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).

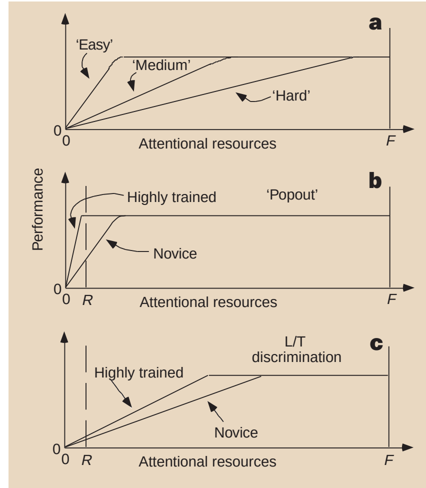

Figure 1 **a,** Hypothetical task performance as a function of allocated attentional resources for three levels of task 'difficulty'. Maximum performance in all tasks is achieved when the full attentional capacity *F* is allocated. **b,** Additionally imposing an RSVP task reduces the attentional resources 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.

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.

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