MENTAL REPRESENTATIONS OF OCCLUDED OBJECTS: SEQUENTIAL DISCLOSURE AND INTENTIONAL CONSTRUAL

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Abstract. What subjects report with successive disclosure of occluded shapes depends on how they strive to construe the presentation: Shown the individual (closed) pacman of a Kanizsa triangle, serially but with positional information, subjects perceive the amodally completed triangle when they strive to perceive the pacman as a moving hole; but see only individual orientation-changes when striving to see it as a moving tile. With individual segments of a figure-ground pattern, presented as a pattern being serially displaced (with positional information) behind a hole, subjects perceive a coherently moving shape when the figural polarity that they are striving to hold as figure (e.g., black vs white) is the one which offers the high-contrastive shape; but when it is not, they tend to perceive instead a circular pattern in incoherent change. No matter what other arguments may enter the top-down discussion in the case of simultaneously presented incomplete objects, the constraints provided by intentional construal require some active role for mental structure in theories of successive disclosure.

In our view the visual cognition of any object or event depends on a process of construal which yields a particular mental representation. By «construal» – a term which Chambers and Reisberg (1985) introduced in discussing imagery – we mean fitting some interpretation or explanation (which may be partial or inconsistent) to the sensory input, avoiding any implication of a reasoning-like process. The need for a notion of mental representation is most evident when different variables of stimulus information which have in common only that they may be construed as arising from the same virtual distal object (i.e., accessing the same mental representation) may, within some limits, be perceptually equivalent. For example, four very different ways to indicate an object’s orientation toward the light-source may have equivalent effects on the object’s apparent reflectance (Hochberg & Beck, 1854). We use the term «mental structure» for such inter-re-

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1Although this could be a critical example of mental structure, if we could be sure that it was through their effects on perceived slant that the different depth cues a-
sponse constraints or perceptual couplings as those between apparent orientation and apparent reflectance, or between apparent size and distance, etc., which cannot presently be explained in terms of equal sensory response to different proximal stimuli (Cooper & Hochberg, in press; Hochberg, 1956; Hochberg & Peterson, 1987).

Such equivalence does not by itself, of course, necessarily imply mental structure. In form perception, for example, very different displays (dots, black/white, size, and other transformations) may be equivalent, suggesting to Gestalt psychology that the configuration itself is the effective stimulus variable that those differing presentations share. In fact, it is very difficult to make a truly foolproof case for mental structure that is not vulnerable to some variation of a configurational approach (e.g., Gibson, 1979). For form, at least, it has been shown that configuration alone does not determine the form that we see: knowledge and intentions also contribute (Davis, 1985; Girgus, Rock & Egart, 1977, Hochberg & Peterson, 1987; Peterson & Hochberg, 1983; Rubin, 1915). It has been assumed that the configuration determines the very first organization, but Peterson and her colleagues argue that structural representations in shape memory can influence initial figure-ground organization, long held to be immune to such «topdown» influences (Peterson & Gibson, 1991; Peterson & Gibson, 1999; Peterson, Harvey, & Wein. bacher, 1991). Moreover, viewers' intentions to construe the same configuration as one mental representation rather than another have perceptual consequences consistent with the structures implied by those construals (Hochberg & Peterson, 1987; Peterson, 1986; Peterson et al., 1991), arguing that those intentions affect what is perceived and not merely what is reported.

Finally, many of the facts of completion over space and time invite some representational mediation. Drawing on the methods, assumptions, and stimuli used to study the other phenomena discussed above, we will try to show that such completion can also be affected by knowledge and intentional construal in ways that implicate mental structure. Kanizsa's robust and spectacular triangle (1955; 1976) is a demanding example of completion over space, which we know to work over time as well (Kellman & Cohen, 1984). We will be concerned in particular with amodal completion (For an explication of this distinction, see Kanizsa, 1979). It is clear to informal observation that in many cases of completion the viewer can perceive other alternatives by an intentional reconstrual (e.g., see Bradley, Dumais & Petry, 1976; Kellman & Loukides, 1987). That is our interest here. Specifically, we are concerned with the effects of intended construal when the configuration is shown not simultaneously but serially: For example in the sequence i, ii, iii, the triangle defined by the three tokens in Figures 1 is still perceived in some sense as being present, even though 2/3 of it is occluded at any moment of time (this holds also for open «pacmen», as in the center of Fig. 2A). This is true for a variety of forms and objects that are viewed in piecemeal succession, whether the contours are fully disclosed and «real» (Hochberg, 1968, 1986) or remain incomplete and subjective (see Kellman & Cohen, 1984; Kellman & Loukides, 1987). Because such shapes are never all present at once, there is a question

Figure 1: A «Kanizsa triangle» in successive amodal completion (sequence: i, ii, iii).

Figure 2: A triangle viewed through a hole (A, B) or as displayed piecemeal on a tile (C, D). In Experiment 1, the display (hole plus surround, or tile within its surround) was so displaced that the pacmen was presented in the same location as in Figure 1. All pacmen in this experiment were «closed», as in Figures 2B and 2D.

1 As usual in such discrete displays, too short an SOA (say, less than 250 msec) provides coincidence of content and apparent motion between whatever contours fall near each other, whereas with too long a period the connection between views is lost (see Hochberg, 1968).
of what is «actually perceived at any moment» as distinguished from the cognitive consequence of the event after it is complete; that question is not unique to cases of successive presentation, however, but can be raised as well in every other case of perception.

The fact that the parts do not simultaneously present their configuration invites us to speculate about a mental representation to which they contribute. But the loci of the features in Fig. 1 do indeed specify a triangle (among other things), as ecological realists talk of specification. Such specification does not however provide a direct or automatic basis for completion: It seems effective only if the viewer construes the moving token as a hole; if instead the viewer chooses to construe it as a moving tile, the pattern on its surface appears instead to change abruptly between the three orientations in Figure 1: Construal of one aspect of the event constrains the construal of a second aspect in accordance with some mental structure which binds the two aspects in what we call a perceptual coupling (Hochberg, 1956; Hochberg & Peterson, 1987; Peterson, 1986).

The task of instructed construal seems more readily communicated if the tokens are presented within the context of a drawing of a hole in a moving plate (Figures 2A and 2B) or in the context of a drawn moving tile (Figures 2C and 2D; these show the first and third views within the sequence represented in Figure 1). Kanizsa has already noted (see also Parks & Rock, 1990) that a drawn 3D structure inconsistent with an occluding shape can interfere with the perception of that shape and of its subjective contours. Although neural explanations have been essayed here (Peterhans & von der Heydt, 1989), such facts are also often offered in support for more mentalistic accounts. Thus, in intuitive terms, it is more likely that an object will be successively revealed by a moving hole than that it will be successively displayed on the surface of a tile moving over the same locations. Although such explanations are often offered as evidence that perception reflects the physical ecology, or that perception rests on unconscious inference, or that perception is governed by a simplicity principle, we feel (as apparently Kanizsa does; 1979) that unpredicted exceptions make each of these rubrics inapplicable. Instead of consistent and physically-possible things which actually lie before us we may perceive physically inconsistent or impossible, nonrigidly-deforming objects (Hochberg, 1968; 1988; In press); only if they were given principled ways to predict such exceptions could these theories be taken as explanations for any given phenomenon. We do not, therefore, here offer perceptual couplings to support a specific theory of mental structure, but rather to serve as a possible methodological device to help identify the perceptual consequences of intentional construal.

The three experiments we report in this paper examined whether an effect of construal could be measured in amodal completion (although it is confounded with display differences in the first experiment). In all three experiments we use variations of the «opposed-set» procedure (Hochberg & Peterson, 1987; Peterson, 1986; Peterson and Hochberg, 1983) in which observers view potentially ambiguous displays under instructions to try to see a specified one of two alternative organizations on each trial. This helps to control the viewer’s intentions (which we know can exert an influence in any case) and allows us to measure their effects. To reduce the chances that viewers simply report whatever they have been requested to try to see (rather than providing an indication of what they really perceived), we try, when possible, to request reports about a variable that is perceptually coupled to the variable to which the intention instructions refer, rather than reports about the latter variable itself.

Two perceptual couplings are involved in Experiments 1 and 2. The first, is between two alternative responses and two threedimensional construals. The perceptual response alternatives are whether (a) a coherent shape – a larger occluded triangle – is revealed by successive disclosure (or presentations) of individual features at different real or indicated locations, on the one hand, or whether (b) disjoint localized motions of the pacman are perceived to occur instead. These should be coupled, respectively, to whether the setting in which each token appears is construed (and/or drawn) as a three-dimensional hole or as a solid tile. That is, the first two experiments presented the three tokens of Figure 1 sequentially, embedded in either the depiction of a hole (display b, as in Figures 2B, 3B) or the depiction of a tile (display t, as in Figures 2C, 2D, 3A): viewers were instructed to construe the tokens as viewed through either a hole (H condition) or as a tile (T condition). In Experiment 1, we demonstrate that these two variables are indeed coupled when observers’ intentions coincide with the threedimensional structure (hole or tile) that was actually represented by the drawings. (This was a necessary first step; if no coupling had then been found, we would have tried more realistic displays.) In Experiment 2, we examined how reports of the coherent shape-in-motion (the occluded triangle) varied when viewers’ instructed intention coincided with and when it was opposed to, the stimulus information (the represented 3D structure); in addition, the token itself was stationary while the background was indicated as moving. The results argue that the perception of the occluded triangle is coupled to the perceived organization (hole vs tile), rather than being an obligatory response to the stimulus information.

In Experiment 3, we used different displays and eliminated all stimulus information about whether the inducing elements were holes.
or tiles. Instead, we used sequences of three tokens; the tokens were each divided by a contour into a black and a white region and, if all were viewed simultaneously, would depict a familiar shape if the region on one side of the contours was seen as figure, and an unfamiliar shape if the region on the other side was figure. We used instructed intentions, as well as shape-familiarity, to attempt to manipulate which side of the contour was seen as figure and whether a coherent object should appear to be successively disclosed by each sequence.

**General procedure:** For each stimulus sequence, three monochromes 640 × 350 images were viewed from 36 cm on a 29 cm dia. monitor subtending a visual angle of 1.9 deg for the diameter of the pacman; the heavier lines were .15 deg and the shading lines were .07 deg. Each image was displayed for ca. 800 msec, presented in double-buffered animation and frame-line changes. Each sequence of three views was repeated 5 times in succession, followed by a pause of at least 8 sec, and then by another sequence. Key-presses in response to the task-instructions (to press when a single coherent object was perceived as sampled by the sequential views) were collected and analyzed by the same software. Eight observers, uninstructed as to the purpose of the research, served in all three experiments.

In all three experiments, the viewer's main task was to try to maintain the instructed construal (hole or tile in Experiments 1 & 2, white or black figure in Experiment 3); the sole response task, however, was to press a key whenever it appeared that a coherent shape was being presented by successive partial views, and to abstain from responding whenever it seemed that incoherent irregular changes occurred from view to view.

**EXPERIMENT 1**

Each sequence in the first experiment consisted of either the three views of the $h$ figures or of the $t$ figures, repeated 5 times; each sequence was preceded by a 2000 msec preparatory view of the first frame of that sequence and by a 200msec dark frame, to help the subject to establish the construal that had been requested. Sequences were viewed under opposed-set instructions (Hochberg & Peterson, 1987; Peterson, 1986; Peterson & Gibson, 1991; Peterson & Hochberg, 1983) to attempt to see and maintain the token as a hole through which a surface was being viewed (the $H$ set) or as a tile with an image on its surface (the $T$ set). In this experiment, instructed set always coincided with what the drawings represented: i.e., the $H$ and $T$ sets were requested for the $h$ and $t$ displays, respectively. The order of presentation was $Hh$, $Tt$, $Th$, $Ht$, $Hh$, $Ht$.

**Results and discussion**

The summary statistics on mean proportions of keypress durations for each condition are given in Table 1. The effects of conditions is significant across viewers ($t = 6.84, p < .001$) and significant for all but one viewer (that viewer misunderstood the instructions, and specifically imposed a constraint — a reflecting surface on the tile — that would permit the larger object to be perceived in the $t$ condition).

<table>
<thead>
<tr>
<th>Display</th>
<th>Hole</th>
<th>Tile</th>
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<tr>
<td></td>
<td>601</td>
<td>600</td>
</tr>
<tr>
<td>(sd: .18)</td>
<td></td>
<td>(sd: .11)</td>
</tr>
<tr>
<td>Mn diff: .544, se: .079, $t = 6.84, p &lt; .001$</td>
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In Experiment 1, intention instructions always coincided with the drawn 3D layout. To separate these two variables, observers in Experiment 2 viewed each display under two different instructed intentions (hold hole, and hold tile). In addition, the tokens were all presented at the same location, rather than at loci corresponding to the corners of the occluded triangle as they were in Experiment 1. (This change was made to avoid the argument that the three loci in Experiment 1 specified the occluded triangle sufficiently that discussion of any mental structure was gratuitously). In Experiment 2, therefore, since the tokens' loci remained fixed, what changed were the positions of a rectangle (see Figures 3A, 3B) that was partially occluded by the surface on which the tokens appeared in either the $t$ or the $h$ display (Figures 3A and 3B, respectively). The rectangle could readily be construed as the moving image-bearing surface visible through the hole, when the viewer attempted that construal. In addition, in this experiment, the match between token and position was scrambled (semirandomly) in two of the eight sequences (these were 80% longer to allow more response opportunity), providing catch trials. If key-

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1 The animating software was DPLCS, provided by Jonathan Hochberg.
presses were made during this sequence, they would tell us that the viewers were pressing the key with no attention to the relationship between the token and its construed position; if such responses had occurred to any extent, we could not be sure what it would mean to report an impression of the occluded triangle under such conditions; such keypresses were virtually absent.

Sequences were presented in four runs of eight trials as follows: the small letter is the display (h or t for hole and tile, respectively); an (s) in parenthesis means that the token motion was scrambled; and the large letter indicates the 3D structure, hole or tile (H, T) which the viewer is to construe:

Run 1. Hh, Th, H(s)h, Th, Hh, Th, T(s)t, Hh
Run 2. Hh, Th, H(s)h, Th, Hh, Th, H(s)t, Hh
Run 3. Th, Th, T(s)h, Th, Th, Th, T(s)t, Th
Run 4. Hh, Th, H(s)h, Th, Hh, Th, T(s)t, Hh

Results and discussion

Summary data for the different conditions are shown in Table 2. Even though the token was stationary throughout these trials, subjects predominantly reported the occluded triangle, during the H conditions, except when the token orientation was scrambled. The effect when instructed set was tied to corresponding display (Hh vs. Th) was again significant, as in Experiment 1. In addition, the effect of construal was also significant between runs 2 and 3, in which the same stimuli were subjected to opposing instructions. We cannot therefore dismiss these findings as the effects of the b & t displays, as stimuli. Moreover, the results here strongly argue for a role of mental structure in that viewers’ intentions to fit one or another 3D structure to the display clearly influenced perceived organization, despite

<table>
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<tr>
<td>Mean Proportion of Times During Which Key is Pressed</td>
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<tr>
<td>Condition 1: (Display and set correlated, i.e., Hh &amp; Th)</td>
</tr>
<tr>
<td>Display and set:</td>
</tr>
<tr>
<td>Hole (Hh)</td>
</tr>
<tr>
<td>.656 (sd: .16)</td>
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<tr>
<td>Condition 2: Set «See Hole», for all displays (Hh &amp; Th)</td>
</tr>
<tr>
<td>Hole (Hh)</td>
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<tr>
<td>.71 (sd: .06)</td>
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<tr>
<td>Condition 3: Set «See tile», for all displays (Th &amp; Ti)</td>
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<tr>
<td>Hole (Th)</td>
</tr>
<tr>
<td>.148 (sd: .10)</td>
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<tr>
<td>Difference:</td>
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<td>Hole conditions 2:3</td>
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<tr>
<td>(Hh-Th) = .56, se. .04, t = 14, p &lt; .001</td>
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<tr>
<td>Tile, conditions 2:3</td>
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<tr>
<td>(Th-Ti) = .58, se. .04, t = 14, p &lt; .001</td>
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<th>Table 2b. Experiment 2</th>
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<tr>
<td>Mean Proportion of Times During Which Key is Pressed</td>
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<tr>
<td>Display:</td>
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<td>H</td>
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<td>Cond. 1 &amp; 4</td>
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<td>Cond. 2</td>
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<td>Cond. 3</td>
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Gibson, 1991; Peterson & Gibson, 1993). They used figure-ground patterns to which those sampled in Figure 5B and 5D are roughly similar. For such stimuli, there was high inter-observer agreement that what are shown as the black regions in Figures 5A and 5C depicted a face and a standing woman, respectively, whereas there was little agreement about the white regions. The high denotive regions became low denotive regions when the stimuli were inverted (Peterson et al., 1991). With such stimuli and the opposed-set procedure, instructed intention was found to influence both the initial figure-ground organization and the mean duration with which each region is figure, and high denotive regions were figure earlier and longer when upright than when inverted (Peterson & Gibson, 1991; Peterson & Gibson, 1993). We should remember that denotivity is a fact about responses, not about physical stimuli, nor about any mental representations isomorphic to physical stimuli. Experiment 3 drew on these facts, as well as on the fact that for such reversible figure-ground stimuli the same physical pattern may access two mental representations so different that one cannot be recognized as related to the other (Davis, 1985; Rubin, 1915).

EXPERIMENT 3

Experiment 3 asked the viewer to construe the token always as viewed through a hole, but to perceive either the black area (b) or the white area (w) as the figure throughout the view sequence. As in Experiment 2, the circular token was stationary and a partially-occluded rectangle moved; here the movement was cyclically up and down (Figure 4 shows half a cycle). The two basic figures were a face (Figure 5A) and the half-figure of a woman (Figure 5C). In Figure 5B and 5D, the three views are shown, connected, for each integrated figure. (We must stress that viewers did not see these, and never saw more than one token at any time. The views were presented in the sequences shown (from bottom to top and back again: i, ii, iii.

![Fig. 4. Piecemeal disclosures of occluded figure-ground patterns: Similar to the display procedure in 2, a white rectangle moves up and down behind a light-gray strip, which partially occludes it, and a darker background. A circular aperture in the light-gray occluder reveals a part of a larger pattern.](image)

A B C

![Fig. 5. The two basic patterns used, in full outline (B, D) and as segmented for successive presentation (A, C).](image)

![Fig. 6. The sequences from which the trials were drawn.](image)

In runs (1) and (4), the viewer was to attempt to "hold" (perceive and maintain) the black fields as figures in each view and over the sequence as a whole, whereas in runs (2) and (3) the white fields were to be held as figure. In order to improve the odds (successfully, it turns out) that on the first run we would have at least the first two sequences perceived as unrecognizable and incoherent shape sequences, the high-denotive shapes in those patterns were both inverted and white, whereas the viewers were instructed to hold black as figure on runs (1) and (4).
Results and discussion

As is shown in Table 3, significantly more coherent motion was seen for trials 3-6 (the black, upright high-denotative figures) under the b (black) than the w (white) instructions (p < .001). If we consider only runs 1 and 2 (to minimize the effects of increasing familiarity with the low-denotative regions), not one of the eight viewers reported as early or as much coherent motion under the w (run 2) as under the b (run 1) instructions. Significantly earlier and longer responses of coherent motion were made, in runs 1 & 4 (and even more so within run 1 itself) to the upright black high-denotative figures in trials 5+6 than in their inverted versions in trials 7+8. (Considered separately, 6Biv provided coherent motion more frequently than we expected from its denotivity, although less than 6Bii, whether due to the specifics of the task or to the fact that an effort had been made to provide more good continuation between the tokens Bi-iv than between Ai-w.) Trials 1 and 2, in which inversion and black-white reversal, as well as lack of familiarity with the figures, combined to keep the occluded figure from being recognized, showed no coherent motion at all, for any viewer.

We hope that this technique will help us to move beyond the usually-undefined perceptual moment in the visual cognition of objects. It may be that the parts of the high-denotative figures, when those are in the polarity (black vs. white) that the subject is striving to maintain, are themselves more memorable from one view to the next, and can therefore be more convincingly integrated into a single moving shape; in that case, the visual memory of the segment, and the overall sequence, require some form of storage – some mental representation. Or (what is not quite the same thing), it may be that the effort to maintain a coherent shape across the multiple independent views is easier when the parts extracted (e.g., black) fit a high-denotative figure. In either case, we see that the figure-ground polarity that the viewer has been asked to hold provides the same stimuli with different consequences, with differences in mental representation.

Our data are therefore consistent with assigning causal efficacy to the structure of mental representations: That is, of the construal of a surface behind a hole rather than a surface on a tile, in Experiments 1 and 2; and of the consistency with which the assumption of a mental representation of the successively presented figures fit the Experiment 3.

If some determinants like those we have here termed mental representations participate causally between measurable stimulus and perceptual consequence, they should, it seems to us, not be dismissed in any of the several ways in which they usually are set aside: as complicating factors which appear only when other more «valido» factors are absent (a supposition for which there is no evidence whatsoever); as expressions of unconscious reasoning, when the premises and the rules have never been defined; as reflections of the physical world, which at least the orientation-specific denotivity factors are not; or as minor deviations on some simplicity principle to which both the facts of denotivity and the effects of intended construal raise principled exceptions. They should instead be one of the central systematic concerns, and explicitly addressed by any attempt at a general theory of visual cognition.

Finally, we might note that the procedure we have introduced here is not in any case only a laboratory game: it underlies a great deal of the technique by which motion pictures and television communicate much of our visual world (Hochberg, 1986).

REFERENCES


4 One reason to use the word construal, rather than problem-solution, is that algorithms much smaller than the whole packet of an object’s physical interdependencies work better, as in the case of the impossible figures, or as with the Ames window which is difficult to explain if we seek a complete solution, but which seems to follow quite directly from what Gogol calls the phenomenal geometry (Gogol, 1990; Hochberg & Beer, 1991).


CANDILEC SEHE BE PRIMED?
THE AUTONOMY OF ORGANIZATION

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Abstract. The role of figural context in the primary access of the perceptual organization of a visual pattern was examined using a tachistoscopic part-probe task. Sequences of a simple meaningless line figure «F» and a test pattern «T» were shown, each during 10 msec with an onset asynchrony of only 40 msec. Three T's were derived from an F pattern by deleting some lines. Each T was part of a different organization of F. Subjects had to indicate which T was presented by choosing among three alternatives shown after each trial. The percent correct was used to 'probe' whether the organization of F depended upon the context of a priming stimulus P shown a few seconds before the sequence. P was a variation of F and was designed to impose one of the three organizations on F that were probed by the T patterns. T patterns were correctly recognized more often if the prime imposed an organization on F that T was a part of. However, by a response-bias correction, the 'true' effect of P was discriminated from the bias (due to P and F). P patterns had a strong effect on the bias component, but not on the true score. In a control experiment without an F pattern, primes did increase the true recognition of the test patterns. This lack of a context effect on the organization of F suggests that primary stages of shape organization are very much stimulus oriented and resistant to earlier acquired knowledge. It is argued that context effects on shape perception are either due to a so-called 'evaluative' evaluation of stimuli or to a task simplification leading to selective attention to a local feature.

Many laymen, but also students in perception (Uhlrik et al., 1977; Peterson, 1986) do not make a clear-cut distinction between perception and cognition. In the past as well as nowadays there are proponents of the assumption that logical inference processes are involved in perception (Helmholtz, 1867; Rock, 1983). One of the great scientific contributions of Kanizsa (1969, 1975, 1976, 1979, 1982, 1985) is that he shows this assumption to be wrong.

In practice, logical inferences make use of knowledge. The pre-

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