Seeing the forest but not the trees

Patrick Cavanagh

In peripheral vision, individual item information becomes inaccessible in the presence of distractors. Parkes *et al.* now show this information is not lost, but integrated into accurate ensemble statistics, suggesting that such 'crowding' may be related to texture perception.

Each word on this line falls into focus as you read it, but the words a short distance to the left or right of where you are looking are blurred and indistinct. You might think this is just poor focus away from the center of gaze (the fovea) or coarser sampling outside the fovea. Not so. These are important factors, but there is more to it than this. When single letters are placed alone off the center of gaze, they are seen much better than the same letters in words at the same distance (**Fig. 1**). The dense string of letters within the word are together unresolvable, even when each letter could be clearly distinguished on its own. It is not the optical clarity nor the coarse sampling that limits the visibility of the items in this case—it is the density of the items. This phenomenon, known as 'crowding', has traditionally been conceived as a form of masking in which items, when close enough, interfere with each other, degrading their representations. Beyond this particular density limit of the visual system, loss of item information is just the price that we pay. The traditional view of crowding as masking suggests that such details are thrown away early in visual processing. This story was modified recently with the finding[1] that crowded grating patches can induce aftereffects specific to their orientation. This adaptation occurs even though crowding prevents observers from being able to report the orientation of the patches. The individual items are evidently registered at some early level, perhaps primary visual cortex, but then never reach awareness.

But why would individual items be analyzed initially, only to then be blocked from awareness and higher levels of analysis? In this issue, Parkes and colleagues[2] provide a striking insight into this puzzle, and in doing so suggest a new conception of crowding. The authors show that even though the individual identities in a crowded array are blocked from awareness, they nonetheless do get through to higher levels, albeit in the form of individual, highly accurate contributions to the array's texture.

As shown in Fig. 1 of the paper[2], when eight horizontally oriented patches encircle a central patch, the orientation of the central patch cannot be reported, symptomatic of crowding. This can occur even when the central patch deviates from the horizontal by as much as 90 degrees. The surprising finding is that an observer can make a global orientation judgment of such an array that nonetheless depends on all the patches, falling midway between the orientations of the central patch and those surrounding it. It is as if some average orientation of the group were available despite the inability to access the individual items. The authors offer convincing evidence of this linear averaging, focusing mainly on cases where orientations differ by 45 degrees or less. Clearly, when the element orientations differ to a greater degree, it does not make sense to compute an average. In the case of 0 and 90 degrees, for instance, there is no average orientation, as it could just as well be 135 degrees as 45. It remains to be seen whether other ensemble statistics such as the variance of local orientation are extracted in such cases.

Is crowding nothing more than texture perception occurring when we'd rather it didn't? Parkes *et al.*[2] show that the extraction of mean orientation accompanies the loss of individual element identities in crowded stimuli. Could it be that one of these processes causes the other? This does not seem to be the case; in other situations, we can have both texture statistics and individual access for the same array. Recent work on ensemble judgments shows that we have an accurate sense of the 'average' feature of an array, even when the items are spaced widely enough for each to be perceived and reported on its own. Parkes *et al.* show this averaging or pooling with their task in the fovea where each item can be reported, but only when the observers do not know where the target is. However, Ariely[3] has shown that uncertainty is not necessary. When observers are asked to make judgments about the average size of the elements in an array where the individual items are clearly seen, they do so with great precision. Indeed, these ensemble judgments seem to be as accurate as those for comparing isolated individuals. Similar results are found for sets where the individual elements are presented in sequence over time. In these conditions, observers act as if they have a very accurate estimate of the running average of the last several items in the stream[4]. These findings indicate that ensemble statistics may be derived for regions as a default whether or not they are dense enough (in space or time) to prevent access to individual elements. Apparently, the averaging process in itself need not

Fig. 1. When fixating the dot on the top left, the K to the right is easily identified. When fixating the dot just below, the K seems to meld into a jumbled texture. This is the crowding effect of the surrounding items on the availability of an individual item. Notice that this is not just a function of eccentricity, as the letter S, even farther in the periphery, can be identified. Parkes *et al.*[2] now show that the K is not in fact lost but contributes efficiently to our judgments of the texture itself.

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obliterate the details of the individual elements when they are sparsely arrayed.

If texture statistics and individual identities can be available simultaneously in less dense arrays, why is access to individual identity abandoned beyond a certain density? Could there be any utility to the crowding effect that prevents access to local detail? Perhaps texture statistics and the segmentation they support are more efficient when no local item identities clutter the region to be analyzed. There is no evidence from Ariely[3] or Parkes *et al.*[2] to indicate a disadvantage when items in the array can be individually accessed, but this comparison has not been tested explicitly. It is thus unclear whether crowding is advantageous for texture processing or simply an unavoidable limit that happens to permit texture analysis to continue unimpaired. But although we do not yet know why crowding works as it does, we can still ask how it works. It might be lateral masking at a level beyond the early levels where pooling and aftereffects are mediated. Or it might be the limited spatial resolution of attention[1]—the inability to pick up individual items if more than one item falls within the smallest 'window' of attention available at that eccentricity. The details of this process remain to be discovered.

Whether or not ensemble statistics like the average orientation are more accurate in crowded displays, their high degree of accuracy is intriguing. Parkes *et al.*[2] demonstrate that the ensemble average is not a rough estimate but a highly accurate value computed over the orientation signals. If the goal of the ensemble statistic were simply to compress the description of the details in a region, there is no obvious reason to make this description so accurate. Certainly ensemble statistics may be useful to characterize a surface as one material or another (grass, wood, water, hair, textiles and so forth), and the more precise the characterization, the better the classification of surface materials.

But ensemble statistics may also support a more important function: detecting deviants, identifying items that do not belong. Computationally this is a very complex task, as each item needs to be compared to all the others. Any ensemble statistic that is computed automatically will simplify this task enormously. And here, a more accurate ensemble statistic allows for more sensitive detection of deviance from the ensemble properties.

Deviation from the crowd pops out; it breaks crowding. This may be the most important function of ensemble statistics: rapid identification of deviant items with enormous savings in computational complexity. At least here the precision of the averages discovered by Parkes *et al.*[2] make the most sense, given the importance of detecting odd items that do not belong in the group. On this account, readers familiar with the visual search literature might be puzzled why the extremely deviant orientation (as much as 90 degrees) did not 'pop out' in the reported experiments. One answer may be that even when the patches of oriented grating differ markedly in orientation, they all have identical, circular Gaussian envelopes. Perhaps this level of similarity is enough for the visual system to treat the set of items as a texture of relatively homogeneous elements. Further work would help to clarify this.

The work by Parkes *et al.* bridges two areas of research: crowding and texture perception. Crowding research has long demonstrated the inability to access identity in dense arrays of similar items but has not evaluated how the resulting textures form from and absorb the individual identities. Research on the discrimination and segregation of textures has examined the nature of ensemble statistics of arrays but has ignored whether or not the array items are individually accessible. Parkes *et al.*[2] now show that crowded information is preserved in accurate ensemble statistics whether or not access to individual items is possible. Their work is an important step toward revealing the underlying links between the mechanisms of crowding and texture segmentation.

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A new form of feedback at the $GABA_A$ receptor

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GABA is inhibitory in adults, but it is excitatory in young animals. A recent study shows that activation of the $GABA_A$ receptor itself may promote this developmental switch.

Although GABA is the main inhibitory neurotransmitter in the adult central nervous system, there are several circumstances in which $GABA_A$ receptor activation excites neurons instead of inhibiting them. In the immature nervous system, for example, GABA is universally excitatory. Then, just as synaptic activity develops to the point that runaway excitation seems imminent[1], GABA becomes inhibitory[2]. GABA manages this last-minute functional turnabout by an intriguing activity-dependent change in the chloride reversal potential, described in a recent paper in *Cell* by Ganguly, Schinder and colleagues in the Poo laboratory[3].

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The heavy lifting of synaptic signal transduction is accomplished by ions driven through open channels by the concentration and voltage differences across the neuronal membrane. This driving force is conveniently summarized by the reversal potential, where the voltage and concentration differences balance, and no net ionic flux occurs. For cationic currents, the reversal potentials are well-behaved round numbers: 0 mV for excitatory currents and –100 mV for inhibitory potassium currents. In contrast, the inhibitory anionic currents that flow through the $GABA_A$ receptor channel have a small net driving force, so the $GABA_A$ reversal potential is just a few millivolts more negative than a typical resting membrane potential of –65 mV (**Fig. 1**).

The reversal potential for chloride, the most permeant and plentiful anion, is set by a chloride exporter called KCC2 that derives its energy from the potassium gradient[4], as well as a chloride importer, called NKCC1,