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Common Region: A New Principle of Perceptual Grouping

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A new principle of grouping is proposed that is based on elements being located within a common region of space. Demonstrations analogous to Wertheimer's original displays show that this factor strongly influences perceived grouping and is capable of overcoming the effects of other powerful grouping factors such as proximity and similarity. Grouping by common region is further shown to depend on perceived depth relations, indicating that it is influenced by processes that occur after at least some depth perception has been achieved. Further demonstrations suggest that it is dominated by the smallest background area and that it can follow a hierarchical embedding scheme. It is argued that common region cannot be reduced to the effects of proximity, closure, or any other previously known factor and therefore constitutes a genuinely new principle of grouping. © 1992 Academic Press, Inc.

In 1923, Max Wertheimer asked the fundamental question of perceptual organization: Why is it that people perceive an organized visual world in which there is spontaneous grouping into regions, surfaces, and objects coherently arranged in space rather than the chaotic juxtaposition of different colors that fall on individual retinal receptors? This question, more than any other, launched the Gestalt movement within psychology and led to some of its most important and enduring contributions to perception.

Wertheimer attempted to study the problem of organization by analyzing the stimulus factors that affect perceptual grouping. He constructed simple geometric arrays consisting of discrete elements. He then varied the relations among these elements to determine what caused the visual system to group certain ones together. Logically, an array of n perceptual

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elements can be grouped in at least as many ways as there are possible partitions of n objects. Psychologically, however, only one of these groupings is typically perceived. Wertheimer's realization of this discrepancy and the fact that it requires an explanation in terms of organizational processes was among his most profound insights.

Wertheimer's first investigations concerned a single line of equally spaced circular elements (Fig. 1A). He then varied the properties of the elements in ways that affected the extent to which they formed higher order perceptual groups. For example, when he varied the spacing between them, making some closer and others farther, he found that the closer ones grouped strongly together, as illustrated in Fig. 1B. This factor of relative closeness, which Wertheimer called *proximity*, was the

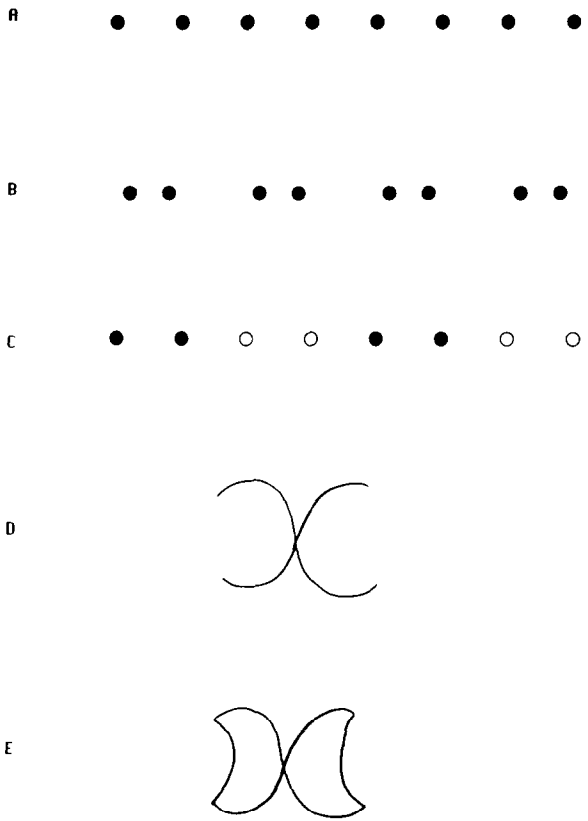


FIG. 1. Examples of Wertheimer's classic laws of grouping: ungrouped dots (A), dots grouped by proximity (B), dots grouped by lightness similarity (C), lines grouped by continuity (D), and lines grouped by closure (E).

first of his well-know "laws" of grouping.[1] Further studies led him to propose several other important principles, including those illustrated in Fig. 1. Figure 1C shows the operation of the principle of *similarity:* all else being equal, the most similar elements (in lightness for this example) tend to be grouped together. Another important factor is what Wertheimer called *common fate:* all else being equal, elements that move in the same way will be grouped together. Common fate is often considered a special case of similarity grouping where the property in question is movement.

Two other important factors that Wertheimer found to affect grouping were *good continuation* and *closure*. Good continuation is illustrated in Fig. 1D. Here, observers see the figure as two intersecting lines rather than as two angles whose vertices meet at a point. All else being equal, then, elements that can be seen as smooth continuations of each other tend to be grouped together. Figure 1E shows that the factor of closure can overcome good continuation. The same segments are now organized as two angles meeting at a point because they are perceived as parts of two closed figures.

The purpose of this article is to report a further factor that strongly affects grouping, which I call *common region*. The proposed principle of common region states that, all else being equal, elements will be perceived as grouped together if they are located within a common region of space, i.e., if they lie within a connected, homogeneously colored or textured region or within an enclosing contour. I argue that common region produces clear and powerful grouping effects, yet cannot be reduced to any other known grouping factor.

DEMONSTRATIONS OF COMMON REGION

Some examples of the proposed principle of common region analogous to Wertheimer's classical demonstrations are illustrated in Fig. 2. Figure 2A shows that a line of otherwise equivalent, equally spaced dots is strongly organized into pairs on the basis of common region when they are surrounded by the same contour. Figure 2B shows that the effect is not specific to regions defined by enclosing lines, but is just as strong for those regions defined by reflectance edges. Figures 2C and 2D show that common region is powerful enough to overcome the proximity and similarity effects given in Fig. 1B and 1C, respectively. In each case, the influence of common region is sufficient to produce groupings counter to those induced by proximity and similarity.

Saying that common region exerts a powerful effect on grouping does

[1] I hereafter refer to the "laws" of grouping more modestly as "principles" or "factors" of grouping because they lack the quantitative structure of standard scientific "laws."

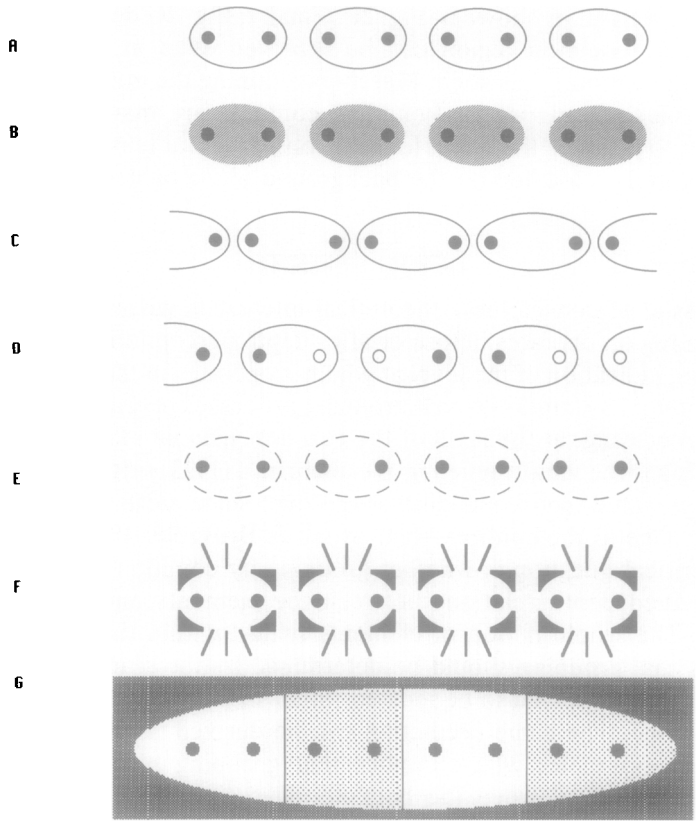


FIG. 2. Examples of the proposed law of common region: enclosure within closed contours alone (A), enclosure within closed reflectance edges (B), common region overcoming proximity (C), common region overcoming lightness similarity (D), common region within dashed contours (E), common region within illusory contours (F), and common region within backgrounds of different lightness (G).

not mean that common region will always dominate other grouping factors, however. The outcome clearly depends on the number and strength of other factors that oppose it. Like all other principles of grouping, the proposed factor of common region is a *ceteris paribus* rule, i.e., all else being equal, elements that are located within the same perceptually defined region will tend to be grouped together. When the principles are applied to complex cases in which two or more factors vary in opposition, there is (as yet) no way to predict the outcome.

A few more demonstrations help to illuminate the robustness of common region as a grouping factor. For example, the boundaries of the surrounding region need not be continuous, geometrically speaking, since dashed contours clearly suffice, as illustrated in Fig. 2E. Illusory contours

are also sufficient, as shown in Fig. 2F. Finally, Fig. 2G demonstrates that grouping by common region can be achieved even in the absence of "enclosing contours" as such. Merely positioning the dots on differently colored backgrounds whose bounding contours are mainly occluded is sufficient to produce the effect for most observers, at least when the dots are perceived as located on the background plane behind the occluding surface.

DEPTH EFFECTS

One issue of considerable theoretical interest is whether grouping by common region operates before or after depth perception, for this would give some indication of the level at which it operates in the visual system. The standard assumption is that grouping processes operate quite early in visual processing, at the level of the two-dimensional image (e.g., Marr, 1982). This is the view implied in Wertheimer's (1923) original article, and it has dominated theoretical discussions ever since, despite some persuasive evidence to the contrary (e.g., Rock & Brosgole, 1964).

The critical question is whether grouping by common region depends on perceived depth relations between the elements and the enclosing regions. The whole notion of elements lying "within the same region" suggests that grouping should be determined by the plane on which the elements are perceived to be located rather than by the two-dimensional retinal image. The same prediction can be derived from Gogel's (1970) adjacency principle, which implies that grouping by common region should be maximal when the background region is coplanar with the elements.

That grouping by common region occurs after stereoscopic depth perception can be readily verified using Fig. 3. Simply trace or photocopy the ellipses shown in Fig. 3A onto a clear plastic transparency and lay it over the display in Fig. 3B so that the two sets of ellipses are aligned with the dots in competing organizations as shown in Fig. 3C. When the sheet of plastic lies flat on the page, there is no differential grouping. To experience the effect of stereoscopic depth, carefully lift the transparency about a half-inch off the page, as illustrated in Fig. 3D, checking with each eye alternately to be sure that the dots stay within the ellipses of the transparency. When you then view it with both eyes open simultaneously, the dots clearly group with the coplanar ellipses on the page. You can follow an analogous procedure to place the dots on the nearer, transparent layer. When viewed binocularly, they again group with the coplanar ellipses. Thus, the processes that underlie grouping by common region must have at least a component that operates after stereoscopic depth perception.

Figure 4A suggests that common region may also operate after pictorial depth information from occlusion has been extracted. It shows a row of

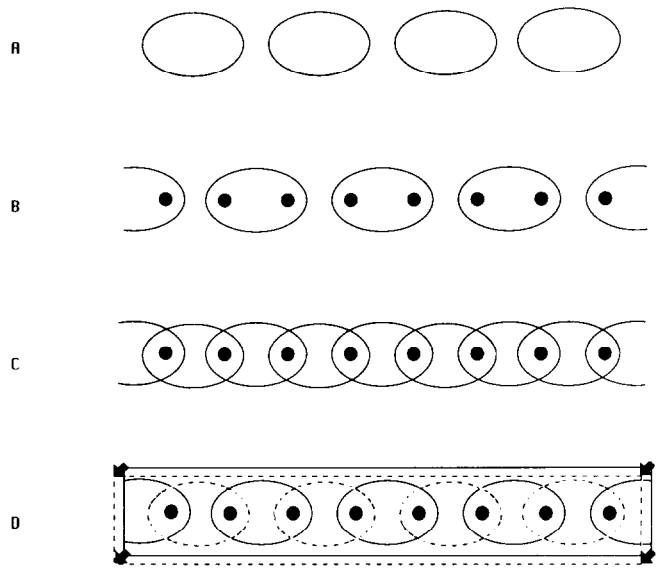


FIG. 3. A demonstration of stereoscopic depth effects on grouping by common region. (See text for explanation.)

equally spaced dots inside elliptical regions that are partly occluded by an "elliptically windowed" surface. The spontaneous impression of most observers to this display is that the dots group within the perceptually coplanar ellipses rather than within the smaller windows in the occluding surface. This outcome is not due simply to dominance by the larger ellipses, however, for the "control" display in Fig. 4B shows that when the same ellipses are perceived as lying in a single depth plane, grouping tends to be dominated by the smaller ellipses rather than the larger ones.[2]

Based on these demonstrations, it appears that grouping by common region cannot be regarded as an early visual process that works exclusively at the level of two-dimensional image structure. It must operate, at least in part, at the level of perceived depth. It is possible that common region works at both levels, of course. Preliminary grouping may occur based on image structure, but it clearly can be overridden by the more salient grouping that results after depth relations have been perceived. This conclusion is consistent with previous results showing that grouping by proximity is strongly influenced by perceived depth relations (Rock &

[2] It should be noted that the depth display in Fig. 4A is actually ambiguous. The dots can be seen as grouped within the smaller ellipses, but this occurs when they are perceived as coplanar with the closer, occluding surface. This does not appear to be the preferred organization, however.

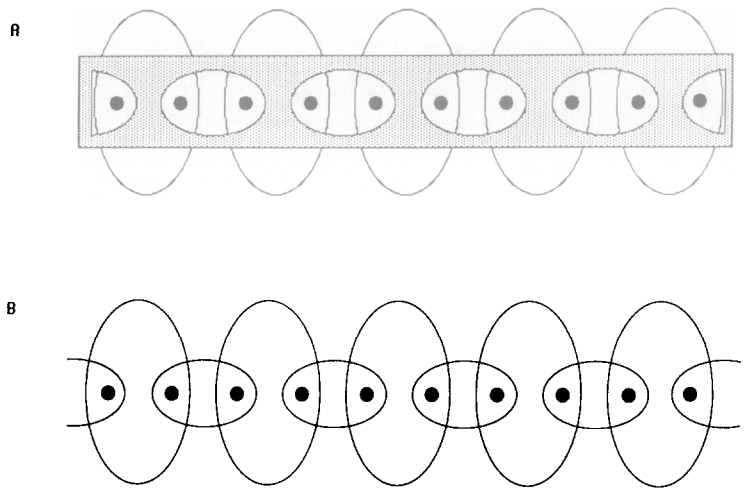


FIG. 4. A demonstration of pictorial depth effects on grouping by common region. The dots are grouped within the occluded vertical ellipses in A when they are perceived as coplanar with them, the elliptical windows being perceived as in front of the dots. The opposite grouping dominates in B when both sets of ellipses are perceived in the same plane as the dots.

Brosgole, 1964). It also fits with more recent results showing that grouping by lightness similarity (Rock, Nijhawan, Palmer, & Tudor, in press) and grouping by element connectedness (Palmer & Rock, in preparation) occur relatively late in processing, after depth and constancy have been achieved.

EFFECTS OF MULTIPLE REGIONS

The dominance of grouping within smaller ellipses over larger ones in Fig. 4B raises the issue of how grouping by common region is determined when objects are located within multiple regions. There are two cases of particular interest: one when the groupings conflict and the other when they are compatible, but nested.

In the case of conflict, there are many factors that might influence which region dominates grouping. We already know from Fig. 3C that if the enclosing contours are equal, no differential grouping is perceived, and from Fig. 4B that if they are unequal in size, a noticeable preference is observed in favor of the smaller contours. The larger enclosing region does appear to produce a noticeable conflict compared with the corresponding case in which there is no larger region (see Fig. 2A). There are a host of other factors that might also affect which of two conflicting regional organizations might dominate: their shape, orientation, interior

color, and so forth. Quantitative experimental procedures will be required to assess the relative dominance of these different properties, however, for spontaneous impressions are variable and difficult to assess.

In the case of nested, consistent regions, it should be possible to construct hierarchical groups via common region. That this is possible is illustrated in Fig. 5A. The subjective impression from this display of equally spaced dots is of three complex groups within the larger ellipses, each of which consists of a pair of dots inside the smaller ellipse plus a single dot to its right. The strength of the grouping produced by these ellipses is thus consistent with both their size and their level of embedding, which are correlated. The phenomenal impression of grouping that results from this display is not unlike that produced by the roughly corresponding proximity structure shown in Fig. 5B. Hierarchical structure in grouping has not been discussed much in previous studies of visual perception, although it has been described in the perception of musical structure (e.g., Lerdahl & Jackendoff, 1983).

RELATION TO OTHER GROUPING PRINCIPLES

The reader's phenomenal experience of the demonstrations in Figs. 2–4 should leave no doubt as to whether common region has an effect on grouping. The remaining question is whether it constitutes a new grouping factor or is reducible to one of those identified previously.

The most obvious possibility is that common region might be just another example of the principle of closure. As exemplified in Fig. 1E, closure applies to situations in which two or more elements are part of some closed contour. In the present case, however, the grouped dots are neither part of any larger closed contour nor do they approximate a closed contour; they are merely inside one. I argue, therefore, that common

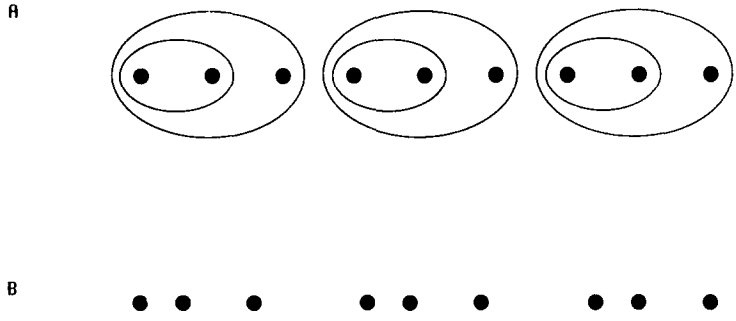


FIG. 5. Examples of hierarchical embedding. (A) An embedded grouping structure created by embedded common regions. (B) A roughly corresponding embedding structure created by proximity.

region is a grouping factor fundamentally different from the classical principle of closure.

Another possibility is that common region can somehow be analyzed in terms of the effects of proximity to the enclosing figure or contour. That is, perhaps the dots in Fig. 2A are grouped as they are because they are more proximal to the enclosing figure than they are to other enclosing figures. Although this is in fact true of the displays, I argue that it is irrelevant to grouping by common region, because the same grouping occurs when most of the enclosing boundaries are not visible, as in the case of the differently colored regions in Fig. 2G.

"Real world" examples of grouping by common region are not uncommon, although it is not easy to find examples that are free from the confounding influence of other grouping factors. Some relatively pure examples can be found in the grouping of cities on maps according to the state or country in which they are located. As shown in Fig. 6, Pittsburgh is closer to Columbus than it is to Harrisburg, yet it is perceptually grouped with Harrisburg because both are in Pennsylvania.

It is perhaps worth mentioning at this point that no claim is made that grouping by common region creates any distance *illusion,* only that the cities are spontaneously perceived as *grouped* according to the states in which they lie. In other words, Pittsburgh may still be seen as *closer* to Columbus, even though it is *grouped* with Harrisburg. The situation is roughly analogous to that in Fig. 2C, where the dots inside common ellipses are clearly perceived as farther apart than adjacent dots in different ellipses. It is perhaps also worth noting that grouping by common region is more powerful in Fig. 2C than in Fig. 6. This may be due to



FIG. 6. A "real world" example of grouping by common region: Pittsburgh is grouped with Harrisburg because of common region even though it is closer to Columbus.

several factors, including the increased spatial proximity of the ellipses to the dots in Fig. 2C, the colinearity of the dots, and the fact that the grouping structure is repeated many times.

Other real world examples of the influence of grouping by common region can be found in graphic design, where enclosing figures, separating contours, and different background regions are often used effectively to partition two-dimensional space into distinct regions. If a designer wants to indicate that a particular set of dials or displays are related and wishes them to be seen as a group, for example, they can be enclosed inside a common contour or placed on a common background. Similar devices can be used to group verbal materials. Figure 7, for example, shows two signs containing the same configuration of four words, differentiated only by their groupings according to common region. The effect on the perceived meaning of these two political placards, however, is profound.

Still, it is most unlikely that the evolutionary utility of grouping by common region is either to help people group cities on maps or to aid in reading political placards. A much more likely possibility is that common region helps to organize texture elements within a contour as going with each other and as belonging to the surface or object that is bounded by

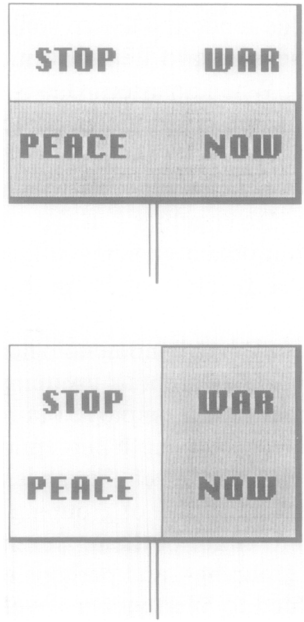


FIG. 7. The effect of grouping by common region on two political placards containing identical configurations of words.

that contour. For example, it may work in concert with similarity in color, size, and shape to help in grouping the leopard's spots or the grains of wood on a board. It seems likely that the common-region effect would generalize to three-dimensional stimuli, such as grouping objects within a bounded volume of space. It is not clear what the ecological significance of this tendency would be, however, given that most surfaces are opaque and that objects inside them could not be seen from the outside.

INTRINSIC VERSUS EXTRINSIC GROUPING PRINCIPLES

Why might Wertheimer have missed common region as a principle of grouping in his studies of perceptual organization? One likely possibility is that common region is a different *kind* of grouping principle from the others he examined. The important difference is that common region is an *extrinsic* grouping effect, whereas most of the classical factors are *intrinsic*. That is, grouping by common region requires reference to something other than the elements that are grouped—namely, their "belonging" to a region—whereas classical grouping factors work just on the intrinsic relations among the elements themselves.[3]

Figuring heavily in grouping by common region is the fact that elements located within a contour or on a region tend to be *captured* by it in the sense of being seen as *belonging* to it—and possibly even attached to it—rather than as floating in front with no visible means of support. A compelling example of this tendency to see something as attached to its surrounding region is the standard demonstration of the size–distance relation in Emmert's law. When an afterimage is viewed against surfaces at different distances, it is perceived to lie on the surface that surrounds it. Given this tendency, two or more elements that are thus attached to the same region or object would naturally be considered as related in this respect and therefore to "go together" in the sense of classical Gestalt grouping. Without the additional organizing influence of the extra entity—the common region—there would thus be no basis for the organization that is perceived.

In summary, I have argued on phenomenological grounds that common region is an effective factor in perceptual grouping using the same type of arguments that Wertheimer (1923) employed in his original paper. It operates at least to some extent after depth perception, although it may have an earlier component as well. And even though it seems superficially to be related to the well-known principles of grouping by closure and proximity, it cannot be reduced to either of them. Common region thus appears to be a new principle of grouping—and perhaps even a new *kind* of principle—that should be added to Wertheimer's well-know list.

[3] The classical principle of closure may also involve other elements, but it need not.

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