Replacing the frontal lobes? Having more time to think improve "implicit" perceptual categorization. A comment on Filoteo, Lauritzen & Maddox, 2010.

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Filoteo, Lauritzen and Maddox (2010) reported an experiment in which participants who learned a complex "information-integration 3-dimension" (II3D) perceptual categorization task, while also completing a secondary working memory scanning (WM) task, outperformed participants who only learned the categorization task. Filoteo et al. explained this counterintuitive result in terms of a COmpetition between Verbal and Implicit Systems (i.e., the COVIS model; Ashby, Paul, & Maddox, 2011). This account holds that when WM resources are tied up elsewhere (or the "frontal lobes are removed" as the title of Filoteo et al.'s paper put it) control of performance on the category task is more readily transferred from the verbal to the implicit system. The implicit system yields superior accuracy because it predecisionally integrates information from the multiple dimensions present in the II category structure (see also Maddox, Ashby, Ing & Pickering, 2004).

This striking finding led Filoteo et al. to claim that their results have substantial applied implications. For example, they suggest "it may be possible to enhance the training of radiologists by having them perform a secondary task while learning to read X-rays" (p.422)[1]. However, a methodological confound in Filoteo et al.'s design compromises this strong conclusion: Participants given the WM task also had an additional 2500ms of inter-trial-interval (ITI) in which to process corrective feedback from the category task. The two leftmost columns of Figure 1 highlight this confound in the Filoteo et al design. This confound leaves open an alternative explanation for the "paradoxical effect" (Filoteo et al., p.417): participants given the additional WM task outperformed those learning the category task alone because the former had more time to think (explicitly) about the feedback.

[INSERT FIGURE 1 ABOUT HERE]

To test this alternative account, we ran an experiment with the same II3D stimuli, WM scanning task and number of trials (600) as Filoteo et al., but crossed the length of the ITI duration (Short: 2000ms, Long: 4500ms) with the position of the WM task in the trial sequence (before (WM-II3D) or after (II3D-WM) responding on the category task), in a 2 x 2 between-subjects design (i.e., the four conditions surrounded by the black rectangle in Figure 1). Given this design, COVIS predicts that participants who complete the WM task after the category task and have a short ITI (II3D-WM-SHORT) should be most accurate because there is maximum opportunity to disengage the explicit system and switch to the superior implicit one: there is limited time to process feedback, and this is interrupted by the WM task, so the implicit system should be relied upon. Poorest performance should be seen for the group WM-II3D-LONG: there is no disruption because the WM task is completed *before* the category task, and there is more time to think; factors which should lead to perseveration with the 'sub-optimal' explicit system. Our alternative explanation makes the opposite prediction: WM-II3D-LONG allows uninterrupted thinking, whereas II3D-WM-SHORT disrupts processing and provides less time. For both accounts, the remaining two conditions (WM-II3D-SHORT, II3D-WM-LONG) should fall between these two extremes.

We tested 80 UNSW undergraduate participants[2] (mean age 19.4 years, 48 females), randomly assigned to one of the four cells of the 2 (task order: WM-II3D vs. II3D-WM) x 2 (ITI: 2,000 vs. 4,500ms) between-subjects design. We followed the procedures of Filoteo et al. as closely as possible. (Further details of our stimuli and design are presented in the Supplementary Materials.)

Performance on the category learning task across the 600 trials is illustrated in Figure 2a. As expected, accuracy increased across trial blocks (Linear Trend Contrast, $F(5,80) = 115.54$, $p < .001$). Any account would, of course, predict little difference between conditions early in the experiment because all participants will start at chance. COVIS, however, specifically predicts that some failed hypothesis testing is needed before a switch to the implicit system will be seen (e.g., Ashby et al., 2011). Therefore, we made an a priori decision to focus our primary analysis on the final block of 100 trials, where the clearest difference between the accounts should emerge. Figure 2b shows that in the final block highest accuracy was achieved by the WM-II3D-LONG group and lowest by the II3D-WM-SHORT group. This is the pattern predicted by our alternative explanation because participants in the WM-II3D-LONG condition have the most uninterrupted time to process corrective feedback, and those in the II3D-WM-SHORT have the least. This pattern is *opposite* to that predicted by COVIS.

[INSERT FIGURE 2 ABOUT HERE]

Figure 2 demonstrates that ITI length rather than WM task position is the more important factor in determining accuracy. This observation is supported by a 2 (task order) x 2 (ITI length) ANOVA conducted on final block accuracy scores which revealed an effect of ITI length $F(1,80) = 5.597$, $p < .05$, indicating improved accuracy with longer ITI, but no effect of task order, $F(1,80) = 1.404$ $p > .05$, and no interaction, $F(1,80) = 0.839$ $p > .05$.

In summary, we re-examined the surprising and 'paradoxical' finding that participants facing a complex categorization task perform more accurately when they also complete a secondary WM task (Filoteo et al., 2010). We found evidence for an alternative, less surprising explanation – that participants who have more time to process feedback (a longer ITI) perform more accurately on an II3D task regardless of the positioning of the WM task. The simple story that emerges from these data is that when one is faced with a complex category structure, having time to think – and presumably test hypotheses – is beneficial. This account requires no counter-intuitiveness, no frontal lobectomies and no recourse to implicit processes. The apparently opposite effects of a secondary WM task in Filoteo et al. likely stem from a failure to equate ITI (and hence thinking time) across the WM task and control conditions of that experiment.

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Footnotes

1. Filoteo et al. assume that reading X-rays is a real-world example of an information-integration categorization task.

2. 92 participants were tested, data for 5 were lost due to computer error; a further 7 were excluded for failing to exceed learning criterion on the category task (50% in final 100 trial block as per Filoteo et al., 2010) or 80% accuracy on the WM task.

Figure Captions

Figure 1. Timeline highlighting the ordering and durations of the category task (II3D), working memory task (WM) and the inter-trial interval (ITI) in the Filoteo et al. experiment and the current experiment. In the former only the two leftmost conditions of the figure were run, confounding the presence of the WM task with additional time in the inter-trial interval. In our experiment the four conditions encapsulated by the black rectangle were run thereby unconfounding the influence of the WM task and the time available for processing category-task corrective feedback. The jagged lines breaking the category task and WM task boxes indicate that these tasks were response terminated and thus of varying length across participants (see Supplementary Materials for more details of the tasks and timings).

Figure 2. A: Accuracy across six blocks of 100 trials. Average accuracy within each block is shown for each condition. B: Average Accuracy (proportion correct) in the final (sixth) block of 100 trials for each condition. Condition names refer to the sequence of the category and working memory task (e.g., II3D-WM means participants completed the category task first then the WM task) and the length of the inter-trial-interval (ITI, Long - 4500ms, Short – 2000ms).

Figure 1

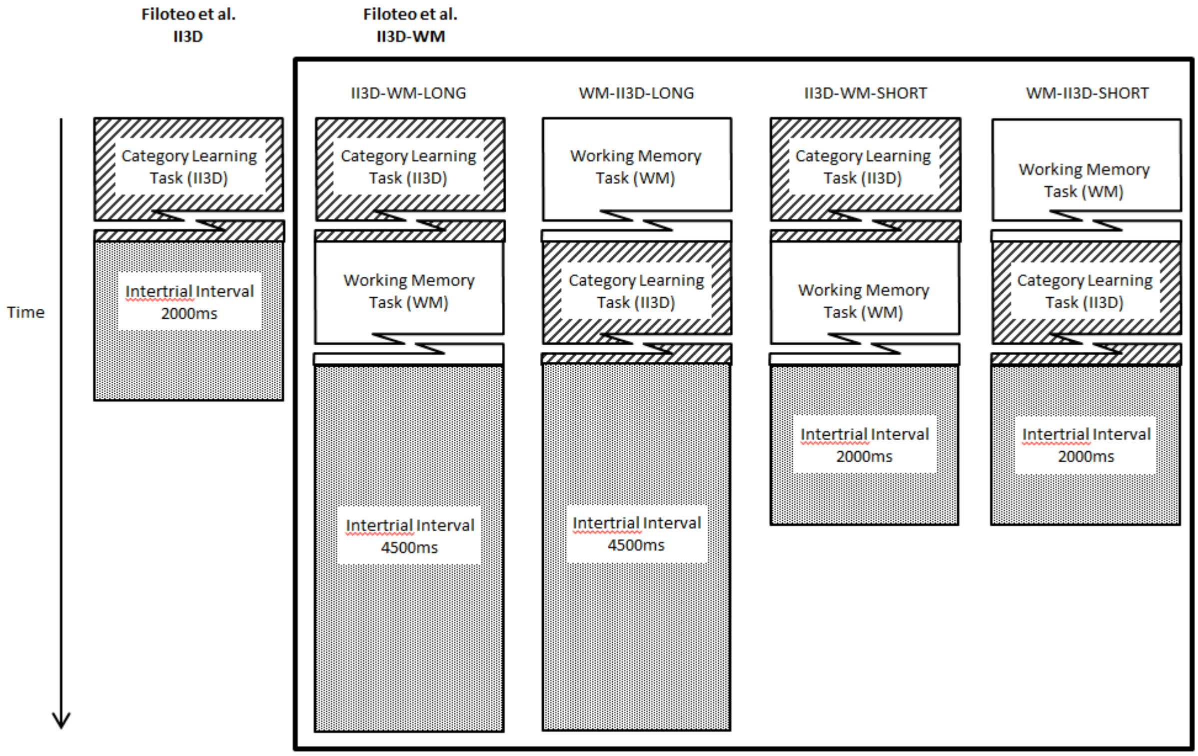
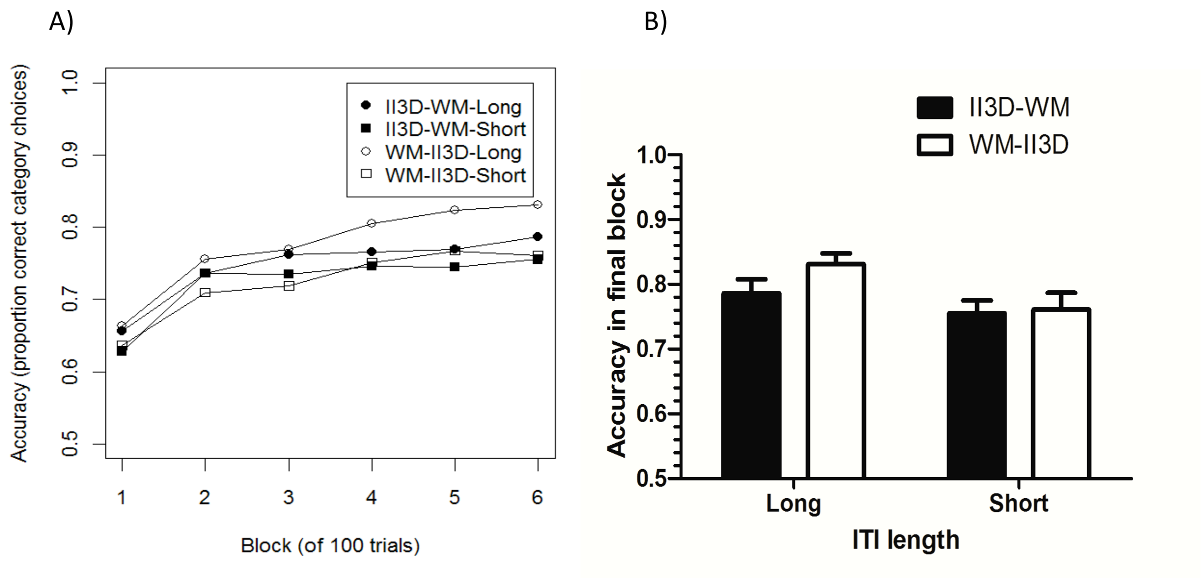

Filoteo et al.
II3D
Filoteo et al.
II3D-WM
II3D-WM-LONG
WM-II3D-LONG
II3D-WM-SHORT
WM-II3D-SHORT
Time
Category Learning
Task (II3D)
Intertrial Interval
2000ms
Category Learning
Task (II3D)
Working Memory
Task (WM)
Intertrial Interval
4500ms
Working Memory
Task (WM)
Category Learning
Task (II3D)
Intertrial Interval
4500ms
Category Learning
Task (II3D)
Working Memory
Task (WM)
Intertrial Interval
2000ms
Working Memory
Task (WM)
Category Learning
Task (II3D)
Intertrial Interval
2000ms

Figure 2


A)
Accuracy (proportion correct category choices)
0.5
0.6
0.7
0.8
0.9
1.0
II3D-WM-Long
II3D-WM-Short
WM-II3D-Long
WM-II3D-Short
1
2
3
4
5
6
Block (of 100 trials)
B)
II3D-WM
WM-II3D
Accuracy in final block
1.0
0.9
0.8
0.7
0.6
0.5
Long
Short
ITI length

On line Supplementary Materials

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This document provides additional information concerning the stimuli and design used in the experiment reported in Newell, Moore, Wills, & Milton (2012).

Stimuli

In our experiment, as in that of Filoteo et al. (2010), participants learned a two-category structure in which the stimuli were straight lines that varied on three stimulus dimensions (3D): length, orientation (rotation) and screen position (from left to right on the horizontal axis). Two of these dimensions were relevant to the category decision (length and orientation) and the third (screen position) was not. The category boundary was placed so that information from the length and orientation dimensions had to be integrated to make correct categorization decisions (see Figure S1). We thank Todd Maddox for providing the stimuli files.

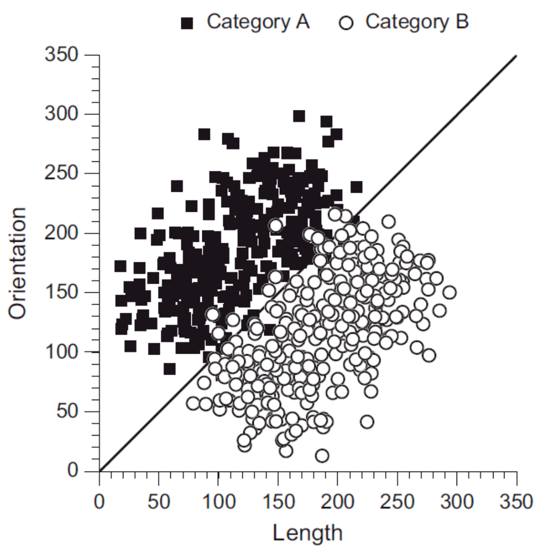

Figure S1. Category structure for the stimuli used in the Experiment (and in the Information Integration conditions of Filoteo et al., 2010). This figure is adapted from Filoteo et al. (2010). Each stimulus was created by converting the x value of these arbitrary units into a line length (measured in pixels) and the y value (after applying a scaling factor of $\pi/500$) into line orientation. The scaling factor $\pi/500$ was chosen to approximately equate the salience of line length and line orientation. The third dimension – horizontal screen position of the stimulus measured in pixels – varied according to the distribution specified by Filoteo et al. (2010, Table 1), with the mean of the distribution mapped to the center of the screen.

Design

Filoteo et al. described the configuration of each trial in their experiment in the following terms: "For the conditions that included the sequential working memory task, corrective feedback was also provided for 500ms following a response, but instead of the 2-s intertrial interval, working memory trials followed the feedback" (p.417). This description might be taken to suggest that, for those in the WM conditions, the working memory task was conducted during what would otherwise have been a 2-s period of inactivity, and the trials were otherwise the same. However, such an interpretation would be incorrect because, as Figure 2 of Filoteo et al. illustrates, the WM task is followed by an additional delay of 4,500 ms.

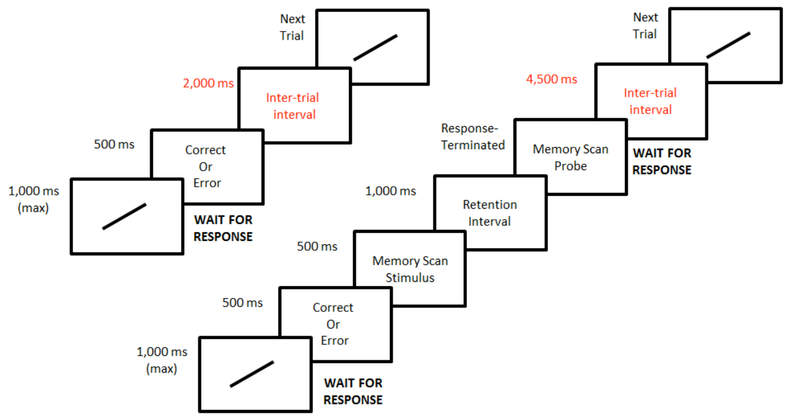

Figure S2. Trial structure for Filoteo et al.'s II3D (left) and II3D-WM (right) conditions.

Figure S2 clarifies the trial structure for the II3D and II3D-WM conditions of Filoteo et al. (2010), and illustrates that the introduction of the working memory task is confounded with an increase in the inter-trial interval. It was this confound that our Experiment was devised to address.

Filoteo et al. employed a response-terminated secondary-load task and a between-subjects manipulation of secondary load. In the interests of keeping as close to their original design as possible, we felt it was important to retain those aspects of their design. One consequence of that decision was that there was, as far as we could ascertain, no way to design a satisfactory No Load condition. For example, one could equate the ITI lengths across No Load and WM conditions. Unfortunately, this would likely lead to longer response-stimulus intervals (RSI) for the categorization task in the WM condition than in the No Load condition, due to the time taken to perform the WM task. Or, one could attempt to match response-stimulus intervals in the categorization task by reducing the ITI in the WM condition by the duration of the WM task, on a trial-by-trial basis. Unfortunately, this means the WM and No Load conditions would not match on the duration of an unfilled delay (the ITI). It is not possible to adequately compensate for this through a yoked control, due to the Church Effect (Church, 1964).

We therefore decided to instead manipulate the order of presentation of the WM and categorization tasks within the trial, between subjects, hence matching the duration of the unfilled delay (ITI), and keeping the RSIs comparable across conditions to the extent it is possible to do so in a response-terminated design. Filoteo et al.s hypothesis is that "the addition of the secondary task would behaviorally limit the contribution of the frontal lobes by overly engaging working memory processes during the processing of the corrective feedback" (p. 417). On the basis of this hypothesis, moving the WM task to a point before the categorization stimulus is presented should presumably reduce the interference with feedback processes. The trial structure used in our Experiment is shown in Figure S3.

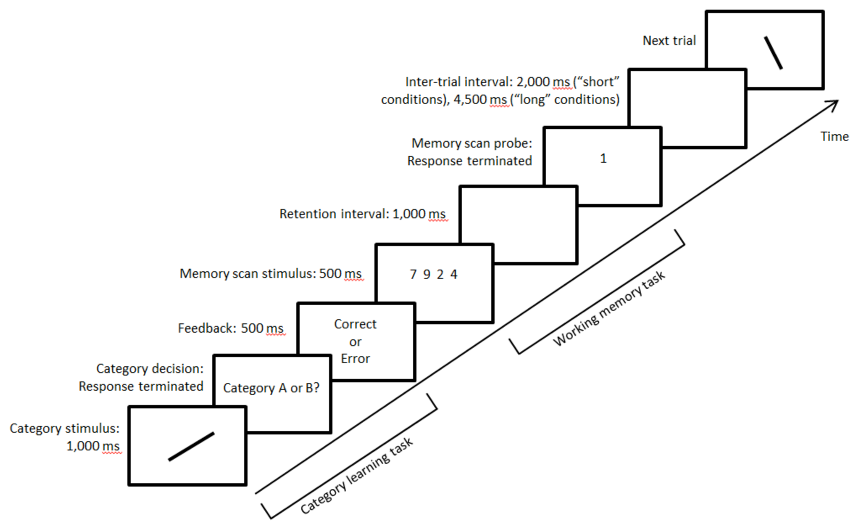

Figure S3. Trial structure for II3D-WM conditions. The category stimulus was presented for 1,000ms, after which it was removed from the display. Instructions to categorize the stimulus remained on the screen until a decision was made. Feedback was presented for 500 ms. Then the memory scan stimulus (four numbers between 0 and 9) was presented for 500 ms. The screen was blank for 1,000 ms, after which the probe was displayed with instructions until a response was made. The next trial began after an inter-trial interval of either 2,000 ms (II3D-WM-short) or 4,500 ms (II3D-WM-long). The trial structure for WM-II3D conditions was identical except the working memory task preceded the category learning task.

Conjectures about Conjunctions

In addition to the Information Integration conditions, which were the focus of our paper, Filoteo et al. also examined the effect of a secondary WM task on categorization accuracy for a 3-dimensional conjunctive category structure (see Filoteo et al., 2010, Figure 1A). The conjunction structure permits description by a readily verbalisable AND rule ("short length AND large angle -> category A, otherwise category B"). Filoteo et al. found no significant effect of their WM task on the conjunctive category structure, which might initially be considered surprising given previous reports that a secondary task significantly lowers accuracy on this type of categorization structure (Zeithamova & Maddox, 2006). Further, given that our Experiment indicates that the main factor at work in the increased accuracy under WM load in the information integration conditions is the longer ITI in the WM condition, one might reasonably ask why a comparable effect was not seen in the Conjunction conditions of Filoteo et al., particularly as the information integration and conjunction structures are of comparable difficulty in the absence of load.

A first point to note is that drawing conclusions about the existence of qualitatively distinct systems on the basis of the presence or absence of dissociations across different tasks (i.e., II and CJ) is fraught with difficulties (e.g., Newell & Dunn, 2008; Newell, Dunn & Kalish, 2011). Finding that variable A (e.g., cognitive load) has a detrimental effect on task X but no effect on task Y does not allow one to conclude that task X and task Y are subserved by qualitatively different systems. Even if task X is detrimentally affected whilst task Y is simultaneously facilitated – a double dissociation – this still does not allow –logically – conclusions to be drawn regarding the number of systems (or independent processes) producing the data.

With that caveat in mind, one could construct an account of the dissociation between CJ and II tasks with respect to load and ITI that is consistent with an alternative dual systems model. One possibility is that secondary load disrupts the acquisition of rule-based categories more than information integration categories (e.g., Maddox, Ashby, Ing & Pickering, 2004, although see Stanton & Nosofsky, 2007). Under such an account, the absence of a significant effect of WM load in the conjunction conditions of Filoteo et al. may be due to the superimposition of a detrimental effect of load on this rule-based category structure, and a beneficial effect of an extended time to think (longer ITI) in the load condition. Clearly, our Experiment does not speak to this possibility one way or the other, and it thus remains an important empirical question for future research to pursue.

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