DO SUBLIMINAL STIMULI ENTER THE MIND UNNOTICED?

TESTS WITH A NEW METHOD

Anthony G. Greenwald and Sean C. Draine

University of Washington

Acknowledgment: Research reported in this chapter was partially supported by grants from National Institute of Mental Health (MH-41328) and National Science Foundation (DBC-9205890). A report based on this research was presented at the meetings of the Psychonomic Society in Washington, DC, November 5, 1993. Portions of the introduction closely resemble passages in Greenwald, Klinger, and Schuh (in press), to which the topic of this report is closely related.

Abstract. Existing methods to test for subliminal activation by undetectable stimuli have been criticized as intrinsically inconclusive. A new method, analyzing the regression relation between direct and indirect measures of responses to near-threshold stimuli, overcomes these criticisms. Obtained results indicated that subliminal stimuli, even when unnoticed, influenced consciously guided performances. Several potential criticisms of the new method are considered, but are found not to undermine this conclusion.

DO SUBLIMINAL STIMULI ENTER THE MIND UNNOTICED?

TESTS WITH A NEW METHOD

In the last decade there has been a dramatic increase in the acceptability of theoretical interpretations of research findings in terms of unconscious cognition. Part of the shift is in language — many psychologists have become willing to use the word *unconscious* in sentences that, previously, would have been acceptable only by using alternate terms such as "unattended," "automatic," "procedural," or "implicit." However, to characterize this recent change as being just a matter of linguistic style would be to underestimate it severely. There has also been a conceptual and empirical revolution. An important factor in this revolution has been the demonstration of replicability for a class of findings that, until very recently, were widely regarded with great skepticism — findings of *subliminal semantic activation* (see Balota, 1983; Bornstein, 1992; Dagenbach, Carr, & Wilhelmsen, 1989; Fowler, Wolford, Slade, & Tassinary, 1981; Greenwald, Klinger, & Liu, 1989; Groeger, 1988; Hardaway, 1990; Marcel, 1983). Subliminal semantic activation (SSA) can be defined as "indirect evidence for analysis of semantic content of target word stimuli under conditions that limit or prevent awareness of the presence of these words" (Greenwald, 1992, p. 768).[1]

Although at least some types of SSA are now treated by many experts as replicable phenomena (see Greenwald, 1992, p. 779), SSA continues to be the focus of controversies. Debate over proper *description* of SSA findings is central to these controversies. Studies of SSA often examine effects of marginally perceptible stimuli on actions the subject is instructed

---

[1]The term *subliminal* implies a theory of the perceptual threshold or (limen) that is no longer justified in the modern era of signal detection theory (Green & Swets, 1966). A more theoretically neutral designation of the class of stimuli with which this chapter is concerned is *marginally perceptible*. The chapter uses "subliminal" and "marginally perceptible" as interchangeable designations.

to perform (direct effects), while concurrently observing uninstructed (indirect) effects that are interpreted as likely indicators of unconscious semantic activation. In a 1986 review, Holender argued that strategies being used by researchers to assess direct effects of marginally perceptible stimuli in SSA studies were insufficiently sensitive to conscious stimulus effects and, consequently, Holender judged the then-available evidence to be inadequate for assessing crucial details of relationships between direct and indirect effects (see also Merikle, 1982; Purcell, Stewart, & Stanovich, 1983).

A Holy Grail of Subliminal Activation Research

A *direct effect* of a stimulus is its effect on an instructed response, typically assessed by a measure of accuracy at the instructed task. By contrast, an *indirect effect* is an *un*instructed effect of the task stimulus on behavior, and is often assessed by including an irrelevant or distracting component in the task stimulus, then measuring influences of this distractor on latency or accuracy of instructed responses to it. As illustration, a very well known indirect effect is the increased latency of response observed in Stroop's (1935) task of naming the color of ink with which a word is printed, caused by (the task-irrelevant stimulus of) that word being the name of a different color.

It has been an elusive goal of SSA research to demonstrate an indirect effect of word stimuli under conditions that preclude any direct effect. Claims to have achieved this long-sought *indirect-without-direct-effect* data pattern have often been met with skeptical appraisals (e.g., the appraisals by Greenwald, 1992; Holender, 1986; Merikle, 1982; Reingold & Merikle, 1988; Purcell, Stewart, & Stanovich, 1983).

In order to argue that a set of data demonstrate an indirect effect in the absence of a direct effect, it has been necessary for researchers to claim that a null result has been achieved. In particular, the claimed null result is that the experiment's stimulus presentation conditions had no influence on the direct measure. Such a claim is susceptible to the familiar criticism of inappropriately asserting the truth of a null hypothesis. For this reason, the strongest statistical claim that can be made from existing attempts to demonstrate the indirect-without-direct-effect pattern is that an indirect effect occurred when performance on a direct measure was very likely within some range that included the value of zero. Of course, even stated in that cautious way, the claim may be quite impressive if enough data have been collected to make the statistically credible margin around zero a small one.

Regression Method for Seeking the Indirect-without-direct-effect Pattern

The research reported in this chapter used a data-analysis strategy that bypasses the usual statistical problems associated with asserting the truth of a null hypothesis. The major innovation in this method was to analyze data using tests of the regression relationship between direct and indirect measures. This regression relationship can be described by a plot of the equation that relates expected scores on an indirect measure to observed scores on a direct measure. Figure 1 illustrates some of the linear functions that might be revealed by regression analysis.

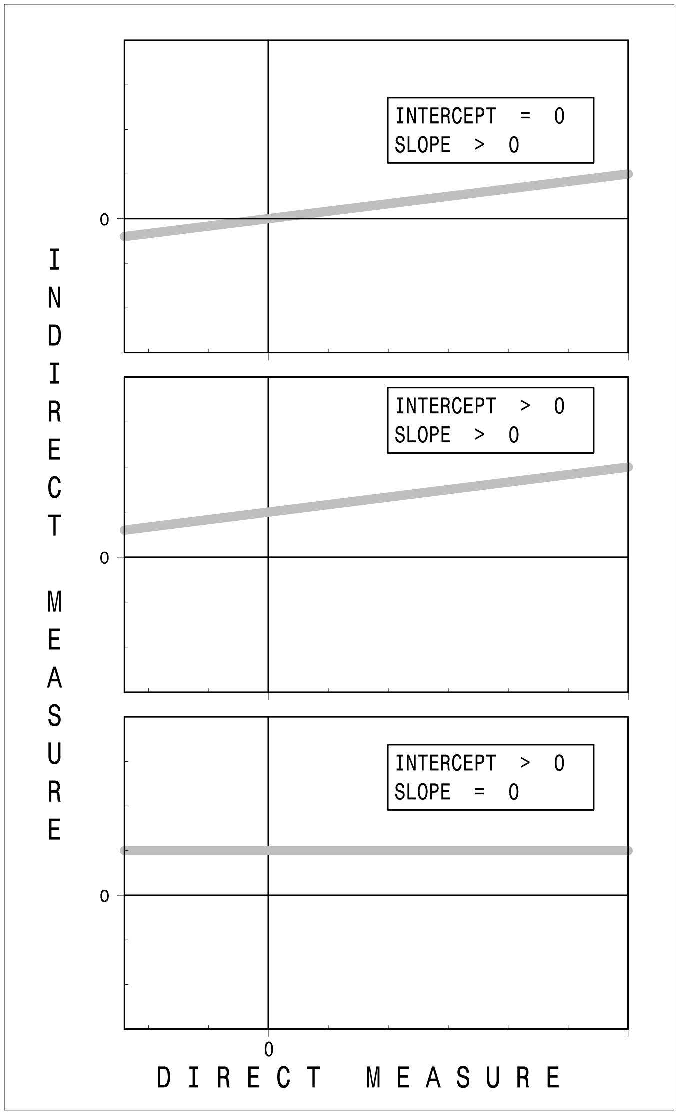

Figure 1. Some expectations of data patterns for linear regression of an indirect measure on a direct measure.

Regression functions such as those in Figure 1 provide answers to questions of the form, "What is the level of performance on the indirect measure that is associated with some specific level of performance on the direct measure?" If, for example, one wishes to know what level of performance on the indirect measure is associated with the *mean* level of performance on the direct measure, the answer will be the mean of the indirect measure. The significance test for the (null) hypothesis associated with this question, i.e., the significance test for the hypothesis that *level of performance on the indirect measure associated with mean performance on the direct measure = 0*, is the usual statistical significance test for the difference of the mean of the indirect measure from zero. In order to test for the indirect-without-direct-effect pattern, the level of performance on the indirect measure associated with the value of *zero* on the direct measure can be tested for the significance of its difference from zero. The sought value in this case is the intercept of the regression equation (the place at which the regression function crosses the vertical axis), and the needed significance test is usual test of statistical significance (of difference from zero) for this intercept.

This regression analysis strategy entirely reverses the usual difficulty associated with asserting the truth of a null hypothesis. In the context of the regression strategy, researchers who claim that the indirect-without-direct-effect pattern does *not* exist are the ones left in the position of claiming the truth of a null hypothesis. In particular, they must claim that the regression relation passes through the origin, thereby asserting truth of the null hypothesis that the intercept is equal to zero.

METHOD

The data to be used with the regression-analysis method described above were obtained from three experiments in which subjects' main task was to detect 4-letter words that were accompanied by simultaneous dichoptic masking (see Figure 2). In Experiments 1 and 2, subjects performed at a detection task in which they pressed a key with the right index finger when they judged that a word was presented, or a key with the left index finger when they judged that no word was presented. Experiment 3 also included a detection task; however, for half of the subjects, the assignment of response keys was reversed so that key-presses with the left index finger indicated that a word was presented, and key-presses with the right index finger indicated that no word was presented. All words were four letters in length. By using effective masking conditions, performance on the detection task was reduced to a low value for most subjects, but was nevertheless allowed to vary across subjects. Responses to the stimuli `LEFT` and `RIGH` (shortened from `RIGHT` so that stimulus width was constant for all stimuli at four characters) , which were used on a subset of trials in Experiment 1, and on all trials in Experiments 2 and 3, provided the basis for an indirect measure of semantic activation. Specifically, the indirect measures assessed the extent to which the stimuli `LEFT` and `RIGH` directed subjects' responses to the left and right response keys, independently of their instructed task.

The direct measure was the signal detection analysis measure of *d'*, which is based on hit and false alarm rates. For purposes of having comparable units, the indirect measure was also computed as a *d'*, by counting presses of the right key in response to `RIGH` as hits, while counting presses of the right key in response to `LEFT` as false alarms. (The same value of *d'* would result from treating left-key responses to `LEFT` as hits, and left-key responses to `RIGH` as false alarms.)

Subjects

For the series of three experiments, a total of 881 undergraduate students from lower-level psychology courses at University of Washington volunteered in exchange for a modest course credit. Data for 29 subjects were discarded prior to conducting hypothesis tests, either because of equipment malfunction or because they volunteered to the experimenter at the conclusion of the experiment that they had deliberately closed one eye at some time during the experiment. This left analyzable data for 431 subjects in Experiment 1, 175 subjects in Experiment 2, and 246 subjects in Experiment 3.

Apparatus and Masking

Up to three subjects participated concurrently, each in a small (1.5m by 2.5m) room containing a table on which was a 33-cm (diagonal) color monitor and keyboard controlled by an IBM/AT-type (80286) computer. Subjects viewed a color (Enhanced Graphics Adapter [EGA]) display through a viewing apparatus that presented the images from the left and right halves of the display screen to the left and right eyes, respectively. (The same type of apparatus was used by Cheesman & Merikle, 1986; Greenwald & Klinger, 1990; and Greenwald, Klinger, & Schuh, in press.)

The apparatus obliged subjects to view the computer's display from a distance of 65 cm, through rotary prisms that were adjusted to superimpose the left-eye and right-eye images. Stimuli (such as instructions) that were presented simultaneously to both halves of the screen were easily viewed with binocular fusion. The placement of the keyboard, on the table that supported this viewing apparatus, allowed the subject to press the "A" key with left forefinger and the "5" key (on the keyboard's numeric keypad) with right forefinger, these keys being marked with green adhesive dot labels. All responses to the major experimental tasks were made with just these two keys.

Masks were constructed using items in a software-fabricated "character set." Each item in the software character set was composed by blackening selected pixels in the 8 (horizontal) X 14 (vertical) pixel array that comprises a character space for the EGA-interface display. These fabricated characters were constructed so that, with appropriate side-by-side and top-to-bottom juxtapositions, regularly spaced gratings oriented vertically, horizontally, or in either diagonal direction could be constructed. However, rather than using regular grating-like masks, masks were constructed by randomly selecting, on each trial and with replacement for each position in a 3 row X 15 column rectangular array, elements corresponding to a selected thickness. Sample masks are shown in Figure 2.

Figure 2. Examples of mask patterns and letter strings used in experiments. These masks are not as wide as those actually used, and frames have been added to facilitate the reader's simulating the effect of dichoptic masking. By de-converging eyes (as if focusing on a more distant object) while looking at a mask+word pair from about 8 in., the reader should be able to superimpose the two, subjectively seeing three rectangles side by side (as in Examples 1–3 at the bottom). If two of these three rectangles contain a word, as in Example 1, then the eye it names is (at least at the moment) dominant. Example 3 shows the subjective appearance if the right eye is dominant when looking at the topmost mask+word pair. An apparent mixture of the two images in the middle rectangle (as in Example 2) may also occur, and simulates the experience of some subjects in the present research. The topmost mask is made of mask elements 5 pixels thick and the one below it is of elements 2 pixels thick. The reader may find that the mask with 5-thick elements more effectively obscures the word than does the mask with 2-thick elements, when mask and word are superimposed.

Procedure

Although the detection task is the focus of this chapter, all experiments included at least one additional task that provided an alternative direct measure. For example, an additional task used in all experiments was position discrimination, which required subjects to judge whether a dichoptically masked 4-letter word was displayed to the left or right of a fixation point. Critical trials with stimuli LEFT or RIGH were included in the position discrimination task, much as for the detection task.[2]

In all experiments, the first task (detection in Experiment 1, position discrimination in Experiments 2 and 3) included practice at 120 trials of masked displays, and permitted adjustment of masking conditions (usually by making them more difficult) contingent on the subject's performance on a direct measure. Next came two blocks of trials of the experiment's second task, which was position discrimination in Experiment 1. Experiment 1 continued alternating sets of two blocks of trials of its two tasks, until a total of 4 post-practice blocks (56 trials each) had been completed for both tasks.

In Experiment 2, after the 120 trials of position discrimination practice, data were collected for a block of 50 trials of position discrimination, followed by 50 trials of the detection task, 50 trials of a lexical decision task, and 50 trials an evaluative decision task, and then a second round of 50-trial blocks for each of these four tasks. Each new task was preceded by 10-20 practice trials to assure that subjects understood its instructions. The major purpose of the additional tasks in Experiment 2 was to provide alternative direct measures that were used in regression

---

[2]The position-discrimination data from Experiment 1, along with those from several other experiments that did not include a detection task, were reported by Greenwald, Klinger, and Schuh (in press). Greenwald et al. (in press) reported regression analyses for the position-discrimination task that paralleled those for the detection task reported in this chapter.

analyses. Results from these alternative analyses are described briefly in the Discussion, below.

After practice with the position discrimination task in Experiment 3, data were collected for two 50-trial blocks of position discrimination, after which were two 50-trial blocks of the detection task. After these, there were two more blocks of each task, so that subjects completed 200 trials of each task, not including the initial practice at position discrimination.

In all experiments, all stimulus parameters that could vary across trials within any block of trials (especially side to which the mask was presented and stimulus identity) were varied by an on-line randomization routine that resulted in a unique sequence of trials for each subject. There were four potentially important differences among procedures for the three experiments.

First was the manner in which stimuli were positioned for the detection task. In Experiment 1, detection stimuli were positioned alternately to the left or right of the fixation point, just as for the position discrimination task. This variable positioning (which subjects knew about from instructions and practice) is unusual for a detection task, and was done in order to use exactly the same stimuli for the detection and position discrimination tasks. Experiments 2 and 3 permitted the potential replication of findings of Experiment 1 using a more standard stimulus presentation for the detection task, with all stimuli centered on the fixation point.

Second, in Experiments 2 and 3, *all* stimuli were critical stimuli (i.e., *only* `LEFT` and `RIGH` were used as stimuli for the detection task), which permitted more powerful tests of indirect effects with fewer trials overall.

Third, in Experiment 1, data for indirect measures were obtained only on trials using masks to the subject's dominant eye (i.e., the eye to which the mask was observed to be more effective during the practice phase). By contrast, in Experiments 2 and 3 critical trials were presented to both eyes, allowing both direct and indirect measures to be obtained with masking to each eye. The data for Experiments 2 and 3 were analyzed separately for mask to left eye and mask to right eye.

Fourth, whereas all subjects in Experiments 1 and 2 were instructed to press a key with their right finger to indicate word-presence and their left finger to indicate word-absence, Experiment 3 included a between-subjects manipulation of response key assignment. Thus, approximately half of the data in Experiment 3 were collected using the key assignment of Experiments 1 and 2 (hereafter referred to as the *standard* assignment), and half were collected using the *reverse* key assignment (left key response to indicate word-presence, and right key response to indicate word-absence). The manipulation of key assignment was used to control for the possibility of bias in indirect measures that could have been caused by differences in the detectability of the specific stimuli, RIGH and LEFT. Note that indirect effects of semantic activation on detection judgments are shown by relatively more right-key responses when the stimulus is RIGH, rather than LEFT. With the standard key assignment, the same pattern of responses would also be expected if RIGH were more detectable than LEFT. That is, there would be more right-key (i.e., word-present) responses to RIGH. With the reverse key assignment, the effect of RIGH being more detectable than LEFT would be relatively more *left* key responses to RIGH. Thus, the variation of key assignment in Experiment 3 permitted the influence of possible differential detectability of RIGH and LEFT to be distinguished from semantic priming.

Each experiment's procedure involved a total of 550-600 trials divided among the various tasks. Each experiment required about 50 min. to complete, with some variation in session durations resulting from subjects being allowed both to self-initiate trials and to rest ad lib between blocks of trials. Subjects going at the most rapid rate could initiate new trials about 1 s after response to the prior one.

Analysis Strategies

Because of concern that tests of intercept effects might be sensitive to the presence of outlying scores in either direct or indirect measures, more than thirty regression analyses were conducted for each experiment, using alternative criteria for trimming the predictor and criterion *d'* measures. The direct measure (the predictor variable) was trimmed on its high-accuracy end, based on reasoning that subjects scoring extremely high on this measure were unlikely to show any unconsciously mediated effects on the indirect measure. Two levels of trimming were done on the direct measure, either eliminating scores of *d'* greater than 3.29 (corresponding to about 95% correct responding) or greater than 2.5 (corresponding to about 90% correct responding). Neither slope nor intercept estimates varied more than slightly between these two levels of trimming.

There were two justifications for trimming the indirect measure (the criterion variable). The first reason was to avoid problems stemming from the possibility that a few subjects had misunderstood the instructions — mistakenly believing that their task was to press the right key if they saw `RIGH` and the left key if they saw `LEFT`— and, as a result, had shown unusually high scores on the indirect measure. The second reason was to reduce the variance of the measure, which in turn increased the power of both regression slope and intercept tests. To avoid biasing tests of the intercept effect, subjects were dropped in equal number from both the high and low ends of the distribution. In various tests, between 0% and 4.8% (Experiment 1) or 11.4% (Experiment 2) or 0.5% (Experiment 3) were trimmed from each tail of the criterion indirect measure. In Experiments 1 and 2, degree of trimming of the indirect measures in had no systematic effect of increasing or reducing numerical values of intercepts, but greater trimming did tend to produce higher *t* values (and, therefore, lower *p*-values of significance tests) because of reduced error variances. In Experiment 3, greater trimming was associated with both larger numerical intercept values and higher *t* values.

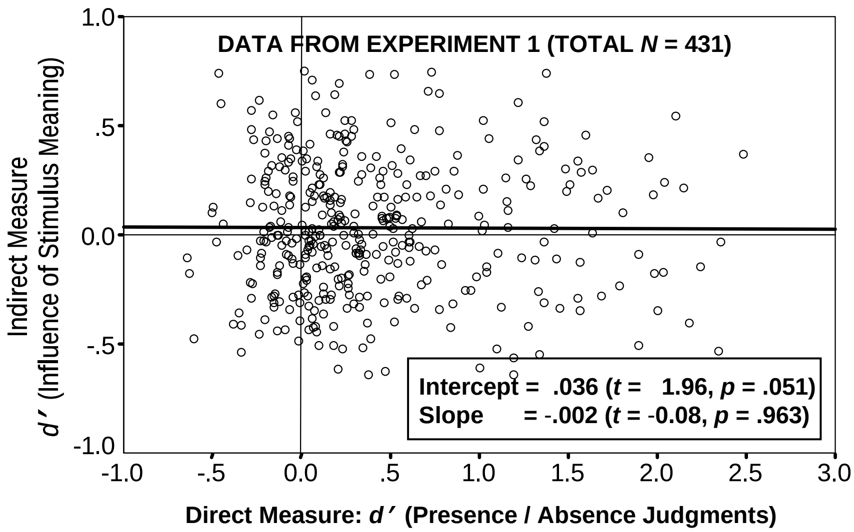

Figure 3. Regression test for Experiment 1 showing indirect measure ($d'_{(i)}$, based on response to position meaning of `LEFT` or `RIGH`) as a function of direct measure ($d'_{(d)}$, based on position discrimination accuracy for dichoptically masked left- or right-positioned 4-letter words). The scatter plot is for a representative analysis of the experiment's data (see text).

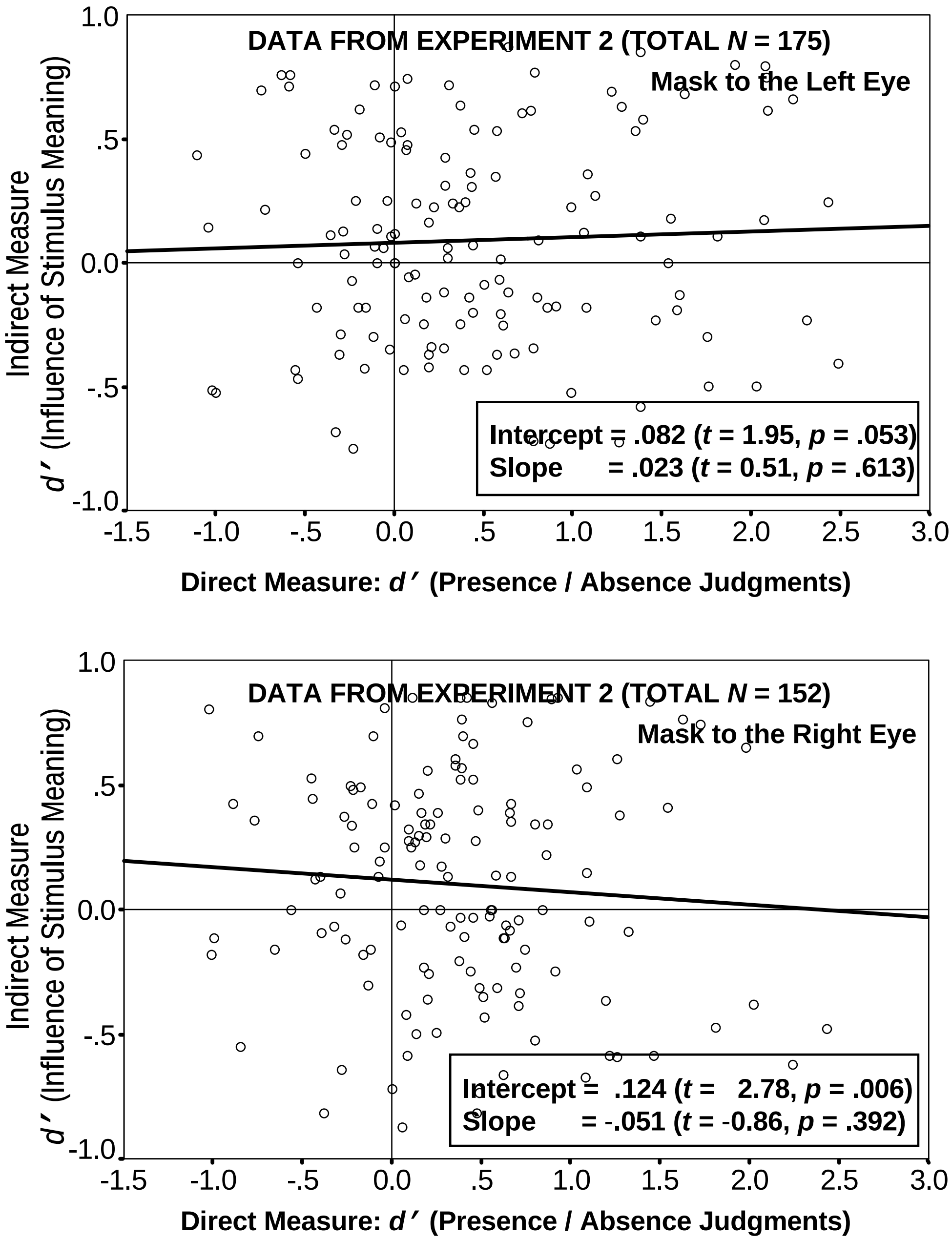

Figure 4. Regression tests for Experiment 2, presented separately for data collected with mask to left eye and mask to right eye. (See Figure 3 caption.)

RESULTS

Experiments 1 and 2. Figures 3 and 4 give results that are representative of the sets of analyses done with varying degrees of trimming on the direct and indirect measures, described just above. Figure 3 presents an analysis with an intercept test that is right at the conventionally significant *p*-value of .05, two-tailed. (This was selected as representative because most of the analyses fell near this value, but not consistently either above or below it.) The analyses presented in both figures dropped cases with *d'* scores greater than 2.5 on the direct measure. For Figure 3, the presented analysis of Experiment 1 also dropped the extreme 3.2% (14 cases) from each tail of the indirect measure, and for Figure 4 the presented analyses of Experiment 2 dropped the extreme 8.6% (15 cases) from each tail of the indirect measure. Figure 4 gives two analyses for Experiment 2, one based on trials with mask presented to the left eye, the other based on trials with mask to the right eye.

Significance tests and effect sizes. For all regression analyses of Experiments 1 and 2, the value of the intercept was positive. The *t* values of the intercept test for the three tests were, respectively, 1.96 (df=394, *p*=.051), 1.95 (df=133, *p*=.053), and 2.78 (df=135, *p*=.006), for Experiment 1, Experiment 2 with mask to left eye, and Experiment 2 with mask to right eye. Considered as effect sizes using a **d** statistic (intercept value divided by the untrimmed standard deviation of indirect measure), these intercepts corresponded to **d** values of .095, .134, and .183, approximating the level conventionally regarded as "small" (**d**=0.2; Cohen, 1977).

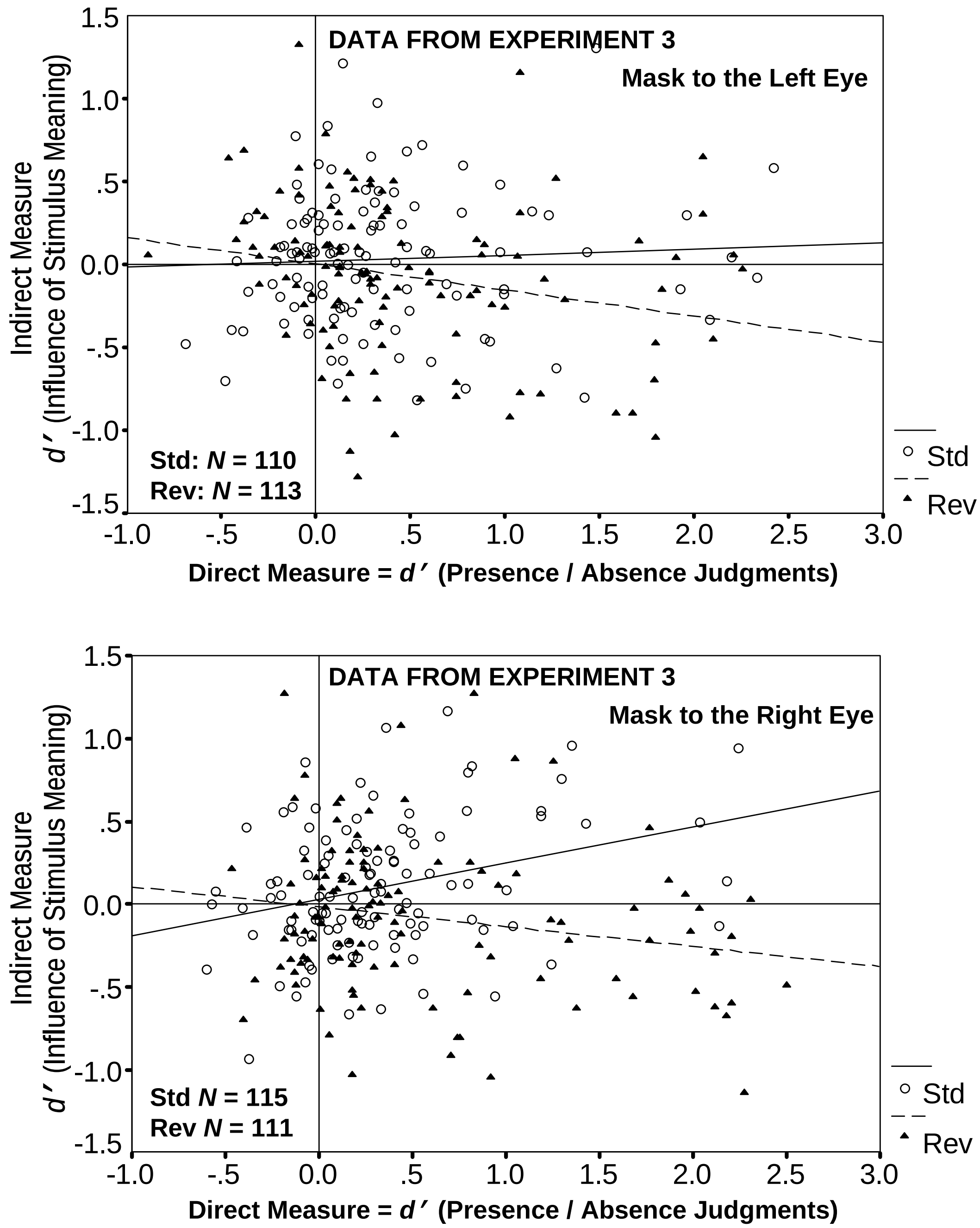

Figure 5. Regression tests for Experiment 3, presented separately for data collected with mask to left eye and mask to right eye. Analyses are further broken down according to response key assignment conditions. The black and gray lines show the best fitting linear regression for the standard and reversed key assignment conditions, respectively. Data from the scatter plot are shown as open circles for the standard condition and triangles for the reversed condition. Significance tests and parameter estimates for the intercepts and slopes are reported in the text.

Experiment 3. Figure 5 shows two analyses for Experiment 3 — one based on trials with mask presented to the left eye, the other based on trials with mask to the right eye. As with the previous experiments, cases with *d'* scores greater than 2.5 on the direct measure were dropped from the analysis. In addition, analyses were conducted using various criteria for trimming indirect measures. In contrast to analyses of Experiments 1 and 2, however, greater trimming of indirect measures from Experiment 3 had the systematic effect of increasing the size of intercept parameters. Thus, in the analyses reported below, only one extreme case from each tail of the indirect measure was dropped from the trials with the mask to the right eye.

Significance tests and effect sizes. Consistent with the previous two experiments, analyses of the standard key assignment condition showed positive intercept values of .025 and .028 with the mask to the left and right eye, respectively. The *t* values associated with the intercept tests were 0.55 (df=108, *p*=.58) with left-eye masking and 0.67 (df=109, *p*=.50) with right-eye masking, neither of which approached statistical significance. The effect sizes corresponding to the intercepts of the standard condition were **d** = 0.058 and **d** = 0.063 with masks to the left and right eye, respectively. In contrast, analyses of the reversed condition revealed negative intercept values of –0.001 with left-eye masking and –0.23 with right-eye masking, with associated *t* values of –0.02 (df=113, *p*=.98) and –0.45 (df=115, *p*=.65), respectively. The effect sizes for both left and right masks in the reversed condition were also small, with associated **d** values of –0.002 and –0.051.

As can be seen in Figure 5, the slopes of the regression functions in Experiment 3 appeared to differ between the standard condition (positive slopes) and the reversed condition (negative slopes). The standard condition yielded a slope of .035 with the mask to the left eye (*t*=0.54, *df*=108, *p*=.59), and .219 with the mask to the right eye (*t*=3.3, *df*=109, *p*=.001). In the reversed condition, the slope was –.117 with masking to the left eye (*t*=–1.81, *df*=113, *p*=.07), and –.112 with masking to the right eye (*t*=–1.99, *df*=115, *p*=.048). This difference in slopes is discussed a few paragraphs below.

DISCUSSION

The intercept effects obtained in Experiments 1 and 2 conformed to the pattern sought as demonstrating an indirect effect in the absence of a direct effect. If these results validly warrant the conclusion that indirect effects indeed occurred in the absence of direct effects, then a *yes* answer to the title question of this chapter ("Do subliminal stimuli enter the mind unnoticed?") is justified. However, the strength of the case for that interpretation is moderated by nonreplication of the intercept effect in Experiment 3. Given that the procedures of the standard key assignment condition in Experiment 3 matched those of Experiment 2 in all but a few minor details, no obvious explanation — beyond the uninformative one of Type II error, possibly due to Experiment 3 having the smallest N of the three experiments — is available for its failure to replicate the findings of the previous two experiments.

Implications of Experiment 3

The difference between regression functions across the two key assignment conditions indicated that subjects were more likely to indicate the presence of `RIGH` than of `LEFT`. Further, the slopes of these regression functions indicated that, as overall detection performance diminished, so did the relative advantage in detectability of `RIGH` over `LEFT`. This trend was corroborated by additional analyses, including a series of contrasts between detection performance for `RIGH` and `LEFT` based on subject samples with increasingly poorer overall detection performance.

For example, *overall* mean detection performance for RIGH was greater than for LEFT with left-eye masking (difference=.050, t=1.71, p=.089) and right-eye masking (difference=.098, t=3.53, p=.001). However, when contrasts were restricted to data points (subjects) with detection performance lower than d' =0 .5, the difference in detection performance between LEFT and RIGH was much reduced for both left-eye (difference=.023, t=.69, p=.49) and right-eye (difference=.036, t=1.21, p=.229) masking conditions.

Is it possible that the intercept effects obtained in Experiments 1-2 were caused by RIGH being more detectable than LEFT, rather than by the semantic content of these words? Under close scrutiny, this possible conclusion appears both theoretically and empirically implausible. Theoretically, in order to dismiss the intercept effects as artifacts of differences in stimulus detectability, it is necessary to claim that RIGH was more detectable than LEFT when stimulus presentation conditions made the words *undetectable overall*. That is, when average detection performance for both words was at chance, the word RIGH must nevertheless have been more detectable than the word LEFT. This, however, could only be true if LEFT was *less* easily detected than no stimulus at all. Given the perplexity of such an argument, a more plausible explanation of the intercept effects of Experiments 1 and 2 is that they were caused by the differing semantic content of the word stimuli. Empirically, the evidence for difference in detectability of LEFT and RIGH in Experiment 3 was statistically inadequate for precisely the range of scores on the direct measure for which this difference would have to be statistically significant in order to provide an alternative interpretation of the Experiment 1 and 2 intercept effects. In other words, differences in detectability of LEFT and RIGH appear capable of explaining slope effects, but not intercept effects, in the regression analysis.

Evidence from the Position Discrimination Task

Because the stimuli LEFT and RIGH were confounded with key-assignment in Experiments 1 and 2, it is impossible to separate the effects of differences in detectability from effects of semantic priming for the detection-task data of those experiments. However, the position discrimination tasks in Experiments 1 and 2 did permit differences in stimulus detectability to be tested independently of priming effects. This was possible because the direct measure in the position discrimination task required both left and right key presses in responses to the stimulus RIGH, as well to LEFT, depending only on the position of those stimuli. If RIGH was more detectable than LEFT, then position-discrimination performance when the stimulus was RIGH should have been superior to when it was LEFT.

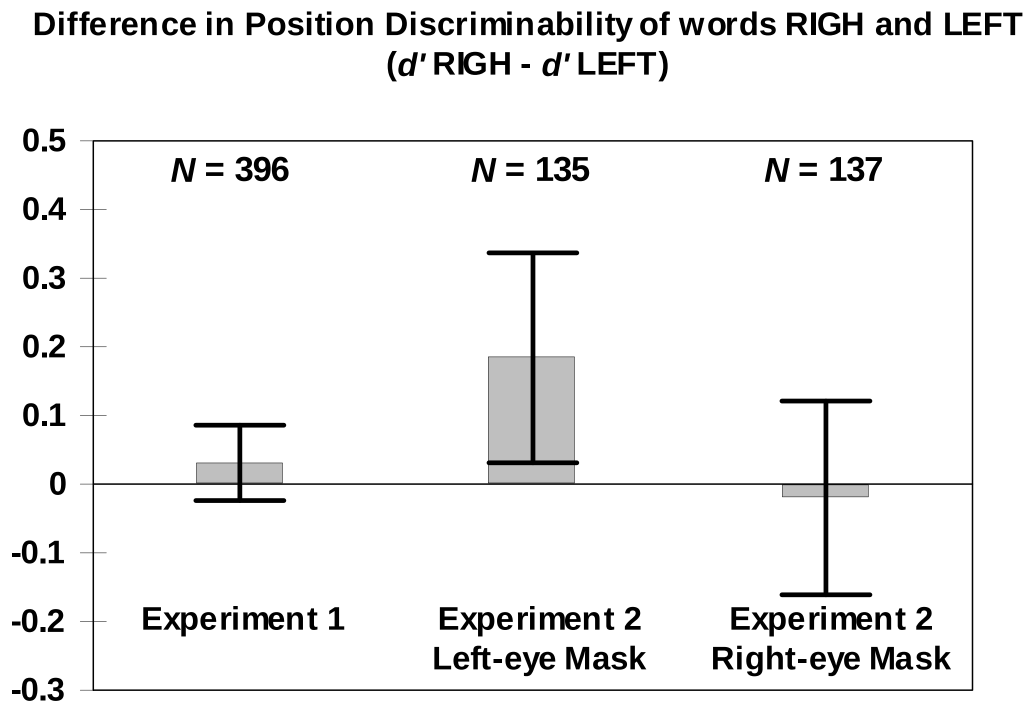

Figure 6. Difference in position discrimination accuracy (computed as *d*′) between trials with `RIGH` vs. `LEFT` as stimulus. The three tests are based on data from Experiment 1 and Experiment 2. Tests for Experiment 2 are presented separately for data collected with mask to left eye and mask to right eye. The horizontal axis represents *d*′ for trials with `RIGH` as stimulus minus *d*′ for trials with `LEFT` as stimulus. Error bars represent the 95% confidence interval corresponding to each test.

Figure 6 shows the differences in position discrimination accuracy for Experiments 1 and 2 between trials with LEFT as the stimulus and those with RIGH. The results from Experiment 1 showed no significant difference (difference=.032, t=1.11, p=.266) in accuracy of position judgments between the two stimuli, suggesting that differences in stimulus perceptibility did not influence performance in that experiment. Results from Experiment 2 are shown separately by mask-side. For trials with masking to the left eye, position discrimination accuracy was significantly greater when RIGH was the stimulus rather than LEFT (difference=.184, t=2.36, p=.019). However, with masking to the right eye, performance with RIGH was slightly *poorer* than that with RIGH, although this difference was not significant (difference= –.020, t=–.28, p=.783). The results, particularly those of the left-eye mask condition in Experiment 2, provide some indication that RIGH was more perceptible than LEFT. However, the failure of this pattern to emerge consistently across the three test conditions suggests that the difference in stimulus perceptibility is not robust, and may be influenced by minor the procedural variations existing across these conditions.

In sum, the argument that the intercept effects of Experiments 1-2 reflect differences in stimulus detectability is theoretically problematic and, also, difficult to integrate with empirical results from the position discrimination task in Experiments 1 and 2, and from the detection task for subjects whose detection scores were low in Experiment 3. Accordingly, the interpretation that intercept effects in Experiments 1 and 2 indicate unconscious semantic activation continues to appear valid.

Meta-Analysis of All Dichoptic-Masked Position Priming Studies.

Meta-analyses of the data from Experiments 1-3 were conducted by computing a weighted mean intercept value, i, with the formula,

$$i = \Sigma w_j u_j \div k \quad (1)$$

where u_j was the intercept value of the *j*th data set, *k* was the total number of data sets, and w_j was a weight for each data set. The weighted mean intercept was tested for statistical significance by transforming the one-tailed *p* values corresponding to the significance test of each intercept into *z* scores (see Rosenthal, 1993). The *z* scores were then combined to yield a single *z* using the formula,

$$z = \Sigma w_j z_j \div k^{-2} \quad (2)$$

where z_j was the *z* score of the *j*th data set, *k* was the total number of data sets, and w_j was a weight for each data set. A X^2 test for heterogeneity of effect among the four data sets was conducted using the formula

$$X^2 = \Sigma(z_j - z_{wm})w_j \quad (3)$$

where z_j was the *z* score of the *j*th data set, z_{wm} was weighted mean z of the data sets, and w_j was a weight for each data set. In both the tests for significance and for heterogeneity of effect sizes, the weight for each experiment was computed as

$$w_j = kdf_j \div \Sigma df_j \quad (4)$$

where df_j was the degrees of freedom for the *j*th data set, and *k* was the total number of data sets.

Because data from left and right eye masking conditions in Experiments 2 and 3 were collected from the same subject population, *z* scores from the two masking conditions were first combined, using formula 2, into a single *z* with corresponding *df* equal to the average *df* of the two conditions. The two key assignment conditions in Experiment 3, on the other hand, represented separate subject populations, and were therefore treated as separate data sets in the meta-analysis. Thus, meta-analytic tests of the intercept effects from the detection task were based on four *z* scores corresponding to the intercept effects of Experiment 1, Experiment 2 (left and right mask conditions combined), Experiment 3 with standard key assignment (left and right mask conditions combined), and Experiment 3 with reversed key assignment (left and right mask conditions combined). The meta-analytic test for significance indicated a strong overall intercept effect for the detection task (i=.039, z=3.38, p= .00036). The nonsignificant test for heterogeneity among the intercept effects suggested that these effects were homogeneous (X^2=4.93, df=3, p=.177)[3].

The present results from the detection task supplement the larger set of data that tested semantic activation in the position-discrimination task, reported by Greenwald, et al. (in press). Together, these two data sets include well over 2000 subjects, each participating in one of five versions of the position discrimination task, and thus provide a very powerful test of SSA effects obtained from position priming experiments using dichoptic masking. Using the meta-analytic techniques described above, the combined test of significance for the intercept effects of the position discrimination tasks of the two data sets indicated a strong aggregate effect (i=.020, z=3.85, p=.00006), but with some heterogeneity of effect sizes (X^2=10.88, df=4, p=.020).

Meta-analytic combination of the intercept effects from *both* the detection and position discrimination tasks indicated a highly robust aggregate effect (i=.025, z=5.14, p=.0000001) and, again, significant heterogeneity of effect sizes (X^2=15.52, df=8, p=.05). The mild heterogeneity of effects remains unexplained (see next paragraph). However, the meta-analytic tests for significance of the combined intercept effects demonstrate that those intercept effects, although small, are almost certainly *not* Type I errors.

---

[3]A second meta-analysis was conducted in which left and right eye masking conditions were treated as separate data sets. The resulting significance tests were consistent with those of the former procedure, yielding a weighted mean intercept of .040 (z= 3.52, p= .0002) with X^2= 8.146 (df=5, p=.23), indicating statistically acceptable homogeneity of findings across experiments.

Cautious Conclusion. The conclusion that the intercept effects in Experiments 1-2 demonstrate semantic activation must be stated cautiously. There is not yet a clear explanation for the failure of Experiment 3 to replicate the intercept effects observed in Experiments 1-2, and there was a similar unexplained failure to find an intercept effect in a portion of the position discrimination data of Greenwald, et al. (in press). At the same time, as demonstrated above, examinations of all available statistical tests of intercept effects — including the few nonsignificant effects — provide overwhelming support for the statistical significance of the intercept effect in the full combined set of relevant data.

Evaluation of Assumptions Underlying the Regression Analysis Strategy

Four assumptions underlie the regression method used here to conclude that indirect effects occur in the absence of direct effects of marginally perceptible stimuli. First, both the direct and indirect measures must have rational zero points. That is, zero values on both measures must indicate absence of their respective effects. Second, the relation between direct and indirect measures is assumed to be linear. Third, the predictor variable (in this case, detection accuracy) is assumed to be measured without error. Fourth, the logical analysis underlying use of the regression method to infer existence of unconscious cognition assumes that the direct measure is at least as sensitive as the indirect measure to consciously perceivable stimulus effects. Possible criticisms of the claim to have demonstrated the indirect-without-direct-effect data pattern and, with it, the existence of unconscious cognition, follow from possible error of these four assumptions. Consider now the possible failure of each assumption.

1. **Rational zero points**. The assumption of rational zero points is easily met, because the theory underlying the *d'* measure (i.e., signal detection theory) provides this property. At the

same time, it is reassuring that other measures that have rational zero values also produced the same pattern of positive intercept effects. In particular, the present analyses were repeated using both gamma and the very simple measure of hit rate minus false alarm rate, both of which also have zero values that indicate absence of stimulus effects. The analyses based on these two alternative measures yielded the same pattern of significant and nonsignificant results that were obtained with *d'*, and in some cases yielded even stronger evidence of statistical significance than did the *d'* measure.

2. **Linear relation between direct and indirect measures**. The assumption of linearity may well be wrong. However, because the regression method is readily extended to nonlinear functions, incorrectness of the linear-relation assumption need not be conclusion-damaging. In order to examine the possibility that a nonlinear function might provide a superior fit to the data, the regression method was used to test several forms of nonlinear functions, especially the quadratic (U-shaped) function that was observed in a subset of the data reported by Greenwald et al. (in press). In the present data, nonlinear effects were generally not apparent. In any case, analyses that fit nonlinear functions did not alter the statistical significance of intercept effects, nor did they alter magnitudes of intercept effects more than slightly.

3. **No measurement error in the predictor variable**. The assumption of error-free measurement of the predictor is very clearly invalid. Evidence concerning reliability of the predictor was obtained in Experiment 1, by computing the direct measure separately for trials on which the stimuli were `LEFT` or `RIGH`, and ones on which the stimuli were other 4-letter words. Although the reliability correlation between these two measures was high (*r*=.907), it was clearly less than perfect. Evidence for measurement error in the predictor is important because there are circumstances under which such error can cause a statistically significant intercept to

materialize when the true underlying regression function passes through the origin. This possibility is illustrated in Figure 7. However, a spurious intercept effect of the type illustrated in Figure 7 can appear only when (a) the true regression function has a markedly positive slope, and (b) the mean of the predictor is substantially above zero. For those regression analyses yielding significant intercept effects, shown in Figures 3 and 4, it can be seen that (a) regression slopes were essentially flat, and (b) the means of the predictor variables were not much above zero. As a result, measurement error in the predictor is not plausibly responsible for the statistically significant intercept effects of Experiments 1 and 2.

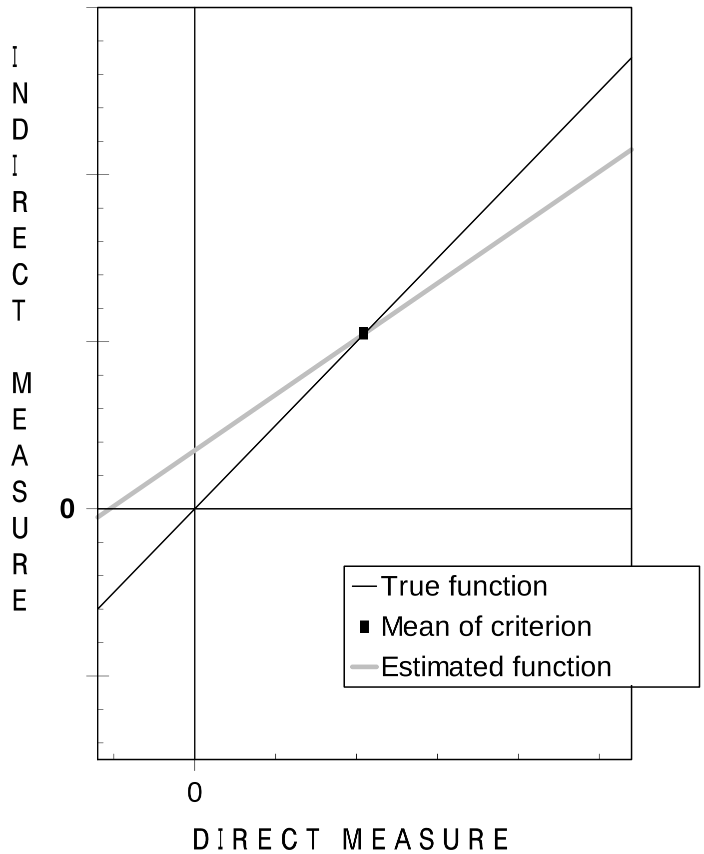

Figure 7. Possible effect of unreliability of the regression predictor variable on the estimate of the regression intercept (intersection with Y-axis). The predictor's unreliability causes the regression slope, but not the mean on the criterion variable — through which the function passes — to be slightly underestimated. This results in an overestimate of the intercept to the extent that (a) the predictor mean is greater than zero *and* (b) the regression slope is positive. An overestimate of the intercept should *not* have occurred in the present research, because observed regression slopes were approximately flat (see plotted slopes in Figures 3 and 4).

4. **Direct measures are at least as sensitive to conscious stimulus effects as indirect measures**. As many (especially, Holender, 1986, and Reingold & Merikle, 1988) have noted, the translation of data patterns involving indirect and direct effects into assertions about unconscious cognition depends critically upon one's assumptions about how conscious and unconscious cognition map onto direct and indirect measures. Figure 8 (left panel) shows the assumptions made by Holender (1986; as analyzed by Reingold & Merikle, 1988) in arriving at a skeptical conclusion about the existence of unconscious cognition. Holender assumed that, in order to draw conclusions, direct measures must be sensitive to *all* conscious effects of task stimuli, and must reflect *only* conscious effects. With these (exhaustiveness and exclusiveness) assumptions, the demonstration of an indirect effect in the absence of a direct effect provides unambiguous evidence for unconscious effects, as well as indicating that unconscious effects are dissociated from conscious cognition. The relevance of intercept-effect findings such as those in the present experiments to conclusions about dissociation has been discussed in detail by Greenwald, et al. (in press).

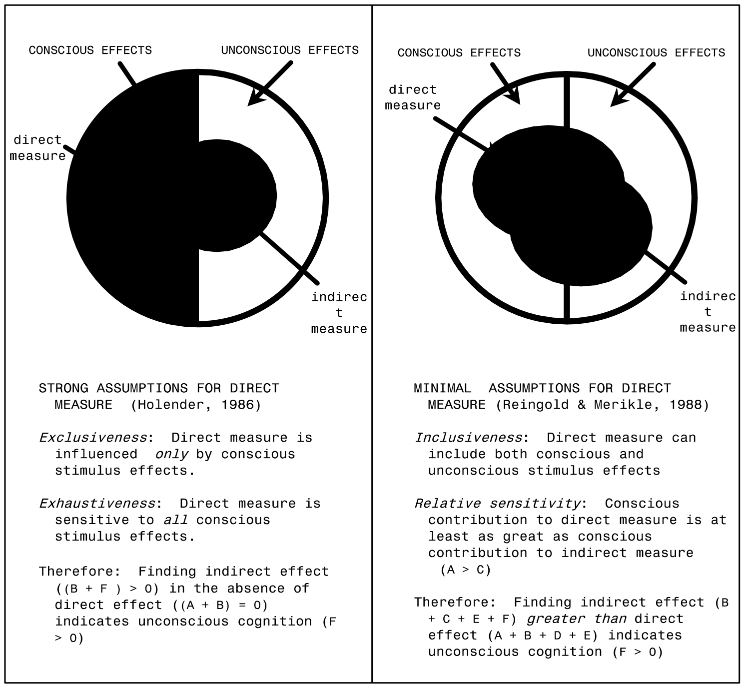

Figure 8. Alternative assumptions about use of direct and indirect measures as indicators of conscious and unconscious cognition. Both panels use an inclusiveness assumption for the indirect measure — that is, the indirect measure can be sensitive to both conscious and unconscious stimulus effects. For the right panel, not only the indirect-greater-than-direct effect (as diagramed) but also the indirect-without-direct-effect finding yields the conclusion of unconscious cognition (F > 0), as follows: When the direct effect (A+B+D+E) is zero, then A, B, and E must all be zero; C = 0 then follows from the relative sensitivity assumption (A >= C); and F > 0 then follows from the indirect effect (B+C+E+F) being greater than zero, given that B, C, and E have been demonstrated to equal 0. (Areas represent magnitudes of stimulus effects on direct and indirect measures, and cannot be negative.)

Although Holender's exclusiveness and exhaustiveness assumptions simplified the problem of empirically defining unconscious cognition, those assumptions also sparked controversy. The controversy was well articulated by Reingold and Merikle (1988), who considered implausible both that unconscious stimulus effects would have *no* influence on direct measures, and that direct measures would generally be sensitive to *all* conscious stimulus effects. Accordingly, Reingold and Merikle suggested that subsequent analyses of unconscious cognition be based on the more cautious assumption that direct measures (like indirect measures) might include *both* conscious and unconscious contributions (see also Jacoby, Lindsay, & Toth, 1992) and, further, that direct measures need not be sensitive to all conscious stimulus effects.

Replacing Holender's exclusiveness assumption for the direct measure with the inclusiveness assumption shown in Figure 8 (right panel) had the undesired side effect of making it impossible — in the absence of any other changes of assumptions — to interpret *any* patterns of direct and indirect effects in terms of unconscious cognition. Reingold and Merikle responded to this difficulty by introducing what they described as a *minimal* assumption to enable conclusions about unconscious cognition. Their additional assumption was that direct measures were *at least as sensitive* to conscious stimulus effects as were *comparable* indirect measures. In the right panel of Figure 8, this *relative sensitivity* assumption is interpreted as assuming that the region labeled 'A' is at least as large as that labeled 'C'.

Importantly, Reingold and Merikle's (1988) analysis did not logically exclude interpretation of the indirect-without-direct-effect data pattern, such as the one evidenced by a significantly positive intercept effect using the present regression method. Examination of their assumptions, as shown in the right panel of Figure 8, reveals that the indirect-without-direct-effect data pattern yields a conclusion of demonstrating unconscious cognition (i.e., region 'F' > 0; see Figure 8's caption). Based on this analysis, the significant intercept effects found in Experiments 1 and 2 provide evidence for existence of unconscious cognition.

In the present research, two strategies addressed the possibility that the relative sensitivity assumption was not met (i.e., the possibility that indirect measures were relatively *more* sensitive to conscious stimulus effects than were direct measures). First, the experiments provided two other direct measures, a position-discrimination measure based on discriminating the left vs. right spatial position of 4-letter word stimuli (in both experiments) and a lexical-decision task based on judging whether 4-letter stimulus words were displayed forwards or backwards (in Experiment 2). When the detection measure was replaced by either of these other direct measures in the regression analysis, the same positive intercept effects were obtained. The second strategy followed from the use of a detection task to provide the major direct measure. Because of the nature of the detection task, *any* consciously perceived stimulus attribute, whatever the stimulus, should have led subjects to respond with a hit. Thus, to the extent that subjects perceived any information that might have produced above-zero scores on the indirect measure, their scores on the direct measure should also have been (at least as much) above zero.

Dissociation Interpretation of Regression Functions

Debates in the recent literature concerning the nature of unconscious cognition encompass three competing views: (a) unconscious cognition does not exist (nonexistence), (b) unconscious cognition exists, but only in association with conscious cognition (association), and (c) unconscious cognition exists and is independent of conscious cognition (dissociation). As discussed above, the intercept effects of the present study, in conjunction with the relative sensitivity assumption, reject the nonexistence view. However, decisive interpretation of the intercept effect findings as supporting the strong conclusion of dissociation (rather than the weaker conclusion of association), requires the exhaustiveness assumption employed by Holender (see left panel of Figure 8) — the assumption that the direct measure is sensitive to *all* conscious stimulus effects. Although the exhaustiveness assumption is clearly not generally valid, it may nevertheless be valid for the direct measure provided by the detection task, which should have been sensitive to the effects of *any* consciously perceived stimulus attributes. To the extent that the exhaustiveness assumption holds for the detection task, the present findings can be seen as supporting the dissociation view. (See Greenwald et al., in press, for detailed consideration of the plausibility of the exhaustiveness assumption for the direct measures provided by detection and position discrimination measures in the present series of experiments.)

CONCLUSION

Using a data analysis strategy based on regression of indirect on direct measures, the present research found evidence for an indirect-without-direct-effect pattern in the form of positive intercept effects. Validity of the resulting conclusion that indirect effects can occur in the absence of direct effects depended on appraisal of four assumptions underlying the regression analysis method. A detailed analysis of the possibilities for failure of each assumption provided no basis for revising the conclusion. The present data, further, support the conclusion that unconscious effects can occur in the absence of conscious effects (dissociation), *if* — as is plausible, but not definitively established — the direct measures used in the present research are accepted as providing exhaustive measures of conscious stimulus effects. The dissociation interpretation constitutes an affirmative answer to the title question — it amounts to the conclusion that subliminal stimuli *can* enter the mind unnoticed.

Theoretically, evidence for dissociation is important because it is incompatible with the large class of models that assume sequential processing of information through an ordered series of increasingly complex levels (or stages) of analysis. Such models generally assume that some processing occurs at a stage prior to focal attention. Unconscious cognition has often been identified with this preattentive processing stage. In these information processing models, any stimulus that is processed preattentively should be capable of achieving focal attention (i.e., conscious awareness) when it is goal-relevant, as it was in the detection task of the present experiments. Interpreted in terms of such models, the present findings indicated that stimuli that must have been preattentively processed (as indicated by their producing indirect effects) were not focally attended (as indicated by their failing to produce effects on the direct-effect measure of detection). Such findings are inconsistent with models that treat outputs of preattentive processing as being routinely available for focal attention.

Practically, evidence for dissociation is important because it implies the possibility of cognitive influences that, because they are produced by undetectable stimuli, cannot be consciously defended against. Subliminal techniques of the sort used now in laboratory research could possibly be developed for use in mass media to produce significant influences on behavior. Importantly, such influences have not yet been compellingly demonstrated in research. Nevertheless, in a recent ruling, a court in the state of Nevada suggested that evidence for subliminal influence could justify an exclusion of subliminal messages from the constitutional protection of free speech afforded by the First Amendment of the United States Constitution (Vance v. Judas Priest, 1990).

Because of (a) the theoretical and practical importance of indirect-without-direct-effect data pattern, and (b) the long history of skeptical regard for claims to have obtained that finding, it is unlikely that those who have been skeptical about previous claims to have found this long-sought pattern will be thoroughly persuaded by the present findings. At the same time, the present methods avoided problems for which previous claims have been criticized and, therefore — together with the similar findings of Greenwald, et al. (in press) — provide substantially stronger support for the indirect-without-direct-effect pattern than has been available previously. The strong claim for the present findings, that they constitute evidence that subliminal activation is producible by stimuli that entirely escape conscious detection, no doubt invites, even provokes, further skeptical reaction. This is as it should be. Only by continued findings of data patterns such as those in the present research will the conclusion survive skeptical criticism and become strongly established.

References

Balota, D. A. (1983). Automatic semantic activation and episodic memory encoding. *Journal of Verbal Learning and Verbal Behavior*, *22*, 88-104.

Bornstein, R. F. (1992). Subliminal mere exposure effects. In R. F. Bornstein & T. S. Pittman (Eds.), *Perception without awareness: Cognitive, clinical, and social perspectives* (pp. 191-210). New York: Guilford Press.

Cheesman, J., & Merikle, P. M. (1986). Distinguishing conscious from unconscious perceptual processes. *Canadian Journal of Psychology*, *40*, 343-367.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences* (Rev. ed.). New York: Academic Press.

Dagenbach, D., Carr, T. H., & Wilhelmsen, A. (1989). Task-induced strategies and near-threshold priming: Conscious influences on unconscious perception. *Journal of Memory and Language*, *28*, 412-443.

Draine, S. C., & Greenwald, A. G. (1994). Dissociation of Unconscious Semantic Activation from Conscious Cognition. Paper presented at 1994 meeting of the Midwestern Psychological Association.

Fowler, C. A., Wolford, G., Slade, R., & Tassinary, L. (1981). Lexical access with and without awareness. *Journal of Experimental Psychology: General*, *110*, 341-362.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York: Wiley.

Greenwald, A. G. (1992). New Look 3: Unconscious cognition reclaimed. *American Psychologist*, *47*, 766-779.

Greenwald, A. G., & Klinger, M. R. (1990). Visual masking and unconscious processing: Differences between backward and simultaneous masking? *Memory and Cognition*, *18*, 430-435.

Greenwald, A. G., Klinger, M. R., & Liu, T. J. (1989). Unconscious processing of dichoptically masked words. *Memory and Cognition*, *17*, 35-47.

Greenwald, A. G., Klinger, M. R., & Schuh, E. S. (in press). Activation by marginally perceptible ("subliminal") stimuli: Dissociation of unconscious from conscious cognition. *Journal of Experimental Psychology: General*.

Groeger, J. A. (1988). Qualitatively different effects of undetected and unidentified auditory primes. *Quarterly Journal of Experimental Psychology*, *40A*, 323-329.

Hardaway, R. A. (1990). Subliminally activated symbiotic fantasies: Facts and artifacts. *Psychological Bulletin, 107*, 177-195.

Holender, D. (1986). Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: A survey and appraisal. *Behavioral and Brain Sciences*, *9*, 1-23.

Jacoby, L. L., Lindsay, S. S., & Toth, J. P. (1992). Unconscious influences revealed: Attention, awareness, and control. *American Psychologist, 47*, 802-809.

Marcel, A. J. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology, 15*, 197-237.

Merikle, P. M. (1982). Unconscious processing revisited. *Perception and Psychophysics, 31*, 298-301.

Merikle, P. M., & Reingold, E. M. (1991). Comparing direct (explicit) and indirect (implicit) measures to study unconscious memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 224-233.

Purcell, D. G., Stewart, A. L., & Stanovich, K. E. (1983). Another look at semantic priming without awareness. *Perception and Psychophysics*, *34*, 65-71.

Reingold, E. M., & Merikle, P. M. (1988). Using direct and indirect measures to stud perception without awareness. *Perception and Psychophysics*, *44*, 563-575.

Rosenthal, R. (1993). Cumulating evidence. In G. Keren & C. Lewis (Eds.), *A handbook for data analysis in the behavioral sciences: methodological issues* (pp. 519-559). Hillsdale, New Jersey: Erlbaum.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643-662.

Vance v. Judas Priest, CBS, Inc., et al. (1990). Nos. 86-5844, 86-3939, 1990 WL 130920 (Nev. Dist. Ct. Aug. 24, 1990).