Experimental psychology

In a blink of the mind's eye

Jeremy M. Wolfe

Imagine a stream of characters appearing, one at a time, on a computer screen at a rate of about eight per second: P-D-E-X-G-4-F-K. You can read characters at this rate — if asked, you could successfully push a button when you saw a 4. But if you were asked to report on Xs and 4s, you would fail miserably: specifically, you would be unable to respond to the 4 when it appeared, a quarter of a second after the X. Something about the extra attention that is given to the X makes it very hard to respond to other items for the next several hundred milliseconds. Known as the 'attentional blink'[1,2], this is one of the more interesting attentional phenomena to have been described in recent years.

Two papers in this issue offer new insight into what is and is not possible during an attentional blink. Joseph *et al.*[3] (page 805) find that attentional blink makes it impossible to perform some very easy visual tasks that were thought not to require attention. In contrast, Duncan *et al.*[4] (page 808) show that a blink of the mind's eye does not produce a blink of the mind's ear, and vice versa. Both of these results provide new information about attentional blink, but they are more valuable for the broader light that they shed on conscious visual experience (in the paper by Joseph *et al.*), and on the nature of attention (in the case of the paper by Duncan *et al.*).

When we use the term 'attention' colloquially — as in "pay attention" — we treat it as a single entity. In fact, whether attention is singular or plural has long been debated. Consider: you are attending to this text. You could, without moving your eyes, attend to some other visual stimulus. You could also attend to the pressure of your posterior on the seat. You were not attending to that tactile stimulus a moment ago — now you are. In the first case, attention is deployed within a single sensory modality whereas in the second, attention is moved between modalities. Does a single, limited attentional resource select prose or posterior as needed? Or, alternatively, are there different pools of attentional resources for different senses?

Duncan *et al.*[4] provide clear evidence that there are separate resources — at least for vision and hearing. The study is elegantly simple. Two streams of stimuli are presented to the subject, and each can be visual or auditory. One target item appears in each stream, and the subject just reports the targets. The authors found that attentional blink occurs when both streams are visual or when both streams are auditory. However, if one stream is visual and the other is auditory, there is no blink. In other words, when a visual target consumes visual attentional resources, it leaves resources available for an auditory task. But those resources must be specifically auditory, because they are not available for a second visual task.

Although this result shows that there are modality-specific attentional resources, it does not rule out the existence of global attentional limitations that can work across modalities. Shakespeare provides an illustration, as depicted in the scene reproduced below, when the witches prophesy that Macbeth shall be "thane of Cawdor ... and ... king hereafter". Macbeth's attention is so consumed by this "great prediction of noble having and of royal hope, that he seems rapt withal" (Act 1, scene 3). He seems not to hear or to see — some global attentional process has restricted his consciousness to the inner world of his thoughts.

In the other study, Joseph *et al.*[3] investigate 'preattentive vision'. They asked subjects to find a right-tilted target among a number of left-tilted stimuli. In such tasks, the ability to find the target does not depend on the number of left-tilted stimuli. This has been called preattentive vision, because subjects do not need to attend to each item in turn: the target simply 'pops out', as if the entire visual field were processed in parallel[5,6]. This has sometimes been taken to mean that such tasks require no attention at any stage, from input to motor response, as if there were separate attentive and preattentive visual systems. Indeed, there is reasonable evidence that searches for features such as a tilted target are possible while attention is tied up elsewhere[7]. Joseph *et al.* neatly disproved this by having subjects perform the feature search at the same time as they performed an attentional-blink task (Fig. 2). They found that in trials where the search stimuli appeared during a blink, accuracy for the simple search task was severely impaired.

There are at least two ways to think about this result. Both challenge our usual experience of a visual world, full of visible and meaningful objects. The result could be seen as evidence for what Mack and her colleagues call 'inattentional blindness'[8]. They argue that you can only consciously perceive what is currently attended. Alternatively, the result could be evidence for what I would like to call 'inattentional amnesia'[9]. Attentional blink may make it impossible to attend or respond to other stimuli for several hundred milliseconds. Those blinked stimuli might be seen, but forgotten by the end of the blink. There is evidence that words presented during attentional blink can be read, even if they cannot be reported after the blink[10].

Figure 1 **"Rapt withal" — Macbeth consumed by the witches' prediction, as painted by Henry Fuseli (1741–1825).**

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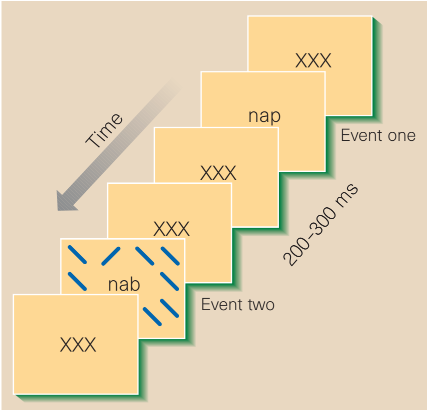

Figure 2 **Suppose you were asked to respond to events one and two in a stream of stimuli. Duncan *et al.*[4] found that subjects missed the second word if both words were visual stimuli or if both words were auditory stimuli, due to the phenomenon known as 'attentional blink'. But subjects could identify the second word if one was auditory and the other was visual. Joseph *et al.*[3] found that if event one was visual, subjects could not say whether there was a right-tilted line in the event two display, indicating that attentional blink makes it impossible to carry out easy visual tasks that were previously thought not to require attention.**

Moreover, unattended stimuli can produce geometric visual illusions[11].

Vivid demonstrations from several labs have pointed to the fleeting nature of visual experience[12–14]. For instance, Rensink *et al.*[15] presented observers with a scene. After a very brief, 80-millisecond blank period, the same scene was presented in the same location with a single change. Even though observers could clearly perceive and remember the gist of the scene in a second, it took many alternations of the two versions before the change was noticed — even when that change was quite dramatic. For example, subjects failed to readily notice a jet engine appearing and disappearing in a scene where the plane was the most prominent object[15]. Although observers may know the gist of the scene, only the present contents of attention can be monitored for change.

In sum, the message of the paper by Joseph *et al.* is that attention is required to carry even the most basic of visual tasks through to completion. If a stimulus is presented while attention is summoned elsewhere, "ere a man hath power to say 'Behold!' The jaws of darkness do devour it up: so quick bright things come to confusion" — although Shakespeare's Lysander is probably not discussing the allocation of visual attention when he speaks these lines in *A Midsummer Night's Dream.* □

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Gamma-ray astronomy

New sights in the high-energy sky

Hans Bloemen

Gamma-ray astrophysics deals with the world of extremes and fundamentals, from the creation of the elements to the disappearance of matter into black holes. γ-rays are the most energetic electromagnetic radiation, and reveal the most violent phenomena. Six years after the launch of NASA's Compton Gamma Ray Observatory, a 15-ton spacecraft containing the most advanced γ-ray instruments, astrophysicists met* to assess its achievements so far. In some respects, the observations have confirmed theory and expectations, but the γ-ray sky appears to be even richer than anticipated. An unexpected 'fountain' of antimatter far above the Milky Way has been reported, many active galactic nuclei and more than a hundred unidentifiable point sources have been detected, and increasing evidence for γ-ray lines has been seen.

The Compton Observatory carries four instruments, each with its own specific goals and accomplishments. BATSE (Burst and Transient Source Experiment) made us realize that γ-ray bursts are among the most puzzling phenomena in astrophysics. The Energetic Gamma Ray Experiment Telescope (EGRET) and the Compton Telescope (COMPTEL) have mapped for the first time the entire γ-ray sky, from ~10 GeV (giga-electron volts) down to the MeV (mega-electron volts) regime, where nuclear decay and nuclear interactions produce γ-ray lines. An intense glow from the Milky Way dominates this whole spectral region, which can largely be attributed to diffuse emission from cosmic rays hitting gas nuclei and photons in interstellar space. This reveals the distribution of cosmic-ray particles throughout the Galaxy, which is vital information for understanding their origin.

But a growing number of γ-ray sources is being seen, amounting to over 200 now. A small subset can be identified with radio pulsars, not from their positions (which can only be roughly determined by current γ-ray telescopes), but through their distinctive timing signature. And intense γ radiation from more than 50 active galaxies has been discovered, from outflowing plasma jets pointing in our direction, which probably originate from massive black holes (of the order of 100 million solar masses) in the galactic nuclei. Less massive ones in our Galaxy (of a few solar masses or so) are occasionally bright sources in the X-ray and soft γ-ray sky, when a giant extra scoop of ambient matter is accreted. But most of the γ-ray sources remain unidentified. Given their distribution on the sky (loosely following the Milky Way), they are probably within our Galaxy. They are likely to be massive-star remnants of some sort, with pulsars perhaps forming a subclass.

γ-ray spectroscopy is carried out by COMPTEL and by the fourth instrument, OSSE (Oriented Scintillation Spectrometer Experiment). Lines in the γ-ray spectrum are the signatures of nuclear-decay and nuclear-interaction processes. They can provide direct, and often unique, information on many important problems in high-energy astrophysics, including nucleosynthesis,

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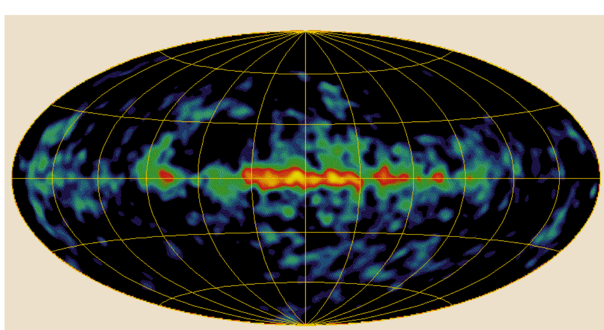

Figure 1 **The Milky Way in the light of the 1.809-MeV line from the nuclear decay of ^{26}Al, which has a lifetime of about a million years, obtained with the COMPTEL instrument. This traces sites of recent nucleosynthesis in the Galaxy.**

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