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Perception, Gestalt Principles of

Intermediate article

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Gestalt principles of perception are those aspects of perception that cannot be defined in terms of smaller, constituent elements. Gestalt *is a German word which translates in English as whole, configuration, or pattern.*

WHOLES AND SUMS OF PARTS

The visual world we experience is of people, trees, buildings, coffee cups, and other objects. Yet, light shining onto the eye from these objects produces regions of abrupt changes in luminance and color (edges), regions of gradual changes (shading), and regions of relative uniformity (shapes). The problem of how the brain analyzes these sensory events so as to provide us with the experience of objects is the problem of *perceptual organization*.

Perceptual organization was first identified as a central problem by the Gestalt school of psychology in the 1920s. Among the most influential in this school were Max Wertheimer, Kurt Koffka, and Wolfgang Köhler. They emphasized that the perceived object is different from, and sometimes even more than, the sum of its sensory parts. Modern researchers tend to divide perceptual organization into the smaller subproblems discussed below.

Edge Perception

Edges are the building blocks of vision. When eye movements are prevented, so that edges are no longer stimulating the eye over time, we quickly lose all visual experience. Figure 1 allows you to experience something like a stabilized image by staring at the center dot for about one minute. As you stare at the dot, the fuzzy gray border will begin to disappear because it stimulates a part of your eye that is sufficiently distant from the high-resolution centre that it is unable to register this fuzzy edge. As far as your brain is concerned, the fuzzy border no longer exists, and so the brain

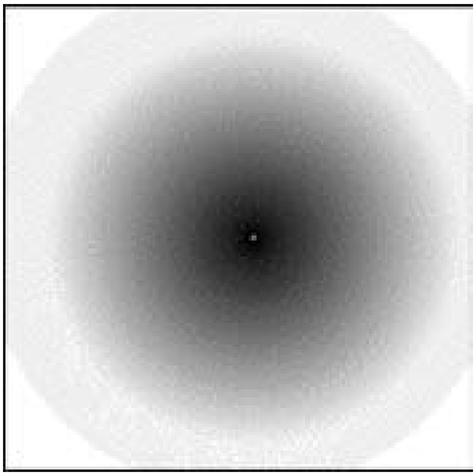

Figure 1. Stabilizing a fuzzy edge on the retina. Stare at the central dot for about a minute with one eye. The fuzzy inner edge will soon disappear and be replaced by a uniform light gray.

concludes that the light gray region (which is defined by a sharp border) is continuous.

Edges interact in cooperative and competitive ways (Field and Hayes, 1993). This can be seen at work in Figure 2, where a large O-shape has been drawn in two ways. In Figure 2(a), the easily seen O is defined by line segments whose extensions form a continuous curved arc. In Figure 2(b) the same O-shape has been drawn, using the same number of line segments, but the line segments now lie at a 90-degree angle to the arc of the curve. The O is now very difficult to see and you will have to inspect individual segments to confirm it. This illustrates the cooperation that exists between nearly continuous edges and the competition that exists between edges of different orientation.

Feature Extraction

When observers are asked to respond rapidly to image features, it is apparent that certain features are more basic, including luminance, color, the principal axis of a shape, and shape curvature. Tasks that require observers to respond rapidly to arbitrary combinations of these features are generally done slowly and with many errors (Beck, 1982; Julesz, 1984; Treisman, 1986). However, there are some combinations that do permit rapid analysis. These are *emergent features* since they form *gestalts* that cannot be predicted from the component features (Pomerantz, 1986). Examples are shown in Figure 3 (Enns and Rensink, 1991; Nakayama and Silverman, 1986; Ramachandran, 1988).

Figural Assignment

The assignment of some shapes as belonging to objects that are important to the observer and other shapes as belonging to the background is one of the crowning achievements of vision. It permits actions that are appropriate to objects in the environment, based solely on vision. Some of the complexities involved in the analysis are illustrated in Figure 4, a version of the ambiguous face–vase figure made famous by Rubin (1921). Observers of this display may see a pair of silhouette faces gazing at each other or they may see an ornate vase. The two interpretations also alternate in consciousness over time, illustrating that the assignment of *figure* and *background* is a product of brain processes, and not one determined by the image.

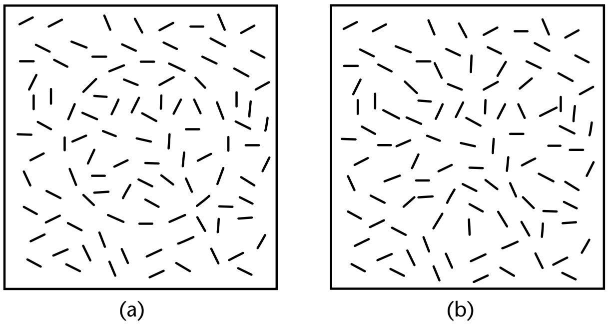

Figure 2. O-shaped configurations defined by (a) nearly continuous line segments, and (b) the same number of line segments oriented at 90 degrees to the continuous curve.

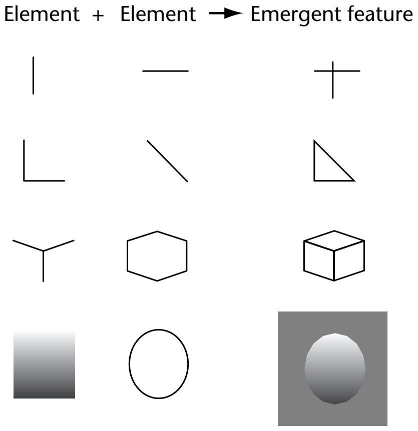

Figure 3. Component elements that create emergent features when combined.

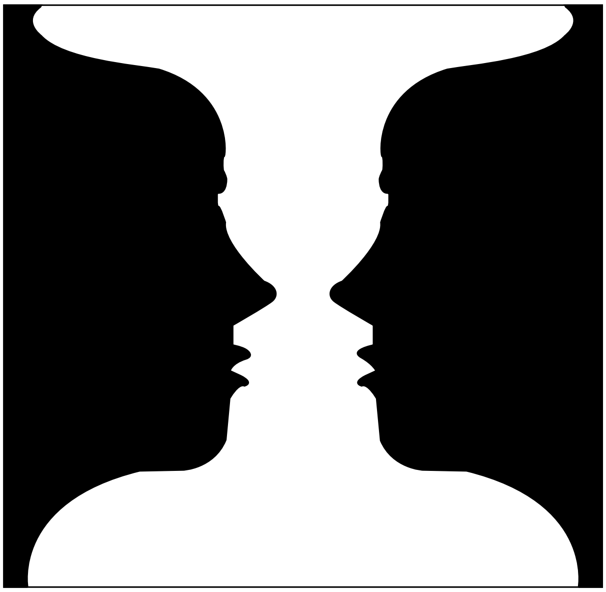

Figure 4. A display that can be seen either as a pair of black faces or as an ornate white vase.

Three-dimensional Structure

Once a three-dimensional interpretation has been made of the figures in an image, the object can be acted upon by the motor systems of the organism. The leading theories in this area have proposed that shapes in the image are assigned to *volumetric primitives*, or simple, convex solids that comprise the three-dimensional building blocks of vision (Biederman, 1987).

PERCEPTUAL FIELD

Perceptual field has two distinct meanings for Gestalt perception. An older sense derives from the early Gestalt theories of brain processes as analogous to electrical force fields. As illustrated in Figure 5(a), Gestalt theories claimed that a single dot viewed on an otherwise blank page, in analogy to a charged particle, had a force that spreads out uniformly in all directions. They hypothesized that if a second dot were added, as in Figure 5(b), the two fields of energy would interact. The Gestalt psychologists hoped that such neural interactions would begin to explain perception. However, this theory failed because neuroscientists were unable to find brain mechanisms that followed these patterns. Instead, the dominant metaphor for neurons is the electronic circuit, which means that neurons can perform simple arithmetic operations. In the modern view, neurons do interact with one another in excitatory and inhibitory ways but these interactions do not resemble the spread of energy around magnetic dipoles.

A second sense of *perceptual field* refers to the spatial region over which vision functions. Only a subset of the entire field of view is at any moment contributing to the performance of the task. Some researchers refer to this as the *useful field of view*. Consider how the perceptual field differs depending on the task. If the task is to detect a bright light flashed anywhere in the visual field, the visual field is usually estimated to be almost 180 degrees wide and 100 degrees high. However, if the task is to read letters in a standard row of text, without moving the eyes, then the perceptual field may shrink to only 4–6 degrees wide.

Modern research emphasizes the role of *attention* in perception. Where an observer attends, and what the observer expects to see there, has a powerful effect on what is seen. This dynamic aspect of perception is studied in tasks where observers are asked to detect changes in scenes that are separated by a shift in viewpoint (Simons, 2000) or a short temporal interval (Rensink *et al*., 1997). The main finding is that observers are 'blind' to changes in objects they were not attending to. In other studies, observers perform a visually demanding task and then are suddenly and briefly shown a surprise stimulus. The detection of these unannounced stimuli is so infrequent that the term *inattentional blindness* has been coined (Mack and Rock, 1998). These studies emphasize the 'piecemeal nature' of perception (Hochberg, 1982) and that very little of the available information is consciously registered (Shapiro, 1994).

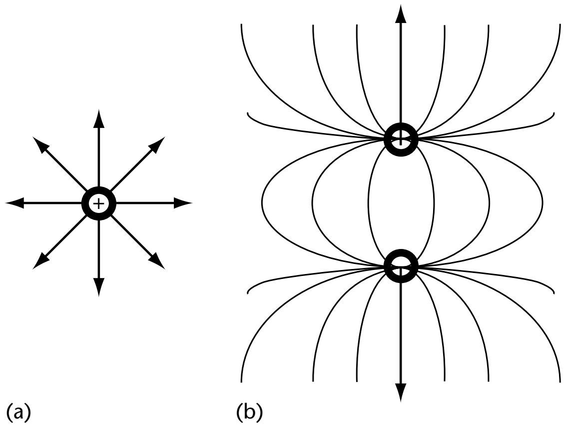

Figure 5. (a) A single particle with a positive electrical charge. (b) The same particle along with a nearby particle with a negative charge. Lines illustrate the electrical field forces.

GROUPING

Which parts of an image belong together and which belong to different objects? This is the problem of grouping that early Gestalt psychologists are best known for. Wertheimer (1923) went so far as to call his answers 'laws', since he believed them to be as reliable as other physical laws. Today reseachers tend to use the term *principle* to reflect their important, but not absolute, influence on perception.

The classic Gestalt principles were illustrated using the elements of dots and line segments. They included the principle of *proximity* (elements that are relatively close tend to be seen as belonging to the same perceptual unit), *similarity* (elements that are relatively similar tend to be seen as belonging together), *good continuation* (elements following a simple curve will tend to be grouped together), *common fate* (elements with common motion direction will tend to cohere), and *closure* (elements which enclose a region will tend to be seen as belonging to the same figure).

Although these principles operate reliably when applied to the drawings of Gestalt psychologists, they are difficult to apply in other settings. There are several reasons for this failure. First, the 'elements' of perception were never defined. Unfortunately, natural images are not coded in the sharply defined dots and lines used in the drawings of Gestalt researchers. Second, the features to which 'similarity' and 'common direction' should be applied were not defined, making the basis of similarity unclear. Third, the spatial region over which the laws applied was not defined. It was simply assumed that each drawing in its entirety would submit to the principles in a coherent manner. This ignores the importance of attentional limits on perceptual field size (Hochberg, 1982).

Some limitations of the classic Gestalt view are being addressed by modern research. For instance, one proposal defines the elements of an image as regions of *common brightness* (Palmer and Rock, 1994). Elements so defined are then grouped further based on a principle of *common region* (elements located within the same enclosed region of space will tend to be grouped) and *element connectedness* (elements in physical contact with other elements will tend to be grouped). However, the initial elements defined by common brightness may also be parsed in greater detail, using the heuristic of segmentation at *regions of deep concavity*. Examples of these principles are shown in Figure 6.

PROXIMITY

An important question for modern research is the perceptual space in which grouping occurs. For example, is the relevant distance for grouping by proximity the retinal image or distance in three-dimensional space? This question has been studied by creating a dot lattice using luminous beads attached to threads, as shown in Figure 7 (Rock, 1997). If observers see the dots as lying in a plane perpendicular to the line of sight, then grouping is influenced primarily by the proximity between dots as measured in the retinal image. On the other hand, if they perceive the dots as part of a surface receding in depth, then the apparent proximity of the dots on the surface determines whether row or column grouping is seen. Related experiments have studied the relations between perceived proximity and the perceptual completion of partially occluding objects. In all cases, it is clear that grouping mechanisms based on proximity work in cooperation with other processes such as depth perception. Similar findings have been reported for grouping by temporal proximity (Lee and Blake, 1999).

SIMILARITY

Whereas early Gestalt researchers assumed that similarity was based on such obvious properties as color, brightness, and shape, more recent studies have shown that this too is task-dependent.

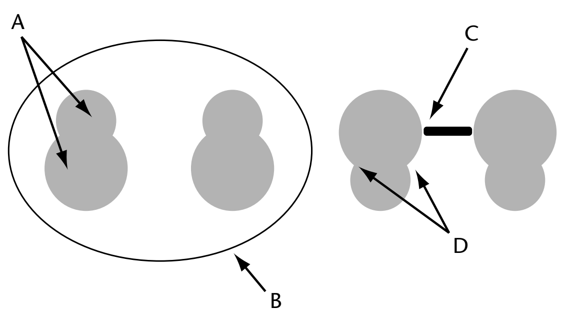

Figure 6. Illustrations of several new principles of grouping (Palmer and Rock, 1994). (A) Common brightness: the two 'bubbles' are grouped because they share brightness. (B) Common region: the two pairs of bubbles are grouped because they are enclosed by a common outline. (C) Element connectedness: the pairs of bubbles are grouped because they are joined by a bar. (D) Image segmentation based on concavities: the two bubbles are seen as separate objects because of the concavities in the surrounding edge.

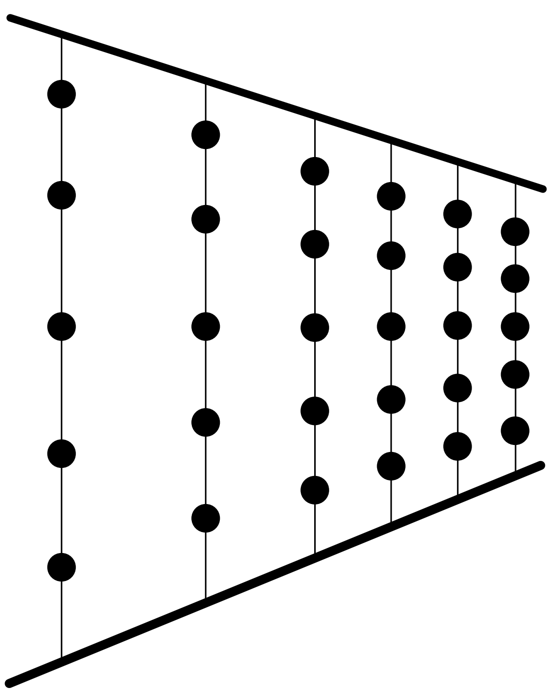

Figure 7. Grouping by proximity depends on whether lattices such as these are seen as lying perpendicular to the line of sight or as receding in depth.

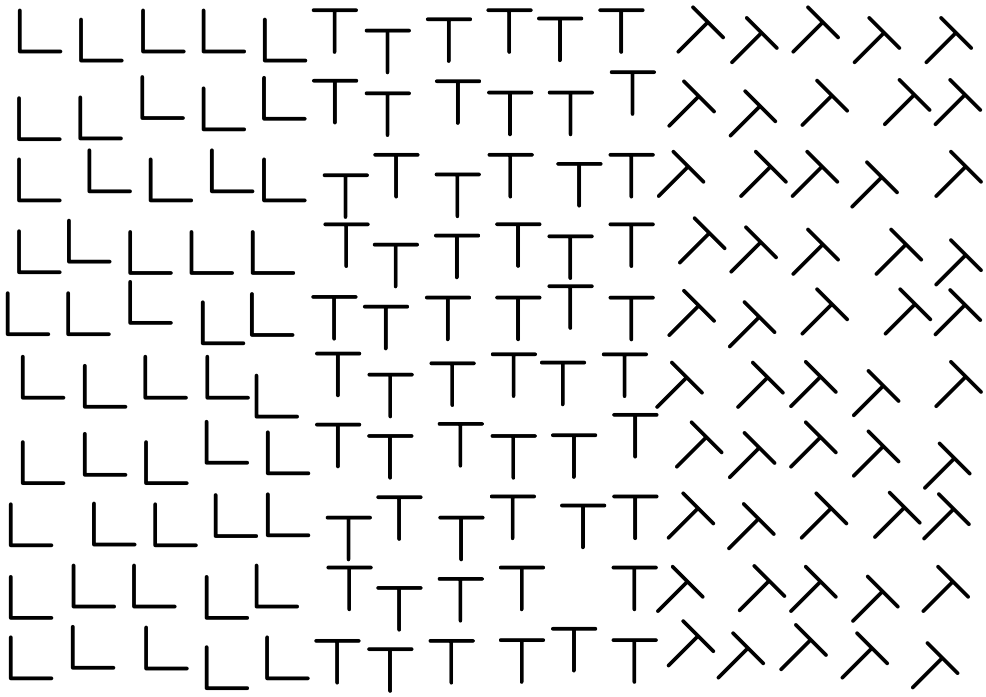

Figure 8. Grouping by similarity in dense textures follows different rules from grouping by similarity of individual texture elements.

Consider, for example, whether an L-shape or a tilted T-shape is more similar to an upright T-shape. When observers are shown this triplet of elements in isolation, they tend to agree that the tilted and upright Ts are more similar to each other than either one of these two is to the L-shape. However, as shown in Figure 8, when large numbers of these shapes are used to form a texture, borders are formed where regions of uniform elements meet one another. Now it is clear that the strongest border lies between the upright Ts and the tilted Ts (Beck, 1982). This demonstrates that similarity varies with the visual task. Seeing a dense texture of elements leads to an emphasis on differences in element orientation, whereas seeing elements in isolation permits an analysis of the spatial relations among component segments.

In studies of perceived brightness and similarity, it has been shown that grouping depends on the apparent brightness, not on the physical luminance intensities of elements (Adelson, 1993; Rock, 1997). This means that observers take into account the role of shadows and assumed light sources in their evaluation of similarity based on luminance. As such, it also demonstrates once again that visual grouping does not operate in isolation from other perceptual processes, especially those involved in the interpretation of an image as being generated by light reflecting from three-dimensional surfaces.

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Perception, Haptic

Introductory article

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Haptic perception of two-dimensional patterns
Perception of objects and their properties
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Applications of research

Haptic perception is that derived from the sense of touch.

INTRODUCTION

The word 'haptic' comes from a Greek term meaning 'able to lay hold of'. Another word of Greek origin, 'stereognosis', is often used synonymously, particularly in medical contexts. Haptic perception is based on combined sensory inputs from the skin, muscles, tendons, joints and mucosae exposed to the environment (particularly in the mouth). Although these inputs could arise passively, as when an object is pressed against the skin, more commonly they result from active, purposive touch. Special receptors in these sites respond to stimulation from external surfaces or from a person's own movement. Receptors that lie within the skin (cutaneous) include mechanoreceptors, which respond to pressure; thermal receptors, which respond to thermal changes; and nociceptors, which respond to high-intensity, noxious stimulation such as sharp pricks, extreme pressure or very hot or cold surfaces. The word 'kinesthesis' is used to describe perception based on mechanoreceptors in muscles, tendons and joints (and also in the skin of the hand), which give rise to perceived movement, position or strain in body parts.

The cutaneous receptors comprise four types, as defined by the size of the skin surface over which they detect stimulation (receptive field size) and by how quickly they cease firing when stimulation remains constant (rate of adaptation). For example, a class of mechanoreceptors called slowly adapting type I (SA-I) has a small receptive field and adapts slowly, so that it identifies a small area of skin and gives a sustained response when pressure is applied there. These attributes enable it to provide