Supplementary Materials


Ben R. Newell¹, Christopher P. Moore¹, Andy J. Wills², and Fraser Milton²

1. School of Psychology, University of New South Wales, Sydney, Australia.
2. Department of Psychology, University of Exeter, UK.

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](image)

**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 intertrial 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 I13D-WM conditions. The category stimulus was presented for 1,000 ms, 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 (I13D-WM-short) or 4,500 ms (I13D-WM-long). The trial structure for WM-I13D 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.

References


