Book review

Review of Visual Attention and Cortical Circuits J. Braun, K. Christof & J. Davis; MIT Press, 2001; ISBN 0-262-02493-4

Action Editor: Stefan Wermter

R. Farivar

Department of Psychology, McGill University, Montreal, QC, Canada

Attention and consciousness. These are perhaps the holy grails of our scientific quest into the mind. Whereas the latter is so difficult to even define, the former is somewhat more comprehensible, if not at least definable. Attention can be considered as the process that causes one to better process some important or relevant information at cost of reduced processing of irrelevant information, as measured by accuracy and/or reaction time. Within this formulation, at least two types of processes require further investigation: (1) how attention improves processing of relevant information, and if it truly does this, and (2) what happens to the processing of unattended stimuli. What is attention good for? Where does it occur? What initiates it, carries it, and terminates it when it is no longer needed? Finally, how does the brain carry out this formidable process? The papers presented in Visual Attention and Cortical Circuits attempt to shed light on these important questions.

The primary goal of the book is to bring together the many approaches used in attention research, from imaging studies, electrophysiological recordings, to behavioural experiments and computational modeling. This goal is achieved through the fourteen chapters of the book. Although the Overview chapter makes an attempt at giving the reader some organizational guidance of the book, the book would have benefited from proper divisions of papers into chapters with section prefaces. Without this, it can often be difficult to find a direct relevance amongst the different articles.

What are some of the major advances in attention research? First, it should be noted that attention involves the interaction of multiple brain areas. This is to be expected of a function that serves to affect almost all types of behaviour. Through a process-analysis, one can decompose attention (or tasks involving attentional manipulation) into several sub-components. For example, Corbetta and Shulman (Chapter 1) make a distinction about expectation signals and attentional modulation. Using event-related fMRI, the researchers show that advanced information about a visual event can increase activation in relevant brain areas while reducing activation in irrelevant pathways. This augmentation of relevant and suppression of irrelevant pathways then interacts with the incoming visual information to affect perception and thus behaviour. This is consistent with a number of prominent models of attention, including the Guided Search Model (Wolfe et al., 1989) and the biased competition model of Desimone and Duncan (1995). Such models typically posit the existence of a top-down biasing mechanism that enhances the feature maps that code for the expected

visual event, thereby improving the processing of focal-attention information. One limit of their study that they do note is that it does not disambiguate between the possible mechanisms underlying attentional modulation—does attentional modulation bring about the enhancement of signal processing through elevated baseline activation of a region or does it suppress noise in competing areas? The answer to this central question is still unknown.

Duncan (Chapter 4) reports on the role of prefrontal areas in attentional control as well as general high-level cognitive functions. Using PET imaging, the author reports on studies showing frontal activity that is ipsilateral to the attention-focused hemifield. Duncan proposes that the prefrontal cortex modulates attention through inhibition of contralateral fields. This is consistent with lesion studies showing unwanted behaviour directed to the space contralateral to the prefrontal lesion site. However, as the author correctly points out, it is not possible to directly infer from this that the prefrontal areas inhibit competing hemifields, because the same effect may be observed if competitive connections between two hemifields were reduced.

How do we orient attention to a given object or area? How does attentional selection occur? Thompson, Bichot, and Shall (Chapter 8) report on the interesting role of the frontal eye fields in selection of attended stimuli and its role in deciding on impending actions (e.g., saccadic planning). They report on physiological recordings of both visual and motor neurons in the frontal eye fields, suggesting that the two populations may be functionally distinct: visual neurons may represent a saliency map where a ''pop-out'' stimulus evokes a stronger 'peak' in the saliency retinotopic map, even in the absence of a saccadic eye movement, suggesting at a minimum that neurons in the frontal eye fields are contributing to a selection process and not solely to the planning of saccadic eye movements. The authors suggest that this selection mechanism is the same one responsible for the psychological ''pop-out'' phenomenon, and thus suggest that the frontal eye fields may be involved in attentional selection.

What is the extent of attentional influence? Does information outside the visual modality affect visual perception? Shimojo, Watanabe, and Sheier (Chapter 12) report on a striking effect whereby the percep-

tion of ambiguous motion is biased by the concurrent presentation of auditory stimuli. The ambiguous motion stimuli used in their study are two diagonally crossing dots; the ambiguity comes about at the crossing point—do the dots continue their straight paths or do they ''bounce-off'' each other? Typically people report perceiving the continuous motion of the dots, but when a sound is presented at the incidence of the two dots, subjects report seeing two dots bounce off one another. Furthermore, exogenous distracters that co-occur with the incidence point (but are spatialy segregated) also invoke the bouncing perception. Together, the authors suggest that focussed attention is involved in temporal recruitment of motion signals, which then leads to the perception of streams whereas decreases in attention reduce the recruitment process thereby allowing for alternative perceptions to occur. This is consistent with an earlier finding that divided attention reduces the motion after-effect—the illusory perception of motion in the opposite direction of a previously-moving stimulus stream (Chaudhuri, 1991).

One important lesson taken from the above discussion is that attention modulates processing at multiple stages. Until recently, evidence for attentional modulation in area V1 had been lacking. Heeger, Gandhi, Huk and Boynton (Chapter 2) report an intriguing fMRI study where moving sinusoidal gratings are presented in both hemifields, but subjects are asked to discriminate the speed of the two gratings either in the left or in the right hemifields. Their data shows clear alternation of the BOLD signal in the striate cortex that corresponds with the alternation in the hemifields, evidence that attention modulates activity even at the level of the striate cortex.

But why has it taken so long before attentional influence in V1 to be observed? Ito, Westheimer, and Gilbert (Chapter 5) suggest that it is because researchers were not using the appropriate stimuli. They report attentional modulation of contextual influences brought about by lines flanking a target line in a line-brightness decision task. When attention was focused, brightness thresholds were significantly lower in presence of flanking lines than when attention was divided. Additionally, the authors show that the elevated threshold under divided attention is reduced after extensive training, suggesting that

when animals are over-trained in an attention task in preparation for electrophysiological recordings, the attentional effects may be attenuated, and this may be one reason why attentional influences in area V1 have not been observed in single-unit recordings. Using this approach of assessing contextual influences in area V1 and electrophysiological recordings in the macaque, the researchers corroborate the results from Heeger et al. (Chapter 2), showing attentional modulation in V1.

Reynolds and Desimone in Chapter 7 also provide examples of cortical interactions in visual attention, where they show that when two stimuli are presented within the receptive field of one neuron, the effect of the distracter stimulus is altered such that the response of the neuron under focal attention is similar to when the target stimulus was solely presented. The authors suggest therefore that the modulatory effect of attention is to shift the response of a neuron to the level it would have with its native stimulus alone. Maunsell and McAdams (Chapter 6) reach a similar conclusion, but differ on the mechanisms they hold responsible for attentional effects. These researchers believe that the effect of attention directly affects the response of a neuron rather than modulate the neuron's response indirectly. In both models, attention effects are thought to be modulated by the stimulus itself rather than the behavioural context (i.e., bottom-up effects instead of top-down influences). The notion of bottom-up influences produced by interaction of cortical units is probed through psychophysical studies employing concurrent tasks by Braun, Koch, Lee and Itti (Chapter 11).

Aspects of the psychophysical and neurological findings are integrated by models offered by Sperling and colleagues (Chapter 10) and Tsotsos, Culhane, and Cutzu (Chapter 14). Both groups build on the concept of a saliency map (see above) to account for attentional effects. The first model proposed by Sterling et al. describes how an attention window could be constructed in successive episodes and also how such windows may control access to information in short-term memory. The second model expands on the idea of a salience map using a method involving third-order motion, where it was found that attentional focus enhanced the salience of colour information significantly. It should be noted that the focus of the model is not the enhancement of

colour information in the motion stimuli, but only its salience (how much attention it grabs). This model demonstrates that a saliency map could be the main mechanism for a number of tasks, such as guided search and memory access.

The model proposed by Tsotsos and colleagues is somewhat different, in that it suggests that bottom-up processing alone cannot guide direction of attention, because stimulus-driven search is a computationally intractable problem (Tsotsos, 1989, as cited in the same chapter). The basic component of their model represents attentional mechanisms as top-down, task-dependent processes that direct competition among overlapping (or conflicting) neural elements. This model also integrates ideas relating to a salience map of attentional guidance, but the object-selection mechanisms for target of attention are primarily top-down signals. They report both computational and psychophysical data in support of their model.

The impression that one gets from reading this book is that our understanding of attentional mechanisms is still poor, but that we appear to be moving in the right direction. For example, it still remains difficult to compare attentional effects observed under different measurements, such as behavioural, single-unit recordings, and fMRI. A comprehensive theory of attention must close the gaps between all the different possible measurements of attention, and this is presently lacking. Luckily, models of attention are becoming more neurally plausible, paving the way for a more direct comparison of the different methods.

Interestingly, some of the most basic questions relating to attentional control remain unanswered. First, does attention occur at all levels of processing? If this were true, then one should be able to find attentional effects modulating processing at the level of the lateral geniculate nucleus of the thalamus, but evidence for this is still lacking. Even evidence for attentional modulation at the level of V1 is relatively new. The image one gets from the different neurological measures is that attentional modulation is truly not simple—just looking at some of the problems with single-unit recording studies of attention in area V1 point to the inherent problems. Why do single-units not show any attentional effects whereas BOLD signals do? As Ito et al. (Chapter 5) suggest, this may be because the proper stimuli have not been

employed or because monkeys were over-trained. But until such time as we can have more corroborating evidence for the ambiguous performance of area V1 neurons under attention, we have only a vague idea about attentional modulation of low level visual processing. A related question that cannot be easily answered is whether or not attentional modulation at early visual stages is greater or weaker than at later stages. Until we have more valid tasks that can tap into different stages of processing, we cannot readily draw conclusions about strength of attentional modulations.

A second fundamental question that is left unanswered is whether or not unattended stimuli are processed. From the discussion on bottom-up competitions, one can have a faint idea as to the answer to this questions: if two stimuli compete for activity, such that greater salience of one stimulus is at the cost of weaker salience of the other, then perhaps focal attention to one stimulus causes complete inhibition of the neural representation of the unattended stimulus, thereby reducing any subsequent processing that may be conducted on it. However, following recent evidence about the processing of sub-threshold stimuli, it is unclear to me why the processing of unattended stimuli is still a contentious point.

To elaborate on this point, one may look at a recent article by Watanabe et al. (2001) who suggest that sub-threshold coherent motion can influence supra-threshold and near-threshold coherent motion detection, even when focal attention is strongly dissuaded from the central task through the use of a flickering letter-detection paradigm. In other words, coherent motion that is already undetectable, when presented concurrent with a focal attention task, can still induce observable effects! Such an effect of sub-threshold stimuli is further backed by Tanaka and Sagi (1998) who show that sub-threshold Gabor stimuli can facilitate detection of a near or supra-threshold stimulus. This also suggests that subthreshold stimuli are indeed processed. Relating this to the problem of processing of unattended stimuli, it would appear that if attention is attenuating the signal from unattended stimuli, then their level of activation is perhaps analogous to subthreshold stimuli, which recent evidence suggests must be processed nonetheless. More concretely, the results of Watanabe and colleagues points even more strongly to this direction in that it shows even with attention divergence, sub-threshold stimuli are processed and do have an observable effect.

Overall, this book is appropriate for any researcher interested in expanding their knowledge of attention research or commencing work in the field. It is perhaps most appropriate for a graduate-level seminar on visual processing, as the chapters do lack a great deal of detail for the purpose of making themselves more accessible. However, the book does lack structure, as each chapter seems quite unrelated to the others, even when the topic of the book is so narrow. Yet one could find the same problem with many compiled books, and this would not be a criticism had the goal of this book not been to make the material accessible to a large population.

On a positive note, this book represents a comprehensive survey of the current approaches to the study of visual attention and its underlying neural circuitry. It contains recommended reading for beginning graduate students or researchers with interests in visual processes.

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