Conscious and Nonconscious Processing of Visual Object Identity

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Priming as implicit memory

Recognizing a perceptual stimulus improves with familiarity. This experience-specific facilitation is termed *priming*. In a typical priming experiment, subjects are initially exposed to a set of briefly presented stimuli in the prime block and their performance in naming, for example, is recorded (usually reaction times and correct responses). In a subsequent test block, subjects are presented with either the same stimuli or stimuli that have some defined relationship to the prime stimuli. Any improvement that is specific to the stimulus is taken as a measure of priming.

Priming is considered an implicit type of memory because it does not involve explicit recollection of previous experience. It is believed to exist as an independent mechanism, while closely interacting with other memory systems (Tulving & Schacter 1990). Amnesic patients, for example, can show almost intact priming while their explicit recognition memory (as measured in an old/new judgment task) has been severely impaired (Weiskrantz & Warrington 1970; Warrington & Weiskrantz 1974; Cave & Squire 1992). In other types of experiments, it has been shown that elaborating the study material improved explicit memory (e.g., measured by a cued recall of stem completions),[1] but not priming (Graf & Mandler 1984). Priming and explicit memory have also been suggested to have different retention time courses (Jacoby 1983). Priming of object naming can last 48 weeks after a single exposure to a picture (Cave 1997), and priming of word completions can even last as long as 16 months (Sloman, Hayman, Ohta, Law & Tulving 1988).

Although the contribution of priming is implicit, it has been shown to facilitate tasks that require explicit knowledge, such as object naming[2] (Bartram 1974; Biederman & Cooper 1991; Schacter, Delaney & Merikle 1990). The mechanisms subserving the interaction between priming and explicit reports, as manifested in object recognition, will be the focus of this chapter.

Working definitions

The terms *subliminal* and *visual awareness* are being used extensively. The following are working definitions for these concepts.

Subliminal is taken here in its literal meaning: below-threshold. The threshold is defined by the task. Therefore, if subjects are required to detect the presence or absence of a certain stimulus on the screen and they cannot do it above chance, this detection is considered to be below their threshold, and therefore subliminal. However, if the task is naming briefly presented objects, the threshold is identification. A trial in a naming task is then considered subliminal if subjects cannot name the objects, even if they are above chance in detecting their presence. The tasks of detection and naming differ largely in the information that they require for successful performance, and the thresholds are expected to be different. In addition, in light of the priming phenomenon, this threshold should not be considered as fixed but rather as a measure that can vary with experience. As demonstrated by the experimental work reviewed here, subjects could gain from subliminal presentations information that can render the same stimuli supraliminal in subsequent trials.

Work on signal detection theory (Swets 1961; Green & Swets 1966) challenges the existence of a sensory threshold. The threshold is described instead by a bell-shaped curve representing the distribution of the probability for correct performance. In the present context, "subliminal" is used to describe success (or, rather, failure) in performing the task at hand, and in that sense it is a binary concept. "Visual awareness," on the other hand, is taken to be more like a continuum, and therefore closer to the threshold definition of signal detection theory.[3] If a presentation of an object is too brief for identification, it is subliminal in that subjects cannot identify it, and therefore they are unaware of the name. At the same time, however, they might be aware of other aspects of the identity, such as orientation and texture. In that sense, awareness is a set of dimensions on which a threshold may be defined.

Such "intermediate-awareness" of the identity is often hard to infer from subjects' reports. In trying to estimate the awareness of subjects with regard to different aspects of the stimulus, the experiment should be designed so that the report will be minimally affected by subjective factors. When subjects cannot name the stimulus, intermediate reports can vary significantly, and they are likely to depend on individual differences in verbal articulation, visual memory, etc. In addition, subjects can make accurate discriminations even when they believe that their knowledge is insufficient for a correct judgment (reported as early as Sidis, 1898, and more recently, Kolb & Braun 1995). Indeed, Cheesman and Merikle (1984) distinguish between "subjective-threshold," when subjects believe they are guessing while their performance is above chance, and an "objective-threshold," which is chance-level performance. Self-judgments of awareness and confidence are thus highly subjective, and should be augmented with objective measures of performance.

Subliminal perception and visual awareness

Direct tests such as recognition are likely to involve effects of both explicit and implicit processes. To distinguish their contribution, Jacoby (1991) developed the process dissociation task. He assumed that "implicit" and "nonintentional" are representing unconscious processes, and that "explicit" and "intentional" are representing conscious processes. The rationale behind Jacoby's task is that the contribution of intentional and nonintentional processes can be inferred by comparing performance between conditions in which they are acting together and conditions in which they are competing. For example, after studying a list of words, subjects were required to complete stems of words with either words from the study list (*inclusion* condition), or with words not from the study list (*exclusion* condition) (Jacoby, Toth, Yonelinas 1993). The difference in performance between the two conditions was taken to indicate an intentional retrieval, and any study items that are provided in the exclusion condition to indicate nonintentional use of memory. The results show that study words that were presented very briefly (Debner & Jacoby 1994), or in a divided attention task[4] (Jacoby *et al.* 1993) were given equally often on inclusion and exclusion conditions, and at a rate that was significantly higher than baseline.[5] Therefore, under these conditions, all the priming was nonintentional.

This technique has been proven useful and is extensively used for similar assessments of conscious and unconscious effects. Other demonstrations, using various paradigms, have shown that the effect of subliminal presentations might range from the bias of judgment and affect to the facilitation of visual object recognition.

In one type of such studies (Marcel 1983; Merikle, Joordens & Stolz 1995), subjects were required to name the color of a target patch that was presented on the screen until they responded. The patch was preceded by a subliminal (individually determined for each subject) color name (e.g., 'GREEN'). Performance was affected by the congruency between the name and the color patch (Stroop effect) such that color-congruent words shortened reaction times (RTs), and color-incongruent words delayed RTs. Therefore, although the prime was not recognizable it affected responses in the subsequent naming task.

Another example is the effect of subliminal presentations on subsequent liking judgments (Zajonc 1968). In one such study (Kunst-Wilson & Zajonc 1980), subjects were first presented with irregular octagons for a very brief duration (1 ms). Then, pairs of such octagons — one new and one from the set that had been presented previously — were displayed on the screen for 1 sec. Subjects were required to: (a) choose which octagon they liked more, and (b) judge which of the two octagons they had seen before (old/new judgment). Although they were at chance in the old/new judgment task, they tended to like the old stimuli more than the new ones. Consequently, the authors concluded that the subliminal presentations only affected judgments of liking. Experiments reviewed here show that subliminal presentations can also facilitate object identification (Bar & Biederman 1998; 1999). An implication of these results is that priming of perception may be more affected by a subliminal stimulus than the explicit measure of old/new judgments.

Finally, in a recent study of subliminal semantic activation (Greenwald, Draine Abrams 1996), a prime word was presented very briefly before the presentation of above-threshold target words. Subjects were required to judge whether the target was a pleasant or unpleasant word, or whether it represented a male or female name. Their judgments were biased by the subliminal prime. For example, a prime word "kill" biased judgments of a target word "bomb" towards unpleasantness, while a prime word "happy" biased the judgment of the same word towards pleasantness. This subliminal priming, which was purely semantic (as the prime and the target were different words

that could only be semantically related), has been found to be very short-lived: the target word had to be presented within 100 ms following the prime in order to obtain the effect. Subliminal visual priming, on the other hand, is suggested later to persist for longer durations. Therefore, this ephemeral nature might be unique to subliminal semantic priming.

We turn now from studies of subliminal priming to consider the related issue of visual awareness. While studying visual awareness in general has a long history, the underlying neural mechanisms have been addressed only recently. Two related phenomena that have been studied extensively are *blindsight* and *binocular rivalry*.

Blindsight is the ability of patients with a damaged primary visual cortex (or the projections to it) to report aspects of a stimulus that is presented to the blind area of their visual field (Weiskrantz 1986). Such patients perform reliably above chance (typically in localization tasks), often despite their low confidence in their response. Blindsight may thus be considered as an example of perception without awareness.

Experimental methods have been devised to induce behavior similar to blindsight in healthy human observers (Meeres & Graves 1990; Kolb & Braun 1995). For example, when subjects had to locate an open circle that was presented very briefly in one of six possible positions (Meeres & Graves 1990), they were significantly better than chance in guessing its location, even when they reported that the circle was absent. In such studies, however, the relation between subjective confidence judgments and awareness is not completely defined.

The capacity of blindsight is likely mediated by alternative connections to other areas. Hypotheses regarding the anatomical basis of blindsight include the retinocollicular pathway (i.e., the pathway from the retina to the superior colliculus), the direct projections from the thalamus to extrastriate cortex, and residual projections that survived the damage (Stoerig 1993). Each patient might have a different type of damage, and therefore blindsight might have different substrates in each instance. The important common aspect is subjects' ability to perform successfully in spite of their low confidence.

Findings from studies of form-agnosia further extend the blindsight phenomenon. One striking example is patient D. F. (Milner & Goodale 1995), who has suffered damage to her visual cortex following carbon monoxide intoxication. While visual areas V2, V3 were severely damaged, area V1 remained mostly intact. D.F. is unable to recognize familiar faces, line draw-

ings of objects, or even simple geometric shapes. She also cannot discriminate between objects that differ in size or orientation. Her basic visual abilities (e.g., contrast sensitivity, visual field), however, are relatively intact. In one study (Goodale, Meenan, Bülthoff, Nicolle, Murphy & Racicot 1994), D.F. was required both to discriminate between blob-like wooden objects (same/different task), and grasp them using shape information. Although she failed to discriminate between the shapes, she had no difficulty in choosing stable grasping points on the circumference of the object. These results suggest that D.F. could match her grasping points to the specific object form without being aware of its shape.

Another class of studies related to visual awareness is binocular rivalry. When the two eyes are presented with conflicting information, our perception alternates between the two interpretations rather than combining them into one percept.[6] This phenomenon turned out to be an excellent tool for correlating neuronal activity with subjective experience. In a series of experiments, Logothetis and his collaborators (Logothetis & Schall 1989; Logothetis & Leopold 1996) presented monkeys with motions in different directions in each eye while recording from area MT (medial temporal cortex; believed to process primarily visual motion). Many neurons fired as a response to the retinal stimulus (i.e., they fired whenever their preferred direction of motion was presented to either eye, regardless of the perception of the monkey). However, the activity of other neurons reflected the reports of the monkey (i.e., fired to their preferred direction of motion only if it was presented to the "active" eye). These neurons are likely to reflect the subjective rather than sensory experience. Similar findings were obtained from cells in V4 (Leopold & Logothetis 1996), when the conflicting stimuli were gratings in different orientations. Because these neurons reside in the deeper layers of the cortex, this activity is likely to be projected to other areas. Tracking the destination of these projections has a good potential of revealing areas that are more closely involved in visual awareness (Koch & Braun 1996).

Subliminal visual priming — The basic phenomenon

Priming is often used as a tool for studying representations, but it can also be considered as a mediating phenomenon that allows the study of visual awareness during the different stages of object recognition. While recognizing

objects is often immediate and unambiguous, it is not clear at what stage do we become aware of the interpretation of the visual input. Studies addressing this and related questions will be reviewed here, as well as speculations regarding mechanisms and cortical localization.

In typical demonstrations of visual priming (Bartram 1974; Biederman & Cooper 1991; Schacter, Delaney & Merikle 1990), observers are generally able to name the stimulus on its first presentation. Priming is then manifested by improved performance in subsequent encounters with this stimulus (i.e., supraliminal priming). Can visual priming be evidenced even if the observer cannot recognize the prime, or even guess its name from among a few alternatives? As will become clearer in this section, priming of object recognition is possible although subjects are not aware of the identity of the prime, and a considerable amount of time and intervening information buffer between the prime and the test images.

In a study by Bar & Biederman (1998), line-drawing images of objects and animals were flashed very briefly (at an average of 48 ms), and were followed by a highly effective mask. Following each stimulus presentation, subjects were required to identify the object by name, even if they had to guess, and then to choose from four object names in a 4-alternative forced-choice (4AFC) test. The subsequent 4AFC task was used in order to assess the information extracted from unidentified presentations.[7] The experiment included two blocks of pictures of objects. The objects in the second block had the same names as the objects in the first, and were presented in one of four possible conditions relative to the image with that name on block 1: either at the same or different position, and either with the same shape or as a different exemplar of the same object (Figure 1). Changes in position were incorporated to study translation invariance[8] in subliminal priming, and to compare it with the complete translation invariance reported for supraliminal priming (Biederman & Cooper 1991). Different exemplars were used to assess a possible semantic component in the priming (Bartram 1974). (Stimulus-specific improvement can stem from either visual or semantic priming. Subtracting the priming of different-exemplar conditions from same-exemplar priming provide an assessment of visual and semantic priming.) Two control blocks were incorporated: one before the first experimental block, and the other after the second experimental block. The images of the second control block had different names than those in the first control block. Any improvement in naming objects in the second control block, compared with the first control