Grouping and Occlusion in Perception and Art

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Abstract

In the first part of the lecture several meanings of the term "perceptual grouping" as it applies to contour and texture will be distinguished, especially grouping as segregation and grouping as cohesion. This will be expanded to a discussion of the segregation of surfaces in depth and the occlusion cues on which this is based, which also underlie the perception of "subjective contours". Special attention will be given to the way pictorial cues interact with binocular stereopsis to influence perceived surface occlusion. Finally, the depiction of occlusion will be discussed as a major feature of art, with support for Kanizsa's view that this is a perceptual not a conceptual achievement. As such I show that surface segregation can fail perceptually even when the conceptual intention is clear.

1. Grouping

1.1. Major grouping concepts from Gestalt until now

- Definition. "Grouping: the fact that observers perceive some elements of the visual field as going together more strongly than others" (Wagemans, Elder, Kubovy, Palmer, Peterson, Singh & von der Heydt, 2012, p. 1180).
- Grouping results in "emergent features". These are properties of the group that are different from the sum of the parts.
- *Prägnanz*. The visual system sees the "best" figure possible given the current conditions. "Best" is usually interpreted as the most regular. (Regularity has been quantified in various ways).

The following distinctions are largely absent from traditional and current treatments:

- Grouping as SEGMENTATION of elements versus grouping as COHESION.
- Grouping as UNIT FORMATION (producing emergent features) versus grouping as AGGREGATION (without emergent features).

I'll show that these processes can be operationally distinguished with different roles.

1.2. Laws of grouping (illustrated in Figure 1)

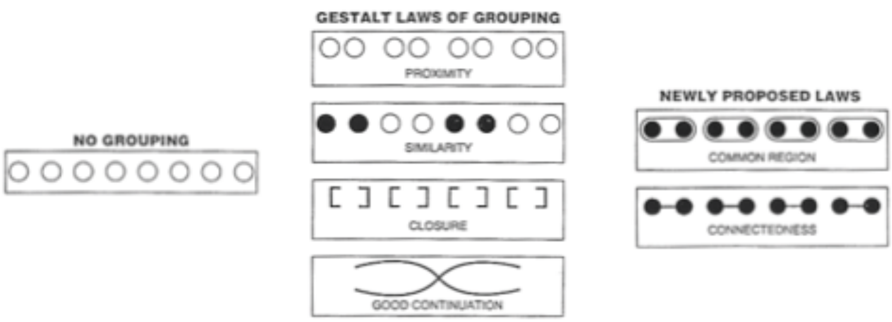


Figure 1. (from Rock and Palmer, 1990) illustrates a number of the well-known Wertheimer principles of grouping plus two new ones.

1.3. Grouping as cohesion

- The laws shown in Figure 1 are all in accordance with the Wagemans et al. (2012) definition (which is based on Wertheimer's). That is, they all reflect *relative* belongingness. There is nothing within a segregated pair (e.g., any pair in the proximity or similarity rows of Figure 1) that indicates whether it is or is not a group in an absolute rather than a relative sense. That would require some evidence for *cohesion* among the parts.
- Koffka (1935) and Beck (1982) both recognised that "the forces of segmentation and the forces of cohesion" (Koffka's terms) are confounded in demonstrations of grouping and in grouping measures based on visual search.
- Can cohesion be isolated and measured?
- One criterion of cohesion is to show that elements behave alike with respect to an ambiguous property. See the Attneave triangles (Figure 2).

Figure 2. The Attneave triangles (Attneave, 1968). Each triangle appears to point in a certain direction. If you keep looking, it changes its direction of pointing towards another of its three axes. The critical point is that when one triangle changes direction, so do all the others.

- The triangles are grouped in the sense that the same pointing direction is applied to all. This is cohesive grouping. It is not based on segmenting elements from a context. The elements are also not just an unrelated clump. They do not however possess an emergent feature. The whole is not different from the sum of the parts in that taking any part away would not influence the appearance of the rest. This form of grouping has been called *aggregation* to distinguish it from *unit formation*. (For detailed discussions see Gillam, 2001, 2005).

1.4. The rotational linkage criterion

Motion can provide another kind of ambiguity from which joint resolutions of parts allow cohesive grouping to be inferred. This method also allows grouping strength to be measured. In the rotational linkage paradigm – whose name was coined by Eby et al. (1989) – lines or shapes are rotated in depth around a central vertical (or horizontal) axis. They exhibit a powerful kinetic depth effect but because of the use of parallel projection, their direction of rotation (clockwise or counterclockwise) is ambiguous with reversals common. Degree of cohesive grouping is assessed by the proportion of the time (over say 10 rotations) that the lines/shapes appear to be rotating in the same direction; reversing together. Some of the stimulus determinants of rotational linkage are described below.

i. **Similarity and proximity.** Two parallel lines exhibit strong rotational linkage, which decreases with their separation relative to length (support ratio). This dependency is not consistent with *Prägnanz*. Degree of rotational linkage also decreases monotonically with a difference in the orientation of the two lines (as in the internal lines of Figure 3).

ii. **Common region.** Rotational linkage increases strongly when lines are within a common (planar) region (Figure 3 left) much more when the boundary of the region shares a vanishing point with the enclosed lines as in Figure 3 right (Gillam & Broughton, 1990).

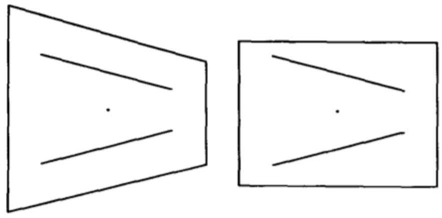


Figure 3. Lines enclosed in a region sharing their vanishing point (left figure) group strongly while those with an incompatible vanishing point (right figure) do not.

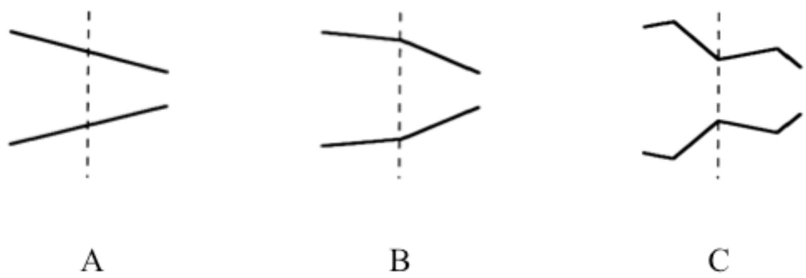


Figure 4. Lines with redundant symmetry (B and C) show significantly more rotational linkage than lines with simple symmetry (A).

iii. **Symmetry**. Simple symmetry, as in the Figure 4A, results in poor rotational linkage. However when symmetry is more redundant, as in B and C, rotational linkage significantly increases.

iv. **Good continuation.** Two separate and unaligned Ames windows with opposite perspective orientation (Figure 5a) appear during rotation to oscillate in opposite directions with the longer side always nearer. However when the figures are aligned (Figure 5b), good continuation of the vertical edges groups the two windows into a single object (a parallelogram) that no longer oscillates but rotates as a unit, reversing more randomly than its component parts, now that perspective control is removed. This is purely cohesive grouping. However unlike grouping of the Attneave triangles, in this case a new unit is formed by the cohesion that behaves differently from either of the parts. As the aligned Ames windows are separated more, their cohesion declines. They begin to oscillate in opposite directions. Separation effects are difficult to explain with *Prägnanz*.

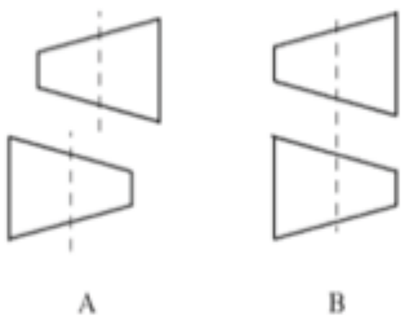


Figure 5. Ames windows with opposite linear perspective. When misaligned (A) they oscillate in opposite directions. When aligned (B) and not far apart they are grouped vertically by good continuation. A new unit is formed that has a different pattern of rotary motion from the component parts.

v. **Good continuation and the cohesion of collinear lines**. The rotational linkage behaviour of a pair of *collinear* oblique lines shows that aggregation and unit formation can depend on different stimulus parameters. At small separations, collinear lines are rigidly connected and always rotate and reverse as a unit (a single line with a gap). However at larger separations, although they remain aggregated for direction of motion, they no longer maintain a rigid relationship. The lines appear to rotate around different axes. In this case it is very clear that parts are aggregated but not a perceptual unit. (Gillam & Grant, 1984).

1.5. Summary of general conclusions concerning grouping

- Grouping research has often confounded cohesive and segregative processes.
- When cohesive grouping is isolated, it is found that grouping may not be different from the sum of the parts. Elements may "aggregate" for depth and motion resolutions but not form a unit with emergent features.
- In other cases (such as closure) cohesive grouping may form a unit with emergent features.
- What is the function of aggregation, since no new unit is formed? It seems to be a response to redundancy, allowing depth and/or motion to be resolved in common for the group.
- Aggregation is not all or nothing. It can apply to some percepts and not others; e.g., to direction of rotation but not to axis of rotation.
- Grouping traditionally and currently tends to be presented as a single process in which the main issue concerns the relative strengths of grouping "laws" or "principles". However cohesive grouping lends itself to parametric investigation rather than establishing laws.
- Grouping has multiple roles in perception. Occlusion perception, to which I now turn, richly depends on various kinds of groupings both monocular and binocular.

2. Grouping and Occlusion

2.1. Two-dimensional occlusion cues

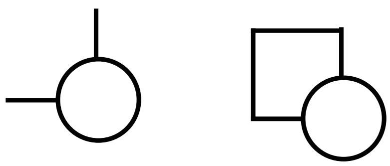
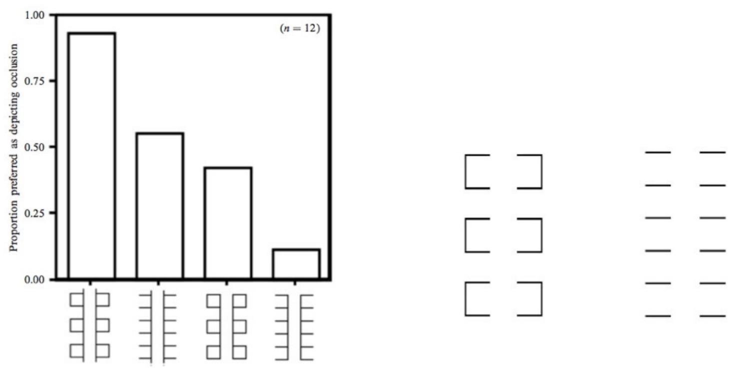


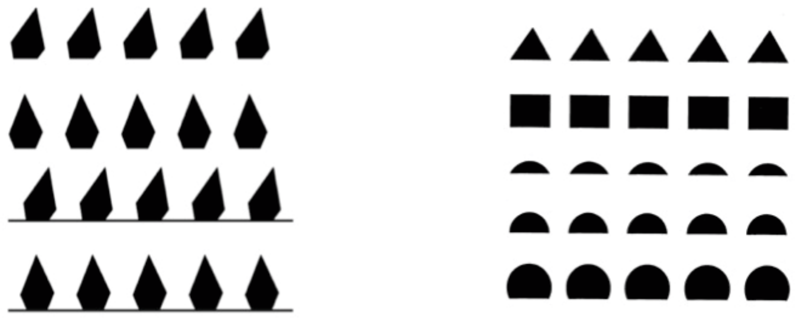
Figure 6. Closure of lines increases perceived occlusion at T-junctions (and thus amodal completion).

2.1.1. **Closure**. Lines forming T-junctions with a potential occluder are much more likely to be seen as occluded if closed (Figure 6). Figure 7a confirms this observation showing measures of perceived occlusion by gaps in closed and unclosed lines. Figure 7b goes further, showing even that when a potential occluder is not delineated, closure enhances seeing a subjective contour in the gap (Gillam et al., 2010). Closure allows figural properties to be influential.



(a) (b)

Figure 7. (a) Probabilities from a paired comparison experiment of seeing each of four figures as having a gap that appears as an occluder (rather than a part of the background). (b) A gap between sets of horizontal lines has a much stronger subjective contour when the lines are closed at their outer edges.



(a) (b)

Figure 8. (a) Perceived occlusion and strong subjective contour for asymmetric but not symmetric figures. (b) Regular figures when aligned (top two rows) do not give rise to perceived occlusion or a subjective contour. The three incomplete circles do. Occlusion allows them to perceptually complete.

2.1.2. ***Prägnanz* or extrinsic edges?** Figure 8 illustrates perceived occlusion that allows irregular figures to become regular if completed behind the occluder. Is this a tendency to impose *Prägnanz*? I prefer to think of this effect as due to the alignment of potentially "extrinsic" edges - shape edges that are *poorly grouped* with the rest of their shape. In the first and third rows of Figure 8a, the bottom edges are not parallel to nor orthogonal to the major axes of their shapes. In the lower three rows of 8b the bottom edges are straight while the shape is otherwise curved. When a set of such potentially extrinsic edges is aligned, their extrinsic status is reinforced and occlusion is seen. When a physical line is absent a subjective contour signals perceived occlusion.

2.1.3. **Extrinsic gaps.** Figure 9 shows sets of highly regular horizontal lines forming strong groups. The gaps either create two sets of lines with the same orderly structure (c & d) or violate orderly group structure by non-orthogonality with the lines (a & b), non-parallelism with the group edges (e & f) and unequal line widths. The latter four gaps are extrinsic to their group and are seen as occluders indicated by subjective contours along their edges.

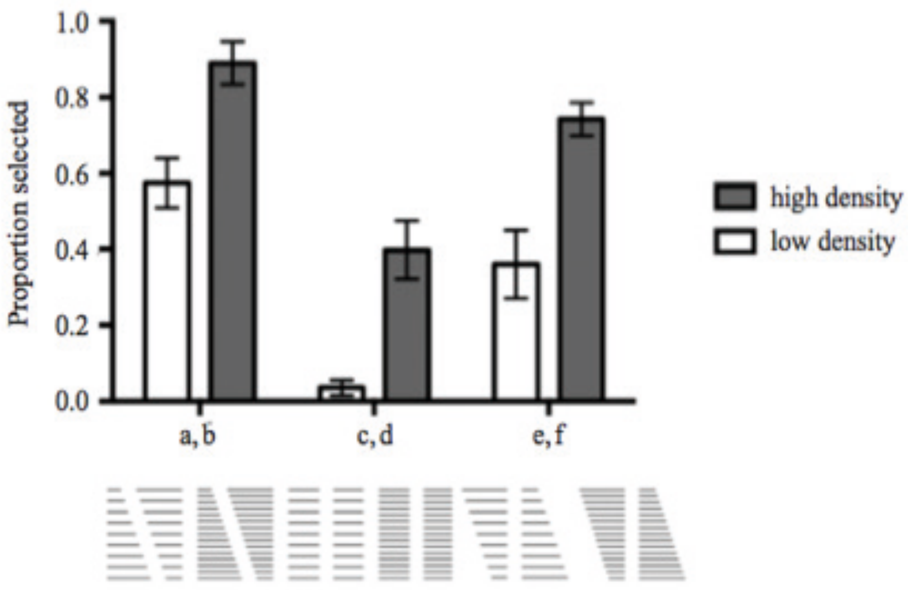


Figure 9. Extrinsic gaps are much more likely to appear as occluding strips than gaps consistent with properties of the group (see text). Probabilities are from a paired comparison experiment (Gillam et al., 2014). Density also had an effect but extrinsic gap produced stronger subjective contours at both densities.

2.1.4. **Poor grouping (disorder) of line or shape inducers can increase the strength of occlusion perception and subjective contours.** An occluding surface cuts off anything behind it. Occlusion is the only condition in which very different objects or contours are terminated in an orderly alignment. Conversely, we have shown that alignment of disordered and poorly grouped elements is a very strong occlusion cue. Figure 10 shows a much stronger subjective contour for regular gaps in disordered or poorly grouped lines (10A) than in orderly lines (10B). The tendency of an alignment of disordered elements to appear occluded is also shown in 10C The disordered elements appear through (and cut off by) an aperture to which they are not attached, while similarly aligned orderly lines (10D), with the same average orientation, appear as a single unit with the outline, which does not appear to occlude them.

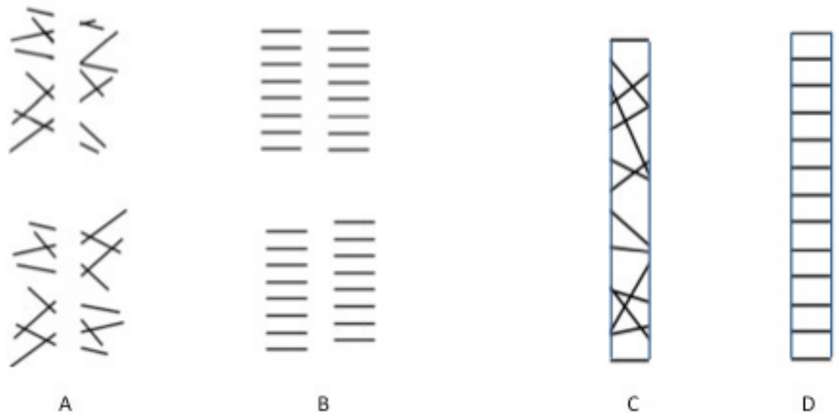


Figure 10. Showing the strong effects of disorder (poor grouping) on perceived occlusion at an alignment (compare A & C with B & D). Experiments in Gillam & Grove (2011) and Gillam et al. (2014).

Poorly grouped (disordered) *shapes* are also much more likely to appear occluded at a smooth alignment than orderly shapes (Figure 11). Gillam & Chan (2002) carried out two paired comparison experiments, one asking subjects to compare 8 sets of 5 shapes (including the three shown in Figure 11) for apparent occlusion at a bottom line and another, using different subjects and omitting the line (Figure 11 right) with the shapes compared for strength of subjective contour along the bottom. The probabilities of choice for equivalent stimuli (shown for three examples in Figure 11) were remarkably similar across experiments. Note that both the second and third sets of shapes in Figure 11 have disordered inducers. However the third set also has another occlusion cue. Each shape has one edge neither parallel to nor orthogonal to its other edges. These are potentially extrinsic edges and when aligned, combine with the disorder across the set to produce a very strong sense of occlusion even though there is only a single edge. Amodal completion across an occluding surface is thus not necessary to give a strong sense of occlusion. This is just as well, since frequently only one edge of an occluding surface is visible in the natural environment.

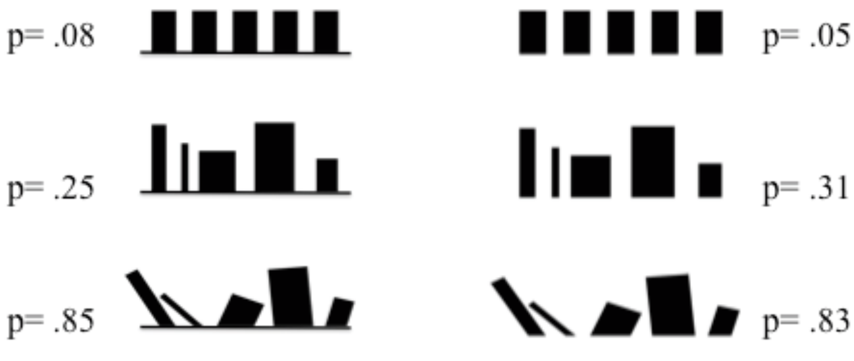


Figure 11. Probabilities are shown beside each figure of its being chosen as producing a stronger impression of occlusion (left column) or having a stronger subjective contour (right column). There were 8 figures in all (Gillam & Chan, 2002). Occlusion and subjective contour strength both increase strongly with disorder.

2.2. Stereoscopic occlusion cues

2.2.1. **Poorly grouped inducers provide the richest disparity information for seeing occlusion in depth.** Figure 12 shows three stereograms (for crossed fusion) increasing in disorder from top to bottom. Depth was introduced by attenuation of the left image of each pair along its bottom diagonal alignment. This is consistent stereoscopically with the presence of a diagonal occluder in depth (with both horizontal and vertical image disparities increasing with the degree of uniocular attenuation). Thresholds for detecting depth were measured for each stereogram type using a two alternative forced choice task. Thresholds were lowest for C, then B, then A, for all 6 subjects (Gillam & Anderson, 2014). The *relative* magnitude of vertical and horizontal disparities for oblique occlusion varies with inducer orientation. The lower depth threshold for C therefore indicates that the more varied and complex the pattern of disparities supporting a given depth arrangement the stronger the depth will be.

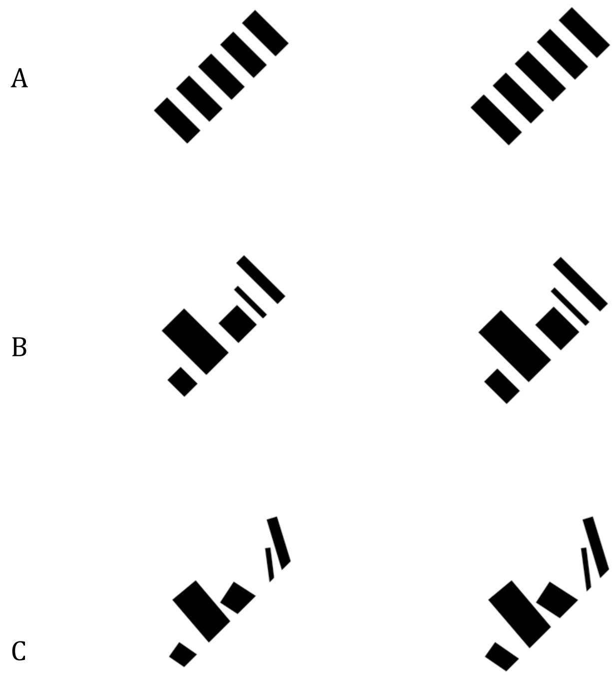


Figure 12

2.2.2. **Binocular vertical occlusion determined by depth grouping not image abutment.** Figure 13 consists of a number of stereograms. The left and middle images of the top row is a stereogram of a planar surface at the bottom which is nearer than and abutting a "forest" of sticks (varying depths) at the top. There is a strong subjective contour where the two surfaces abut, with the near plane appearing to occlude the far forest. The middle and right images of the top row when fused have the reverse depth arrangement. The forest is now stereoscopically nearer than the plane. The subjective contour disappears. Why? Well a forest is not a surface so cannot be an occluder. The middle and bottom rows show the same stereo arrangements as the top row but now the forest and plane are slightly separated and slightly overlapping respectively. The subjective contour persists for the left pair in both lower rows and it is always seen at the edge of the forest. The separation allows us to see that the subjective contour appears along the *occluded* not the *occluding* elements. The edge of the plane appears to continue beyond its defining lines up to meet the forest. In the overlapping case, the lines of the plane continue beyond its apparent edge, which again is determined by the forest. It is clear that perceived occlusion depends on the scene implications of the depth arrangements and is not determined at the image level. I shall argue that the perceptual consequences of manipulating the forest and the plane in depth cannot be explained by any theories trying to apply a principle.

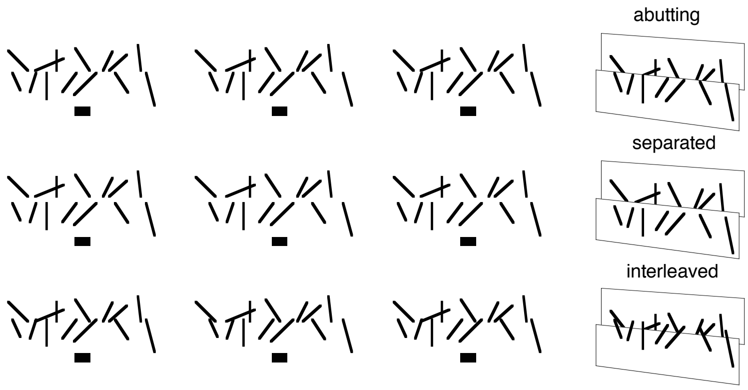


Figure 13. Stereograms showing how the existence and the locus of perceived occlusion (as shown by a subjective contour) depends on the depth grouping and arrangement of the inducers and not on image abutment (Gillam & Nakayama, 2002).

3. Occlusion and Art

I shall end my talk by showing how 2-D cues are used to depict occlusion in painting; especially Australian aboriginal painting, which often uses perceptual occlusion cues in a rather pure form. In other examples I'll support Kanizsa and Massironi's (1989) contention that cognitive indicators of occlusion do not work in art without perceptual support.

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