The Conditions for the Perception of the Covering and Uncovering of a Line

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It is shown that a line of changing length is generally perceived as a line of constant length undergoing covering or uncovering when stimulus information (or the perception of objects to which such information gives rise) is compatible with that 'inference,' namely, that the line is contiguous with a phenomenally opaque object large enough to cover its disappearing portion. Otherwise, the line tends to be seen as of changing length. However, there is a preference for the constancy solution, so that a tendency toward perceptual rationalization occurs when the sensory information does not support that solution.

There are several possible perceptions that can result from a change in the length of the retinal image of a line. One can perceive a line of changing length; one can perceive a line of constant length changing its orientation in depth; one can perceive a line-as-a-whole changing its distance; or one can perceive a line of constant length undergoing covering or uncovering by another object.

In this paper we are concerned with the conditions that lead either to the first or to the last of these perceptual outcomes. The second outcome, the perception of a line changing its orientation in depth, tends not to occur spontaneously if the line does not simultaneously change its orientation in a frontal plane (Wallach and O'Connell, 1953). Furthermore, if the line has any perceptible thickness, the absence of any perspective gradient of thickness as it changes in length will serve as a cue that no change in depth is occurring. The absence of any change in thickness would also tend to oppose the perception of a line approaching or receding from the observer, the third outcome. Otherwise, the change in overall size of the image would surely lead to an impression of an object of constant size moving back and forth in the third dimension. In the research to be described, these factors — plus the possible additional one that the image of the line was displaced only at one end — effectively eliminated either of these kinds of perceptual impressions of change in the third dimension.
Concerning the other two possibilities, perceived change of length and perceived constancy based on covering and uncovering, one might predict that the latter would be dominant because the progressive change in length constitutes information that the end of the line is undergoing occlusion or disocclusion (Gibson, Kaplan, Reynolds, and Wheeler, 1969; Kaplan, 1969). The hypothesis guiding our research, however, was that no such objectively specifiable change in the proximal stimulus determines the perceptual outcome; rather, that which is perceived is the result of an inferencelike process and depends upon the most plausible 'solution' to the 'problem' posed by the changing proximal stimulus.

If, for example, nothing is visible except a line whose length is changing, the only supportable inference is that the line is undergoing a change of length. For if the line is being occluded or revealed by an opaque object, why is no such object visible? (Whereas an observer might still make a nonperceptual inference that the line is being covered and uncovered, it is our contention that perceptual inference must be rooted in stimulus information.) But if, on the other hand, a large rectangle remains adjacent to the end of the changing line, then an alternate inference is possible, the inference that a line of constant length is being alternately covered and uncovered by the rectangle. However, it should be added that the change-of-length solution remains possible here: the line with a rectangle at one end could be undergoing a change of length.

**EXPERIMENT I**

Experiment I compared three main conditions. In condition A, the observer viewed an isolated line that was changing in length, alternately elongating and shrinking. In condition B, the observer viewed a line that was changing in length as in condition A, but a large outline rectangle moved in such a way that one of its ends was always in contact with the displacing end of the line. The rectangle here was large enough to cover the segment of the line that was eliminated by its shrinkage. In condition C, the observer viewed the line with a rectangle at one end as in condition B, but the rectangle was too narrow to cover the eliminated segment of the line. Consequently, it was predicted that the observers in this condition would tend to perceive a line that was changing rather than constant in length. Figure 1 illustrates these displays.

As a supplementary experiment, an additional condition was included, condition D, to determine whether the narrow rectangle used in condition C would lead to different results if the display changed in such a way as to be compatible with the 'solution' of a line of constant length under-
going occlusion and disocclusion. To that end, the line was now visible on both sides of the rectangle. Under this condition, some portion of the segment of the line that is eliminated on one side of the rectangle can be interpreted as constituting the now-enlarged segment of the line on the other side of the rectangle. This interpretation is not possible in condition C. As a control for condition D, an additional group of observers, condition E, was shown a display in which there was a gap in the line; the gap was of the same width as the rectangle, but no rectangle was visible. Thus, there were two lines here, one of which was undergoing elongation as the other was shrinking, and vice versa. Therefore, it was predicted that observers would tend to perceive this display as two line segments one of which is elongating and the other of which is shrinking. However, we did consider the possibility that this display might lend itself to an
impression of some not fully visible structure with subjective contours covering a moving gap.

Method

Animated photography was used to create video tape recordings of each of the displays. Referring to the display as seen by the observer on the television screen, for all conditions the displacing end of the line moved back and forth a distance of 5% in. at a rate of .2 in. per sec. The line was ¾ in. thick and changed its length from ½ to 5% in. In condition B, the rectangle was 3% in. high and 8% in. wide; in condition C it was 3% in. high and 1½ in. wide. The line and the outlines of both rectangles were black.

The display was visible for 10 sec, which in most conditions was equivalent to about two complete cycles of increasing and decreasing line length. The observer sat 6 ft from the television screen. He was told simply to look at the picture, and as soon as it was turned off, he was asked to describe what he had seen. Approximately 90% of the descriptions were unambiguous, but when they were not, the observer was questioned carefully until it could be established whether he had perceived a line of changing length or a line of constant length being covered and uncovered. In order to avoid ‘leading’ questions, care was taken that no question implied that the line either changed length or was covered. ‘How long was the line?’ is an example of such a neutral question. The only nonneutral terms used in the questioning were those the observer had already introduced into the dialogue. In all experiments combined, less than 3% of the observers claimed to have perceived the line both as changing in length and as remaining constant while being covered and uncovered, and these observers are not included in the results given below.

College students naive about the purpose of the experiment were randomly assigned to the different conditions, a given observer participating in only one condition. There were 14, 15, and 16 observers in conditions A, B, and C respectively, and 16 and 12 in conditions D and E.

Results

All but one observer in condition A perceived a line changing its length. By contrast, only 5 of the 15 observers perceived the line in this way in condition B, 10 perceiving a line of constant length being alternately covered and uncovered. In condition C, 12 observers perceived the line changing its length and 4 perceived it as constant in length. The distribution of responses for condition B differs significantly from that of condition A and condition C, but the latter two distributions do not differ significantly from one another.

In condition D, 12 observers perceived one line of constant length with a rectangle moving over it; 4 perceived two line segments undergoing elongation and shrinkage. In condition E, 11 observers perceived two line
segments undergoing enlargement and shrinkage; I perceived one line of constant length. The difference is, of course, statistically significant.

EXPERIMENT II

In condition B of the previous experiment, the rectangle was large enough to support the ‘solution’ of a line of constant length undergoing covering and uncovering. The majority of observers did perceive the line in this way. However, this solution presumably requires that the rectangle be perceived as opaque. If it were instead perceived as hollow, as a mere line perimeter, this solution is no longer plausible. Experiment II, therefore, compared a display intended to create the impression of a hollow rectangle moving back and forth, condition F, with a display like that in condition B of the previous experiment, condition G.

Method

The method followed that of Experiment I except that in condition F the line and large rectangle were seen on a field of oblique lines. The oblique lines were ½ in. wide, light gray, stationary, and ¾ in. apart. Therefore, the display created the impression of a hollow rectangular perimeter moving back and forth. For purposes of comparison, condition B of the previous experiment was repeated. In this condition, condition G, the oblique lines were not present. There were 15 naive observers in condition F and 15 in condition G.

Results

In condition F, 8 observers perceived the line as changing its length and 7 perceived it as of constant length being alternately covered and uncovered. In condition G the corresponding distribution was 1 and 14. The difference is statistically significant.

EXPERIMENT III

In this experiment, the entire line, one end of which remained contiguous with the outline contour of a human head, displaced upward and downward. Thus, the change in length of the line was given solely by the fact that one end maintained contact with the contour. The opposite end of the line did not displace horizontally. In condition II, the line was on the inside or ‘figural’ side of the contour. Consequently there would be no basis for perceiving it as undergoing covering and uncovering if the outside of the contour is seen as ground. In condition I, the line was on
the outside or ‘ground’ side of the contour, allowing the perception of the line as moving behind the figure.

Method

The line, which was ½ in. thick, varied in length from 3½ to 5 in. and displaced 5½ in. vertically at a rate of 2½ in. per sec. The head contour was 8½ in. high by 6½ in. wide.

There were 14 naive undergraduate observers in condition H and 15 in condition I.

Results

Nine of the 14 observers in condition H perceived the line as changing in length as it moved vertically; 5 perceived it as of constant length and undergoing covering and uncovering. Thirteen of the 15 observers in condition I perceived the line as constant in length and going behind a figure; 2 perceived it as changing in length. The two distributions differ significantly.

EXPERIMENT IV

All of the experiments above used a solid line as the figure to be described. There are reasons for believing that a dotted line might yield a different result. One might argue that there are no textural elements visible in a solid line, elements whose successive accretion or deletion is the stimulus information that leads to the perception of occlusion or disocclusion. Against this, however, is the fact that the line visibly changes its length so that the ‘elements’ can be thought of as hypothetical subparts of the line — as well as the fact that the line is perceived as undergoing occlusion and disocclusion by a majority of observers in some conditions and by some observers in all conditions.

Another reason for believing a dotted line might yield a different result concerns the question of phenomenal identity. When the line is perceived as constant in length and being covered and uncovered by another figure, each point of the line retains its identity. But when the line is perceived as enlarging or shrinking, the situation is ambiguous. Such changes could occur if new parts of the line were suddenly appearing or old parts disappearing, but they could also occur if the visible portion of the line was undergoing elastic stretching or compression. In the former case, the identity of points is maintained, but in the latter case, it is not. If instead of a solid line a dotted line is used, the identity of each point is unambig-
uously given and, therefore, the possibility of elastic deformation is excluded. With this alternative essentially ruled out, more observers might perceive a line of constant length undergoing occlusion and disocclusion. Accordingly, two of the conditions tested in Experiment I, conditions A and C, were repeated here as conditions J and K with a dotted line instead of a solid line. In condition J, the dotted line alone was visible, and in condition K, a narrow solid-outline rectangle remained next to the displacing end of the dotted line.

Method

Except for the displays, the method and procedure were identical with those of Experiment I. A condition analogous to that of condition B in Experiment I, that using a large rectangle, was not included because the change to a dotted line was, if anything, expected to lead to more observers perceiving a line of constant length being occluded. In condition B of Experiment I, a majority had perceived the line in this way.

There were 15 naive undergraduates in condition J and 15 in condition K.

Results

Eleven observers perceived the dotted line elongating and shrinking in condition J, but only 5 did so in condition K. Conversely, 4 observers perceived a line of constant length undergoing occlusion in condition J, and 10 did so in condition K. The difference in the distribution of results for the two conditions is statistically significant. The difference between the results of condition K and the results of the corresponding condition, condition C, in Experiment I is also significant.

DISCUSSION

We believe there is a strong preference to perceive a line whose retinal image changes its length as a line of constant length undergoing occlusion and disocclusion, a preference strong enough that wherever this solution is supported by the stimulus information or can be rationalized, it will occur. That is why the line was generally perceived in this way in conditions B, D, G, and I. Conditions such as A, E, and J offer no such support and, therefore, this solution rarely occurred. That it occurred at all in these latter conditions is surprising, but it is possible that it is rationalized by the perception of a subjective contour of a covering surface.

All the remaining conditions are somewhat more equivocal insofar as the stimulus information is concerned. Condition C of Experiment I pro-
vides an outline of a rectangle that tends to yield an impression of being a solid rectangle and can therefore be perceived as covering and uncovering the solid line. However, it is not large enough for this solution to make complete 'sense.' Therefore, a majority of the observers perceived the line as changing in length, but a few nonetheless perceived it as being covered and uncovered. But when the line is dotted rather than solid, as it was in condition K of Experiment IV, the majority then perceived it as being covered and uncovered. We suspect that this shift occurs because with the dots unambiguously establishing the identity of points on the line, it is no longer possible to perceive the line as elastically stretching and compressing. Therefore, one must either perceive the dotted line as inexplicably increasing and decreasing in length as the rectangle moves back and forth, or as undergoing covering and uncovering. (In passing it is interesting to note that several more observers saw the line being covered and uncovered in condition J of Experiment IV than in the corresponding condition, condition A, of Experiment I). How the perceptual system tolerates the contradiction implied by the small width of the rectangle (or absence of the rectangle in condition J) in favoring the covering/uncovering solution is not clear.

Condition F of Experiment II is also equivocal. Here the rectangle is large enough to support the covering/uncovering solution, but it ought to be perceived as hollow rather than opaque. The presence of the oblique lines that presumably lead to this perception clearly has a powerful impact, because eight times as many observers perceived the line as changing in length than did so in condition G. Yet 7 of the 15 observers perceived the line as undergoing covering and uncovering. Again, the question arises as to how the perceptual system rationalizes the contradiction. It is, of course, possible to perceive the rectangle as opaque in spite of the oblique lines. One can somehow ignore the oblique lines. In this connection, it is interesting that of 6 observers in this condition whom we questioned directly afterward, the 4 who had reported a line being covered and uncovered did not recall seeing oblique lines within the rectangle; the 2 who had reported a line changing in length did recall the oblique lines.

It is perhaps also worth noting that in conditions such as G, K, or F (and, of course, in other conditions where a line is contiguous with a rectangle), the stimulus conditions for interposition obtain. Therefore, even in a stationary display of this kind, there would be a predisposition to perceive a line that is partly covered by a rectangle. Therefore, the stage is set for the observer to perceive covering and uncovering even before any motion is introduced.

It should not be possible to solve the problem posed by condition H of
Experiment III by perceiving the line as being covered and uncovered because there is no figure under which the end can be perceived to be moving. Yet 5 observers did perceive the line in this way. What we believe happened is that the region intended to be perceived as ground was in fact perceived as figure by these observers. Some of them reported this fact in the interview after the period of observation, and the authors and several other observers in our laboratory have experienced the same effect. In principle, of course, the figure is reversible, but ordinarily the combined factors of closure and familiarity strongly favor perceiving the region of the face as figure. Without the moving line it is doubtful any naive observer would experience a reversal of this figure during the brief period of observation. But the presence of the moving line changes the equation, so to speak. The preference to perceive the line as undergoing covering and uncovering leads to a figure/ground reversal which then fully rationalizes that perception.

The basis for the preference to perceive an object as of constant size and undergoing occlusion or disocclusion is not known, although it is consistent with the general tendency to perceive objects as constant rather than as distorting wherever possible. It is certainly rare in either the natural or man-made environment that objects increase or decrease in size in a brief period of time, whereas it is quite common that objects become occluded by other objects. Therefore, the preference could be based either on an innate selective principle that emerged because of its adaptive value or on past experience. However, from the view of perception presented here—namely, the view of perception as the end result of problem solving—one might say that the perception of an object as changing its length under certain conditions is not an elegant solution. If, as in several conditions of our experiment, a second object is contiguous with the object undergoing change (the line), then the presence of that second object and its continued contiguity with the line must be a matter of pure coincidence if the line is perceived as changing in length. In other words, by this solution the moving object plays no role at all, and yet its motion is perfectly correlated with the change in the length of the line. But all aspects of the proximal stimulus are accounted for by the solution that the line is undergoing covering and uncovering by the second object. What we are suggesting, then, is that the preference is based on a more general tendency of the perceptual system to seek the most elegant solution and to reject coincidence.

The experiments reported here are relevant to the claim of Gibson and his associates that the perception of the covering of one surface by another—with the consequent phenomenal impression of permanence of
the object covered — is based on the stimulus information of accretion or
deletion of textural elements. Typically, units of one region progressively
are deleted when it moves behind another region or that region moves
in front of it; and units of a region are accreted when it moves out from
behind another region or that region moves away from it. It is not clear
from this statement whether it is believed that the second, unchanging,
region must be a 'figure.' In describing an experiment on the progressive
disappearance of a disk where nothing but the disk is visible (Michotte,
Thinès, and Crabbé, 1964), Gibson (1966) implies that the progressive
deletion of parts of the object is what is crucial, since no other figure is
visible. (Interestingly enough, in this demonstration the disk is perceived
to be undergoing occlusion by passing under a slit although no slit is
physically present.) In subsequent reports, all examples refer to two sur-
faces or regions, the units of one of which are undergoing accretion and
deletion and the units of the other of which are unchanging (Gibson et al.,
1969) or the units of both of which are undergoing accretion and deletion
(Kaplan, 1969). But the question nevertheless arises whether it is a
necessary condition of Gibson's hypothesis that a second surface be pre-
sent and, if so, how its presence is defined. One might argue that this
question is meaningless because the changing surface is necessarily adja-
cent to some other surface whether that be perceived as belonging to a
bounded figure or to unformed ground. If so, one wonders why our ob-
servers generally did not perceive the changing line as an object under-
going occlusion and disocclusion in those conditions where no figure other
than the line itself was visible.

Therefore, for the accretion/deletion hypothesis to be viable, it seems
necessary to assume that the region perceived as occluding the other sur-
face be perceived as a figure rather than as ground. This in itself would
seem to be a very serious challenge to the view that one can state the
conditions for phenomenal covering and uncovering purely in terms of
proximal stimulus features. Figure/ground organization is a perceptual
outcome, not something given by the proximal stimulus. But passing over
this question, the further fact remains that for the covering/uncovering
effect to predominate, other properties of the 'covering' object are impor-
tant. Ideally, it should be phenomenally opaque and sufficiently large.
We do not see how Gibson and his associates can account for findings
such as those of conditions C and F.

The outcome of the experiment on the progressively disappearing disk
cited above (Michotte et al., 1964) constitutes a problem for the theory
we are defending. The disk is perceived as undergoing occlusion despite
the absence of a visible object that can be interpreted as the covering
object. On the face of it, the result is a direct contradiction of what we found to occur with an isolated line. There seem to be two differences between the disk experiment and our isolated-line conditions: the first is that the disk is two-dimensional, so that occlusion affects its width as well as its height (and thereby alters its shape); the second is that the disk as a whole moves until one edge reaches the (invisible) occluding edge. Either of these factors or both together may explain why in this case as compared to our one-dimensional line, observers have the impression that a constant object is progressively disappearing from view, provided that the observer 'perceives' ('imagines') that an invisible object is covering the disk. The two-dimensional character of the disk produces a phenomenal 'edge' behind which the disk can be seen to go. In other words, the strong preference for the constancy outcome that we found to obtain in most of our conditions in this case leads to the subjective construction of an opaque surface with only a minimum of supporting 'evidence.'

There is one feature of our findings that we believe has important theoretical significance. Perception can often only be understood as resulting from or dependent upon certain other, temporally prior, perceptions. Thus, for example, we can understand the main trend of the results of Experiment III only if we assume that the line is perceived in terms of the figure/ground organization of the display. Therefore, the information used by the perceptual system in arriving at 'solutions' is often given in the form of already achieved perceptions, although admittedly such a two-stage process is very rapid and we are not phenomenally aware of separate stages. There are many examples in the field of perception where one can argue that such a process occurs, and recently additional evidence of this kind has been reported for the perception of a figure through a moving aperture (Rock and Sigman, 1973) and the perception of stroboscopic movement (Sigman and Rock, 1974).

Intuitively, most of our results are not particularly surprising. One might even ask how the outcome could be other than what it was. For example, would anyone expect an isolated line that changes its length to be perceived as a line of constant length being covered and uncovered? On an intuitive level the answer is no, but why does this answer cause so much difficulty on a theoretical level? The intuitive answer is based on the certainty we feel that to perceive one thing going behind another, that other thing must itself be perceived. This means that intuitively we grasp the fundamental fact that perception is rational, but there is nothing in current psychological theory to require that it be.
Notes

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References


