile stimulation in the order of

presentation. These experiments replicated the Hebb Repetition Effect and, importantly, found that this effect was still reported when the forearms used for learning and recall differed. These findings further demonstrate cross-modal similarity with respect to the serial position function and the Hebb Repetition Effect. However, it is unclear how such tactile sequences are represented within the working memory model.

24. Remembering letters and cases – is the visuo-spatial sketchpad involved?

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This paper aims at investigating whether visuo-spatial working memory is involved in the retention of letters. The experiments are based on a research paradigm introduced by Logie, Della Sala, Wynn, and Baddeley (2000, QJEP) who demonstrated that similarity in the shape of upper and lower cases (e.g. C/c, s/S vs. B/b, R/r) influences verbal recall when the retention of case information is instructed. This visual similarity effect has been attributed to the visuo-spatial sketch pad (VSSP). We claim that the VSSP is involved only when the functioning of the working memory component normally used for processing verbal material is impaired. Two experiments replicate the original experiments in German while avoiding a potential confound and demonstrate that the visual similarity effect is restricted to a condition in which articulatory suppression prevents phonological recoding of the written letters (Fürstenberg, Rummer, & Schweppe, 2013, Memory). In an additional triple-task experiment, we demonstrate that this effect is not influenced by whether participants additionally retain pictorial or non-verbal auditory stimuli. We conclude that letter shapes can be retained in working memory but that they are not stored pictorially in the VSSP. Alternatively, we suggest that orthographic representations in long-term memory can contribute to working memory performance if phonological storage is hindered.

25. Working memory supports bilingual children to develop equally both of their languages.

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Bilingual children are facing a challenging situation in their everyday lives, as they have to master two languages. Recent findings suggest that bilingual children have an advantageous development over their working memory capacity (Morales et al 2013). This observation is considered part of the "bilingual advantage". Besides the beneficial consequences that bilingualism has on working memory, there is a possibility that a good function of working memory assists bilingual children to

better address the challenge of bilingualism. In the present study, we investigate this hypothesis by comparing two groups (a high working memory capacity group of 30 children and a low working memory capacity group of 35 children) of bilinguals aged 8-12 years, on vocabulary knowledge in both languages. All 65 participating children develop literacy in both languages although to different degrees, as they grow up in either Greece or Germany and the school settings differ. All children were assessed with verbal and non-verbal working memory tasks as well as for non-verbal intelligence. Vocabulary production was assessed in Greek and in German and used to determine children's verbal age and proficiency in each language. The preliminary results show that bilinguals with advanced working memory perform better on language tasks on both languages, while bilinguals with low performance on working memory tasks perform worse on language tasks in only one of the two languages. These results suggest that a good function of working memory allows bilinguals to develop equally their two languages, while poor working memory function forces bilinguals to leave behind one of the two languages.

Morales,J., Calvo, A., Bialystok, E. *(2013)* Working memory development in monolingual and bilingual children *Journal of Experimental Child Psychology* Volume 114, Issue 2, 187–202

26. Refreshing memory traces: Does "thinking of" an item change its status in memory?

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Attentional refreshing is a general mechanism assumed to serve the maintenance of information in working memory (WM). Studies have suggested that the instruction to "think of" WM items prompts participants to engage in *attentional refreshing.* So far, however, no study attempted to manipulate which items participants refresh at which point in time. The aim of the current study was to explicitly control which (and how often) items were refreshed during the maintenance period of a visual recall task. Participants encoded an array of six colors and were asked to report the color of a highlighted item by selecting it from a continuous color-wheel. During the retention interval, four arrows pointing to locations in the memory array were shown sequentially, and participants were instructed to "think of" the item the arrow pointed to. The arrows were not predictive of the item to be reported. The number of times the tested item was cued as target of refreshing was manipulated: 0, 1 or 2 times. The reported color of items refreshed more often deviated less from the item's true color compared to items refreshed less often. The data were fitted with a mixture model that decomposes the distribution of responses into three memory error components: precision of recall, guessing, and transposition errors. Items that had been refreshed more often were recalled with a higher probability, but their precision remained unchanged. These results are the first evidence that the pattern of *attentional refreshing* modulates WM performance.

27. Applying a serial recall model to recognition: An extension for serial-order in the Box model

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In this study, a connectionist model for serial recall– Serial-Order in the Box (SOB)(Lewandowsky & Farrell, 2008; Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012) – is extended for explaining data from short-term recognition. In SOB, the memory representation consists of bindings between items and contexts (i.e. position markers of serial positions). The structure of the network and encoding process are kept unchanged for the recognition model, while the retrieval process for the recognition task differs from the serial-recall task. The retrieval process is modeled as comparing the probe to the memory content retrieved from the context, and the context used for retrieving the memory content changes with time. At the beginning of the retrieval process, the context used for retrieval is the last-encountered context (i.e. the context bound with the last presented item), and it subsequently shifts to the context which is most strongly associated to the probe. Thus, the retrieved memory content is uninformed by the probe at the beginning, and then gets narrowed down to the memory content which is most similar to the probe. Currently, the recognition model is able to simulate the list-length effect, the serial-position effect, and the speed-accuracy trade-off in both Sternberg's memory scanning task and the local recognition task (Oberauer, 2003). Also, the model is able to explain the difficulty to reject recent negative probes (McElree & Dosher, 1989). This is the first computational model explaining both recognition and serial recall of information in working memory.

28. Disentangling the relationship between bilingualism and the development of working memory and executive control in childhood

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It has been suggested that bilingualism affects cognitive abilities in the sense that bilingual children show an accelerated rate of development in executive functions such as inhibitory control, metacognitive awareness and working memory compared to monolingual children (Bialystok & Viswanathan 2009; Carlson & Meltzoff 2008). This study reports data deriving from the on-going *BALED* project, financed by the European Social Fund and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework. The project's main aim is to include the factors of monolingual/bilingual education and type of bilingualism in the detailed investigation of the interaction between linguistic and cognitive abilities and their development. One hundred and twenty bilingual Greek-Albanian children (60 8-10 year-olds, and 60 10-12 year-olds) were compared to 60 monolingual controls, matched for age and SES (30 8-10 year-olds, and 30 10-12 year-olds). Bilinguals belonged to two sub-groups: "submersion" (N=30) and "maintenance" (N=30) bilingual education, according to the type of education they have received. Among

a variety of linguistic and cognitive measures, participants were evaluated with a cognitive battery assessing verbal and visuospatial working memory, as well as executive control (inhibition, task switching, updating, and planning). Differences between language groups (bilinguals of different types, and monolinguals), as well as relationships among the cognitive variables within each group, are discussed. Furthermore, the effects of children's age and educational experience are taken into consideration in shedding more light on the nature of the cognitive and linguistic interaction in the context of bilingualism.

29. Attentional competition and target representation in human frontoparietal and visual cortex

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Target objects required for goal-directed behavior are typically embedded within multiple object displays, where all elements compete for processing resources. In non-human primate prefrontal cortex, we previously showed how targets gain control of neural activity (Kadohisa et al., 2013) as a function of the strength of competition from accompanying nontargets. Here we adapted the previously-used task to examine similar questions in the human brain, using multivoxel pattern analysis (MVPA) of functional magnetic resonance imaging (fMRI) data. Displays contained one or four images, drawn from six semantic categories. For each block of trials, two categories served as targets. To manipulate the strength of attentional competition, we used two kinds of nontargets: Two categories for each block were nontargets that served as targets in other blocks ('inconsistent nontargets'), while the remaining two categories never served as targets, therefore were never behaviorally relevant ('consistent nontargets'). Univariate comparison showed extensive activation of frontal, parietal and occipital cortex with increased attentional competition. These results matched behavioral data, with increased response time for four-object compared to one-object displays, and for inconsistent compared to consistent nontargets. MVPA results showed representation of task-critical stimulus distinctions, especially target vs. nontarget, across multiple frontal and parietal regions. In contrast, there was little or no representation of the visually salient but behaviorally irrelevant distinction between one target category and another. In frontoparietal cortex, the distinction of targets and nontargets was seen irrespective of attentional competition, suggesting that the fMRI signal is dominated by a focused representation of the final behavioral decision.

30. Visual-spatial memory encoding: Does it benefit from eye-movement strategies?

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In the verbal domain one process to counteract fading of representations has been widely demonstrated: Subvocal or vocal rehearsal. Whether an analogue exists in the visual-spatial domain has been discussed, with eye-movements as likely candidate to support activation of spatial memory representation. Here we report two experiments demonstrating the opposite (Lange & Engbert, QJEP, 2013) as well as one follow-up, trying to test specific interference between eye movements and memory encoding. In the first experiment participants were free to move their eyes without any specific instruction. Eye movements were recorded during sequential presentation of digits at different locations in a 5-by-5 grid. Either digit identities (verbal task) or digit positions (spatial task) had to be encoded for serial recall. Whereas the gaze followed the items in the verbal task closely, fixation probabilities on items decreased dramatically in the spatial task. Results indicate saccadic suppression at spatial encoding. In a second experiment participant were instructed to either follow each upcoming stimulus closely or to fixate centrally. Saccadic activity interfered with spatial as well as verbal memory, showing strong dual-task costs. Saccadic suppression did not affect memory performance at all. Hence, eye-movements clearly do not support spatial memory encoding. In a follow-up experiment we are now trying to create specific interference between forced eye-movements to relevant positions and spatial representation. First data indicate that we succeeded. To sum, we assume that eye-movements do not play a critical role in building up spatial memory representations.

31. Reducing involuntary flashback memories after analogue trauma using visuospatial tasks: Applying working memory to psychopathology.

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Introduction: Over the course of their lifetime most people will experience a traumatic event such as interpersonal violence, natural disasters, war or terrorism. A significant minority will develop post-traumatic stress disorder (PTSD). A hallmark symptom of PTSD is the presence of involuntary image- based memories of the trauma (e.g. flashbacks). We suggest that tasks that selectively compete for resources in visual memory may reduce later flashbacks when completed during the memory consolidation time window. We seek to understand this within cognitive models of working memory (i.e., the visuospatial sketchpad and phonological loop).
Method: We synthesise a series of studies that have used the trauma film paradigm to investigate the differential effect of competing cognitive tasks on later flashback development. These tasks have been given at a range of time points after trauma film viewing. We test the prediction that visuospatial tasks after film viewing *selectively* compete for resources required for flashback formation

reducing their frequency, whereas other types of task (e.g., verbal-based tasks) do not.
Results: Findings suggest that visuospatial tasks undertaken after viewing a trauma film (during memory consolidation) can reduce subsequent flashback frequency for the film. In contrast, non-visuospatial tasks do not, and in some cases may increase flashback frequency.
Conclusions: There appears to be a modality-specific effect in that visuospatial tasks reduce subsequent flashback frequency whereas verbal tasks do not. Findings warrant further investigation to inform treatment strategies aimed at reducing flashbacks. Future work should seek to investigate our modality-specific hypothesis within mainstream neuroscientific models of memory. These models suggest that any demanding cognitive task, regardless of modality, should be effective in eroding flashback memories. Further, we seek to understand what aspects of visuospatial tasks, such as the computer game Tetris, yield the beneficial flashback-reduction effects.

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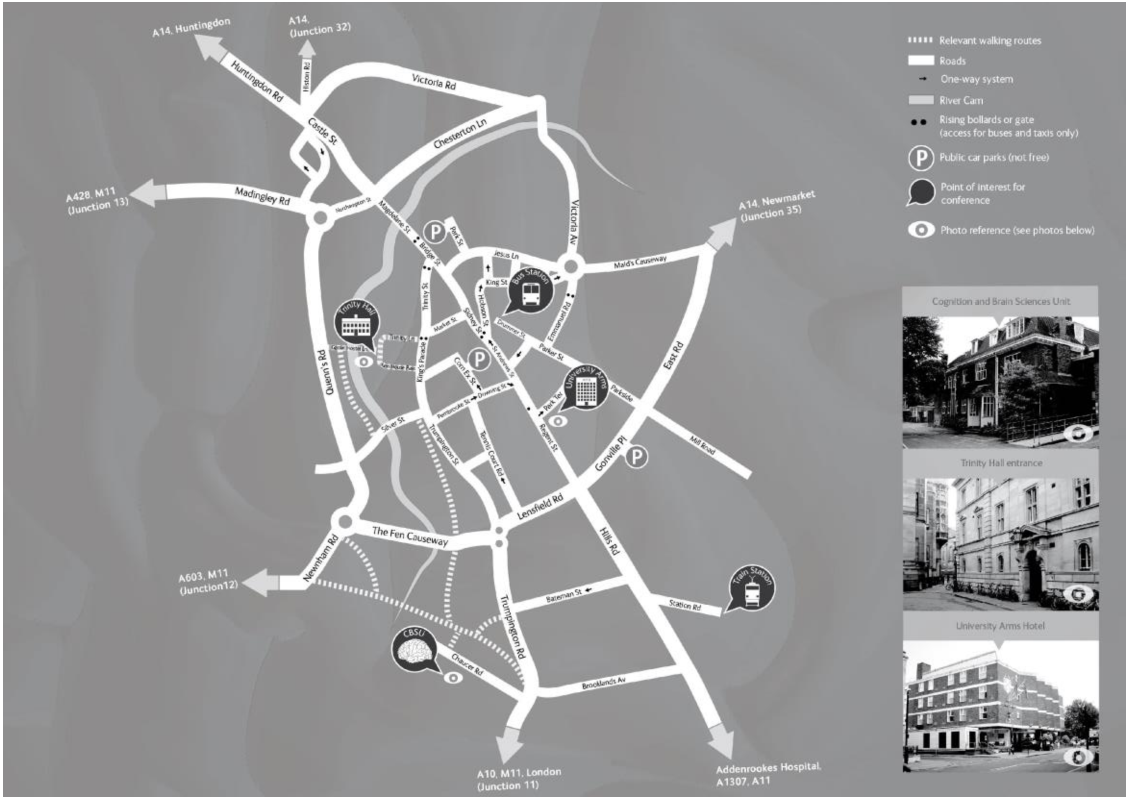
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A14, (Junction 32)
A428, M11 (Junction 13)
A14, Newmarket (Junction 35)
A603, M11 (Junction12)
A10, M11, London (Junction 11)
Addenrookes Hospital, A1307, A11
Huntingdon Rd
Histon Rd
Victoria Rd
Castle St
Chesterton Ln
Madingley Rd
Northampton St
Magdalene St
Bridge St
Park St
Victoria Av
Jesus Ln
Maid's Causeway
King St
Bus Station
Trinity Hall
Trinity St
Market St
Sidney St
Hobson St
Drummer St
Emmanuel Rd
Parker St
Quenn's Rd
King's Parade
Corn Ex St
St Andrews St
University Arms
Parkside
East Rd
Park Ter
Pembroke St
Downing St
Silver St
Trumpington St
Tennis Court Rd
Regent St
Mill Road
Gonville Pl
Lensfield Rd
Hills Rd
The Fen Causeway
Newnham Rd
Bateman St
Station Rd
Train Station
Trumpington Rd
CBSU
Chaucer Rd
Brooklands Av
Relevant walking routes
Roads
One-way system
River Cam
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