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Two stages of visual feature binding: inside and outside the focus of attention

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Despite of the fact that visual features are processed separately in specialized subsystems in the brain, our perceptual experience is of coherent objects. It has been suggested that visual attention acts as a "glue" to bind separate features−such as color, shape, size, motion, and location—into objects (Triesman & Gelade, 1980). This theory would suggest that features outside of visual attention remain unbound perceptually. We tested (1) whether binding occurs outside the focus of attention, and (2) whether feature binding was automatic or dependent on top-down attention to each feature individually. To determine whether two features were bound together, we probed whether paying attention to one feature (color) would also influence the processing of another, task-irrelevant feature (motion) of the same stimulus (cross-feature attention: CFA: Sohn et al., in press). These CFA effects were tested both within the focus of attention (focal attention) and outside the spatial location of attention (global attention).

Methods

The first test was to detect a luminance change in one of two colors of dots (red or green) clustered in one visual hemifield. After a beep, the subject was cued to pay attention to a cluster of dots in the opposite hemifield for a motion direction discrimination task. Unbeknownst to the subject, a brief (150 ms) sub-threshold motion prime was present in the unattended dots during the first (luminance) task (for details of the motion prime, see Melcher & Morrone, 2003). The use of a sub-threshold prime excluded the possibility that the motion signal was attended directly. The prime was presented either in same color of dots attended for the luminance task or in the other color.

In addition to this test of the influence of the prime outside the focus of attention, separate blocks were run in which the prime was in the same dots as those attended for the luminance task. In this case, only the dots in one hemifield were attended during the trial.

Results

We found that global CFA modulation outside the focus of attention spreads to spatiotemporally co-localized features, while inside the focus of attention CFA modulation spreads between all features belonging to the same surface or object. In other words, CFA effects outside the focus of attention were color-specific. An influence of the prime was found only when the prime dots were the same color as those attended in the opposite hemifield for the luminance test. When both tasks were in the same dots, however, the prime dots in the cluster always influenced the later motion test, suggesting that the entire cluster of dots was bound together as a surface.

Conclusions

These results suggest several implications for the role of attention in feature binding. First, these findings imply the existence of a binding mechanism at the local stages of visual processing that links spatiotemporally co-occurring features across the visual field, and that this mechanism is independent of attention. Secondly, these results support previous suggestions of another binding mechanism that acts at the level of coherent surfaces and links all features of the same surface (object-based attention: Duncan, 1984; O'Craven et al., 1999). Third, the CFA effects found here suggest that features are bound automatically, rather than depending on top-down attention to each feature separately. The use of the sub-threshold stimulus showed that attention influences visual processing even when the feature is below the level of conscious awareness.

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