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Meaning Can Be Accessed For The Ground Side of A Figure

People readily perceive and act upon objects, but before objects are perceived, perceptual processes operate to organize the visual input into coherent units. One function of perceptual organization is to determine which borders in the visual field are bounding edges of objects or surfaces, which are borders of patterns or shadows, and which are corners formed by the intersection of two planar surfaces. Those that are deemed to be bounding edges of objects are perceived as separate entities at different distances from the viewer. The near entity appears to be shaped, or configured, by the border (this is the *figure*); the far entity appears shapeless near the border it shares with the figure and appears to continue behind it as a local background, or *ground*. There has been much debate regarding what factors influence figure and ground assignment and when and where it occurs in the visual processing hierarchy.

Early in the 20th century, the leaders of the Berlin school of Gestalt Psychology (e.g., Koffka, Köhler, and Wertheimer) argued that inborn responses to image features such as convexity, enclosure, small area, and symmetry produced the first figure assignment, and that factors such as past experience and meaning could exert an influence only after those "autochthonous" image features determined the initial percept. Thus, in their view, figure-ground assignment occurred early in a serial processing hierarchy. Although some contemporaries of the Berlin Gestaltists (e.g., Rubin 1915/1958; Sander, 1930) held that past experience with a stimulus and/or its meaning influenced the way it was perceived, the Berlin school's majority view prevailed and served as the basis for a foundational assumption held by most visual perception researchers during the 20th century – the assumption that stored structural and semantic representations of previously seen objects are accessed only after the initial perceptual organization is determined. This assumption entails that these higher-level representations are accessed only for figures, and not for grounds. This majority Gestalt position was buttressed by their demonstrations that figure assignment could occur for novel displays where past experience and meaning could not play a role, and later by Julesz's (1971) evidence that binocular disparity alone was sufficient for the perception of depth and form in random-dot stereograms.[1]

[1] Note, however, that evidence that figure-ground perception *can* occur without influence from past experience and meaning does not constitute evidence that it *always* occurs without such influences (Peterson, 1999).

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Similarly, figure-ground perception has been assumed to take place in low levels of a structural hierarchy of visual processing (e.g., Vecera & O'Reilley 1998, 2000; Zhou, Friedman & von der Heydt 2000). This assumption can fit a feedforward view of perception, in which high-level knowledge regarding past experience with object shape or meaning is accessed after functions localized at earlier hierarchical levels are completed and exerts no influence on those lower-level functions (e.g., Zhou, et al., 2000). Many modern feedforward models lack an explicit stage at which figure-ground perception occurs, but they espouse the view that low-level representations feed into high-level representations, whereas the reverse flow either does not occur, or is unnecessary for most perceptual tasks (e.g., Serre, Oliva & Poggio 2007; DeCarlo et al. 2012).

There is ample experimental evidence that high-level representations of object category can be accessed rapidly, and this evidence has been taken to support feedforward models. For instance, Thorpe, Fize, & Marlot (1996) asked participants to indicate via a go/no-go judgment whether or not a briefly exposed scene contained an animal. (Subjects withheld response when an animal was present in the scene.) Thorpe et al. found that event-related potentials (ERPs) over frontal leads were more negative when an animal was present in the scene (i.e., on no-go trials) as early as 150 ms after stimulus onset. This latency was considered too short for feedback from the high-level representations engaged by their categorization task to have affected the responses of lower-level neurons, and therefore was interpreted as support for a feedforward model. Consistent with the earlier finding, Kirchner & Thorpe (2006) showed that within 120 ms of the simultaneous onset of two stimuli, subjects could initiate a saccade toward the one containing an animal. Serre et al. (2007) obtained similar results that fit successfully with a feedforward model without an explicit stage at which figure-ground assignment occurs. (For analogous results with monkeys, see Delorme, Richard & Fabre-Thorpe 2010.)

It remains unclear, however, whether ultra-rapid access to high-level representations is sufficient for subjective experience, and therefore, whether feedforward models can account for subjective perceptual experience. The representations of many more objects than are ultimately perceived may be accessed in a first fast pass of processing. Perceptual organization processes may reject some of these representations (via inhibitory competition, for example), such that those that are rejected are not subjectively experienced. Indeed, Lamme & Roelfsema (2000) and Bullier (2001) proposed that an initial, fast, feedforward sweep through the visual system is followed by feedback and recurrent processing. They proposed that recurrent processing is necessary for conscious vision in general (Lamme & Roelfsema 2000). Experimental evidence supports these proposals (e.g., Heinen, Jolij & Lamme 2005; Hupé, James, Payne, Lomber, Girard & Bullier 1998; Scholte, Jolij, Fahrenfort & Lamme 2008), and models demonstrate that feedback architectures can also account for evidence that has been taken to support feedforward architectures (e.g., Jehee, Lamme & Roelfsema 2007).

Contrary to serial hierarchical views of figure-ground perception in which figure assignment necessarily precedes access to object memories, Peterson, Harvey & Weidenbacher (1991; Gibson & Peterson 1994; Peterson & Gibson 1993; 1994a &b) showed that, *ceteris paribus*, a border is more likely to be assigned to the side where a portion of a familiar object is suggested when that object is portrayed in its typical upright orientation rather than its inverted orientation. Because inverted objects can be recognized, albeit more slowly than upright objects, Peterson et al. interpreted the orientation-dependency of their effects as evidence that representations of familiar structure must be accessed quickly in order to exert an influence on figure assignment. Peterson & Gibson (1994a; Peterson & Skow, 2008) proposed that properties of objects that might be perceived on both sides of a border are assessed early in processing.[2] These properties engage in inhibitory competition. The side of the border that wins the competition is perceived as the shaped figure, and the object potentially present there is recognized, if it's familiar. The potential object on the opposite side of the border is suppressed, and partially in virtue of this suppression, that region is perceived as a shapeless ground.

Supporting this proposal, Peterson and Lampignano (2003; Peterson & Enns 2005) provided evidence that figure-ground assignment entails competition between objects that might be perceived on opposite sides of shared borders. Peterson & Skow (2008) went further and showed that the competition entails suppression of the loser: They used displays in which a portion of a common object (e.g., a table lamp) was suggested on one side of a border, but the figure was perceived on the opposite side of the border because other properties (e.g., symmetry, closure, small area, fixation, and expectation) biased the competition for figure assignment in favor of the other side. Hence, the side of the border where the table lamp was suggested was perceived as a shapeless ground. Subjects viewed these displays but did not respond to them. They made object decisions regarding line drawings of objects shown immediately after each silhouette. Object decision response times were *longer* when the line drawings depicted objects from the same versus a different basic-level shape category as the common object that lost the competition in the preceding display (e.g., another table lamp versus a duck). Peterson & Skow interpreted their results as evidence of suppression of responses to the structural representation of the object that lost the competition for figural status. Peterson & Skow's results showed that before figure assignment, representations of objects that might be perceived on opposite sides of borders are activated, at least at the level at which shape structure is

[2] This proposal is similar to the proposals made by Lamme & Roelfsema (2000) and by Bullier (2001).

represented. Therefore, their results are inconsistent with feedforward models of figure assignment in particular and of perception in general. In the present experiment, we go beyond the previous research and investigate whether high-level knowledge regarding the meaning of objects that are potentially present in a scene is accessed prior to figure assignment, as proposed by Sander (1930).

The Experiment

In the present experiment, we investigated whether high-level conceptual knowledge regarding a potential object suggested on the outside of a figure's border (i.e., the side ultimately determined to be a shapeless ground) is accessed before figure assignment. To do so, we asked participants to categorize words as naming either natural or man-made (artificial) objects. The words were shown one at a time following silhouettes like those shown in Figure 1. The silhouettes were biased toward the interpretation that the enclosed black region was the figure by the figural cues of small area, symmetry around a vertical axis, and enclosure, as well as by fixation and expectation (and subjects did indeed perceive the enclosed silhouettes as the figures; see Methods). A portion of a real-world/meaningful object was suggested along the outside of the left and right borders of each silhouette (which observers nevertheless perceived as a shapeless ground).[3] We reasoned that if observers' word categorization responses differed as a function of whether the object suggested on the groundside of the preceding silhouette was from the same or a different conceptual category, that would indicate that high-level knowledge had been activated for an object that competes for figural status, but ultimately loses the competition. This is not only because the participants' task involved making a judgment regarding a high-level conceptual category, but also because conceptual knowledge necessarily mediates any effects of the prior presentation of an object on the response to a word (e.g., Dehaene, Naccache, Le Clec'H, Koechlin, Mueller, Dehaene-Lambertz, Van De Moortele, Le Bihan 1998; Jackendoff 1983). A finding that word categorization responses differ as a function of whether the object suggested on the outside of the silhouette was from the same or a different conceptual category would show that, contrary to feedforward models of vision, activation of conceptual knowledge sufficient to affect behavior does not necessarily result in subjective experience.

We tested the three conditions illustrated in Figure 1. Words shown after the silhouettes named either the same object (SO) or a different object (DO) as the one suggested (but not perceived) on the outside of the silhouette. When

[3] Readers of this article are likely to see the real-world objects suggested on the outside of the silhouettes. But the participants in the experiment were naïve in that they did not read about past research and theory regarding figure assignment before participating in the experiment. In fact, we did not mention figure-ground perception at all. Experimental participants were highly unlikely to perceive the real-world objects, as ascertained by rigorous post-experiment questioning (see Methods).

different, the objects could either be from the same category (DO-SC) as the one suggested on the outside of the silhouette [i.e., words naming natural (artificial) objects followed a silhouette with a different natural (artificial) object suggested but not seen on the outside] or from a different category (DO-DC; i.e., words naming natural objects followed a silhouette with an artificial object suggested but not seen on the outside, and words naming artificial objects followed a silhouette with a natural object suggested but not seen on the outside). Examples of these pairings are shown in Figure 1.

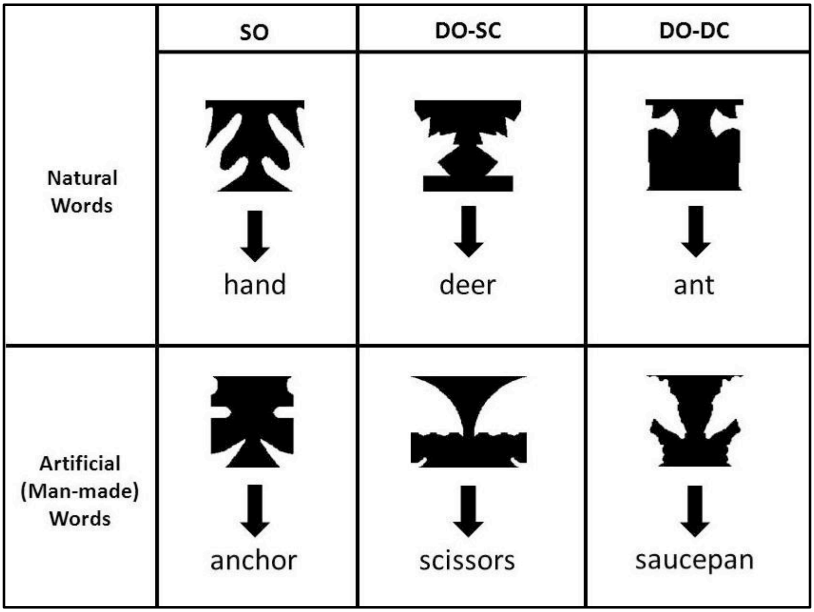

Fig. 1 Sample stimuli from the Same Object (SO) condition, DO-SC (Different Object, Same Category) condition, and DO-DC (Different Object, Different Category) condition for both natural and artificial words. In the first column (the SO condition), the top row shows a silhouette with a portion of a hand (a natural object) suggested on the groundside followed by the word "hand" (the same natural object); the bottom row shows a silhouette with a portion of an anchor (an artificial object) suggested on the groundside followed by the word "anchor" (the same artificial object). In the second column (the DO-SC condition), the top row shows a silhouette with a portion of a leaf (a natural object) suggested on the groundside followed by the word "deer" (a different natural object); the bottom row shows a silhouette with a portion of an umbrella (an artificial object) suggested on the groundside followed by the word "scissors" (a different artificial object). Thus, the word names an object with a different shape but from the same category (natural/artificial) as the object suggested on the groundside of the preceding silhouette. In the third column (the DO-DC condition), the top row shows a silhouette with a portion of an axe (an artificial object) suggested on the groundside followed by the word "ant" (a natural object); the bottom row shows a silhouette with a portion of a seahorse (a natural object) suggested on the groundside followed by the word "saucepan" (an artificial object). Thus, in the DO-DC condition, the word names an object with a different shape from a different category (natural/artificial) than that of the object suggested on the groundside of the silhouette.

Predictions

The predictions for the SO and DO conditions, and within the DO condition for the DO-SC and DO-DC conditions, differ as a function of whether or not conceptual information for an object suggested on the outside of the experimental silhouette is accessed, and if it is, whether or not it is suppressed.

If broad conceptual knowledge (i.e., knowledge relating to whether an object is natural or man-made) is activated and *not suppressed* for objects that are not consciously perceived by virtue of being assigned ground status, then categorization responses should be faster in the two same category conditions (SO and DO-SC) than in the different category condition (DO-DC). This is because the appropriate category response for the word would be primed by the activation initiated by the portion of the object suggested on the outside of the experimental silhouette in the same category conditions, whereas the incorrect category response for the word would be primed by the activation initiated by the object suggested on the outside of the experimental silhouette in the different category condition.

On the other hand, broad conceptual knowledge, like structural knowledge (cf. Peterson and Skow, 2008), may be activated and *suppressed* for objects suggested but not perceived on the groundside of the silhouette borders. In that case, performance should be worse in the same category conditions (SO and DO-SC) than in the different category condition because correct category knowledge (and hence, response) for the word would be suppressed when the object suggested on the outside of the experimental silhouette loses the competition; consequently, it would take the conceptual system longer to settle on the appropriate response. In contrast, in the different category condition (DO-DC), performance should be better because conceptual knowledge regarding the incorrect category would be suppressed, and as a consequence, it would take less time for the conceptual system to settle on the appropriate response.

Finally, broad conceptual knowledge may not be accessed for objects that are suggested by a border but are not ultimately accorded figural status. In that case, word categorization performance should be equivalent in all three experimental conditions (SO, DO-SC and DO-DC).

Design

We chose the words for the different conditions (SO, DO-SC, and DO-DC) on the basis of a preliminary experiment (Experiment 1A) in which participants saw words only (no silhouettes were present). The goal of Experiment 1A was to equate baseline response times for the words in the different silhouette-word pair conditions so that between-condition differences in the words would neither contribute to, nor obscure, any effects of the relationship between the silhouettes and the words, which was tested in Experiment 1B.

Methods

Participants

The participants were all undergraduate students from the University of Arizona who participated in this experiment after giving informed consent in order to partially fulfill requirements for their introductory psychology class. All participants reported normal or corrected-to-normal visual acuity. There were 29 participants (17 F) in Experiment 1A. An additional 3 participants were removed from the analysis: 1 for having an error rate that exceeded our criterion (> 15%), and 2 for having a mean score in at least 1 condition that differed from the condition mean by more than 2 standard deviations (these subjects were classified as outliers). There were 56 participants in Experiment 1B (40 F). Data from an additional 17 participants were not analyzed; 12 because their error rate exceeded our criterion, and 5 because they were determined to be outliers.

Stimuli and Apparatus

Experiment 1A. The stimuli were 259 words that named natural or artificial (i.e. man-made) common real-world objects. Of these, 124 were names of natural objects (e.g., flower, seahorse, blueberry), and 135 were names of artificial objects (e.g., anchor, guitar, saucepan). Of these words, 32 named the objects suggested on the groundside of the silhouettes used in Experiment 1B (16 natural objects; 16 artificial objects); these words thus comprised the SO condition. The other words tested in Experiment 1A were chosen so that they approximately matched the words in the SO condition in length and frequency because both of these factors have been shown to affect categorization time (Balota, Yap, & Cortese, 2006; Monsell, Doyle, & Haggard, 2006). Frequency (words per million) was determined for each word using the Subtitle Frequency Word Form Frequency corpus (Brysbaert & New, 2009); these numbers were cross-referenced with the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993) to ensure reliability. A 21-in. Sony CRT monitor with a personal computer was used to present the stimuli and record responses. Participants viewed the monitor from a distance of 96 cm and utilized a chin rest to maintain their head position and viewing distance. At this distance, the words subtended an average of 0.6^{o} x 1.7^{o} of visual angle in height and width, respectively. The words were presented in black Times New Roman font centered on a white background. Participants used a foot pedal to initiate each trial and to advance through the instructions. The presentation software was DMDX (Forster & Forster, 2003). Responses were recorded using a custom response box with two horizontally arranged buttons.

Experiment 1B. Both words and silhouettes were used as stimuli. The words were those listed in Appendix A (N = 64), chosen after examining the results of Experiment 1A. The silhouettes (N = 32) were a subset of those used by Trujillo, Allen, Schyner, & Peterson (2010; see also Peterson & Skow, 2008): They were small, closed, surrounded, and symmetric, thus favoring the percept of the black, inside region as figure. The silhouettes subtended an average of approximately 2.9º x 3.4º of visual angle in height and width, respectively. All silhouettes portrayed novel shapes in the black region on the inside of their borders, and portions of real-world objects were suggested (but not perceived) in the white regions on the outside of the left and right borders of the silhouettes. The objects suggested on the groundside were natural objects for half of the experimental silhouettes (N=16) and artificial objects for the remainder (N=16).

The silhouettes and words were paired in three conditions (see Figure 1): (1) The SO condition, in which the name of an artificial or natural object was paired with a silhouette suggesting an exemplar of the same basic-level object on the groundside of its borders (examples are shown in Figure 1 column 1); (2) The DO-SC condition, in which half of the silhouettes used in the SO condition were paired with names of different objects from the same conceptual category as the object suggested on their groundsides (examples are shown in Figure 1 column 2); and (3) The DO-DC condition, in which the other half of the silhouettes used in the SO condition were coupled with names of different objects from a different conceptual category as the object suggested on their groundside (examples are shown in Figure 1 column 3). The experimental set-up and apparatus were the same as in Experiment 1A.

Procedure

In both Experiment 1A and 1B, instructions were read to the participants by an experimenter while they followed along on the computer screen. Participants were told that their task was to categorize words as naming natural or artificial objects as quickly and as accurately as possible. For further clarification, they were told that a natural object is considered something that is found in nature (i.e. animals and plants) or something one is born with (i.e. body parts), while an artificial object is something that is man-made (i.e. tools, appliances, and instruments). Participants made their "Natural" or "Artificial" category judgment by pressing the left or right button on the response box (assignment of the left and right buttons to Natural/Artificial was balanced across subjects in each experiment). No feedback was given.

Each trial began with a central fixation cross; subjects were instructed to fix their eyes on it and to press the foot-pedal when they were ready to begin the trial. Upon foot-pedal press in Experiment 1A, a word appeared immediately in the center of the screen. Upon foot-pedal press in Experiment 1B, a black silhouette immediately appeared in the center of the screen. The silhouette was displayed for 50 ms, followed by a blank white screen for 33 ms, and then by a word shown in the center of the screen. The silhouette exposure duration and inter-stimulus interval between the silhouette and the target were the same as those used by Peterson & Skow (2008); with these presentation parameters, they observed inhibition of responses to objects in the same basic level category as the object suggested on the groundside of the silhouette. In both Experiment 1A and 1B, participants pressed a button to indicate their category response. After they made their response or after 1500 ms elapsed without a response, the fixation cross for the next trial appeared.

Experiment 1A. Before the experimental trials, subjects completed 8 practice trials during which they responded to 4 natural and 4 man-made (artificial) items; none of these words was used during Experiment 1B. During the practice trials, subjects were given feedback on their performance; the word "correct" or "wrong" was displayed on the screen after each response. Following the practice trials, subjects were presented with all 259 words, each repeated once, totaling 518 randomly intermixed experimental trials.

Experiment 1B. Before the experimental trials, subjects completed 18 practice trials during which they responded to 9 natural and 9 man-made (artificial) items following control silhouettes (i.e., novel silhouettes like those used in Experiment 1B, but no real-world object was suggested on the outside of the control silhouettes' borders). None of the words or silhouettes used on practice trials was used during the experiment. During the practice trials, subjects were given feedback on their performance; the word "correct" or "wrong" was displayed on the screen after each response. Following the practice trials, subjects were presented with 64 randomly intermixed experimental trials: 32 in the SO condition and 32 in the DO condition. Within the DO condition, half of the trials were DO-SC trials and the rest were DO-DC trials. Each word appeared once, and each silhouette appeared twice: once with a SO word and once with a DO word.

After the experimental trials, subjects were asked a series of questions to determine whether they had seen any of the real-world objects suggested on the outsides of the experimental silhouettes. Participants typically reported that they did not see any real-world objects because the silhouette presentation time was short and their attention was focused on the words, not the silhouettes. To ascertain this, though, the experimenter showed the subject a sample silhouette and identified and traced the portion of the real-world object suggested on the outside, while asking directly if the subject ever noticed anything suggested on the outside of the silhouettes during the experiment. If they reported that they did, subjects were probed further and asked to describe what real-world objects they saw and what percentage of the time they saw these objects. The data from subjects who reported that they saw or thought they saw any familiar objects suggested on the outside of the silhouettes were eliminated from analysis. The data from 1 additional subject were not analyzed for this reason.

Results

Experiment 1A. Mean RTs were calculated for each word based on the first presentation and based on both presentations. In what follows, we discuss means calculated on the first presentation because in Experiment 1B, only one presentation was used. We note that the means calculated over both presentations showed the same pattern.

Given that the words in the SO condition (N = 32) were fixed by our stimuli, we chose words for the DO-SC and DO-DC conditions to match the words in the SO condition as closely as possible, with primary weight given to RT, and secondary weight given to word length and frequency. Using this procedure, we chose 32 words to use in the DO condition of Experiment 1B (16 in the DO-SC condition and 16 in the DO-DC condition). Half of the words in each condition were natural; the rest were artificial. The mean frequency and word length for the words chosen for the three intended experimental conditions are shown in Appendix A.

Figure 2A shows the mean RTs for the words chosen for the 3 conditions to be tested in Experiment 1B (collapsed across natural/artificial). A one-way ANOVA showed no main effect of condition, $F(2,56) = 1.30$, $p > 0.28$. Thus, categorization RTs for the words in the three conditions to be tested in Experiment 1B were approximately equal. Therefore, any effects of condition found in Experiment 1B cannot be attributed to baseline differences in performance with the words used in the different conditions.

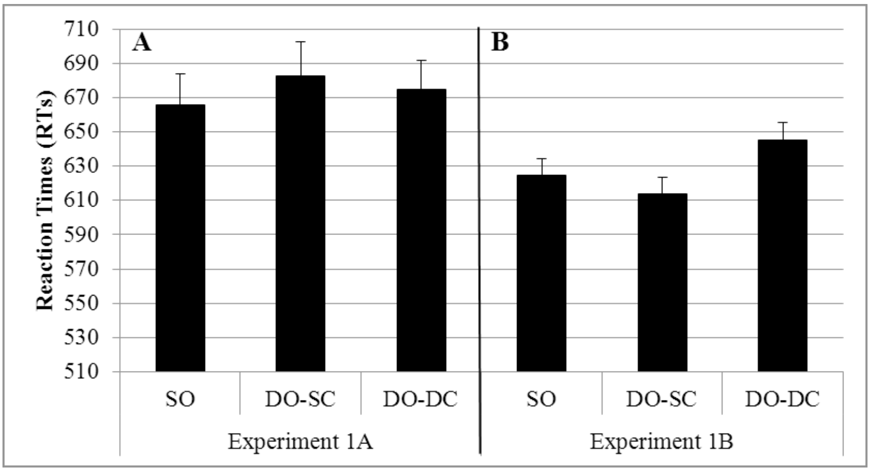

Fig. 2 Mean RTs per condition. SO = same object; DO-SC = different object, same category; DO-DC = different object, different category. (A) Results of Experiment 1A, and (B) Results of Experiment 1B. Error bars represent SEM.

Experiment 1B. The mean categorization RTs for words in the three experimental conditions are shown in Figure 2B. Participants' RTs were shortest for words in the DO-SC condition and longest for words in the DO-DC condition. A one-way ANOVA revealed a main effect of condition, $F(2,110) = 16.93$, $p < 0.001$. Paired comparisons showed that RTs for words in the SO and the DO-SC conditions were significantly shorter than RTs for words in the DO-DC condition ($p < 0.02$ and $p < 0.001$, respectively). In addition, RTs for words in the DO-SC condition were significantly faster than for words in the SO condition ($p < 0.002$). That RTs were faster in the same category condition than in the different category condition shows that before figure assignment is determined, conceptual knowledge is accessed for candidate objects that are ultimately rendered shapeless by virtue of being perceived as grounds. Moreover, our results show that conceptual knowledge regarding candidate objects that lose the competition for figural status is not suppressed.

Comparing performance in Experiments 1A and 1B. An ANOVA with one between-subjects factor (Experiment) and three within-subjects factors (Condition: SO, DO-SC, and DO-DC) compared the results of Experiments 1A and 1B. Participants in Experiment 1B responded faster than participants in Experiment 1A, as revealed by a main effect of experiment, $F(1,83) = 6.62$, $p < 0.02$. Critically, RTs in Experiment 1B were speeded more in the SO and DO-SC conditions than in the DO-DC condition, as revealed by an interaction between Experiment and Condition, $F(2,166) = 7.18$, $p < 0.01$. Planned comparisons indicated that RTs were significantly shorter in Experiment 1B than in Experiment 1A in the SO and DO-SC conditions ($p < 0.04$ and $p < 0.002$, respectively), but not in the DO-DC condition ($p > 0.11$). Thus, the between-experiment comparison provides additional evidence that the meaning of the object suggested on the groundside of a border is facilitated compared to baseline.

Discussion

In our experiment, word categorization performance was facilitated when a silhouette suggesting an object from the same broad category (natural versus man-made) on its groundside preceded the test word compared to a condition in which a silhouette suggesting an object from a different category on its groundside preceded the test word. It is important to note that subjects were not aware of the objects suggested on the groundsides of the silhouettes; their subjective experience was that the black silhouette figures lay on a locally shapeless white background. Thus, the present results show that conceptual knowledge is activated for an object that might have been perceived had a different figure-ground organization been fitted to the display—that is, had the figure been assigned on the outside of the silhouette border rather than on the inside. These results refute assumptions, held in many feedforward architectures of vision (and dating to the majority

Gestalt view on perceptual organization), that figure assignment occurs before representations of meaning are accessed. These results also refute models lacking an explicit figure assignment stage, but accounting for perception via feedforward processes alone. To date, such models do consider the possibility that candidate objects that have activated high-level conceptual knowledge may ultimately be rejected from perception because they lose the competition for figural status. Instead, the present results are consistent with Sander's (1930) view that form and meaning develop jointly (see also Rosenthal 2004).

Our results show that conceptual knowledge regarding potential objects is activated before perceptual organization processes determine where objects lie in the visual input. Thus, they support the proposal that potential objects on both sides of a border are evaluated at both low levels and high levels in a fast feedforward sweep of processing, but that the feedforward sweep is not sufficient for perception. Perceptual organization selects a subset of the activated representations for perception; those representations correspond to the perceived figures. There is evidence that figure assignment entails feedback (e.g., Likova & Tyler 2008; Salvagio et al. 2012; Scholte et al 2008), consistent with proposals that perception emerges from a dynamical multi-level process (Bullier, 2011; Lamme & Roelfsema 2000; Barense, Ngo, Hung & Peterson, 2011).

Consistent with the results of Experiment 1, Sanguinetti, Allen & Peterson (2012) found that the N400, a brain potential indexing access to the conceptual system, is reduced when novel silhouettes with a portion of a familiar object suggested on their groundsides are repeated but not when control silhouettes are repeated, providing electrophysiological evidence that conceptual access has occurred for regions ultimately perceived as grounds.

It is interesting to compare our results with those of Peterson & Skow (2008) who investigated whether high-level knowledge regarding object structure was accessed early in the course of perceptual processing. The results of both studies provide evidence that before figure assignment occurs, high-level knowledge is accessed for candidate objects that ultimately lose the competition for figural status -- structure in Peterson & Skow's experiment, meaning in our experiment. Differences are evident as well; Peterson & Skow found that structural representations of objects that lose the competition for figural status are suppressed, whereas we find that the meaning of the losing contender is facilitated and not suppressed. In this regard, the finding that RTs in the DO-SC condition were significantly shorter than those in the SO condition is interesting. This difference may reflect the fact that in the SO condition, the structural representation of the object suggested on the outside of the border is suppressed. Because representations of object structure are an integral part of the conceptual system for concrete objects (Barsalou, Simmons, Barbey & Wilson 2003; Kutas & Federmeier 2011; Moss, Tyler &

Taylor 2005), the net activation of conceptual knowledge may therefore be lower in the SO condition than in the DO-SC condition. This reduced activation may account for the reduced facilitation found in the SO condition compared to the DO-SC condition. In general, however, the finding that RTs were speeded in the SO condition compared to the DO-DC condition indicates that, at least within the time frame examined here, suppression of shape structure does not spread to other types of conceptual knowledge regarding an object. In future experiments, we plan to use longer delays between the onset of the silhouette and the onset of the test word in order to better explore the temporal dynamics of activation in the conceptual system.

An open, and related, question concerns how long conceptual priming lasts. Is it short-lived like suppression of the structural representation and the spatial location of a losing contender (Peterson & Skow 2008; Salvagio et al. 2012)? Some evidence suggests that conceptual priming may be long-lived: Many years ago, Eagle, Wolitzky & Klein (1966) found that conceptual knowledge regarding an object that was "concealed" by virtue of being assigned ground status influenced perceptual imagery generated seconds later. This experiment suggested that meaning was accessed for objects suggested by regions ultimately perceived as grounds (see also Schafer & Murphy 1943). These earlier results were not accepted because they were not consistent with the Zeitgeist, which was still dominated by Gestalt psychologists in the Berlin school and their followers (see critiques by Smith & Hochberg 1954; Potter & Young 1966; for review, see Peterson 1999). Of course, a systematic exploration of the longevity of conceptual priming must be conducted. But our observation that control trial performance was contaminated when intermixed with experimental trials in pilot experiments is consistent with the possibility that conceptual priming is long-lived, as suggested by Eagle, et al.'s results.

In closing, our results show that meaning is not secondary in perception as in the traditional Gestalt view and in current feedforward models. Instead, it can be said to be primary in that it seems to be accessed in the first pass of processing. These results call for a reexamination of the ideas of Sander (1930) and others in the Leipzig school of Gestalt psychology. Their view of perception as a dynamic process in which meaning and form develop together (interactively) seems surprisingly modern in light of the present results (see also Rosenthal 2004).

Summary

Figure-ground perception entails inhibitory competition between potential objects suggested on opposite sides of a border. The winner is perceived as the figure; the loser is suppressed and perceived as a shapeless ground. We investigated whether the meaning of an object that ultimately loses the competition for figural status is activated prior to figure assignment, and, if so, whether it is suppressed. Participants categorized words as

naming natural or artificial objects. The words followed novel silhouettes with portions of real-world objects suggested along the outside of their vertical borders. The silhouettes were designed so that the inside would be seen as the figure, the outside would be seen as a shapeless ground, and participants would be unaware of the real-world objects that lost the competition for figural status. Participants categorized words faster when the real-world object suggested on the groundside of the preceding silhouette was from the same versus a different category. Thus, the meaning of real-world objects that are suggested in the visual input, but are not ultimately perceived, is accessed (but not suppressed) in the course of perceptual organization. Our results show that meaning is not secondary in perception as in the traditional Gestalt view and in current feedforward models. Instead, it can be said to be primary in that it seems to be accessed in the first pass of processing.
Keywords: Figure-ground perception, semantics, meaning, inhibitory competition.

Zusammenfassung

Bei der Figur-Grund Wahrnehmung konkurrieren verschiedene Objekte miteinander, die auf gegenüberliegenden Seiten einer Grenze angedeutet werden. Das Objekt, das gewinnt wird als Figur erkannt während das andere Objekt verdrängt und als formloser Grund wahrgenommen wird. Es wurde untersucht ob die Bedeutung eines Objekts, das diesen Wettstreit um den Status als Figur letztendlich verliert, bereits vor Zuordnung der Bedeutung aktiviert wird, und wenn dies der Fall ist, ob diese Bedeutung unterdrückt wird.

Versuchsteilnehmer ordneten ein, ob Begriffe natürliche oder künstliche Gegenstände benennen. Die Wörter folgten auf unbekannte Schattenbilder, deren seitlicher Umriss Teile von real existierenden Objekten andeutete. Die Schattenbilder wurden so konzipiert, dass das Innere als Figur und die Außenseiten als formloser Untergrund wahrgenommen werden sollten. Versuchsteilnehmer sollten dadurch die realen Objekte, die in der Wahrnehmung als Figur unterdrückt wurden, nicht als solche erkennen. Die Ergebnisse zeigen, dass Wörter schneller kategorisiert wurden, wenn der Umriss des zuletzt gezeigten Schattenbildes aus der gleichen Kategorie stammt. Demzufolge wird die Bedeutung von echten Objekten, die im Optischen Feld zwar angedeutet, aber nicht wahrgenommen werden, im Verlauf des Wahrnehmungsprozesses (perceptual organisation), abgerufen und nicht etwa unterdrückt. Entgegen der traditionellen und derzeitigen Gestalttheorien zeigen unsere Ergebnisse, dass semantische Bedeutung nicht der Wahrnehmung untergeordnet ist. Vielmehr wird in erster Instanz des Verarbeitungsprozesses darauf zugegriffen.
Schlüsselwörter: Figur-Grund Wahrnehmung, Bedeutung, Semantik.

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Appendix A

Appendix A: Frequency (words per million) and length of words chosen for Experiment 1B based on Experiment 1A results.

	DO			SO		
	Word	**Frequency**	**Length**	**Word**	**Frequency**	**Length**
DO-DC	celery	2.86	6	anchor	7.41	6
	ant	5.53	3	axe	4.88	3
	crow	4.45	4	boot	11.14	4
	gopher	1.41	6	faucet	1.43	6
	peanut	12.35	6	guitar	15.59	6
	heart	244.18	5	house	514.00	5
	mangoes	0.43	7	hydrant	1.02	7
	rooster	3.86	7	trumpet	4.12	7
	suitcase	13.39	8	elephant	11.37	8
	wallet	22.80	6	flower	22.76	6
	diaper	4.27	6	grapes	3.94	6
	book	172.57	4	hand	279.65	4
	jar	8.31	3	owl	5.61	3
	saucepan	0.16	8	seahorse	0.14	8
	watch	330.02	5	woman	434.63	5
	car	483.00	3	dog	192.84	3
DO-SC	rope	22.71	4	bell	39.33	4
	ferryboat	0.41	9	coffeepot	0.41	9
	hat	53.07	3	jet	14.14	3
	flag	17.49	4	lamp	12.88	4
	scissors	6.69	8	umbrella	7.49	8
	measuring tape	n/a	14	watering can	n/a	12
	napkin	3.61	6	wrench	3.96	6
	radio	77.18	5	train	95.06	5
	whale	11.25	5	bunny	18.55	5
	blueberry	2.57	9	butterfly	5.51	9
	wolf	20.27	4	duck	24.76	4
	deer	8.71	4	leaf	5.20	4
	egg	26.24	3	pig	39.14	3
	cranberry	1.94	9	pineapple	2.55	9
	rose	53.02	4	bear	57.41	4
	puppy	11.45	5	eagle	11.49	6

Note: DO = different object, SO = same object, DO-DC = different object, different category, DO-SC = different object, same category. For each row, the DO word was matched with the SO word as closely as possible.

References

Baayen, R. H., Piepenbrock, R. & Van Rijn, H. (1993): The CELEX lexical database. CD-ROM. Philadelphia, PA.

Balota, D. A., Yap, M. J. & Cortese, M. J. (2006): Visual word recognition: The journey from features to meaning (a travel update). In M. Traxler & M. A. Gernsbacher (Eds.): *Handbook of psycholinguistics* (2nd ed., pp. 285–375). Amsterdam: Academic Press.

Barense, M. G., Ngo, J., Hung, L. & Peterson, M. A. (2011): Interactions of Memory and Perception in Amnesia: The Figure-Ground Perspective. *Cerebral Cortex*. doi: 10.1093/cercor/bhr347

Barsalou, L., Simmons, W., Barbey, A. & Wilson, C. (2003): Grounding conceptual knowledge in modality-specific systems. *TRENDS in Cognitive Science 7(2),* 84-91.

Brysbaert, M. & New, B. (2009): Moving beyond Kucera and Francis: A Critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for american english. *Behavior Research Methods 41,* Number 4, 977-990.

Bullier, J. (2001): Integrated model of visual processing. *Brain Research Reviews 36,* 96–107.

Dehaene, S., Naccache, L., Le Clec'H., G., Koechlin, E., Mueller, M., Dehaene-Lambertz, G., Van De Moortele, P. F. & LeBihan, D. (1998): Imaging unconscious semantic priming. *Nature*, *395*(6702), 597-600.

Delorme, A., Richard, G. & Fabre-Thorpe, M. (2010): Key visual features for rapid categorization of animals in natural scenes. *Frontiers in Psychology (Perception Science).* doi:10.3389/fpsyg.2010.00021

Eagle, M., Wolitzky, D. L. & Klein, G. S. (1966): Imagery: Effect of a concealed figure in a stimulus. *Science 151,* 837-839.

Forster, K. I. & Forster, J. C. (2003): DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers 35,* 116–124.

Gibson, B. S. & Peterson, M. A. (1994): Does orientation-independent object recognition precede orientation-dependent recognition? Evidence from a cueing paradigm. *Journal of Experimental Psychology: Human Perception and Performance 20,* 299-316.

Heinen, K., Jolij, J. & Lamme, V. (2005): Figure-ground segregation requires two distinct periods of activity in V1: a transcranial magnetic stimulation study. *Neuroreport 16* (13), 1483-1487.

Hupe, J. M., James, A. C., Girard, P., Payne, B. & Bullier, J. (2001): Feedback connections act on the early part of the responses in monkey visual cortex. *Journal of Neurophysiol. 85* 134-145.

Jackendoff, R. (1983): Semantics and cognition. Cambridge, MA: MIT Press.

Jehee, J.F.M., Lamme, V.A.F. & Roelfsema, P.R. (2007): Boundary assignment in a recurrent network architecture. *Vision Research 47,* 1153-1165.

Julesz, B. (1971): Foundation of cyclopean perception. Chicago: University of Chicago Press.

Kutas, M. & Federmeier, K.D. (2011): Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology* Vol. 62, 621-647

Lamme, V. A. F. & Roelfsema, P. R. (2000): The distinct modes of vision offered by feedforward and recurrent processing. *Trends in Neuroscience 23 (11),* 571-579.

Monsell, S. S., Doyle, M. C. & Haggard, P. N. (1989): Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General 118(1),* 43-71.

Moss, H. E., Tyler, L. K. & Taylor, K. I. (2007): Conceptual structure. In M. Gareth Gaskell (ed): *The Oxford handbook of psycholinguistics,* pp 217–234. Oxford, UK: Oxford University Press.

Peterson, M. A. (1999): Organization, Segregation and Object Recognition. *Intellectica 28,* 37 - 51.

Peterson, M. A. & Enns, J. T. (2005): The edge complex: Implicit perceptual memory for cross-edge competition leading to figure assignment. *Perception & Psychophysics 14,* 727-740.

Peterson, M. A. & Gibson, B. S. (1993): Shape recognition contributions to figure-ground organization in three-dimensional displays. *Cognitive Psychology 25,* 383-429.

Peterson, M. A. & Lampignano, D. L. (2003): Implicit memory for novel figure-ground displays includes a history of border competition. *Journal of Experimental Psychology: Human Perception and Performance 29,* 808-822.

Peterson, M. A. & Gibson, B. S. (1994a): Must figure-ground organization precede object recognition? An assumption in peril. *Psychological Science 5,* 253-259.

Peterson, M. A. & Gibson, B. S. (1994b): Object recognition contributions to figure-ground organization: Operations on outlines and subjective contours. *Perception & Psychophysics 56,* 551-564.

Peterson, M. A., Harvey, E. H. & Weidenbacher, H. L. (1991): Shape recognition inputs to figure-ground organization: Which route counts?. *Journal of Experimental Psychology: Human Perception and Performance 17,* 1075-1089.

Peterson, M. A. & Skow, E. (2008): Suppression of shape properties on the ground side of an edge: Evidence for a competitive model of figure assignment. *Journal of Experimental Psychology: Human Perception and Performance 34 (2),* 251-267.
Potter. M. C. & Young, J. (1966): Imagery; Effect of a Concealed Stimulus. *Science 8*, 230. [DOI:10.1126/science.152.3719.230]
Rosenthal, V. (2004): Microgensis, immediate experience and visual processes in reading. In A. Carsetti (Ed.): *Seeing, Thinking and Knowing.* Dordrecht: Kluwer Academic Publishers.
Rubin, E. (1958): Figure and ground. In D. Beardslee & M. Wertheimer (Ed. & Trans.): *Readings in perception,* pp. 35-101. Princeton, NJ: Van Nostrand. (Original work published 1915)
Salvagio, E., Cacciamani, L. & Peterson, M. A. (2012): Competition-strength-dependent ground suppression in figure-ground perception. *Attention, Perception, & Psychophysics 74,* 964-978.
Sander, F. (1930): Structures, totality of experience, and gestalt. In C. Murchinson (Ed.): *Psychologies of 1930,* pp. 188-204. Worcester, MA.: Clark University Press.
Sanguinetti, J.S., Allen, J.J.B. & Peterson, M.A. (2012): *ERP evidence that semantic access occurs for objects that are suggested but not perceived on the groundside of a figure.* Unpublished Manuscript.
Schafer, R. & Murphy, G. (1943): The role of autism in a visual figure-ground relationship. *Journal of Experimental Psychology 32,* 335-343.
Scholte, H. S., Jolij, J., Fahrenfort, J. J. & Lamme, V. A. F. (2008): Feedforward and Recurrent Processing in Scene Segmentation: Electroencephalography and Functional Magnetic Resonance Imaging. *Journal of Cognitive Neuroscience 20(11)*, 2097-2109.
Serre, T., Oliva, A. & Poggio, T. A. (2007): A feedforward architecture accounts for rapid categorization. *Proceedings of the National Academy of Sciences 104 (15),* 6424-6429.
Smith, D. E. P. & Hochberg, J. (1954): The effect of "punishment" (electric shock) on figure-ground perception. *The Journal of Psychology 38,* 83-87.
Thorpe, S., Fize, D. & Marlot, C. (1996): Speed of processing in the human visual system. *Nature 381,* 520-522.
Trujillo, L.T., Allen, J.J.B, Schnyer, D.M. & Peterson, M.A. (2010): Neurophysiological evidence for the influence of past experience on figure-ground perception. *Journal of Vision 10 (2),* 1–21.
Vecera, S. P. & O'Reilly, R. C. (2000): Graded Effects in Hierarchical Figure-Ground Organization: Reply to Peterson (1999). *Journal of Experimental Psychology: Human Perception and Performance 26*, 1221-1231.
Zhou, H., Friedman, H. S. & von der Heydt, R. (2000): Coding of border ownership in monkey visual cortex. *Journal of Neuroscience 20,* 6594-6611.

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