Attention: Effect on Perception

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Attention is the mechanism that allows us to select relevant information for processing from the vast amount of stimuli we are confronted with, prioritizing some while ignoring others. Attention can affect perception by altering performance—how well we perform on a given task—or by altering appearance—our subjective experience of a stimulus or object. Visual attention is commonly divided into three types: (1) spatial attention, which can be overt, when an observer moves his or her eyes to a relevant location and the focus of attention coincides with the movement of the eyes, or covert, when attention is deployed to relevant locations without accompanying eye movements; (2) feature-based attention, which is deployed to specific features (e.g., color, orientation or motion direction) of objects in the environment, regardless of their location; (3) object-based attention (which will not be discussed further here). By focusing on different kinds of information, these types of attention optimize our visual system's performance: whereas spatial attention guides an observer to a particular location, feature-based attention guides an observer to a particular feature of the object or stimulus. For instance, when waiting to meet a friend at a café, we may deploy spatial attention to the door (where he or she is likely to appear) and feature-based attention to orange objects (because he or she often wears an orange jacket).

This entry deals with the effects of covert attention on performance and appearance. Note that overt attention also plays a pivotal role in selectively processing information. The eyes can be moved quickly and efficiently, enabling overt attention to compensate for the rapid decline of visual capacities away from the fovea. Thus, the perceptual consequences of overt attention at the attended location correspond to the immediate benefit of high-resolution foveal vision.

Spatial Attention

To investigate covert attention, it is necessary to make sure that observers maintain fixation, and to keep both the task and stimuli constant across conditions while manipulating attention. It is well established that covert attention improves perceptual performance—accuracy and speed—on many detection, discrimination, and localization tasks. Moreover, attention affects the appearance of objects in several tasks mediated by dimensions of early vision, such as contrast and spatial frequency.

There are two systems of covert attention: endogenous and exogenous. *Endogenous attention* refers to the voluntary, sustained directing of attention to a location in the visual field. Experimentally, a central cue—typically an arrow or a bar at fixation— points to the most likely location of the subsequent target. Within about 300 milliseconds (ms), attention can be deployed to that location and can be sustained there. *Exogenous attention* refers to the automatic, transient orienting of attention to a location in the visual field, brought about by a peripheral cue or a sudden abrupt onset of a stimulus at that location. Exogenous attention has a transient effect; its effectiveness peaks at about 80 to 120 ms and decays shortly thereafter.

Spatial Attention and Performance

Endogenous (voluntary) and exogenous (involuntary) attention have some common perceptual effects. Detection or discrimination of a target are typically better (faster, more accurate or both) in trials in which the target appears at the cued location than at uncued locations. For instance, both exogenous and endogenous attention improve contrast sensitivity and spatial resolution. Many studies have shown that spatial attention lowers the contrast threshold at which observers attain a given performance level when they perform tasks mediated by contrast sensitivity. Enhanced contrast sensitivity enables people to better detect the presence or absence of a stimulus, discriminate its characteristics (e.g., was the stimulus tilted left or right? moving upward or downward?), and localize it (e.g., was the stimulus in the right or left visual field?). Interestingly, whereas contrast sensitivity is enhanced at the cued location, it is decreased for the stimuli appearing at uncued locations. This is the case even when few clearly visible stimuli appear in the display, and observers know with certainty the stimuli locations and which stimulus to respond to.

Likewise, when spatial attention is directed to a given location, performance improves in texture segmentation tasks and acuity tasks that are limited by spatial resolution. For instance, when attending to a location observers can resolve information that is unresolvable without attending to that location and can discriminate finer details than they can without directing attention to the cued location. As is the case with contrast sensitivity, the improved performance at the cued location is accompanied by impaired performance at the uncued locations. The same pattern of results has been reported for human and nonhuman primates in acuity tasks.

Despite their similarities, endogenous and exogenous attention can yield different perceptual effects: Whereas endogenous attention improves perception, exogenous attention can in some conditions actually impair perception. For instance, in a texture segmentation task in which performance is influenced by spatial resolution, cueing attention improves texture segmentation in the periphery, where spatial resolution is too low for the task, but impairs performance at central locations of the visual field, where spatial resolution is already too high for the task. In contrast, endogenous attention improves performance across the visual field. Exogenous attention also impairs temporal order judgment, whereas endogenous attention improves it. These findings illustrate that both endogenous and exogenous attention affect performance in spatial (texture segmentation) and temporal (temporal order judgment) tasks, but that the mechanisms underlying these attention systems differ, with endogenous attention being more flexible.

Spatial Attention and Appearance

It is well established that attention improves performance on many tasks. However, for more than 100 years, psychologists, philosophers, and physiologists (e.g., Ernst Mach, Gustav Fechner, Hermann von Helmholtz, Wilhelm Wundt, and William James) have debated whether attention changes one's subjective experience of the visual world. Although the effects of attention on performance may suggest that attention affects the stimulus representation and subjective appearance, many authors have attributed these effects to a decision-making process or selective read-out. The question of whether attention alters appearance has rarely been investigated, though. Which aspects of our visual experience does attention affect? Can attention make a visual pattern seem more detailed, or a color more vivid? Much of the early work on this topic, which is relevant to the topic of subjective experience and awareness, was introspective and conflicting conclusions were often drawn from such subjective methods of investigation. Whether and how attention affects appearance has been systematically investigated only recently. This may be because of the difficulty in objectively testing and quantifying the subjective experience of perceived stimuli and changes in such experience with attention. It is important to distinguish a change in appearance from any bias that may arise because of experimental design and task demands.

A psychophysical paradigm developed by Marisa Carrasco and colleagues enables the assessment of the phenomenological correlate of exogenous (involuntary) attention, and makes it possible to study subjective experience and visual awareness more objectively and rigorously. This paradigm allows for simultaneous measurement of the effect of attention on appearance and performance. It manipulates exogenous attention via an uninformative peripheral cue and quantifies the observer's subjective perception using a task contingent on a comparative judgment between two stimuli with regard to a particular feature. For instance, to investigate the effects of attention on perceived contrast, observers are presented with two stimuli (Gabor patches, commonly used to investigate spatial vision; Figure 1a), one to the left and one to the right of fixation. Observers are asked to report the orientation of the higher contrast stimulus. These instructions emphasize the orientation judgment, when the main interest is in contrast judgments. Observers are not asked to directly rate their subjective experience on contrast, but to make a decision about a stimulus property, its orientation.

On each trial of this paradigm, the "Standard" stimulus is of a fixed contrast, whereas the contrast of the "Test" stimulus is randomly chosen from a range of contrasts near the standard contrast. The orientation of each stimulus is also chosen randomly. By flashing a dot (peripheral cue) briefly, exogenous (involuntary) covert attention is automatically directed to the cued location (at which either the Standard or the Test stimulus will appear).

Carrasco and colleagues have shown that by assessing observers' responses, it was possible to determine the contrast of the test stimulus that the observer judged to have the same contrast as the standard stimulus. This contrast was measured under three conditions: when the dot preceded (1) the location of the test stimulus, (2) the location of the standard stimulus, or (3) the central location (fixation), so that covert focal attention was automatically directed toward the test stimulus, the standard stimulus, or neither stimulus. Exogenous attention was shown to significantly increase perceived contrast (Figure 1b). When observers' attention was drawn to a stimulus location, observers reported that stimulus as being higher in contrast than it actually was, thus indicating that attention changes appearance.

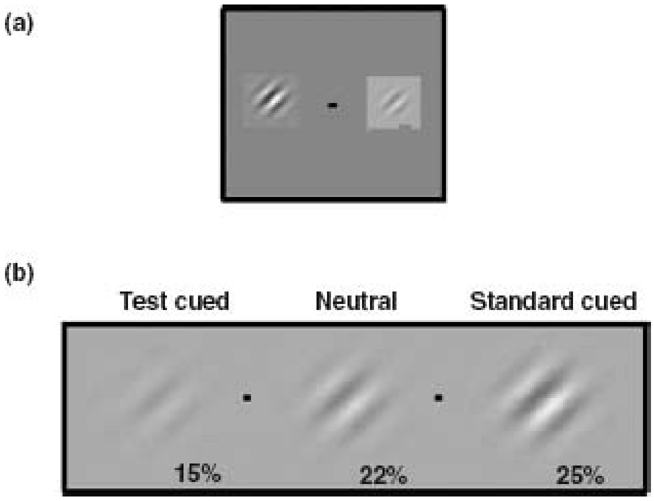

Figure 1 *Effect of Attention on Contrast*

Source: Carrasco, Ling, & Read, 2004.

Notes: (a) Display screen of the type of stimuli observers were shown by Marisa Carrasco and colleagues. Observers saw two stimuli, preceded by a brief neutral (at fixation) or peripheral (attentional) cue (appearing above one of the upcoming stimulus locations). The peripheral cue had equal probability of appearing on the left or right side, and was not predictive of the stimulus contrast or orientation. Observers were asked to indicate the orientation (left versus right) of the higher *contrast stimulus. (b) Effect of covert attention on apparent contrast. If you were to look at 1 of the 2 fixation points (black dot), and the stimulus to the left of that fixation point was peripherally cued, the stimuli at both sides of that fixation point would appear to have the same contrast. With attention, when a 16% contrast stimulus is cued, it appears as if it had 22% contrast, and a cued 22% contrast stimulus appears as if it had 28%. (Note that this effect cannot be appreciated by inspecting the figure because a comparison between both patterns would lead to distributed allocation of attention to both patterns.)*

By coupling this paradigm with control experiments, cue bias or response bias have been ruled out as responsible for the observed effects. For instance, because of the ephemeral nature of transient attention (approximately 120 ms), lengthening the interval between the cue and target should eliminate any effect that it may have on perception, and any residual effect would be attributed to a cue bias. When the cue preceded the stimuli by 500 ms, neutral and peripheral conditions did not differ.

Most studies using this paradigm show that exogenous attention alters appearance of basic spatial (contrast, spatial resolution, color saturation, object size) and temporal (flicker rate, motion coherence, motion speed) visual dimensions. A modification of this experimental paradigm has revealed that endogenous (voluntary) attention also enhances perceived contrast. Although for many visual dimensions the attention effect on appearance is accompanied by an effect on performance (e.g., a higher proportion of correct responses in orientation discrimination), the performance effect is not necessarily mediated by the subjective change in appearance; for example, attention improves orientation discrimination of stimuli defined by hue, but it does not alter hue appearance.

By showing that the spatial deployment of attention leads to a change in phenomenological experience, these studies confirm that covert attention can intensify the perceptual impression of a stimulus. Attention affects how well we perform a visual task and it affects what we see and experience.

Feature-Based Attention

Feature-based attention is the ability to enhance the representation of image components throughout the visual field that possess a particular feature. Directing feature-based attention to specific features—such as color, orientation, and motion direction—increases performance for detecting, discriminating, or localizing those features across the visual field. This type of attention is critical when human or nonhuman primates search a display to detect a target among distracters.

Studies of feature-based attention generally control for spatial selection by using compound stimuli containing multiple features superimposed over the same spatial location, and requiring that observers attend to one of those features. For instance, in a compound motion stimulus (consisting of dots moving right and dots moving left), attending to one motion direction (e.g., dots moving right) produces a motion aftereffect consistent with the attended direction, and in a compound orientation stimulus (consisting of right-tilted and left-tilted lines), attending to one orientation (right-tilted lines) produces an orientation aftereffect consistent with the attended orientation. Psychophysical and neuroimaging studies have shown that the effects of feature-based attention occur at the spatially attended location as well as at non-attended locations across the visual field.

See also

Attention: Covert, Attention: Object-Based, Attention: Physiological, Attention: Selective, Attention: Spatial, Attention: Theories of, Eye Movements: Behavioral, Psychophysical Approach, Visual Search

Further Readings

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