It's Great But Not Necessarily About Attention

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ABSTRACT: I point out that Mack and Rock manipulated both expectation and attention and suggest that their results ('inattentional blindness') may have been caused by lack of expectation rather than lack of attention. This alternative reading of Mack and Rock's results is supported by other findings, which suggest that 'pure' manipulations of expectation produce 'blindness' whereas 'pure' manipulations of attention do not. Why should failure to expect or anticipate a stimulus lead to 'blindness'? In psychophysics, stimuli near threshold typically require a degree of familiarity to be consciously perceived. Perhaps the same is true for the supra-threshold stimuli used by Mack and Rock. This may reflect the fact that the human visual system uses natural and acquired 'priors' to solve the probabilistic problem of perception.

Since its publication in 1998, the monograph "Inattentional Blindness" by Mack and Rock has fired the imagination and challenged the understanding of almost everyone interested in visual perception. The phenomenal impact of the book derives less from the heroic methodology employed -- one critical trial per subject, more than 5000 subjects tested over a period of 7 years -- than from the fact that it reveals a relatively unfamiliar realm of visual perception, where many cherished laws and rules no longer seem to apply. By their own admission, the authors are continually "startled" and "surprised" by their findings and sometimes even at a loss for an explanation (a rare condition indeed among cognitive psychologists). And so the sympathetic reader, too, will often find his- or herself at a loss as to how to integrate this new material with their earlier views on perception. Here I sketch the results of my own attempt to reconcile Mack and Rock's provocative findings with my earlier views of perception. The point of view I with to propose gives full credence to Mack and Rock's data, but departs significantly from their interpretation of these data.

As the reader will recall, Mack and Rock's "Inattention Paradigm" consists of a short sequence of trials in which the observer is instructed to carry out a "distraction task", intended to engage visual attention (e.g., comparing the respective lengths of the horizontal and vertical arms of a cross). In three "critical trials" an additional, unexpected stimulus appears, about which the observer has received no instructions whatsoever. After the first critical trial, the observer is debriefed as to whether he had seen anything else and, if so, what. The main finding is, surprisingly, that many perfectly visible, and even conspicuous, stimuli and features are not consciously perceived in this particular situation. This debriefing implicitly alerts the observer to the possibility of an additional stimulus. In the second critical trial, the observer can therefore be expected to "divide attention" between the distraction task and the additional stimulus. Before the third and final critical trial, the instructions change and the observer is asked to ignore the distraction task and to concentrate fully on the additional stimulus. Now the observer can be expected to devote "full attention" to the additional stimulus. In short, the paradigm compares the conscious percepts (if any) elicited by the critical stimulus under three conditions: inattention, divided attention, and full attention.

As Mack and Rock acknowledge in Chapter 9, their paradigm really combines two elements that might prevent or compromise conscious perception of the 'critical' stimulus. One of these elements is the distraction task, which presumably keeps attention away from the 'critical' stimulus, whence the name 'inattentional blindness'. The other element is the utter unexpectedness of the critical stimulus and the observer's consequent inability to anticipate it. And it is this second element of the paradigm that, according to the results of Chapter 9, may account for 'blindness'. For these results show that 'blindness' occurs even when attention is free to shift to a sudden visual onset, such as the 'critical stimulus' constitutes. As long as the observer does not expect a critical stimulus to occur, 'blindness' is especially pronounced during single long trials (in which the critical stimulus appears during the last 200ms of the 5s trial period; pp. 207ff, 209ff). This is true even when the unexpected stimulus is presented at foveal locations (pp. 210ff). In this modified paradigm, the 'critical' stimulus comes as a complete surprise to the observer but attention is not engaged beyond the need to maintain fixation. These results suggest, then, that 'blindness' results more from the observer's inability to anticipate the critical stimulus than from any lack of attention.

This reading of the data is borne out by work from our laboratory which manipulates attention rather than expectation and does not lead to 'blindness' (Braun, 1994; Braun & Julesz, 1998; Lee, Koch, & Braun, 1999). In contrast to Mack and Rock, we use highly trained subjects who are extremely familiar with the stimuli and tasks and who know fully what to expect before each trial. But like Mack and Rock, we use a distracting task to draw attention away from an additional, 'critical' stimulus. In fact, our distracting task is substantially more effective at detaining attention than that of Mack and Rock. For in our case the respective performances on distracting and critical stimuli are tightly (negatively) correlated, indicating that any attention gained by one stimulus is lost to the other. In Mack and Rock's situation, performance on the distracting task is generally the same, whether or not a critical stimulus is being discriminated. Thus, an analysis of the attentional-operating characteristic (Sperling & Dosher, 1987) would show that our distracting task binds a substantially larger fraction of attentional resources than that of Mack and Rock. Naturally, no distracting task (including ours) is going to be 100% effective at preventing attention from straying towards additional stimuli that the observer knows to be task-relevant.

Given the effectiveness of our distracting task, it is not particularly surprising that visual performance is severely disrupted with respect to other stimuli elsewhere in the display. In fact, in some respects the disruptions are similar to the effect (on monkeys) of a cortical lesion in visual area V4 (Braun, 1994). However, these disruptions are only partial and many demanding visual discriminations continue to be performed well, in spite of the distracting task. For this reason, we sometimes speak of 'vision outside the focus of attention', a notion that is of course completely antithetical to 'inattentional blindness'! The reason we are emphasizing the 'half full' rather than the 'half empty' aspect of our findings (i.e., the discriminations that continue to be performed well rather than those that are severely disrupted), is that current theories of visual saliency predict exactly which types of discriminations should remain possible 'outside the focus of attention'. To a good approximation, visual saliency results when a local feature differential prevails in a global winner-take-all computation (Koch & Ullman, 1985; Itti & Koch, 1999; Tsotsos, 1999). And it is precisely the stimuli and features that are salient in this sense, which can still be discriminated when attention is detained (Braun, Lee, Itti, & Koch, 2000).

Since 'blindness' results from lack of expectation (Mack & Rock, Chapter 9) but not from lack of attention (our results), it is tempting to conclude that expectation rather than attention is at the nub of the matter. To avoid this conclusion, one would have to assume that Mack and Rock's manipulation of expectation produces, as an indirect consequence, a more complete lack of attention than direct manipulations of attention with concurrent tasks. In other words, one would have to assume that expectations play a dominant role in the allocation of attention and that only an unexpected stimulus can ever by completely unattended. However, this would not only require a whole new set of interactions between expectation and attention, but would fly in the face of everything we know about sudden visual onsets and their power to attract attention. To my mind, it seems more parsimonious to assume that Mack and Rock's manipulation of expectation is simply that, a manipulation of expectation, rather than an especially effective (albeit indirect) manipulation of attention.

As the alert reader will have noticed, we differ fundamentally from Mack and Rock on the role that attention plays in providing access to conscious perception. Whereas for Mack and Rock conscious access is the exclusive province of visual attention, for us the necessary condition for conscious access is merely a sufficiently rich and intense neural response. Such a response can come about either as the result of bottom-up mechanisms ("visual saliency") or as the result of top-down intervention ("visual attention"). Both routes to awareness lead to exactly the same phenomenal experience, in our opinion. And in both routes to awareness, it may well be that conscious perception requires also some element of expectation or anticipation. In other words, we believe that a sufficiently rich and intense neural response, perhaps together with some element of expectation or anticipation, are the necessary and sufficient conditions for conscious awareness.

The one burning issue raised by Mack and Rock is undoubtedly the pervasive finding of 'blindness'. Why would the inability to anticipate a stimulus and its particulars lead to 'blindness'? In this context it is interesting to recall the work of Neisser and colleagues on selective looking, which showed that observers often fail to see unexpected objects provided they are engaged in some other task (Neisser & Becklen, 1976; for recent reviews, see Holender, 1986; Simons & Chabris, 1999). In essence, Neisser and colleagues argued that nothing is perceived without expectations. The work of Mack and Rock seems to carry similar implications and may reveal a sizeable kernel of truth in these earlier views.

In this context, it may be also be relevant to consider the transition that commonly occurs as an initially naive observer becomes familiar with a given stimulus and task. Over the course of an hour (and some hundreds of trials), a naive observer generally improves dramatically on threshold discrimination tasks, in particular when these involve flashed and masked stimuli (as many of Mack and Rock's stimuli do). Introspectively, this improvement is accompanied by a distinct increase in awareness, as stimuli that were previously 'missed' or glimpsed only fleetingly now become comfortably 'visible'. This is not necessarily a gradual change, but can sometimes occur almost instantaneously, as if scales were falling off one's eyes ('Eureka effect', Ahissar and Hochstein, 1997). Interestingly, an 'expert' observer who is adept at other threshold discriminations often does not require this period of familiarization, perhaps because their prior experience lets them correctly anticipate the stimuli in question.

I have recently described this familiarization process for tasks carried out during an attentional blink (Braun, 1998). The tasks in question were pop-out detection and letter discrimination, in other words, standard 'pre-attentive' and 'attentive' tasks, respectively. Naive observers were unable to carry out either task during attentional blink. With respect to pop-out detection, this result changed for both trained observers (after several hundred trials on the task in question) and expert observers (new to the particular task but adept at other threshold discriminations), who performed well even during attentional blink. However, neither group was able to discriminate letters, confirming that only 'pre-attentive' discriminations are possible during attentional blink. The relevance of this in the present context is that it constitutes another, admittedly less dramatic, instance where familiarity, or ability to anticipate, seems crucial for conscious access. Indeed, in this case a merely 'generic' familiarity seems sufficient to ensure access (i.e., prior experience with flashed, masked displays).

Further support for the idea that familiarity and anticipation are crucial to 'blindness' matter comes from Chapters 5, 6, and 7 of Mack and Rock. Here the authors find that 'meaningful' stimuli -- such as the observer's name, faces, and natural scenes -- produce very little 'blindness', if any at all. Particularly striking is the difference obtained between the proper spelling of the observer's name and a misspelled version differing in one letter: 0.5% of observers are 'blind' to the former, whereas 60% turn out to be 'blind' to the latter. The results obtained with natural scenes are harder to quantify, but none the less impressive. None of the observers presented with an unexpected natural scene failed to notice the scene (i.e., exhibited 'blindness') and most gave fairly accurate descriptions of its contents. It is tempting to speculate that the distinguishing characteristic of these 'meaningful' stimuli is really that they are being anticipated in a general sense, even though their details are not known in advance. Natural scenes are what the visual system would normally expect to encounter and thus fall within the range of its natural 'priors'. Perhaps the observer's given name is another instance of a stimulus that falls within the range of acquired 'priors'. In any case, there certainly is a striking contrast between 'meaningful' stimuli, one the one hand, and the long list of synthetic stimuli (textures, arrays, simple shapes, moving dots, etc) to which observers are 'blind' in inattention trials, on the other.

In fact, one may argue that Mack and Rock's paradigm produces 'blindness' for all stimuli except those that are natural or 'meaningful'. Although Mack and Rock report lesser degrees of 'blindness' for a number of non-natural and non-meaningful stimuli, many of these data appear suspect to a psychophysicist's eye. In order to compare various situations properly, it would have been desirable to establish detection/discrimination thresholds with practised observers, and to choose the stimulus contrast, velocity, etc., for naive observers accordingly (e.g., at a fixed multiple of threshold). In the absence of such measures, the relative degree of 'blindness' observed with, say, proximity grouping and similarity grouping is difficult to credit. To give a specific example, the authors are at a loss to explain why only 25% of observers are 'blind' to an isoluminant red dot, when 60% are blind to an isoluminant green dot (p. 68). The answer lies probably in the fact that chromaticity (color saturation) was not matched, so that detection thresholds could have been substantially different (e.g., Lu & Sperling, 1999). When physical stimulus details such as these are not considered and equalized, any differences in the degree of 'inattentional blindness' are quite hard to interpret.

In summary, it would appear that 'inattentional blindness' occurs for synthetic stimuli that cannot be anticipated even in a general sense, but does not occur for stimuli such as natural scenes, certain ideograms such as smiley faces or stick figures, and the observer's given name. However, synthetic stimuli penetrate to conscious experience as soon as they acquire some degree of familiarity and thus can be anticipated. For supra-threshold stimuli (i.e., highly discriminable stimuli), Mack and Rock show that a single prior exposure may convey the requisite familiarity. For threshold stimuli, several hundred exposures may be required to obtain full conscious access (Braun, 1998).

The implication of all this is, of course, that conscious vision draws not only on perception but also on memory. I find the idea that conscious visual experience may necessarily require some involvement of memory intriguing for many reasons. Among these are Goodale and Milner's (1995) arguments about the importance of ventral visual pathways for conscious vision and visual memory, and also the attractive computational possibilities offered by bi-directional processing (Ullman, 1995). Mack and Rock are to be congratulated on one of the most stimulating books of the last decade, whose one slight (and I really mean slight) blemish is that it pretends to be exclusively about attention.

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