Demonstrations of judgments or actions being influenced by unperceived stimuli (I) have both interesting and uninteresting possibilities for interpretation. The uninteresting possibility is that perceptual measurements have been insensitive—the critical stimuli may have been perceived, but the research apparatus or procedure failed to register that perception. The more interesting—but also controversial—possibility is that stimulus-triggered cognition has indeed occurred without conscious perception of the initiating stimuli. Tests of the hypothesis of unware perception date from the late 19th century (2). When claims of analysis of semantic information from unperceived stimuli were strongly pressed in the second half of the 20th century (3), methodological critiques (4) of the adequacy of evidence for such claims resulted in widespread skepticism about those claims.

In this controversial domain, experimen-
value used in an experiment (11). Direct measures of prime perceptibility were obtained from separate (later) blocks of trials for which instructions described the pre- and post-masking procedure and asked subjects to make various discriminations of content for the visually masked stimuli (12).

Results from several response-window experiments are summarized as regression functions that relate priming to measures of perceptibility of the primes (Fig. 1). When such regression analyses use priming and perceptibility measures for which zero values indicate absence of priming and perceptibility, respectively, the height at which the function crosses the vertical axis (the regression intercept) provides a critical test of the hypothesis that priming has occurred unconsciously. The regression intercept estimates the magnitude of priming associated with zero perceptibility of the prime. When this priming magnitude is significantly greater than zero, there is evidence for unconscious semantic activation (13). In Fig. 1, intercepts of the regression functions were statistically significant for all three prime durations (17, 33, and 50 ms).

Additional experiments were performed in which 50-ms primes were presented either with pre- and post-masking, making them subliminal for most subjects (14), or with no masking, making them supraliminal (that is, visible). In these experiments (Fig. 2), subliminal priming was generally weaker than supraliminal priming. More importantly, however, the shapes of functions relating magnitude of priming to prime-target SOA were sharply different for supraliminal and subliminal priming. Supraliminal priming was consistently strong, perhaps even increasing in strength, across SOAs varying from 100 to 400 ms. By contrast, subliminal priming was moderated substantially by SOA, being consistently strong only at a very short SOA (67 ms) and decreasing to low levels for SOAs longer than 100 ms. The results shown in Fig. 2 reveal that the temporal span of subliminal priming is very brief in comparison with that of supraliminal priming. In retrospect, these findings demonstrate why subliminal priming has been such an elusive phenomenon in previous research: Virtually all previous studies of subliminal priming have used SOAs that exceeded 250 ms. By contrast, Fig. 2 shows that subliminal priming is readily obtainable only with SOAs of 100 ms or less.

Another empirical pattern (Fig. 3) was found to differentiate subliminal from supraliminal priming. For supraliminal priming, magnitude of priming was affected by the relation between prime and target stimuli on the just-preceding trial. When the preceding trial was an incongruent prime-target pair, supraliminal priming was weaker than when the preceding trial was a congruent pair. This finding indicates that impact of the prime was affected by its recent usefulness (that is, the prime-target congruency), but only for visible primes; that is, supraliminal (visible) primes were more potent in facilitation or interference on the trial just after one on which the prime and target had been congruent, compared to one on which they had been incongruent. This pattern indicates a form of memory for the preceding trial’s prime-target configuration. By contrast, magnitude of subliminal priming was unaffected by the congruency or incongruence of the preceding prime-target pair; that is, subjects gave no evidence of retaining information about the most recent prime-target configuration (15).

The findings in Figs. 1 to 3 collectively establish a convergence of stimulus presentation operations and cognitive indicators that define unconscious semantic activation in the semantic priming experiment. The chief defining operation is the use of visual masking to produce low levels of prime perceptibility. The defining cognitive indicators of subliminal semantic activation are the data patterns shown in Figs. 1 to 3: (i) a significant intercept effect in the regression of measures of priming on measures of the prime stimulus’s perceptibility, (ii) limitation of subliminal priming to target stimuli that occur within about 100 ms of the visually masked primes, and (iii) absence of any effect of the preceding trial’s prime-target congruence on magnitude of

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**Fig 1. Magnitude of priming as a function of performance on direct measures of prime perceptibility.** Each scatterplot point represents an individual subject’s average performances at both priming and direct-measure tasks at the indicated prime duration. Each plot shows both a best-fitting cubic regression function with its 95% confidence interval (22) and a superimposed linear regression function. (A and B) Data are from 67-ms SOA masked-priming conditions of experiments reported by Greenwald and Draine (9, 21), and (C) from two additional experiments that included conditions with 50-ms prime durations and 67-ms SOAs (23). Direct measures of prime perceptibility are from separate (later) blocks of trials on which subjects were asked to discriminate either lexicality (whether stimuli presented between premask and postmask were (A) words versus strings of alternating X’s and G’s (for example, XGXGX) or (C) words versus digits) or semantic meaning (whether masked stimuli were (B) words of pleasant versus unpleasant meaning or male versus female first names). Sensitivity (d*) values for direct measures were computed by treating one category (for example, words) as signal and the other (for example, digits) as noise, such that guessing word in response to a digit stimulus would be treated as a false alarm. Indirect measure (priming) d’ values were computed by scoring a hit when (say) a male-name response was given on a trial with a male-name prime, and a false alarm when a male-name response was given on a trial with a female-name prime. Printed numerical intercepts are those for the linear regression in the panel; N, number of subjects (scatterplot points).
priming. Figures 2 and 3 show that the latter two findings for subliminal priming are markedly different from the data patterns observed for priming by visible words.

These findings relate closely to two long-established categories of findings: (i) The central nervous system monitors stimuli outside its current focus of attention, as evidenced (for example) by humans’ facility in switching attention to a previously unattended sensory channel when important or unexpected content appears in that channel (16); and (ii) visual backward masking (postmasking) interrupts processes that are understood as the transfer of information from a sensory buffer to working memory. Both of these findings were central to the information-processing era, developed in the 1950s and 1960s, that started the modern era of cognitive psychology (17).

Stated in terms borrowed from the information-processing era, one can understand the postmask as interrupting transfer of information about the prime stimulus to sensory buffer to working memory. (In the older paradigm, working memory was sometimes interpreted as an equivalent of conscious awareness.) This hypothesized interruption of transfer explains both the lack of conscious perception of the prime and its lack of persisting effects, particularly the absence of any effect of prior-trial prime-target congruence on current-trial magnitude of priming (Fig. 3). Although the postmask disrupts conscious perception of the prime, it does not prevent semantic activation. The occurrence of semantic activation by consciously unperceived primes indicates that this semantic activation does not depend on the prime reaching working memory (awareness). However, this semantic activation is shown to be a very evanescent phenomenon by the sharply decreasing function (Fig. 2) that relates subliminal priming to SOA (18).

The rapidity of the rise and fall of subliminal semantic activation described here exceeds even the briefest persistence previously demonstrated in cognitive psychology—the approximately 250-ms persistence of unattended visual sensory memory in light-adapted observers (19). Although this approximately tenth-of-a-second flicker of subliminal semantic activation has been described here as a property of stimuli that do not achieve conscious awareness, it remains possible that it is also a property of visible stimuli that are masked after a brief presentation. Findings obtained with mutually masking rapid successions of visible stimuli similarly suggest a brief duration of semantic activation (20).

**Fig. 2.** Magnitude of subliminal and supraliminal priming as a function of prime-target SOA. The measure of priming is the same signal-detection measure of sensitivity of target responses to prime meaning shown in Fig. 1. Error bars give 95% confidence intervals. Data are from experiments in which (A) both supraliminal and subliminal primes were measured and (B) only subliminal priming was measured. Prime duration was constant at 50 ms in all experiments. The results show supraliminal priming to be obtained strongly at SOAs as long as 400 ms, whereas subliminal priming decreased sharply at SOAs >100 ms.

**Fig. 3.** Magnitude of priming after immediately prior congruent versus incongruent priming trials. Priming magnitudes are presented in the same format as those in Fig. 2. The supraliminal priming data are from normasked conditions in which prime duration was 50 ms and SOA was 150 ms, whereas the subliminal priming data are from visually masked conditions that produced largest subliminal priming effects (prime duration = 50 ms, SOA = 67 ms). The results show that for supraliminal priming (but not subliminal priming), a prior incongruent trial weakens priming relative to a prior congruent trial.

**REFERENCES AND NOTES**


8. The term subliminal implies a threshold, or limen, that has been superseded in modern psychology as a consequence of the influence of signal detection theory [D. M. Green and J. A. Swets, Signal Detection Theory and Psychophysics (Wiley, New York, 1967)]. The term “marginally perceptible” carries less excess meaning in designating the class of stimuli that appear to evade conscious perception. We nevertheless use “subliminal” because of its widespread nontechnical use to designate marginally perceptible stimuli and because it continues to be used routinely in psychology even by those who no longer accept the concept of well-defined thresholds.


10. Subjects, all of whom were University of Washington undergraduates, gave consent to participation after having read a preliminary description of experimental procedures.

11. On each trial of the task, a prime word (either a male or female name, or a pleasant or unpleasant word) was brieﬂy displayed and, after a variable short delay, the target word (a different first name or a different affectively polarized word) was presented. Prime and target words were randomly selected on each trial with two constraints: (i) no target word was presented twice in any block of SOAs, and (ii) the proportion of congruent trials (prime and target having the same affective meaning) was constrained to an average of 50%. One hundred different stimuli (words or names) were used for each categorization task. In each task one subset of 50 served as primes and the remaining 50 served as targets, with these assignments appropriately counterbalanced across subjects. Examples of stimuli are as follows: unpleasant (corpse, kill, bomb), pleasant (honor, happy, kiss), male (Mike, David, Kevin), and female (kate, Mary, Sarah). The subject’s instructed task was to classify the target word by pressing a key on the left or right side of a computer keyboard (for example, left key to indicate unpleasant and right key to pleasant). After a few blocks of 10 to 20 trials each for practice with the categorization task, subjects started to practice producing their responses during a “response window” that was initially established as the interval from 383 to 517 ms after onset of presentation of the target word. Some of the experiments took advantage of speed-accuracy trade-offs [W. A. Wickelgren, Acta Psychol. 41, 67 (1977); S. A. Doshi, Cognit. Psychol. 13, 551 (1981)] by shifting the term-
Parallel and Antiparallel (G-GC), Triple Helix Fragments in a Crystal Structure

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Nucleic acid triplexes are formed by sequence-specific interactions between single-stranded polynucleotides and the double helix. These triplexes are implicated in genetic recombination in vivo and have application to areas that include genome analysis and antigen therapy. Despite the importance of the triple helix, only limited high-resolution structural information is available. The x-ray crystal structure of the oligonucleotide d(GGCAAT TGG) is described; it was designed to contain the d(G-GC)3 fragment and thus provide the basic repeat unit of a DNA triple helix. Parameters derived from this crystal structure have made it possible to construct models of both parallel and antiparallel triple helices.

12. Because preliminary findings revealed that direct measure performance was depressed by the requirement to respond rapidly, the response window procedure was not used during blocks of trials that obtained direct measures. Different discrimination tasks produced similar results.

13. The conclusion that unconscious cognition is indicated by the presence of statistically significant inter- cortex effects in the regression analyses of Fig. 1 rests on a methodological analysis by A. G. Greenwald, M. P. Klinger, and E. S. Schuh.

14. The level of perceptibility of masked 50-ms primes can be found from the horizontal distribution of values in the lower panel of Fig. 1, A and C. Levels of direct measure performance corresponding to \( d' \) values < 1.0 are commonly associated with self-reports of No" or nonperceptibility. Findings of SOA effects closely resembling those in Fig. 23 were obtained when the plotted variable was changed to magnitude of intercortex effect from regression analysis; that is, statistically significant intercortex effects were found only for the 67-ms SOA. The intercept-effect alternative analysis confirms that the pattern in Fig. 23 for subliminal priming is a function of SOA and is indeed a pattern for unconscious priming. The plotted analysis in Fig. 23, which includes all subjects who received masked priming, is comparable to the analysis in Fig. 2A for subliminal priming for which regression analysis is not an appropriate method.

15. The result shown in Fig. 3 is related to one previously reported by J. Cheesman and P. M. Meri kel [Can. J. Psychol. 40, 343 (1986)]. They showed that subliminal priming was greater when there was a higher proportion of congruent priming trials in a block of trials. Subliminal priming showed no such effect. Their findings could be explained by the difference in two-trial sequential effects shown in Fig. 3.