SUPPLEMENTARY MATERIAL

Supplementary Results

*fMRI timing validation*. We were concerned that there might be some non-independence between the encoding and trial event estimates. Correlated noise is a problem for individual subject analyses, but not here, since we used a group analysis (based on independent between-subject variance) (Kriegeskorte et al., 2009). However, overlapping sequential events can cause positive correlations, in which higher activity in the earlier event can bias estimates upward in the later event. Importantly, this bias is in the opposite direction of our hypothesized (and observed) sequential effects, suggesting that any bias could not account for our findings.

Some concern remains, however, regarding the ability to properly separate encoding and trial estimates, given that several regions showed multiple BOLD responses time-locked to encoding events. We performed additional analyses to ensure the secondary response was not due to inaccurate separation of serially presented events.

First, we identified a highly active region in left fusiform gyrus (identified in a statistical map of practiced encoding activity vs. baseline (P<0.005, FDR corrected) and consistent with a region known to respond to word stimuli (Jones et al., 2002)). We determined that the region was responsive to all estimated events and that single BOLD responses in this region were well separated by the deconvolution analysis (Supplementary Figure 2). Importantly, we confirmed the expectation (based on there being double the number of visual stimuli during encoding relative to each trial stimulus) that the encoding response was double the size of the trial responses. These results were most informative for the novel conditions, which were not biased in any way by ROI selection.
Second, we performed a simulation using the task event timing (identical to that used in the fMRI study), convolving it with the canonical SPM hemodynamic response function, and adding 5% Gaussian noise (Supplementary Figure 2A & B). We then analyzed the simulated data using deconvolution analysis (identically to how the fMRI data was analyzed), replicating the results in the left fusiform region. Finally, we tested several possible activity-timing patterns in the simulation and found one that showed two BOLD responses similar to those seen in right DLPFC (Supplementary Figure 2C). This timing suggests that regions with doubled responses were active early in encoding and also just before the first trial.

**Supplementary Discussion**

It may appear surprising that the task switching costs were so small for both novel and practiced tasks (both 32 ms). However, this is simply a replication of findings by Allport et al. (Wylie and Allport, 2000; Waszak et al., 2003), who showed that task switching costs are largely driven by stimulus-response and task-stimulus associations in LTM. Since participants almost never saw the same stimuli with the same task (each stimulus was only presented eight times total, with a very low probability of the same stimulus pairing, in 720 trials including 64 tasks), no strong task-stimulus or stimulus-response associations could be formed to interfere with performance on future trials. Further, there was a long delay between task blocks (12-16 seconds), allowing previous task set activity to passively dissipate such that it caused little interference with the next block (Meiran et al., 2000). The remaining task switching cost likely reflects preparation processes common to both novel and practiced tasks, though there may also be some weak influence of task-stimulus associations from the relatively few repeated presentations of a given stimulus.
Existing theories of task set representation suggest that PFC actively maintains task sets (Asaad et al., 2000; Curtis and D'Esposito, 2003), but they do not address where these task sets originate. We suggest that WM integration of rules initially forms novel task sets (i.e., higher-level goal representations that coordinate task rules) during RITL, while practiced task sets are retrieved from LTM. However, it remains unclear where task set LTM is stored. It has been previously suggested that PFC itself contains LTM representations of task sets (Wood and Grafman, 2003; Fuster, 2009), though this appears to contradict evidence that lateral temporal lobe stores consolidated LTM representations in other domains (Miyashita et al., 1998; Lah et al., 2008), including abstract rules (Bunge et al., 2003).

Compatible with these other forms of LTM, the present results suggest that aTL stores task sets in LTM for retrieval during practiced task preparation. Also consistent with aTL representing task sets, aTL is thought to sit at the top of a semantic hierarchy, representing higher-level integrated multimodal and abstract semantics such as during crossmodal integration of object features (Ungerleider and Haxby, 1994; Taylor et al., 2009) and during semantic (as opposed to syntactic) sentence processing (Rogalsky and Hickok, 2008). This suggests that aTL’s involvement here is related to representing task sets applicable to multiple semantic domains. Further, with its direct anatomical connections with aPFC (Rempel-Clower and Barbas, 2000; Petrides and Pandya, 2007), aTL is optimally situated to send such higher-level representations to aPFC during practiced task preparation.
Supplementary Figure 1— The MEG results replicate the major components of the fMRI activity patterns. Like the fMRI results, the MEG results involved left aPFC early in practiced task preparation and right DLPFC late in practiced task preparation, with a reversal during novel task preparation: right DLPFC early and left aPFC late. Time points were chosen for illustration based on their ability to summarize activity in PFC regions identified with the fMRI data.
Supplementary Figure 2 – fMRI Timing Validation and Simulations.

A) Visually evoked BOLD signal was simulated in MATLAB by convolving a canonical hemodynamic response function with the timing of the visual stimuli (depicted). The same timing was used as during the fMRI experiment. B) Visual activity (from the fMRI study) in a left fusiform region was verified to separate accurately between encoding and the three trials. This separation, using an identical statistical model as was used on the fMRI data, was replicated with the simulated data. C) The same method was used to simulate the doubled response seen in right DLPFC. This simulated activity pattern was identified by checking many activity timing patterns for this kind of response shape. The necessary timing to produce this result is depicted on the top.
Supplementary Figure 3 – A summary of the results, illustrating the reversal of information flow for practiced versus novel task preparation. We found that practiced task preparation is primarily ‘top-down’ (specified by internal memory), while novel task preparation (RITL) is ‘bottom-up’ (specified by external stimuli). The roles of the non-PFC regions were inferred from previous studies (in conjunction with the present results); further research will be necessary to fully validate these interpretations. A) Practiced task preparation: Instructions cued LTM retrieval of a goal/’higher-level task set’ representation from aTL to aPFC for rule coordination. This was followed by activation of the individual rules in DLPFC and more posterior regions in preparation for task performance. B) Novel task preparation (RITL): In contrast to practiced task preparation, novel task preparation first involved activation of rule representations as each instruction was read. Lower-level WM (in DLPFC) likely maintained these individual rule representations for later integration by aPFC. Integration specified the relationships among task rules (stored in the goal/’higher-level task set’ representation) for rule coordination during task performance.

References:


