Memory and Learning in Figure-Ground Perception

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Table of Contents
I. Introduction
II. Phenomena taken as evidence for the assumption that figure and ground assignment precedes access to shape and object memories
III. Review of research revealing object memory effects on figure assignment
IV. Questions raised by evidence challenging the figure-ground first assumption
V. Tests of the Parallel Interactive Model of Configural Analysis
VI. Learning: How much past experience is necessary before memory for the structure of an object can affect figure assignment?

I. Introduction

It has long been debated whether or not it is a clear dividing line can be drawn between perception and memory; the debate continues to this day. Nevertheless, since the turn of the 20th century, it has been assumed that certain visual processes occur sufficiently “early” so as to be impenetrable by memory and other higher level processes. An example of one such early visual process is figure and ground assignment. Figure-ground assignment occurs when two regions share a common border (as the black and white regions do in Figures 1A – 1C). One region -- the figure -- is typically seen as shaped by the border. The other region -- the ground -- is seen as shapeless near the border it shares with the figure; it typically appears to continue behind the figure as its background.1 The Gestalt psychologists held that figure assignment imposes shape onto unorganized visual input; shaped entities simply do not exist prior to figure-ground assignment. On the Gestalt view, the shaped entities in the visual field (the figures) provided the substrate for matches to shape or object memories. Thus, it was impossible to access shape or object memories until after shape had been assigned. Following figure-ground assignment memories were accessed only by the shaped entities (the figures), and not by the shapeless entities (the grounds). Throughout this chapter, the assumption that figure-ground assignment precedes access to object memories will be called the “figure-ground first assumption.”

The Gestalt figure-ground-first assumption arose as a counter-argument to the Structuralist view of visual perception. The Structuralists held that past experience (memory) imposed shape onto unorganized, pointillistic, visual input. For instance, in the Structuralist framework, one perceives a tree in Figure 1A because one has seen trees before. This past experience with trees both groups the features and parts of the tree together and specifies that the black region is the shaped entity at its border with the white region. The Gestalt psychologists questioned how the proper memory could be chosen to organize a particular array if no organization had yet been imposed on the visual input. They reasoned that some prior organization of the visual input was necessary to constrain the memory matching process. This prior organization had to be based on cues that were innate. Excluding memory from the process of organizing the visual input into shaped and shapeless entities also allowed the Gestalt psychologists to

Figure 1. Displays illustrating figure-ground segregation. The black regions of A and B are enclosed, symmetric, and smaller in area than their surrounds. A. A deciduous tree. B. A novel object. C. Rubin’s vase/face display.
account for the perception of novel shapes, shapes for which memory matches were destined to fail.

How then, does figure assignment occur? According to the Gestalt psychologists, figure assignment is determined by any of a number of “configural” cues that can operate without accessing memory. Examples of the configural cues are closure, symmetry, convexity, and area. Regions that possess these attributes are more likely to be seen as figures than regions that are open, asymmetric, concave, and larger in area, respectively. The black regions of both Figures 1A and 1B possess all of the configural cues. The Gestalt psychologists would argue that in both cases, the black regions are seen as shaped entities — figures — because they possess these attributes. In the Gestalt framework, the fact that Figure 1A also portrays a well known object — a tree — is irrelevant for figure assignment.

The Gestalt school had a revolutionary impact on the field of visual perception in the early 1900’s. As a consequence, it has long been thought that access to shape/object memories can occur only after the visual field has been organized into figures and grounds. That is, it has been assumed that figure-ground assignment is immune to influences from memory, even from memories that are intrinsically visual (e.g., memory for shape or object structure). Of course, the figure-ground-first assumption entails the belief that a line separating perception and memory can be drawn somewhere between figure assignment and memories of shape or object structure. Research in Peterson’s laboratory has shown that the Gestalt-based figure-ground-first assumption is incorrect, however. Some form of shape/object memory is accessed before, and contributes to, figure assignment.

In this chapter, we begin by showing that the evidence that long served to support the figure-ground-first assumption is really quite weak (Section II). Next, we review some of Peterson and colleague’s early work revealing shape and object memory effects on figure assignment (Section III). In this early work, observers reported their subjective impression of where the figure lay with respect to the border of interest; in other words, figure-ground perception was assessed via direct report. In Section IV, we address a number of questions that are re-opened by the findings of Peterson and her colleagues, questions for which answers generated within the figure-ground-first assumption are no longer valid. We review some research conducted to answer these questions and we introduce a new model of figure assignment (Peterson, 2000; Peterson, de Gelder, Rapcsak, Gerhardtstein, and Bachoud-Lévi, 2000). In this model, memory of shape/object structure serves as one of an ensemble of figure cues, along with the Gestalt configural cues. Hence, this model does not represent a return to the Structuralist tradition where past experience was the only organizing factor, or even the dominant organizing factor. In Section V, the heart of this paper, we describe some recent experiments testing the competitive model. In these experiments processes involved in figure assignment are assessed indirectly via a priming paradigm. In Section VI, we review an experiment showing that a single past experience with a novel border exerts a measurable influence on figure assignment the next time the border is encountered. We close the chapter in Section VII with some remarks concerning learning, memory, and perception.

II. Phenomena taken as evidence for the Figure-Ground-First Assumption

Three lines of argument and evidence have long been taken to support the figure-ground-first assumption, but we will show that the support they provide is weak at best. The first line of evidence is based on demonstrations that the perception of novel shapes can be accounted for by the operation of the Gestalt configural cues. For instance, from demonstrations showing that shape could be imposed on the visual input using only configural cues (e.g., Figure 1B), the Gestalt psychologists concluded that shape was always imposed on the visual input using only configural cues (i.e., the figure-ground first assumption).

The figure-ground first assumption does not follow as a logical conclusion from demonstrating that configural cues can account for shape perception when past experience cannot (because the displays are novel). Such demonstrations do not support the conclusion that past experience cannot affect figure assignment when familiar shapes and objects are present (Peterson, 1999). To reach this latter conclusion, one must conduct investigations involving familiar shapes and show that large variations in familiarity do not affect figure assignment when the configural cues are held constant. Neither the Gestalt psychologists nor their descendents conducted stringent tests using this strategy.

A second line of support for the figure-ground first assumption arose from a neuropsychological investigation conducted by Warrington and Taylor (1973). They presented a visual agnostic patient who, although quite poor at object and shape identification (as visual agnosics are), nevertheless performed figure-ground assignment correctly. Marr (1982) interpreted the patient’s pattern of impaired and spared performance within a serial hierarchical model.
of vision, and took it as evidence that object memories are accessed only after figure assignment has been determined. Marr argued that the patient’s lesion must be located higher than the brain region responsible for figure assignment, but lower than the brain region where memories of objects are stored.

However, naming responses, such as those recorded by Warrington and Taylor (1973) can only index whether or not conscious recognition and identification has occurred. They do not necessarily reveal whether or not some form of object memory was accessed in the course of figure assignment (Peterson, et al., 2000). To address this latter issue, it is necessary to compare figure assignment for regions that are matched for Gestalt configural cues but mismatched in the degree to which they fit the shapes of known objects. Such tests might reveal that, for visual agnosics as well as for normal perceivers, borders may be more likely to be seen as boundaries of regions (or portions of regions) portraying known objects rather than novel objects. (For further discussion and a relevant experiment, see Section IV.)

A third phenomenon that has been taken as evidence for the figure-ground-first assumption is the well-known coupling between figural status and conscious recognition, illustrated by the Rubin vase-faces display in Figure 1C. The vase can be recognized when the central black region appears to be the figure at the border it shares with the adjacent white region, but not when it appears to be ground to the surrounding white region. Likewise, the faces can be recognized when the surrounding white region appears to be the figure at the vertical borders it shares with the black region, but not when the white region appears to be ground at those borders. This coupling between figural status and recognition led many vision scientists to accept the figure-ground-first assumption. A coupling cannot provide unequivocal evidence for a serial sequence, however.

Surprisingly, until the initial tests conducted in our laboratory were published in 1991 (Peterson & Gibson, 1991; Peterson, Harvey, & Weidenbacher, 1991), there were very few direct tests of whether or not past experience contributed to figure assignment. A few experiments had suggested that aspects of past experience might affect figure assignment (Schaffer & Murphy, 1943; Rubin, 1915/1958). These results were dismissed based on procedural criticisms, desultory attempts (and failures) to replicate, and alternative interpretations that did not fit the data any better than the original interpretation did (for review, see Peterson, 1995, 1999). The Gestalt arguments against the Structuralist tradition continued to exert a strong hold on perception psychologists who, despite evidence that memory and past experience affected many other visual processes, continued to believe that figure-ground assignment lay far enough below an implicit line dividing perception from memory to be immune to influences from memory.

III. Review of Peterson’s research revealing object memory effects on figure assignment

Peterson and her colleagues directly tested whether or not memories of well-known shapes were accessed in the course of figure assignment. They began using the displays shown in Figure 2A and 2B, originally drawn by Julian Hochberg. The displays were biased toward a center-as-figure interpretation by the Gestalt configural cues of smallness of relative area, enclosure, and symmetry (or partial symmetry). The monocular depth cue of interposition also favored the interpretation that the black region lay in front of the white region in Figure 2B. In addition, the observers fixated the center region, which increases the likelihood that a region will be seen as figure (Hochberg, 1971; Peterson & Gibson, 1994a). The vertical borders between the black and white regions sketched portions of known objects on the white side (standing women in Figure 2A, and face profiles in Figure 2B). Peterson, et al. (1991) showed these displays to observers who viewed them for long durations (30-40 seconds) and reported continuously whether the black or the white region appeared to be figure by pressing one of two keys.

![Figure 2](image)

Figure 2: The displays used by Peterson, Harvey, and Weidenbacher (1991). The displays are biased toward the interpretation that the black center region is the figure. Portions of known objects are sketched along the white side of the vertical black/white borders in both stimuli, portions of standing women in (A) and face profiles in (B).

Observers viewed all displays in both an upright orientation, as shown in Figure 2, and in an inverted orientation (which can be seen by turning the book upside down). Changing the orientation from upright to inverted did not change the Gestalt configural cues: the center black region is enclosed, symmetric, and smaller in area than the surrounding white region both when the display is upright and when it is inverted. Nor did it change the monocular depth cue of interposition in Figure 2B, or the fact that
observers fixated the black region on all trials. However, when the display is upright, the known object sketched on the white side of the black-white border is portrayed in its typical orientation, whereas when the display is inverted, the known object is disoriented from its typical upright.

![Figure 3](image-url)

Figure 3. Mean durations that the two regions of the displays in Figure 2 were maintained as figures in upright versus inverted displays. The black bars denote the center black regions; the striped bars denote the surrounding white regions.

Access to shape and object memories is orientation-specific. For instance, it takes longer for observers to identify objects and pictures of objects that are disoriented from their typical upright orientation (Jolicoeur, 1988; Tarr & Pinker, 1989). Perrett, Oram and Ashbridge (1998) have shown that it takes longer for a population of cells coding an object to reach some threshold if the object is shown in an atypical orientation. The orientation-specificity of object recognition led Peterson and her colleagues to hypothesize that changing the orientation of the displays might reveal object memory effects on figure assignment by modulating them. Specifically, if object memories affect figure assignment, their influence should be larger for upright displays than for inverted displays. Therefore, Peterson et al. (1991) reasoned that object memory effects on figure assignment would be implicated if the figures appeared to lie on the white side of the vertical black-white borders in Figures 2A and 2B more often when the displays were upright than when they were inverted.

Their results, shown in Figure 3, supported this prediction. Observers saw the white surrounds as figures for longer durations in the upright orientation than in the inverted orientation. Taken alone, this finding could simply indicate that regions portraying familiar objects could be maintained as figures longer once they had obtained figural status. Importantly, observers saw the black centers as figures for shorter durations in the upright orientation than in the inverted orientation. In other words, reversals out of the black center as figure interpretation and into the white surround as figure interpretation were more likely when the displays were upright than when they were inverted. This finding suggested that object memories affected the likelihood that the organization would reverse into the surround as figure interpretation, as well as the likelihood that the surround would be maintained as figure once it was perceived as such.

Peterson et al. (1991) found that the order in which upright and inverted displays were presented did not matter. What mattered was that the parts of the well-known object were presented in their proper spatial relationships, both with respect to the upright and also with respect to each other. Peterson et al also tested conditions in which the parts were re-arranged (scrambled) so that the object was no longer recognizable. The effects of object memories on figure assignment were diminished, as they were for inverted stimuli.

Importantly, Peterson et al. (1991) found that knowledge could not overcome the effects of changing the orientation or rearranging the parts. The orientation effects were obtained even if observers knew that the displays portrayed inverted women or inverted face profiles; the same was true for the effects of scrambling the parts. This finding indicated that knowledge of any type could not produce these effects; access to memories of object structure via the visual input was necessary (see also Gibson & Peterson, 1994).

The results obtained by Peterson et al. (1991) indicated that memories of object structure (at least) are accessed in the course of figure assignment and affect its outcome. It was clear in the original experiments that semantic knowledge alone was insufficient for these effects, the proper structure of the object was necessary. Peterson and Gibson (1991, 1994b; Gibson & Peterson, 1994) showed that the Peterson et al. (1991) results extended to masked displays exposed for brief durations (as short as 28 ms).

The initial results showing that object memories affected figure assignment were obtained using displays that were biased against seeing the figure lying on the side of the border where a well-known object was sketched. Later, Peterson and Gibson (1994a; Gibson & Peterson, 1994) tested whether object memories affected figure assignment using displays, such as those in Figure 4A, in which object structure was the only cue that reliably distinguished between the regions on either side of a central border. They found orientation effects for these displays as well: Observers were more likely to report seeing the figure on the side of the border where the well-known object was sketched when the displays were upright rather than inverted. Thus, object memory effects on figure assignment were evident both with displays.
that should have been unambiguous if only the traditional Gestalt cues were taken to be relevant to figure assignment (e.g., the displays in Figure 2) and with displays that were ambiguous in that configural cues were equated for the two adjacent regions (e.g., displays like those in Figure 4A).

Figure 4. A. Sample figure-ground stimuli in which two equal-area regions share a border; a known object was sketched on one side of the central border. These stimuli portray a guitar, a lamp, and a standing woman, respectively. Although the known objects are always shown in black on the left side of the border in this figure, in the displays used in the experiments, they were shown equally often in white and in black and on the left versus the right of the border. B. "Scrambled" versions of the stimuli in A. To create the scrambled versions, the objects in A. were separated into parts at the concave cusps, and those parts were reassembled so that the new arrangement did not portray a known object.

The next question addressed by Peterson and Gibson (1994b) was how the memory of object structure cue fared when it was placed in competition with a single other cue, such as the Gestalt configural cue of symmetry. Consider displays in which a symmetric region shares a vertical border with an asymmetric region. The asymmetric region portrays a known object, whereas the symmetric region does not. When viewing inverted versions of such stimuli, where the object memory cue was absent or diminished, observers were significantly more likely to report seeing the symmetric region as figure. When viewing upright stimuli, there was a substantial and significant increase in reports that the figure appeared to lie on the side of the border where a well-known object was sketched compared to inverted stimuli. Importantly, the object memory cue did not dominate the symmetry cue in the upright orientation; instead, the two cues seemed to compete with each other on a roughly equal footing. This finding led Peterson and Gibson (1994b) to suggest that the object memory cue is one of many cues that determines figure assignment; it neither dominates the other relevant cues, nor is dominated by them.

In a different series of experiments, Peterson and Gibson (1993) added binocular disparity to displays like those in Figure 4A in which object memory favored seeing the figure on one side of a border, but Gestalt configural cues did not reliably distinguish between the two sides. Binocular disparity indicated that the figure lay either on the same side or on the opposite side of the border as the known object. Peterson and Gibson expected that when both object memory and binocular disparity specified that the figure lay on the same side of the border, the displays would be unambiguous. The stimuli in which object memory and binocular disparity specified that the figure lay on opposite sides of the border were the interesting case. If the addition of binocular disparity rendered the displays unambiguous, then the figure should always appear to lie on the side across the border from the known object. Alternatively, if object memories always overpower binocular disparity, the figure should always appear to lie on the known object side of the border.

Peterson and Gibson (1993) found that object memories did affect figure assignment in these critical displays, but they did not dominate the binocular disparity cue. Instead, for the range of disparities Peterson and Gibson tested, the object memory cue appeared to compete with binocular disparity on a roughly equal footing, as it had with symmetry (see also Peterson, 2002). The figure was seen to lie on the side of the border where the well-known object was sketched approximately half the time, and on the opposite side, favored as figure by binocular disparity, the rest of the time.

The results of these experiments, showing that object memories affect figure assignment in both two-dimensional and three-dimensional displays, challenged the figure-ground first assumption. They also raised anew number of questions, for which answers based on the figure-ground-first assumption were now inadequate. We address those questions in the next section.

IV. Questions raised by evidence challenging the figure-ground first assumption.

A first set of questions is the following. How can object memories be accessed before figure-ground organization has been imposed on the visual field; that is, before shaped figures have been separated from shapeless grounds? What serves as the substrate for access to object memories? Must we return to the Structuralist claim that past experience can be
accessed by completely unorganized pointillistic input?

In response to these questions, Peterson and Gibson (1993, 1994b) proposed that at least the initial stages of edge extraction precede access to object memories and that edges, rather than shaped entities or even whole regions, were the substrate for matches to shape and object memories. They argued that edge-based access to memories of object structure could occur at the same time that the Gestalt configural cues are being assessed. This would allow memories of object structure to serve as one more figural cue (i.e., to add to the traditional ensemble of Gestalt configural cues).

Further, Peterson and Gibson (1993) argued that not all edges could support object memory effects on figure assignment. One critical requirement is that edges must be extracted early in processing; only such edges can support quick access to object memories. Evidence that object memories must be accessed quickly if they are to affect figure assignment comes from the orientation effects. Inverted stimuli do access memories of familiar objects; they just take longer than upright stimuli to do so. The additional time required is sufficient to render object memory effects on figure assignment less likely for inverted displays than for upright displays. This is because figure assignment occurs early in the course of visual processing. Therefore, any factor that delays access to object memories can remove or diminish their effects on figure assignment. If edge extraction takes too long, edge-based access to object memories will not occur quickly enough to affect figure assignment. Consistent with this argument, Peterson and Gibson (1993) failed to observe effects of object memories on figure assignment using random-dot stereograms, where edge extraction takes some time.

Peterson (1995, 2003; Peterson & Hector, 1996) proposed further that object memories could be accessed by portions of edges, rather than by whole continuous edges or borders. Thus, like the Gestalt psychologists, Peterson and her colleagues assume that some organization is imposed on the visual input before object memories are accessed; thus, they do not support a return to Structuralism. However, Peterson and her colleagues clearly assume that a lot less organization has been imposed before object memories are accessed than did the Gestalt psychologists and their followers.

A second set of questions that was raised by Peterson and colleague’s challenge to the figure-ground-first assumption concerns the behavior of visual agnostic patients, such as the one tested by Warrington and Taylor (1973). If tested with displays designed to reveal object memory effects on figure assignment, will visual agnoses behave like normal observers or will they fail to show effects of object memories on figure assignment? If a visual agnostic cannot identify the objects portrayed in figure-ground displays, yet shows spared object memory effects on figure assignment, that would suggest that impaired identification responses cannot be taken to support a serial view of the relationship between figure-ground assignment and access to memories of object structure.

To address these questions, Peterson et al. (2000) tested a visual agnostic patient, A.D. They assessed A.D.’s object recognition/identification abilities via a battery of standard tests, including the Boston Naming Test, the impossible objects subtest of the Birmingham Object Recognition Battery (the BORB, Riddoch & Humphreys, 1993), and the Visual Object and Spatial Perception Battery (VOSP, Warrington & James, 1991). These tests require either a naming response or a decision regarding whether a depicted object is a familiar object or a novel (or impossible) object. The VOSP sub-test uses silhouettes of objects, which were particularly relevant to our displays. A.D. performed considerably below age-matched control observers on all of these tests. This type of performance is typical for visual agnoses, so performance on these tests partially confirmed that A.D. was a visual agnostic and did not simply have name-finding problems.

Other tests indicated that A.D.’s semantic knowledge regarding those objects she could not identify was intact. She could define objects and give a reasonable description of what they looked like. However, it seemed that this knowledge regarding objects could not be accessed by visual inputs, at least as indexed by naming responses or by overt judgments regarding the familiarity/possibility of objects. Again, this is a typical pattern of performance for visual agnoses.

Peterson et al. (2000) also assessed A.D.’s ability to use the Gestalt configural cues of convexity and symmetry to perceive figure-ground relationships in novel displays. A.D. performed well within normal limits on these tasks. Thus, A.D.’s performance on these initial identification tests and figure-ground tests was similar to that shown by the patient reported by Warrington and Taylor (1973).

Next, Peterson et al. (2000) performed the critical test of whether or not object memories could affect figure assignment even in a visual agnostic. They asked A.D. to report which region was the figure (i.e., which region appeared to stand out as having a definite shape at the central border) in 48 displays like those shown in Figure 4. These displays were constructed from two equal-area regions separated by a central articulated border. Half of these displays
were “experimental” displays in that a portion of a familiar object was sketched along one side of the central border separating black and white regions (the displays in Figure 4A). The critical side on which the familiar object was sketched was the left for half of the experimental displays and the right for the other half; the critical region was black in half the displays and white in the other half the displays. The rest of the displays were “control” displays in which the central border did not sketch a known object on either side. The control displays had critical regions that were formed by rearranging (scrambling) the parts of the familiar objects portrayed by the critical regions in the experimental displays such that they were no longer recognizable (the displays in Figure 4B). Thus, the critical sides of the control and experimental stimuli were matched in part structure, but not in spatial structure. Therefore, they were not matched in the degree to which they provided a good fit to memories of object structure. None of the Gestalt configural cues consistently favored seeing one of the two halves as figure in the experimental displays compared to the control displays.

Peterson et al. (2000) reasoned that if object memories affect figure assignment even in the absence of conscious recognition and identification then, like non-brain-damaged participants, A.D. should report seeing the figure lying on the critical side of the central border more often in experimental displays than in control displays. Their results supported this prediction: Like non-brain-damaged age-matched controls, A.D. reported seeing the figure lying on the critical side of the central border significantly more often in experimental stimuli (75%) than in control stimuli (46%). As expected of a visual agnostic, A.D. was not able to identify the objects portrayed by the critical regions of the experimental displays, even though she clearly saw them as figure. Her performance deviated from that of the age matched controls in this respect.

Thus, conscious identification is not necessary for object memories to affect figure assignment. The data obtained from A.D. show that it is erroneous to conclude that figure assignment precedes access to object memories based on a pattern of intact figure assignment and impaired identification. Instead, A.D.’s performance is consistent with the proposal that quick, unconscious access to memories of object structure can occur and can contribute to figure assignment even when conscious recognition and identification is impaired.

A third set of questions raised by the claim that object memories affect figure assignment is the following: If object memories are accessed in the course of figure assignment, how can one account for the fact that regions that would portray familiar objects were they to be seen as figures appear shapeless when they are perceived to be grounds? Recall that Peterson et al. (1991; Peterson & Gibson, 1993, 1994b) showed that, when other configural and depth cues compete with object memories, the figure does not always appear to lie on the side of the border where the known object is sketched. In such cases, if object memories matching the ground region were accessed in the course of figure assignment, why don’t we recognize the familiar object sketched on the ground side of the border? More specifically, why do we generally not perceive both the vase and the faces in the Rubin vase-faces display? Why do we typically perceive only one of these shaped entities at a time? On the traditional figure-ground-first view, grounds were shapeless because they were not matched to object memories. The Parallel Interactive Model of Configural Analysis, introduced by Peterson and her colleagues (Peterson, 2000; Peterson et al., 2000), provides an explanation for the perceived shapelessness of grounds while assuming that memories of object structure are accessed in the course of figure assignment.

The Parallel Interactive Model of Configural Analysis (PIMOCA) is illustrated in Figure 5. PIMOCA assumes that as soon as edges are detected in the visual field, portions of those edges are assessed for configural cues on both sides simultaneously. In PIMOCA, memories of object structure are considered to be a configural cues because previous experiments in our laboratory have shown that the parts of the familiar object must be correctly configured in order for the object memory cue to be effective (Gibson & Peterson, 1994; Peterson, 2003; Peterson, Gerhardstein, Mennemeier, & Rapcsak, 1998; Peterson et al., 1991, 2000). Given that configuration matters, it seems appropriate to include object memories amongst the configural cues.

Figure 5. The Parallel Interactive Model of Figure Assignment proposed by Peterson, et al. (2000). Shortly after edges are detected (e.g., the curvilinear edge in the center of the figure), figural features such as Symmetry (Symm), Convexity (Conv), Closure (Closure), and MOS (MOS) are accessed and interact with configural cues (Conv, Symm) to determine figure or ground.
Memory of Object Structure (MOS) and Closure are assessed for both sides. Features on the same side of the edge cooperate (as indicated by double-headed arrows). Features on opposite sides of the edge compete (as indicated by the horizontal end-stopped line crossing the edge).

According to PIMOCA, configural cues present on the same side of an edge cooperate with each other, whereas configural cues present on opposite sides of an edge compete with each other. When the cues are unbalanced, the cues on the more weakly cued side are inhibited by the cues on the more strongly cued side. The inhibition of configural cues on the more weakly cued side of a border accounts for the perceived local shapelessness of the region lying across the border from a more strongly cued side. Peterson (2002; Peterson et al., 2000) argued that in two-dimensional displays, such as those used in our experiments, one perceives shape by perceiving properties such as symmetry, convexity, area, enclosure, familiar object structure, etc. If those cues are inhibited on the relatively weakly cued side of an edge, shape simply cannot be seen in that local vicinity (provided that configural cues are the only cues present). The cross-border inhibition proposed in PIMOCA accounts for the fact that regions adjacent to strongly cued figures are perceived to be locally shapeless, both under conditions where a portion of a known object is sketched on the more weakly cued side of the border, and under conditions where the more weakly cued side is convex or symmetric.

On the more strongly cued side, continued cooperation among cues leads ultimately to the perception of shape, and interactions between the configural cues and semantic and functional knowledge lead ultimately to recognition, if the shape is familiar (barring brain damage).

In Figure 5 boxes of the same size portray all of the configural cues. By representing the cues in this fashion, we do not mean to imply that all of the configural cues are equally potent. We know that is not the case. Kanizsa and Gerbino (1975) showed that convexity is more potent than symmetry, for example. Likewise, the configural cues all appear to lie on one plane in Figure 5. By presenting all of the configural cues in this way, we do not mean to imply that they are all computed at the same level of processing. Indeed, there is some suggestion that these cues may be assessed at different levels. For instance, cells that respond differentially to convex and concave shapes have been found in V3 (Pasupathy and Connor, 1999). And, based on work by Tanaka (1996) Peterson (2003) has hypothesized that the relevant object memories may be found in the human analogue of V4. The figure is designed to imply that the configural cues (including the memory of object structure cue) are accessed in parallel, and that configural cues accessed on the same side of a border cooperate with each other, whereas those accessed on opposite sides compete with each other.

In PIMOCA, figure and ground assignment is a local outcome of a cross-border competition. It is not a stage of processing through which visual inputs must pass before object memories can be accessed (Peterson, 2002). Nor must figure and ground necessarily be assigned consistently to the same side across a continuous border; figures can be assigned to different sides across different extents of a continuous border (Hochberg, 1962; Peterson, 1995, 2003; Peterson & Hector, 1996). There is evidence that figure and ground assignment is affected by the global context in which a border is found (Kim & Peterson, 2001, 2002; Peterson & Kim, 2001b). We are currently working on integrating context effects into the model.

PIMOCA is one of a class of competitive models of figure assignment (see also Keinker, Sejnowski, Hinton, & Schumacher, 1986; Sejnowski & Hinton, 1987; Vecera & O’Reilly, 1998). PIMOCA is unique in

- Assuming that memories of partial object structure are accessed via edges rather than via regions or shapes. (Sejnowski and colleagues did not consider a role for object memories, and Vecera and O’Reilly proposed a holistic, region-wide match to object memories.)
- Assuming that memories of partial object structure are accessed in parallel with assessments of the Gestalt configural cues.
- Treating figure-ground segregation as simply an outcome of the cross-competitive process rather than as a stage of processing.
- Accounting for the perceived shapelessness of grounds via cross border competition.

V. Tests of The Parallel Interactive Model of Configural Analysis

Peterson and Kim (2001a) tested PIMOCA’s predictions regarding the inhibition of cues on the relatively weakly cued side of a border. To do so, they isolated the memory of object structure cue on the white side of a black/white border where the majority of cues favored assigning figural status to the opposite, black side. Those cues included the configural cues of symmetry, convexity, enclosure, and smallness of relative area, along with other cues such as fixation and expectation. Peterson and Kim’s (2001a) stimuli were black silhouettes like those shown in Figure 6. Because more configural cues favored assigning figural status to the black side of the border and because previous evidence indicated
that the memory of object structure cue did not dominate the other configural cues, Peterson and Kim (2001a) expected that the figure would appear to lie on the black side of the border. They predicted that the object structure memory accessed on the white side of the border would be inhibited.

All of the black silhouettes were novel shapes. Silhouettes like those in Figures 6A – 6C were shown on 75% of the trials; these were control silhouettes. Silhouettes like Figure 6D, where a portion of a familiar object was sketched on the white side of the border, were shown on 25% of the trials; these were experimental silhouettes (see below). The silhouettes were exposed briefly, for 50 msec.

Figure 6. Sample black silhouettes used as primes by Peterson and Kim (2001a). All silhouettes were novel. The figure was seen on the black side of the black/white border because a larger number of cues favored assigning the figure to that side than to the other side (e.g., symmetry, enclosure, smallness of area). A - C. Control primes; the borders of control primes did not sketch a known object on either the inside or the outside of the silhouette. D. Experimental prime. In all experimental primes, the vertical borders sketched a portion of a known object along the outside (the white, ground, side). A portion of an anchor is sketched on the white side of the black silhouette in (D). Hence, for experimental primes the memory of object structure cue is present on the white side of the black/white border.

Observers saw the bounded black regions as the shaped entities; they saw the white regions as shapeless grounds, even for the experimental silhouettes. The stimuli were designed to be seen this way, because (1) a larger number of configural cues favored seeing the figure on the black side of the border rather than on the white side, (2) the experimental stimuli were embedded amongst many control stimuli in which there was no familiar object sketched on either side of the black/white border, and (3) the silhouettes appeared on the point where the participants were fixating.

Observers made no response to the silhouettes; they were asked to simply look at them. Their task was to judge quickly whether a line drawing shown after each silhouette portrayed a familiar object or a novel object. The silhouettes served as primes before the line drawings. The critical trials were those involving familiar line drawings. As shown in Figure 7, half of the line drawings of familiar objects were preceded by experimental silhouette primes in which a portion of the same basic level object was sketched on the white (ground) side of the black silhouette. These were the experimental trials. The other half of the line drawings of familiar objects were preceded by control silhouette primes with no familiar object sketched on the ground side (control trials). Control silhouettes preceded all line drawings of novel objects. The experimental and control silhouettes were matched for size, area, convexity, and curvilinearity so that observers could not distinguish between them. A different unique silhouette was shown on each trial.

Figure 7. Examples of prime and line drawing matches for familiar line drawings. Line drawings shown on experimental trials were preceded by silhouette primes in which an object from the same basic level category was sketched on the ground side. A sample experimental trial is shown in the right panel. Line drawings shown on control trials were preceded by silhouette primes that sketched novel shapes on both sides of the black-white border. A sample control trial is shown in the left panel.

The dependent measure was participants’ latency to correctly categorize the line drawings as familiar or novel objects. We were primarily interested in participants’ responses to the familiar line drawings. If the inhibition proposed in PIMOCA occurs, then object memories accessed for the white side of the experimental silhouette primes should be inhibited. This is because, according to PIMOCA, when the cues for seeing the figure lying on one side of the border are stronger than the cues for seeing the figure lying on the other side (as they are in the silhouette primes), configural cues (including memories of object structure) accessed on the more weakly cued
side are inhibited. Peterson and Kim (2001a) hypothesized that evidence of this inhibition would be revealed if RTs to correctly categorize familiar line drawings were longer following experimental primes rather than control primes. This prediction supposes that the line drawing following the experimental prime must access some of the same memories of object structure as the object sketched on the more weakly cued side of the border of the prime because it is drawn from same basic-level category. If those memories are inhibited because of the cross-contour competition occurring during the perception of the prime, then responses to the line drawings shown on experimental trials should be slowed, provided that the inhibition lasts long enough to be probed by the line drawing. (No familiar object was sketched along any portion of the border of the control primes; hence, no inhibition of specific object memories was expected.)

It is important to point out that although the familiar line drawings shown on experimental trials portrayed an object from the same basic level category as the portion of a known object sketched on the ground side of the silhouette, the contours of the line drawing were not the same as the contours of the silhouette. We made the contours different because we wanted to be sure that any RT differences we observed reflected access to previously established memories of known objects in the course of figure assignment and not simply memory for the specific shape of the border of the silhouette. (See Section VI.) Indeed, it could be argued that the participants had not seen the particular borders of the silhouettes before, although they had certainly seen similar borders bounding objects from the same basic level category (or, at least portrayals of such objects). We designed these experiments to assess whether or not previously established memories of known objects were accessed in the course of figure assignment and were inhibited if they were accessed on the more weakly cued side of a border. 

The novel line drawings were included just so the participants had to categorize the line drawing targets. Although the borders of the control silhouettes shown before the novel line drawings sketched novel objects on both the figure side and the ground side, no attempt was made to match the shapes of the novel silhouettes to the shapes of the novel objects. Hence, responses to the novel line drawings will not be discussed further, except to say that observers took longer to correctly categorize the novel line drawings than the familiar line drawings. 

Peterson and Kim (2001a) reported two experiments. In Experiment 1, the silhouette primes were exposed for 50 ms and the line drawings were displayed following an inter-stimulus interval of 33 ms. In Experiment 2, the silhouette primes were exposed for 50 ms and the line drawings were shown immediately afterwards. In both experiments, the line drawings remained on until a response was made. As can be seen in Figure 8A, the results supported the predictions generated from PIMOCA. In both experiments, observers took significantly longer to correctly categorize the familiar line drawings on experimental trials than on control trials. 

Peterson and Kim’s (2001a) results provide indirect evidence that object memories are accessed in the course of figure assignment. Until these experiments were conducted, the evidence supporting the proposal that object memories were accessed in the course of figure assignment was based on participants’ direct reports regarding their phenomenal experience. Some investigators had wondered whether our observers were indeed reporting the first figure-ground organization they perceived, as we had assumed. Driver and Baylis (1995) suggested that our observers might have been responding to some implicit demand to try to find familiar objects in the figure-ground displays. If so, they might have reversed the first figure-ground organization of the displays in search of familiar objects, and may have reported them when they found them. In the latter case, our direct report evidence could not be taken as inconsistent with the figure-ground first assumption. That Peterson and Kim (2001a) obtained evidence for the inhibition of object memories matched by the more weakly cued side of a border even though the experimental task did not direct participants to make figure reports regarding the silhouettes provides converging evidence that, contrary to the figure-ground-first assumption, memories of object structure are accessed in the course of figure assignment.

Before the Peterson and Kim (2001a) results could be taken to reflect the cross-border inhibition as predicted by PIMOCA, a few questions remained to be addressed. One question stems from the fact that a known object was sketched on the white side of the silhouette primes shown on experimental trials, but not those shown on control trials. As a consequence, more cross-border competition occurred for experimental than control silhouettes. This increased competition may have led to longer resolution times for experimental silhouettes than for control silhouettes. The differences in RTs may reflect differences in the time required to resolve the figural status of the silhouette primes rather than differences in the state of the object memory matching the line drawing itself.

Peterson, Skow Grant, and Kim (submitted; Skow Grant, Peterson, & Kim, 2002) tested this alternative resolution time hypothesis against the inhibition
The hypothesis by altering Peterson and Kim’s (2001a) design such that known objects were sketched on the white sides of both experimental and control silhouettes shown before familiar line drawings. Whereas the known objects sketched on the white side of the silhouettes shown on experimental trials were from the same basic level category as their paired line drawings, the known objects sketched on the white side of the silhouettes shown on control trials were from a different category (e.g., living versus non-living) than their paired line drawings. Thus, in this experiment, the competition for figure assignment was equated for all silhouettes preceding line drawings of familiar objects. The time required to resolve the figure assignment in the silhouettes should be equated as well. (As in Peterson and Kim’s experiment, no familiar objects were sketched along the borders of the silhouettes shown before line drawings of novel objects.)

Peterson et al. (submitted) reasoned that if the slower responses to experimental line drawings than to control line drawings reported by Peterson and Kim (2001a) reflected longer resolution times for the silhouettes shown on experimental versus control trials, then that pattern of results should not be obtained in their experiment. Indeed, there should be no differences in the latencies to respond to familiar line drawings shown on experimental versus control trials. However, if the slowed responses to Peterson and Kim’s (2001a) experimental line drawings reflected the inhibitory component of PIMOMA (and if inhibition is specific to the category of the known object sketched in ground), then responses to line drawings shown on experimental trials should be slower than responses to line drawings shown on control trials.

In the experiment designed to examine the resolution time hypothesis, silhouettes were displayed for 35 ms and were followed by a 70 ms mask (to ensure that participants could not use the silhouette to predict the line drawing type). Because they added a mask to the sequence of stimuli preceding the line drawings, Peterson et al. (submitted) tested two groups of observers. One group was tested with a control condition like that used by Peterson and Kim (2001a) (i.e., for these participants the contours of the control silhouettes did not sketch a familiar object on the ground side). A second group was tested with the new control condition (in which the contours of the control primes sketched an object from a different category than the line drawing shown afterwards). Including both of these conditions allowed Peterson et al. to compare the magnitude of the difference scores obtained with the different types of control primes under similar presentation conditions.

The results were consistent with the inhibition hypothesis rather than with the resolution time hypothesis. As can be seen in Figure 8B, RTs on experimental trials were longer than RTs on control trials for both groups of observers, even though the competition for the borders of experimental and control silhouettes was equated for the observers in the new control condition, whereas it was not equated for observers in the Peterson and Kim (2001a) control condition. The differences between the results obtained using the two different control conditions were not statistically significant. It appears that any differences in the competition occurring for experimental versus control primes is not evident in responses to the line drawings used in these experiments.

An alternative interpretation arising from an attentional framework remained to be considered before these results could be taken as supporting the PIMOMA model, however. Suppose that the longer RTs obtained on experimental trials compared to control trials reflect the fact that participants ignored the silhouette primes. After all, the silhouette primes were irrelevant to the participants’ task, which concerned the line drawings. Milliken, Joordens, Merikle, and Seiffert (1998) showed that when observers ignored primes shown immediately before
target stimuli, they responded more slowly to matched than to mismatched target stimuli. On this alternative attention hypothesis, the withdrawal of attention from the silhouette primes accounts for the RT differences, rather than the fact that the side of the border where the known object was sketched was seen as the ground. In other words, the slowed responses to the line drawings may not have reflected the fact that the memory of object structure cue was accessed on the more weakly cued side of a border. They may simply have reflected the fact that the prime was ignored.

To test the attention hypothesis, we altered the silhouette primes so that the regions seen as grounds in the silhouettes used by Peterson and Kim (2001a) and Peterson, et al. (submitted) would now be seen as figures. We report this experiment here. If the attention hypothesis is correct, the RTs should be slower on experimental trials than on control trials even when memories of object structure matching the experimental line drawings were accessed by regions determined to be figures rather than grounds in the prime. Alternatively if the previous results reflect the ground status of the side of the contour where the known object was sketched, they will not be replicated here. Indeed, a prediction generated from numerous priming experiments conducted by others (e.g., Dell’Acqua & Grainger, 1999) is that RTs will be faster when line drawings are preceded by figures portraying an object from the same category.

We created new figure silhouette primes from the silhouette primes used in the previous experiments (henceforth called “figure” primes and “ground” primes, respectively). Sample figure primes are shown in Figure 9 along with the ground primes from which they were generated. Figure primes were matched to ground primes on a number of dimensions that could influence the results. For instance, the contour sketching the known object was presented in approximately the same location in the figure primes as it had been in the ground primes. This was important in case differences between the locations of the known objects sketched in the prime versus the line drawing affected the magnitude of the priming. In addition, we took care to portray the same portion of the known object in the figure prime as was portrayed in its associated ground prime. This was important because if the new “figure” primes portrayed the entire object whereas the old “ground” primes portrayed only a portion of the known object in the ground, then any differences in the results might reflect those differences in the amount of the object portrayed rather than the change from ground to figure status of the prime. In order to portray a portion of a known object effectively as a figure prime without introducing any spurious edges that could interfere with recognition (Gerbino & Salamaso, 1987), we added gray boxes to the figure primes positioned in such a way that they would appear to be occluding the rest of known object.

In these experiments, half of the figure primes portrayed portions of known objects; the other half portrayed portions of novel objects. We did not mask the primes in these experiments, so we expected that observers might see the differences between the figure primes portraying known objects versus novel objects. Therefore, we designed this experiment so that line drawings of both familiar and novel objects were preceded equally often by primes portraying familiar and novel figures.

As in the previous experiments, our predictions concern responses to the familiar line drawings. The familiar line drawings were divided into experimental and control sets based on whether they were preceded by figure primes portraying known objects from the same basic level category as the line drawing or figure primes portraying novel objects, respectively. If the delayed responding found on experimental versus control trials in the previous experiments was a consequence of inhibition induced by ignoring the primes, then we should obtain the same pattern of results using figure primes rather than ground primes. This is because, as in the Peterson and Kim (2001a) experiments, on experimental trials, the object portrayed in the figure prime matches the basic level category of the object portrayed in the line drawing whereas there is no match on control trials. However, if the previous results reflect the inhibition of the memory of object structure cue accessed on the side of the prime seen as the ground, we should not
observe longer RTs on experimental trials than on control trials in experiments using figure primes. Instead responses might now be faster on experimental trials compared to control trials.

We conducted two experiments using figure primes, using slightly different exposure durations. In the first experiment, the figure prime was displayed for 50 ms and was followed by an ISI of 33 ms. In the second experiment, the figure prime was displayed for 35 ms, followed by an ISI of 35 ms. In both experiments, the line drawing was shown after the ISI; it remained on the screen for 646 ms in the first experiment and for 660 ms in the second experiment.

As can be seen in Figure 10, our results provide no support for the attention hypothesis. An ANOVA conducted on the RTs for correct responses to familiar line drawings showed that, in contrast to the results reported by Peterson and Kim (2001a), responses on experimental trials were faster than responses on control trials, F(1, 27) = 4.36, p < .05 for the first experiment, and F (1, 33) = 4.00, p = .054 for the second experiment. Thus, on experimental trials, when the figure prime portrayed an object from the same basic level category, responses to the target line drawings were faster than on control trials where the prime was a novel figure. The silhouette primes were equally irrelevant in these experiments as they were in the Peterson and Kim (2001a) experiments; yet here RTs were faster on experimental trials than on control trials. Therefore, it does not appear to be the case that the irrelevance of silhouette primes is responsible for the slower RTs recorded on experimental trials versus control trials by Peterson and Kim (2001a) and by Peterson, et al. (submitted). The critical difference between the present experiments and the previous experiments appears to be that the matching known objects were sketched on the figure side of the border of the prime in the present experiments and on the ground side of the border of the prime in the previous experiments.

Based upon the results of the experiments we have summarized here, including the new experiment utilizing figure primes, we are confident that the slower RTs obtained on experimental trials by Peterson and Kim (2001a) and by Peterson et al. (submitted) reflect the cross-border competition and inhibition proposed in PIMOCA. Thus, these experiments provide support for PIMOCA; especially for the proposals that configural cues (including memory of object structure) lying on opposite sides of a border compete and that cues on the relatively weakly cued side of the border are inhibited. Therefore, it is conceivable that cross-border inhibition accounts for the apparent shapelessness of ground regions in the vicinity of more strongly cued figures.

VI. Learning: How much past experience is necessary before memory for the structure of an object can affect figure assignment?

In our initial work investigating whether or not object memories affected figure assignment, we used stimuli in which well known objects were sketched along one side of a border (e.g., objects such as standing women, table lamps, guitars, etc.). On the basis of those experiments, we knew that memories of objects could be accessed in the course of figure assignment, but we did not know how much past experience was required with an object before memory of its structure could affect figure assignment.

We avoided the learning question in part because other research using initially novel displays had failed to find any influence from past experience on figure assignment following a single past exposure to the novel object (e.g., Rock & Kremen, 1957). In those previous experiments, investigators had tested for effects of past experience on figure assignment some time after the experience was induced. Therefore, the results confounded questions concerning how long memories of novel objects last with questions concerning whether or not past experience affects figure assignment. In addition, Rock and Kremen measured direct reports about figure and ground relations; they did not record RTs, which might have permitted them to assess whether or not memories of newly learned objects compete for figural status with other cues, even if they do not dominate them.

Recently, Peterson and Lampignano (2003) found that a single prior exposure to a novel shape was sufficient to observe its influence on figure assignment the next time a portion of the border of the shape was encountered. They obtained these
results using a paradigm initially used by Treisman and DeSchepper (1996; Experiment 6). Treisman and DeSchepper had adapted a negative priming paradigm for use with novel displays. Using this paradigm, they obtained some results that they took to be evidence that, even though the ground of a novel figure-ground display was phenomenologically shapeless, its shape was nevertheless stored in visual memory along with an “ignore” tag. Peterson and Lampignano thought that Treisman and DeSchepper’s results could be better interpreted within PIMOCA than within a negative priming framework. In particular, Peterson and Lampignano thought that Treisman and DeSchepper’s results might show that a single prior experience with a novel figure was sufficient to establish a memory that affected figure assignment the next time the border was encountered. We describe Treisman and DeSchepper’s paradigm in some detail so that Peterson and Lampignano’s variant of it, and the alternative conclusion they reached, can be understood.

Treisman and DeSchepper (1996, Experiment 6) showed observers paired prime-probe trials. On the first, “prime,” trial, an ambiguous figure-ground display was shown on a gray field above a fixation cross. (See Figure 11A.) The ambiguous display had a central articulated border shared by a black region and a white region. Observers were instructed to match the (standard) black region in the figure-ground display shown above fixation to a black comparison shape shown below fixation. They assumed that, in order to perform the shape-matching task, observers perceived the black region as the shaped figure and the white region as the shapeless ground in the prime figure-ground display.

On the next, “probe,” trial, two separated shapes, one black and one white appeared above fixation, and a second white comparison shape appeared below fixation (See Figure 11B.) The left-right arrangement of the black and white shapes above fixation was the same as that of the black and white regions in the prime figure-ground display. On the probe trials, however, the two shapes above fixation did not share any borders. The observers’ task on probe trials was to determine whether or not the standard white shape shown above fixation was the same as the comparison white shape shown below fixation. (The black shape shown on the probe trials was a distractor with a novel border.) On experimental probe trials, the standard white shape was the white region isolated from the prime figure-ground displays (the region that was perceived as a shapeless ground on the prime trial). On control probe trials, the standard (and comparison) white shapes had novel borders that had not been seen previously.  

Figure 11. A. The prime display used by Treisman and DeSchepper (1996, Experiment 6). B. Sample probe displays. Half of the probe trials were experimental trials; the other half were control trials. On experimental probe trials, the white “standard” probe shape shown above fixation was the same as the bounded white ground region of the prime figure-ground display. On control probe trials, the standard white shapes were novel shapes. On half of the probe trials of both types, the white shapes shown above and below fixation were the same; on the other half of the trials, they were different. In the experiment, a given distractor was seen only once, and a given white shape was seen on only one probe trial. The shapes are repeated here for illustrative purposes only. C. The prime display used by Peterson and Lampignano (2003).

In Treisman and DeSchepper’s experiment (1996; Experiment 6), observers took longer to respond on experimental probe trials than on control probe trials. These results led them to conclude that, before figure and ground are determined, equivalent memories are established for the whole shapes of the figure and the ground, regardless of the fact that these regions are perceived quite differently (i.e., the figure is perceived to be shaped by the central border whereas the ground is perceived to be shapeless in the vicinity of that border). Treisman and DeSchepper explained the fact that they obtained longer latency responses on experimental compared to control probe trials as reflecting an “ignore” tag attached to the memory of the shape of the ground.
Peterson and Lampignano (2003) pointed out that, in reaching this conclusion, Treisman and DeSchepper (1996) neglected to consider a critical aspect of their displays. As can be seen in Figure 12, when the shape of the region seen as ground was extracted from the prime display and repeated on the probe display, the shape of the region seen as the figure in the prime was necessarily sketched along the outside of its articulated border. Therefore, any slowing on experimental trials compared to control trials may just as well have reflected competition from a memory of a portion of the figure seen on the prime trial as an ignore tag attached to the shape of the ground. Peterson and Lampignano favored the former interpretation because it is consistent with a competitive model of how figure assignment occurs, such as PIMOCA, and because of its exciting implications that one previous experience with an object was sufficient to establish a memory that could exert an influence on figure assignment. They did not favor the latter interpretation (Treisman and DeSchepper’s interpretation), both because it did not take the process of figure-ground segregation into account, and because it implied an inconceivably large capacity for shape memory. In order to distinguish these two interpretations for the original results Peterson and Lampignano (2003) changed Treisman and DeSchepper’s (1996) design in two ways.

![Figure 12](image)

Figure 12: A sample prime on the left and an experimental probe on the right. The probe has been altered to highlight the fact that a portion of the shape of the black prime figure is sketched along the gray side of the border of the white standard probe shown on experimental trials.

First, they decreased the similarity between what Treisman and DeSchepper would consider the global shape of the ground on the prime trial and the white standard shape shown on the probe trial. They did this by removing the white region from the prime figure-ground display and by presenting the black region alone on the larger gray ground in the standard prime display (see Figure 11C). Their probe displays were the same as those used by Treisman and DeSchepper (1996, Experiment 6). In the probe display, the standard was a closed white shape. Except for the repetition of the articulated border of the prime, the shape of the standard probe was quite different from the ground in the prime display.

Priming effects are larger when the shapes of prime and probe stimuli are the same rather than different. Therefore, Peterson and Lampignano reasoned that this manipulation would diminish the latency differences between experimental and control trials if those differences reflect memory for the shape of the ground, as Treisman and DeSchepper claimed. Alternatively, this manipulation should not diminish the latency differences if those differences reflect cross-border competition for figural status. All that is necessary for competition is the repetition of the border of the prime figure on the probe trial. The competition hypothesis predicts that the memory of the structure of the figure seen on the prime trial will compete with the cues favoring seeing the figure on the inside of the probe shapes. This competition might increase the time required to resolve the figural status of the experimental probes, and consequently, could be responsible for the longer RTs observed on experimental probe trials compared to control probe trials. Note that the competition hypothesis does not require that memories of the structure of the figure seen on the prime trial dominate the perception of the probe stimuli. More cues favor the interpretation that the figure lies on the inside (white side) than the outside of the border of the probe display.

Second, Peterson and Lampignano (2003) attempted to obtain evidence for the competition hypothesis by examining the consequence of adding a second cue that favored assigning the repeated articulated border to the outside rather than to the inside of the standard white probe. This second cue -- partial closure -- was manipulated by positioning the distractor near to or far from the white probe shape, as shown in Figure 13. Partial closure is a variant of the Gestalt configural cues of closure. Gillam (1975) had shown that partial closure served as a grouping cue; Peterson and Lampignano reasoned that it might also serve as a figural cue.

Peterson and Lampignano (2003) found robust slowing on experimental compared to control trials, despite the decreased similarity between the probe shape and the prime ground. They also found that the distance to the distractor mattered more in the experimental condition than in the control condition, suggesting that the addition of another cue, partial closure, favoring assigning the border to the same side as the shape memory cue increased the competition for the border. A second experiment showed that the mere repetition of the border of the figure seen on prime trials was sufficient for these effects; the presence of distractors was not necessary.
Thus, it seems that the Treisman and DeSchepper (1996, Experiment 6) results are better interpreted within a competitive model of figure assignment than within a negative priming paradigm. Peterson and Lampignano’s results show that a single past exposure is sufficient to establish a memory that enters into the competitive figure assignment process the next time the border is encountered. Future research will have to test how long this memory lasts and whether its longevity is affected by exposure to other, similar, novel shapes. In the paradigm used by Peterson and Lampignano, the interval between presentation of the novel stimulus and test was on the order of 1700 ms. Longer intervals (with and without the introduction of new stimuli) must be tested in order to determine how long these new memories last.

Peterson and Lampignano (2003) interpreted their results as evidence of cross-border competition rather than cross-border inhibition for a number of reasons. First, the SOAs they used were much longer than those at which consequences of cross-border inhibition have been observed. The longest SOA over which Peterson and Kim (2001a) and Peterson et al. (submitted) observed inhibitory effects was 105 ms; they failed to find evidence for inhibition using SOAs of 200ms, 350ms, 500ms, and 650ms. And, Treisman and DeSchepper (1996, Experiment 6) obtained longer latencies on experimental probes than on control probes even when the experimental probes were shown three trials after their associated primes. The cross-border inhibition predicted by PIMOCA is expected to be short-lived, and therefore, unlikely to be observed over long SOAs. In contrast, new object memories may last (and can potentially influence figure assignment) for an unlimited duration of time. Second, the articulated border shown in the prime display was repeated on the probe display in Peterson and Lampignano’s experiments and in Treisman and DeSchepper’s experiment, whereas it was not repeated in the experiments conducted by Peterson and Kim (2001a; Peterson et al., submitted; Skow Grant et al., 2002). Thus, Peterson and Lampignano assayed memory for a particular novel border that had been seen only once before the probe trials (i.e., on the prime trial), whereas Peterson and Kim (2001a; Peterson et al., submitted; Skow Grant et al., 2002) assayed the consequences of accessing pre-existing memories of portions of similar basic-level objects. The mechanisms mediating short-lived inhibition and memory for past experience with a previously seen border may be different. They certainly seem to follow a different time course. Future experiments will investigate the relationship between inhibition and competition in more depth.

VII. Concluding Remarks

The body of research reviewed here shows that past experience affects figure assignment. One reason many scientists sought to exclude past experience from inclusion among factors that might affect early perceptual processes was the belief that, were past experience to have an effect, it would necessarily dominate other cues. The cue competition experiments show that object memories do not exert a dominating influence; instead they constitute just one more among many configural cues used by the visual system.

The results showing that past experience does affect figure assignment raised a number of questions that had been answered under the old figure-ground-first assumption. Peterson and her colleagues offered new answers to these questions in the form of the Parallel Interactive Model of Configural Analysis (PIMOCA). They provided some empirical support for predictions arising from the model. But the model must be tested further before its full value can be known.

The surprising results reviewed in the last section showing that a single past experience with a border is sufficient to establish a memory that is accessed the next time the border is encountered suggest that memories of object structure are remarkably plastic. These results were observed in RT measures; they would not have been evident in direct reports regarding what was seen as figure because the past experience cue did not win the cross-border competition. Thus, these experiments attest to the importance of using measures that can reveal the course of figure assignment rather than simply its outcome.

The research reviewed here opens up many avenues for future research using computational,
physiological, and behavioral techniques. One important question is where in the stream of visual-cognitive processes these memories lie, as well as where the configural cues are assessed. The answer to these questions will be valuable, not for finding the place to draw a line dividing visual perception and memory, but rather for understanding both the nature of object memory and the nature of the interactions that determine figure assignment.

References


Footnotes

1 There are some situations in which both regions can be perceived as figures, and there are other situations in which a contour itself can be perceived as the figure. However, the most likely outcome is a figure-ground outcome.

2 Some tests of this assumption were attempted but they were neither straightforward nor stringent. The Gestalt point of view was the Zeitgeist; consequently, evidence consistent with the Gestalt view was sought and obtained. See Peterson (1995, 1999).
Hence, there is no need to distinguish between contours that are intrinsic versus extrinsic to the object before object memories are accessed (see Peterson, 2003). This is important because the figure-ground first assumption has been used to separate such contours.

The traditional view can account for why familiar shapes can’t be seen in grounds. However, it never went far enough to account for why even novel grounds appear locally shapeless.

In any competitive system, cues will inevitably be unbalanced. In PIMOCA, any slight advantage for the cues on one side of the edge will be amplified by the cooperative and competitive interactions.

Even if observers had been able to distinguish between experimental and control silhouettes, they could not have predicted the response to the subsequent line drawing, since control silhouettes appeared before half the line drawings of familiar objects.

Only observers who responded quickly showed these effects. Results obtained from observers whose RTs on control trials exceeded a threshold set by the experimenters were excluded from the analysis. (For details, see Peterson & Kim, 2001a.)

For this experiment, the familiar objects were divided into three sets so that none of the control line drawings portrayed an object from the same basic level category as any of the figure primes. In any given experiment, two sets were shown as line drawings, one as control and one as experimental. The experimental line drawings were preceded by silhouette primes portraying an object from the same basic level category. The third set of objects was shown as figure silhouettes before novel line drawings. These three sets were balanced across these conditions.

The difference in the length of time for the inter-stimulus interval (ISI) was due to computer monitor replacement between the experiments.

On same experimental probe trials, the white region isolated from the prime figure-ground display was shown both above and below fixation.