trum of the diethyl ether extract of this unknown compound(s) (Fig. 2a) was similar to that of standard samples of pheophorbide *a* and pyropheophorbide *a*, and virtually identical with the spectrum of the methyl ester of chlorobium (Cbm) pheophorbide 650, fraction 2. The electron-impact mass spectrum for the methyl esters of the unknown compound(s) suggests that they are Cbm pheophorbides (a mixture of defarnesylated and demetalated derivatives of Cbm chlorophylls, series 650 and 660). High-intensity signals corresponding to the expected main fragments from Cbm pheophorbide 650 methyl esters suggest that the Cbm chlorophyll 650 derivatives predominate.

Energy transfer from the photosensitizer to the visual pigment may involve intersystem crossing to generate an excited triplet state (T_1) of the pheophorbide, which could then transfer energy to the ground state of the visual pigment's 11-*cis* chromophore to generate its triplet state. Such a triplet state of the visual pigment chromophore has been proposed as a normal intermediate of photoisomerization[8]. Energy transfer from the triplet state of the pheophorbide *a* derivative (E_r = 30.7 kcal mol^{-1})[9,10] to the ground state of the 11-*cis* chromophore (E_r<38 kcal mol^{-1}) might be endothermic, but the long lifetime (1 ms) of the pheophorbide triplet state and the high quantum yield of its formations make the triplet photosensitization mechanism highly probable.

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Vision and attention: the role of training

What happens to visual experience in the absence of visual attention? Does lack of attention render us effectively blind[1], or is there a significant residual experience[2–4]? Here I show that the surprising results of a recent study[1] were due not to the novel way in which attention was controlled, but simply to the use of novice rather than expert observers. So the evidence remains strong that some aspects of visual experience are essentially independent of attention.

Joseph *et al.*[1] reported that observers are unable to detect a simple feature difference ('popout') when attention is taken up elsewhere in the display. This is at odds with previous reports[2–4] and a large body of work on preattentive, parallel processes in vision[5–7].

Methodologically, the new study departs from earlier efforts by controlling attention with the help of an 'attentional blink'. This is the lapse in perception that occurs, for example, when a predesignated target letter is recognized in a stream of letters appearing rapidly one after the other. Joseph *et al.* argue that attentional blink removes attention more effectively than the concurrent-task method used in previous studies[2–4].

However, a second methodological difference that they do not emphasize is the use of novice (those who have performed only 480 trials) rather than expert (many thousands of trials) observers.

To ascertain which of these factors was responsible for the outcome, I investigated three observer populations with the attentional blink method of Joseph *et al.* (Fig. 1a): novice observers who had no prior experience with tachistoscopic displays; trained observers who practised the experiment for thousands of trials before data collection; and expert observers with extensive prior experience with tachistoscopic displays but no practice with the present experiment (or other concurrent task experiments).

The results are shown in Fig. 1c, e, g. 'Popout' detection during the attentional blink was at or near chance in novices (Fig. 1c) but close to normal performance levels in trained and expert observers (Fig. 1e, g). As well as popout detection, I investigated the attentionally more demanding 'T/L' discrimination. For this task, the attentional blink severely impaired performance in all three observer populations (Fig. 1b, d, f, h).

It seems, therefore, that the attentional blink method produces the same pattern of results as the concurrent-task method of earlier studies[2–4]: in trained or expert observers, popout detection is largely unaffected but T/L discrimination is severely impaired (Fig. 1e, f, g, h and ref. 4), whereas in novice observers, both tasks are disrupted to the point of being performed at or near chance (Fig. 1c, d; ref. 1, and J.B., unpublished observations).

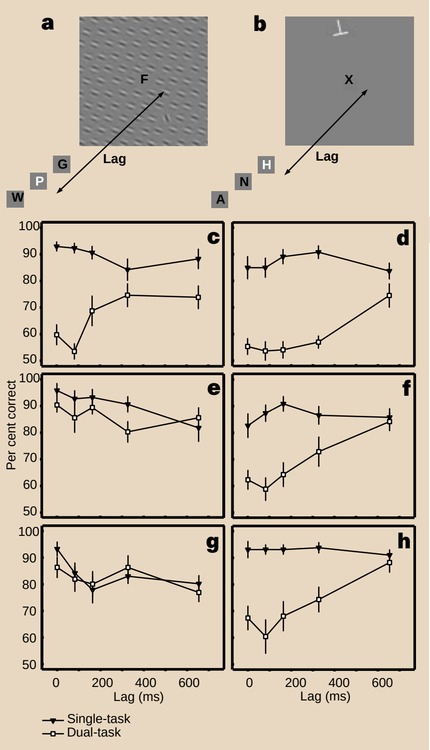

Figure 1 'Attentional blink' experiments[1]. Subjects fixate on a rapidly presented stream of black letters (12 per s) and attempt to identify the one white letter in the stream ('RSVP task', chance performance 3.8% correct). Some time after the white letter (lag time 0, 82, 164, 327 or 655 ms), a second target appears at a more peripheral location (3–4 deg eccentricity). **a,** Second target is a uniquely oriented Gabor element and observers report 'present/absent' ('popout detection'). **b,** Second target is a single white letter (rotated T or L) and observers report 'T/L' ('T/L discrimination'). **c–h,** Peripheral task performance as a function of lag time when the peripheral task is carried out alone (single-task, all trials) and when it is carried out concurrently with the RSVP task (dual-task, trials in which RSVP response was correct, 75–81% of all trials). Average performance ± s.e. shown for all observers. **c, e, g,** Popout detection as the peripheral task. **d, f, h,** T/L discrimination as the peripheral task. **c, d,** Novice observers: six observers in first encounter with tachistoscopic displays. **e, f,** Trained observers: two novice observers after extensive training (4 days/2,560–2,880 trials on **a** and, subsequently, 5–6 days/4,080–4,560 trials on **b**). **g, h,** Expert observers: three observers experienced with tachistoscopic displays but without training on this, or any other dual-task experiment.

So trained or expert observers consistently show large differences in the degree to which various tasks depend on attention, whereas in novice observers the performance of all secondary tasks seems to be equally poor. Clearly, Joseph and colleagues obtained their result because they relied on novice observers, not because attentional blink removes attention any more or less effectively than a concurrent task.

Why are novice observers different? It is often thought that training reduces the attentional demands of visual tasks. However, this would not explain why some tasks (for example, popout detection; Fig. 1c, e) lose so much and others (such as T/L discrimination; Fig. 1d, f) lose so little of their attentional demand. It also fails to explain why prior experience with tachistoscopic displays reduces attentional demands at least as effectively as specific training of a particular task (Fig. 1e, g).

Perhaps a more likely reason is that observers generally fare poorly with unexpected or unfamiliar stimuli[8,9]. Stimuli that are tachistoscopically presented and less than fully attended to do not occur in everyday vision, and to novice observers the subjective appearance of such stimuli may be unfamiliar. Either training or experience may enhance awareness of such stimuli, without any real change in the attentional demands of associated visual tasks.

The main point, however, is that no attentional load seems high enough to prevent performance of certain basic visual tasks by trained or expert observers. In such observers at least, there does seem to be a 'direct route from preattentive processing to perceptual report'[1]. Furthermore, the disparate attentional requirements of various visual tasks are likely to reflect differences in the underlying neural substrate. Thus, experiments with trained or expert observers remain an excellent tool for linking perception and neural substrate.

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Joseph et al. *reply* — We are grateful that Braun has replicated our findings, showing that orientation oddball detection in visual search is severely compromised when paired with an attentional blink task[1]. This confirms our conclusion that tasks that have generally been considered to be 'preattentive', exhibiting parallel search and rapid discrimination performance, actually do require attention. These data favour a unitary large-scale architecture for the visual system, in which all the output of an unlimited-capacity stage (preattentive processing) must pass through a limited-capacity selection stage (attentional selection) before explicit detection. Braun then presents two other experiments which show that such a decrement in performance is reduced with increased training and concludes: "…In such observers at least, there does seem to be a 'direct route from preattentive processing to perceptual report'."

We are surprised by such a statement because it implies a fundamental change in the global visuo-cognitive architecture with practice. Once the novice subject becomes practised, we are meant to suppose, there is then a "direct route from preattentive processing to perceptual report". In fact, there are a large number of degrees of freedom in the local circuitry of preattentive processing that can lead to increased stimulus encoding efficiency, resulting in a reduced attentional load and eventual elimination of task interference with practice. This all occurs within a unitary architecture, without resorting to Braun's scheme for a global architectural change.

To illustrate how a simpler unitary architecture can account for the practice effects observed by Braun and ourselves (page 806 of ref. 1), we refer to Norman and Bobrow's[2] treatment of dual-task studies. Performance in any visual task requires a certain amount of resources (attention), as well as a sufficient stimulus strength to compete with noise in the visual system. Task performance can thus be limited by either of these factors.

Hence, task performance improves with increased resource allocation to the task (Fig. 1a), until resource allocation is no longer limiting; the 'single-task' performance level is then obtained. This is shown in Fig. 1a for a variety of visual tasks of varying 'difficulty'. A relatively 'easy' task has a curve that rises sharply and quickly reaches its maximum performance, while a 'hard' task rises slowly and requires nearly all the resources to achieve its maximum. Practice increases the efficiency with which the stimulus is encoded, reducing its 'attentional load' (the amount of attention needed to reach maximum performance). This is illustrated in Fig. 1b and c as a contraction of each curve to the left after extensive practice.

To demonstrate how these ideas could account for practice effects within a unitary architecture, assume that our RSVP task withdraws a significant amount of attention, lowering the amount available from the full capacity, *F*, to a much smaller remaining capacity, *R*. This is illustrated together with the curves for both novice and highly trained observers engaged in a popout or a peripheral L/T discrimination (Fig. 1b, c).

Because the popout's curve is relatively steep in its resource-limited range, practice has a dramatic effect, essentially eliminating the task interference (Fig. 1b). For the more demanding L/T discrimination task, however, the effect of practice is hardly noticeable (Fig. 1c; observe the differences between the two curves for each task). Regarding Braun's 'expert' observers, extensive practice in tasks with briefly presented stimuli is likely to increase coding efficiency for rapid stimuli in general, again resulting in a reduced attentional load and the observed pattern of results. If we accept this explanatory framework, Braun's changeover from a unitary to a dichotomous architecture with practice becomes unnecessary.

As such, the pattern of practice effects obtained by Braun and ourselves is fully expected within a unitary architecture for the visual system, in which all visual information is required to pass through a limited-capacity stage before it can be explicitly detected.

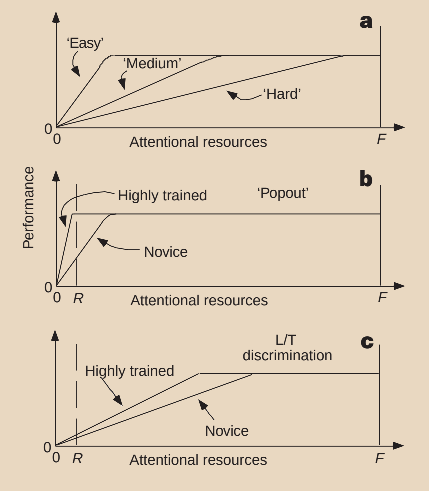

Figure 1 a, Hypothetical task performance as a function of allocated attentional resources for three levels of task 'difficulty'. Maximum performance in all tasks is achieved when the full attentional capacity *F* is allocated. **b,** Additionally imposing an RSVP task reduces the attentional resources available for a 'popout' task, leaving a small remaining capacity, *R*, thus severely limiting performance for the novice but not for highly trained observers. **c,** Imposing an RSVP task in addition to an L/T letter discrimination reduces available resources similarly but does not lead to significantly altered performance when comparing novice and highly trained observers.

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