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Research Focus

Unifying sequential effects in perceptual grouping

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Temporally-extended perception involves a delicate balance of constancy and change. 'This can be seen, for instance, when viewing bistable figures such as the Necker cube. A recent study by Gepshtein and Kubovy of sequential effects in multistable dot lattices demonstrates constancy and change within the same set of data. They propose that these opposing trends might be explained by the same single factor: a persistent random orientation bias that is intrinsic to brain activity. This proposal could form the basis for a new account of multistability.

When viewing multistable figures such as those in Figure 1, observers experience reversals between alternative percepts. Because such reversals occur spontaneously while stimulus information is constant, multistability is generally considered an ideal tool to reveal mechanisms of perceptual organization [1,2]. Despite interesting brain-imaging work [3,4], however, the factors governing perceptual alternations in such figures remain poorly understood. Traditional explanations posit that perceptual alternations are due to reciprocal inhibition between neural networks coding alternative representations: when 'fatigue' occurs within one such network, inhibition is released and this tips the balance in favor of the alternative [5]. In a recent paper, Gepshtein and Kubovy [6] provide intriguing evidence for a different account. Drawing on elegant experiments using multistable dot patterns, they propose that, at least in this type of stimuli, temporal interactions between successive representations could be explained by a random process intrinsic to brain activity.

Measuring opposing trends in dot lattices

In comparison with most other published papers on multistability, the methodology used by Gepshtein and Kubovy is unusual [6]. Rather than using relatively complex drawings such as those in Figure 1, they used dot lattices (see Figure 2), which provide a well-defined stimulus space [7] that is organized according to principles that are well understood [8,9]. In addition, rather than measuring reversal rates during prolonged observation of their displays, they presented pairs of lattices in brief succession and then asked observers to report on perceived organizations. Using this methodology, Gepshtein and Kubovy were able to assess three trends that are typically observed in the spatio-temporal organization of lattices.

The first of these trends was the multistability of the lattices: although the pattern of the data clearly reflected grouping by proximity, giving rise to a predominant perceived orientation that was related to the shortest interdot distance, alternative orientations were also reported with measurable probabilities. This trend replicates previous findings on probabilistic grouping in dot lattices [9]. The second was a negative correlation: the higher the likelihood of perceiving a given orientation in the first lattice, the lower the corresponding likelihood of perceiving the same orientation in the second. This trend is consistent with a phenomenon that has been called adaptation, and has been reported to occur for both perceived and unperceived motion directions [10]. The third of these trends was a tendency of the perceived organization in the first lattice to carry over to the second. This last trend is consistent with a phenomenon known as

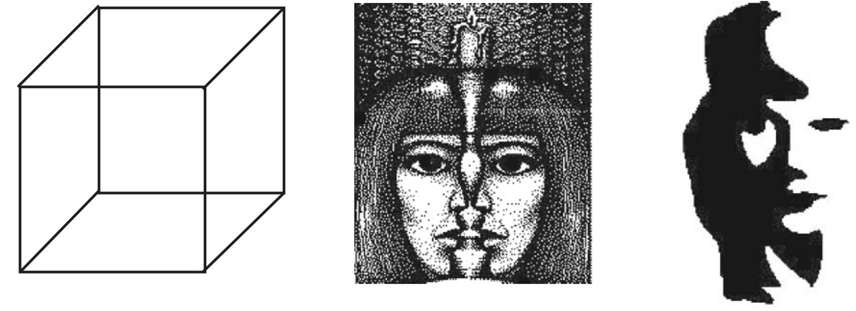

Figure 1. Examples of alternative organizations in multistable figures [1]. **(a)** A bistable wireframe cube, which can be seen as either pointing up and to the right, or down and to the left. **(b)** Either a single face behind a candlestick or two profiles. **(c)** Either a saxophone player or a woman's face.

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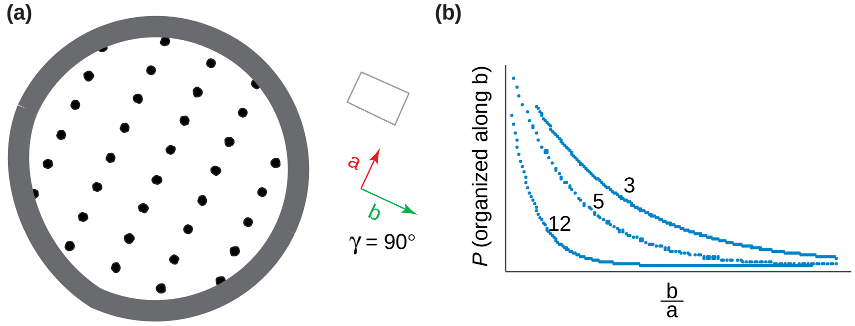

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Figure 2. The geometry of dot lattices, such as used by Gepshtein and Kubovy. **(a)** Formally, a dot lattice is a collection of dots in the plane that is invariant under two translations. Its geometry depends on the length of the translation vectors a and b and on the angle γ formed by them [8]. Shown here is a rectangular lattice. Changing γ and b while keeping a constant generates five other types: oblique, centered rectangular, rhombic, square and hexagonal. **(b)** Grouping by proximity in dot lattices. The probability of organizing a lattice along a given orientation is approximated closely by a decreasing exponential function of relative distance [9]. Examples of such functions are shown, the displayed integers being different constants reflecting observer sensitivity to proximity. Modified from Ref. [8].

hysteresis, which is also commonly observed in multistable figures [11,12]. Thus, Gepshtein and Kubovy were able to demonstrate three known features of spatiotemporal interactions between multistable lattices, within the same set of data.

These results are theoretically challenging, especially because hysteresis (constancy) and adaptation (change) imply mechanisms that oppose each other. Why would one or the other prevail in any given trial? Boldly, the authors suggest that such seemingly opposing effects in grouping might in fact result from a single underlying factor: a persistent, random orientation bias intrinsic to brain activity. They suggest that this bias drifts slightly over time, and sometimes overcomes the orientation signal that is provided by the stimulus geometry. When this happens, observers report organizations that would not be expected from grouping by proximity, hence the multistability of the lattice. And, as the paper convincingly shows, once the effects of stimulus geometry and the persistent orientation bias are combined, across many trials the outcome is both a pattern of negative contingency between the probability of a given organization in the first lattice and the probabiliy of the same organization in the second lattice (adaptation), and a tendency of the first perceived organization to carry over to the second (hysteresis).

Towards a new account of perceptual multistability?

The idea that several different phenomena in perceptual multistability can be predicted by the same factor is very attractive. Compared with the traditional 'fatigue' account, it accommodates a larger body of data with a simple and economical theory. For instance, a strong prediction of neural fatigue is that the longer one organization has been perceptually held, the less likely it is that it will continue to be held in successive views. In many studies, however, the statistics of spontaneous reversal rates reveal independence rather than negative correlation [13,14], a result that cannot be accommodated by the fatigue account. In addition, allthough there is evidence that local adaptation plays a role in multistability [15], as a general concept neural fatigue is difficult to reconcile with hysteresis, and does not predict the multistability of initial organizations. The persistent-bias hypothesis instead provides a natural explanation for both phenomena, as well as for spontaneous reversals during prolonged observation (if the bias drifts slightly over time, it is to be expected that it should cause a reversal sooner or later). Compared with other stochastic models of multistability [16,17], the persistent-bias hypothesis offers the advantage of a unified model with only one free parameter (reflecting observer sensitivity to proximity; see Figure 2), and is grounded on known principles of perceptual organization.

The persistent-bias hypothesis could form the basis for a new general account of multistability, provided that future refinements of the model will be able to handle aspects that could not be included within the present study. A crucial issue with respect to this is the possibility of extending the hypothesis to more complex figures, such as those presented in Figure 1. Such figures often involve a change of edge ownership or depth ordering within edges that maintain the same orientation, and for this reason their multistability cannot be accommodated by a mere orientation bias. Given that the figure–ground preferences constraining such changes are themselves controlled by known factors of perceptual organization [18], the extension of the present Gestalt-inspired work might prove unexpectedly natural. On the other hand, conditions that have also been studied as instances of multistability, such as binocular rivalry [2,19] and ambiguous motion [19], might be more difficult to integrate with the present approach. While we wait for future developments, the elegance of the quantitative analysis and the simplicity of the proposed explanation undoubtedly repays reading of this first report.

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The cognitive neuroscience of auditory distraction

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We are often aware of the content of distracting sound, although typically remain unaware of the processes by which that sound is disruptive. Disruption can occur even when the sound is ignored and unrelated to the task being performed. In a recent major development, Gisselgård *et al.* have used positron emission tomography to reveal how distracting sounds recruit the involvement of dorsolateral prefrontal cortex.

When our mental activities are the most demanding is often when we become most aware of the distracting influences of background sound. Working memory is a function of the brain that permits the short-term maintenance of information that needs to be remembered. The manipulation of that maintained information within working memory is often used in the service of a particular task or goal. It is the mental activities that place heavy demands upon working memory that seem to be most susceptible to the disruptive effects of auditory distraction. Instances of such mental activities include reading, arithmetic or (in laboratory experiments) silently reading a list of numbers and reporting back that series after a brief delay [1,2]. Recently, Gisselgård, Petterson and Ingvar [3,4] have revealed that for auditory distraction to disrupt working-memory performance requires the activation of the dorsolateral prefrontal cortex of the brain. Indeed, this crucial activation was only seen to occur on a difficult working-memory task [4].

When we succeed in ignoring – suppression of a large-scale network of brain areas

Change within the ignored distracting sound has been pinpointed as a key determinant of disruption of working memory by auditory distraction ([5,6], see also [7]). That is, a changing-state sequence of sounds (e.g. ABAB…) typically proves more disruptive than a steady-state sequence of ignored speech sounds (e.g. AAA…). To explain this changing-state effect, cognitive theory has invoked the concept of an involuntary processing of ignored changing-state material, which disrupts the processing of the to-be-remembered material [5]. This changing-state auditory distraction might be related to particular brain processes [8–11] although the functional anatomy of these processes have remained yet to be fully understood.

Two PET experiments conducted by Gisselgård *et al.* [3,4] shed considerable light on the functional anatomy of the crucial brain processes by contrasting the action of ignored steady-state and changing-state speech sound during a working-memory task. This series of experiments not only investigated the effects of different types of speech sound on the accuracy of performance on a task, the working-memory performance, but also used PET to measure regional cerebral blood flow under conditions of steady-state and changing-state auditory distraction. Increases in blood flow in a region were interpreted to reflect metabolism within that brain region (activation), whereas decreases reflected the suppression of that metabolism (deactivation).

The working-memory task – immediate verbal serial recall – entailed the visual presentation of a list of 6 digits

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