Unconscious Perception or Not? An Evaluation of Detection and Discrimination as Indicators of Awareness
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Unconscious perception or not? An evaluation of detection and discrimination as indicators of awareness

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Most investigations of unconscious perception use a dissociation design in which an awareness variable (e.g., detection) is compared with a perceptual processing variable (e.g., identification). Unconscious perception is inferred when the awareness variable lacks sensitivity to the stimulus but evidence of perceptual processing is still obtained. In two studies we examined the relationship between word identification and detection (Study 1) or discrimination (words vs. nonwords; Study 2) with a variety of techniques. In both studies, dissociations suggestive of unconscious perception occurred when the data were examined with subjective threshold approaches, but these differences disappeared when the variables were compared with techniques derived from signal detection theory (SDT). These results do not support unconscious perception in subjective threshold paradigms. In addition, detection appears to be the most sensitive and appropriate task for assessing stimulus awareness, provided that several SDT assumptions are met.

An important issue in the study of consciousness concerns the relative contributions of conscious and unconscious processes in perception. Although most investigators would agree that perception involves both conscious and unconscious elements (e.g., Kahneman, 1973; Treisman & Gelade, 1980), there is disagreement regarding the degree and relative importance of these functions. Some theorists propose that high-level representations (e.g., semantic, holistic) are not likely to exist in a cognitive unconscious (Dulany, 1997; Holender, 1986; Perruchet & Vinter, 2002; Searle, 1992). According to this viewpoint, any behavioral response or verbal report is primarily a reflection of consciously experienced mental activity. By extension, most tasks in experimental psychology are examples of conscious processes. An entirely opposite view is promoted by other cognitive scientists who argue that consciousness is an epiphenomenon (or at most a very late stage in a sequence of complex cognitive processes) that

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provides the results of prior processing that is performed almost entirely on an unconscious level (Kihlstrom, 1987; Libet, 1985; Marcel, 1983; Velmans, 1991). These theorists view consciousness as a passive recipient of unconscious processes, hence its susceptibility to being strongly influenced by stimulus processing that does not enter into awareness.

Obtaining evidence of purely unconscious perceptual processes is a critical issue for resolving uncertainties about the relative contributions of conscious and unconscious processes. The general approach to measuring unconscious perception is the dissociation paradigm, which focuses on measuring perceptual sensitivity when awareness is lacking. Dissociation paradigms typically use two dependent variables, with one variable representing stimulus awareness and the other representing perceptual processing. For example, stimulus detection ("Was the stimulus present? Yes or no?") could be used as an indication of awareness, with perceptual sensitivity being indicated by identification performance ("Which of these two words was shown?"). In these situations, participants may express null sensitivity on the awareness variable ("I didn't see anything!") yet will show evidence of perceptual processing, such as above-chance identification of the stimulus (Haase & Fisk, 2001; Merikle & Reingold, 1990). This type of dissociation between the variables typically is interpreted as unconscious perception because perceptual processing seems to occur despite a lack of awareness. An example of the dissociation approach is that of Merikle and Reingold (1990), who presented masked word and nonword stimuli to participants, followed by detection and two-alternative, forced-choice (2AFC) identification. Identification was significantly above chance after detection misses for word trials but not for nonword trials. This dissociation was interpreted as evidence of semantic processing performed at an unconscious level.

There are several variations of the dissociation paradigm that attempt to ascertain null awareness via different methods. The oldest approach often is called a subjective threshold (or classic) dissociation paradigm. Dissociations in this approach typically take place at stimulus parameters somewhere between an objective threshold, with empirically demonstrated null sensitivity (i.e., chance performance or $d' = 0$), and an internal, subjective threshold where a participant expresses that he or she has not experienced the stimulus (Cheesman & Merikle, 1984, 1986; Merikle & Cheesman, 1986). If the participant reports null awareness yet shows signs of perceptual sensitivity, this dissociation could be interpreted as unconscious perception. The drawback of this approach is that partial awareness could be guiding the responses, making it difficult to rule out the possibility that any perceptual sensitivity after a missed stimulus is completely unconscious. In the objective threshold approach, an empirical, third-person index of sensitivity on the awareness variable is used as an indicator of null awareness, which provides a more stringent criterion of null awareness than the subjective threshold approach. Examples of an objective threshold would be chance performance (Cheesman & Merikle, 1984) or null sensitivity ($d' = 0$; Holender, 1986; Macmillan, 1986) on the awareness variable. Some studies indicate that dissociations suggestive of unconscious perception might occur at an objective threshold (Greenwald, Klinger, & Schuh, 1995; Snodgrass, Shevrin, & Kopka, 1993; Van Selst & Merikle, 1993).

The key pattern in the dissociation paradigm is the demonstration of perceptual sensitivity occurring despite null awareness. The greatest problem concerns the measurement of awareness, which is a subjective, first-person variable that is not amenable to direct measurement. A number of tasks have been suggested as valid indices of awareness. Classic presence–absence detection, such as discriminating words from blank fields, is used in a number of studies (Greenwald et al., 1995; Merikle & Reingold, 1990; Van Selst & Merikle, 1993). One advantage of detection as an index of awareness is that perception of minimal differences of intensity between signals and noise should result in correct detection (Greenwald, Klinger, & Liu, 1989; Merikle & Reingold, 1990; Snodgrass, Bernat, & Shevrin, 2004). A potential drawback is that presence–absence decisions about awareness can be made on the basis of low-level sensory details such as luminance differences, thereby making it difficult to address the state of consciousness involved in higher-order cognitive functions such as semantic processing. Second, the signals must be equally detectable and uncorrelated with the noise (correlated noise would increase confusions between signals and noise on the detection task). Otherwise, null sensitivity might not be a valid index of null awareness. Many studies of unconscious perception use other indices of stimulus awareness in which the signal plus noise and noise trials are matched on luminance and differ only in terms of semantic content. These are essentially discrimination tasks, in which the participants classify words from nonwords, words from character patterns (e.g., "XGXG"), or words from other noise with a similar luminance (Abrams & Greenwald, 2000; Draine & Greenwald, 1998; Greenwald et al., 1995; Haase & Fisk, 2001; Kouider & Dupoux, 2004).

An important issue for advancing the study of unconscious perception concerns the appropriateness of different indicators of stimulus awareness such as detection and discrimination (see Snodgrass et al., 2004). In addition, the sensitivity of dependent variables such as discrimination or identification could be made more or less difficult based on stimulus display parameters, which could be problematic. Therefore, the first goal of the present work was to evaluate detection and discrimination as indices of awareness. Stimulus detection (Study 1) and constrained discrimination (one of two words vs. nonword; Study 2) were compared with identification performance via several different methods, including comparison of identification means at different confidence ratings, d'-based statistics, signal detection theory (SDT) models, and regression. The second goal was to further investigate the usefulness of SDT for describing putative unconscious perceptual processes from dissociation paradigms. These comparisons of identification to detection or discrimination contained elements of subjective threshold approaches, which were then compared with results predicted by SDT.

STUDY 1

According to Reingold and Merikle (1988), the ideal awareness indicator should meet the criteria of being exhaustive (sensitive to all conscious processes) and exclusive (a pure index of consciousness rather than a combination of unconscious and conscious processes). Meeting the exhaustiveness criterion is perhaps the most important given that the unconscious perception literature contains numerous examples of putative unconscious dissociations that are later argued to be the effects of conscious or partially conscious processing. Given that maximizing sensitivity is of the utmost importance, classic presence–absence detection might be the best candidate for meeting the exhaustiveness criterion because of its high sensitivity (Cornsweet, 1970; Snodgrass et al., 2004). Although detection is potentially the best indicator of awareness, many recent studies use discrimination tasks as an indicator of awareness rather than using classic detection, thereby leaving the utility of detection tasks somewhat unclear. Therefore, Study 1 was performed to determine whether dissociations indicative of unconscious processing would occur when detection is used as an indicator of awareness. Detection performance in this study was compared with 2AFC identification (i.e., identifying one of two possible words). This constrained identification task is simpler than absolute identification (identification of the stimulus from all possible English words) and also lends itself to more straightforward SDT model analysis.

METHOD

Participants

The participants were 40 (divided into two groups of 20) undergraduate students from Georgia Southwestern State University who were enrolled in an introductory psychology course. These students received a small amount of extra credit for their participation. All participants spoke English as their native language and had normal or corrected-to-normal visual acuity. The experimental protocol followed standard research conventions (e.g., informed consent, debriefing) and was approved by the Institutional Review Board of Georgia Southwestern State University.

Materials and apparatus

Stimulus presentations were controlled with Micro Experimental Laboratory software (MEL version 2.0 for MS-DOS; Psychology Software Tools, Pittsburgh, PA) running on an American Megatrends computer (Intel 486sx microprocessor, 25 MHz). The stimuli were displayed on a 14–inch VGA computer monitor (Gateway 2000, Crystal Scan 1024 NI) at a distance of approximately 55 cm. The refresh rate of the computer monitor was determined to be 14.2 ms with a PST serial response box (Psychology Software Tools, Pittsburgh, PA), so all stimuli were presented in multiples of 14.2 ms. Responses were entered into the computer via a keyboard.

The visual stimuli were words (signal plus noise trials) and blank fields (noise trials) presented between forward and backward masks of random letters. The word stimuli were five-letter English words obtained from word frequency norms (Kučera & Francis, 1967). The 64 words used in the experiment ranged in frequency from 88 per million (*enemy*) to 787 per million (*world*). On the signal plus noise trials, the word presented during the detection task was designated the target, and another word, which was shown adjacent to the target during identification, was designated as a distractor. A number of precautions were taken to nullify any potential effects based on word frequency (Howes & Solomon, 1951). Targets were paired with distractors of a similar frequency. For example, *world* (787 per million) was paired with *being* (712 per million). In addition, the target–distractor pairings were counterbalanced, so each word served as a target on half the trials and as a distractor on the other half of the trials. The eight masking stimuli were composed of five-letter strings of random letters that did not appear similar to an English word and did not appear similar to any of the target stimuli. All stimuli were presented in white, uppercase letters on a black background in the standard MS-DOS system font. The stimuli were approximately 1.6° of visual angle.

Procedure

The experiment began with a brief (approximately 5 min) practice session to familiarize the participants with the stimuli, masking, and rating scale detection task. The practice task consisted of 4 blocks of 10 trials. The target duration was 142 ms in the first block and was decreased to 71 ms in the second block and 43 ms in the third and fourth blocks. On the signal plus noise trials, participants were shown a nonword forward mask (500 ms), followed by a target word, then a nonword backward mask (500 ms). The probability of a signal plus noise trial was .50 for the practice task and the experimental session. The noise trials composed the remaining 50% of the target stimuli. Each stimulus presentation was followed by a rating scale detection response ranging from 1 (*absolutely sure no word was presented*) to 6 (*absolutely sure that a word was presented*). Participants were told that responses of 2 or higher indicated progressively increasing confidence that a word was presented.

The experimental task was similar to the practice task, with some important additions (Table 1). As in the practice task, participants had a .50 probability of receiving stimuli from the noise condition (nonword forward mask, blank field, nonword backward mask) and a .50 probability of receiving stimuli from the signal plus noise condition (nonword forward mask, word target, nonword backward mask). Although the participants were informed that there would be a 50% chance of seeing a word or nonword, they were not explicitly informed that there were 64 words (32 word pairs). Target duration in the experiments was either 28 ms ($N = 20$) or 43 ms ($N = 20$), which is similar to the display parameters used in other studies of unconscious perception (Debner & Jacoby, 1994; Draine & Greenwald, 1998; Merikle, Joordens, & Stolz, 1995). Thirty-two different word pairs were shown on the signal plus noise trials during the experimental task, with each word being counterbalanced in regard to whether it was shown as a target or distractor. After the stimulus presentation, a detection rating response was made on a 6-point scale similar to that of the practice task. It was emphasized that responses of 2 and higher reflected progressively increasing confidence in the presence of a word on the detection task, just as in the practice trials. The target and distractor words were displayed to the participant during the detection rating decision, as in previous studies (Merikle & Reingold, 1990, Experiment 2; Haase & Fisk, 2001) and as the independent observation model assumes (i.e., detection of known signals; Macmillan & Creelman, 1991). Next, the participants were required to make a 2AFC identification response, which was performed on every trial, regardless of whether a word was shown. The target word and the corresponding distractor were shown side by side during the identification phase of each trial. Word pairs presented during the identification phase of each trial were counterbalanced to ensure that each word in a word pair would be shown an equal proportion of times on the left and the right side of the pair. The participants were required to make an identification response by using the arrow keys, with the right arrow key for indicating the word on the right and vice versa (simple one-of-two identification).

Table 1. Sequence of each experimental trial

Event	Display examples	Duration (ms)
Warning tone	Blank	1,000
Fixation stimulus	— —	1,000
Forward mask	XFBTA	500
Target		
Study 1 (word/blank)	GROUP	28 or 43
Study 2 (word/nonword)	GROUP/TWGCP	28, 43, or 57
Backward mask	KWDYB	500
Detection rating (with word identification choices available)	1–6 rating scale	Until response
Identification	POINT GROUP	Until response
Intertrial interval	Blank	500

The experiment started with eight practice trials to ensure that each participant understood the task. The participants were then allowed to continue the experimental trials (320) without any interruptions from the experimenter. The trials were divided into five blocks with 64 trials in each block. Participants were encouraged to rest between blocks if they felt the need to take a break.

Data analysis

Summary data were generated using the "analyze" program of the MEL software package. Correct identification performance was expressed as a function of detection rating to determine whether identification performance exceeded chance at low confidence ratings, which is a dissociation that would be predicted by a subjective threshold approach. The descriptive and inferential statistics were performed on data for participants who had 10 or more trials at each detection rating level. Single sample t tests were used to compare identification performance to chance identification (.50) at each level of the detection rating scale. The alternative hypothesis specifically predicts above-chance performance at the lowest confidence ratings, so one-tailed t tests were used.

Detection sensitivity was modeled with methods based on SDT (Green, Weber, & Duncan, 1977; Macmillan & Creelman, 1991). Detection sensitivity was expressed as d_a, which is similar to the more familiar d' except that d_a is appropriate for experiments with a rating scale design. Identification d' was calculated with the $\sqrt{2}$ correction, given that there were two choices present, where the participant is assumed to assess the familiarity of each item independently (Macmillan & Creelman, 1991).[1] The detection d_a and identification d' variables were calculated for each participant and compared for all members of an experiment using paired t tests (two tailed). Scatter plots of detection d_a and identification d' were made and fitted via simple linear regression. Response bias, c_2, was calculated to determine the amount of bias from zero in standard deviation units (Macmillan & Creelman, 1991). The data were plotted as receiver operating characteristic (ROC) and identification operating characteristic (IOC) curves. The predicted identification at each ROC point was determined via the recognition theorem (Green et al., 1977; Starr, Metz, Lusted, & Goodenough, 1975) to produce a predicted IOC curve.

$$p_m(R\&C|\lambda_i) = p(R|S,\lambda_i) - ((m-1)/m)\int_0^{p(R|N,\lambda_i)}(1 - p(R|S,\lambda))/(1 - p(R|N,\lambda))\,dp(R|N,\lambda)$$

where

m = the number of choices on the identification task (two for the present studies).

$p_m(R\&C|\lambda_i)$ = the joint probability of the rating and a correct identification response for a given detection criterion, λ_i.

$p(R|S)$ = the probability of the rating, given signal plus noise presentation.

$p(R|N)$ = the probability of the rating, given noise alone presentation.

This formula was based on the area theorem for predicting identification from detection performance (Green & Swets, 1966) with modifications to fit the needs of a rating scale detection task (Green et al., 1977; Starr et al., 1975). The overall identification performance was also predicted from detection sensitivity by calculating the area under the ROC curve via the measure A_z (Macmillan & Creelman, 1991).

RESULTS

Overall identification performance varied as a function of target duration. Overall identification was significantly above chance in the 43-ms experiment, $M = .60$, $SE = .02$, $t(19) = 4.79$, $p < .01$, but was not different from chance in the 28-ms experiment, $M = .496$, $SE = .01$, $t(19) = -.50$, $p > .05$.

The proportions of correct identification were examined at different levels of detection confidence ratings (Figure 1). The goal was to determine whether dissociations occured when detection confidence is low, which would suggest a subjective threshold paradigm. In the 43-ms experiment, identification performance was not significantly different from chance at the 1 detection rating, $M = .56$, $SE = .03$, $t(9) = 1.64$, $p > .05$. However, identification was above chance for the 2 rating, $M = .54$, $SE = .02$, $t(12) = 2.59$, $p < .05$; the 3 rating, $M = .57$, $SE = .03$, $t(17) = 1.89$, $p < .05$; and all the higher detection confidence ratings, *ps* $< .01$). In contrast to the 43-ms experiment, identification performance was not significantly above chance at any level of detection confidence rating in the 28-ms experiment, $p > .05$.

The relationship between identification and detection confidence was also examined by pooling detection ratings into "yes" (4–6 rating) and "no" (1–3 rating) categories to approximate the results from a one-interval, yes–no detection task (see Haase & Fisk, 2001). Identification performance was above chance in the 43-ms experiment for both the "no" rating, $M = .56$, $SE = .02$, $t(40) = 3.15$, $p < .01$, and the "yes" rating, $M = .64$, $SE = .02$, $t(43) = 6.43$, $p < .01$. The presence of above-chance identification for the "no" detection rating is similar to dissociations suggesting unconscious perception reported in previous studies (Merikle & Reingold, 1990). On the other hand, identification performance was not significantly different

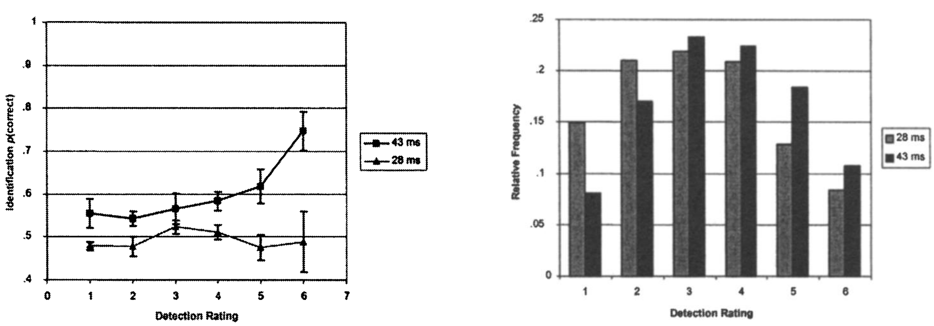

Figure 1. Comparison of identification performance as a function of detection confidence rating from Study 1. Error bars depict one standard error of the mean. Chance identification performance in the 2AFC task was .50

from chance in the 28-ms experiment for both the pooled "no" response, $M = .49$, $SE = .01$, $t(57) = -.60$, $p > .05$, and the "yes" response, $M = .49$, $SE = .02$, $t(44) = -.33$, $p > .05$.

Potential dissociations between detection and identification sensitivity were also analyzed by comparing measures based on the d' statistic. Overall detection performance was assessed using d_a, which is a measure of sensitivity appropriate for rating scale designs that have nonunit slope on plots of z score scaled hits and false alarm rates (Macmillan & Creelman, 1991). Detection sensitivity in the 43-ms experiment, d_a $M = 1.15$, overall $d_a = .96$, slope = .99, was significantly higher than identification d', $M = .37$, overall $d' = .35$; $t(19) = 5.88$, $p < .01$. The bias statistic c_2 was .42, which indicated the presence of conservative bias. Detection performance, d_a $M = .20$, overall $d_a = .21$, slope = .97, was also higher than identification d', $M = -.004$, overall $d' = -.01$, in the 28-ms experiment, $t(19) = 2.08$, $p < .02$, and this experiment also had some conservative bias, $c_2 = .30$. The small value of d_a $M = .21$ was above chance, $t(19) = 2.22$, $p < .05$.

Other SDT-derived approaches also showed that detection sensitivity was superior to identification sensitivity. The ROC plot in the 43-ms experiment shows that participants were generally sensitive to the stimulus presentation, whereas the 28-ms experiment showed less sensitivity (Figure 2). $IOC_{predicted}$ values were generated for each ROC point via the recognition theorem (Starr et al., 1975) to model identification performance as a function of detection sensitivity at each detection rating level. The predicted identification performance was much higher than the actual identification performance in both the 43- and 28-ms experiments. This pattern would be expected if participants could detect luminance differences between the signal plus noise and noise trials. This low-level (probably low–spatial frequency) information would not necessarily aid in stimulus iden-

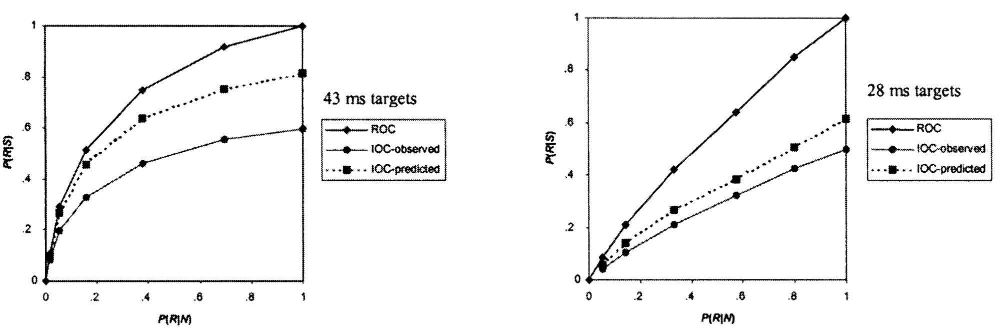

Figure 2. Plots of receiver operating characteristic (ROC), observed identification operating characteristic ($IOC_{observed}$), and predicted identification operating characteristic ($IOC_{predicted}$) for the 43-ms and 28-ms durations from Study 1

tification, especially with small, high–spatial frequency stimuli (Watson, Thompson, Murphy, & Nachmias, 1980). Another method for examining the relationship between detection and identification was to use the area under the ROC curve to predict overall identification performance, which is a measure called A_z (Macmillan & Creelman, 1991). Comparison of overall identification with A_z showed that A_z was substantially higher (43 ms, $A_z = .75$; 28 ms, $A_z = .56$) than the obtained identification performance (43 ms, $M = .60$; 28 ms, $M = .49$) in both experiments. Both techniques yield higher estimates of identification performance than the actual result because of the highly sensitive nature of detection.

Another approach for comparing detection and identification sensitivity is the regression approach introduced by Greenwald et al. (1995). Scatter plots and regression lines of the data from the 43- and 28-ms experiments are shown in Figure 3, with detection d_a shown on the x-axis and identification d' on the y-axis for each plot. The y-intercepts from the regression lines of both the 43-ms experiment, $y = .30x + .03$, and the 28-ms experiment, $y = -.05x + .00$, were not significantly above zero: 43 ms, $t(19) = .23$, $p > .05$; 28 ms, $t(19) = .10$, $p > .05$. Likewise, the combined data from both the 28- and 43-ms experiments did not yield a significant y-intercept, $y = .29x - .01$, $t(39) = -.21$, $p > .05$. The slope of the 28-ms experiment was not significant, $t(19) = -.44$, $p > .05$, but the slope of the 43-ms experiment was significant, $t(19) = 2.99$, $p < .01$. Both the 43-ms and combined 28- and 43-ms experiments showed a moderately strong correlation between detection and identification, $r = .58$ and $.65$, respectively, $p < .01$, but there was no relationship between these measures in the 28-ms experiment, $r = .10$.

These identification sensitivity measures were calculated using the $\sqrt{2}$ correction (Macmillan & Creelman, 1991). However, some investigators have suggested that the $\sqrt{2}$ correction may be misleading and unnecessary (Snodgrass et al., 2004). To address this possibility, these comparisons were reconsidered without the $\sqrt{2}$ correction in the identification calculations. Removing the $\sqrt{2}$ correction had a negligible effect on the results. Mean identification d' for the 28- and 43-ms groups changed to $-.010$ (overall $d' = -.015$) and $.53$ (overall $d' = .50$), respectively, but detection sensitivity was still significantly higher than identification sensitivity, as in the aforementioned results: 43 ms, $t(19) = 4.61$, $p < .01$; 28 ms, $t(19) = 1.98$, $p < .03$). For the regression results, removing the $\sqrt{2}$ correction changed the slopes and y-intercepts slightly (43 ms, $y = .425x + .0433$; 28 ms, $y = -.0492x + .0049$), but the y-intercepts were still not significantly different from zero (43 ms, $t(19) = .23$, $p > .05$; 28 ms, $t(19) = .10$, $p > .05$). Removing the $\sqrt{2}$ correction does not change the obtained t values for the y-intercept because this transformation simultaneously changes both the magnitude of the values and the standard error. In summary,

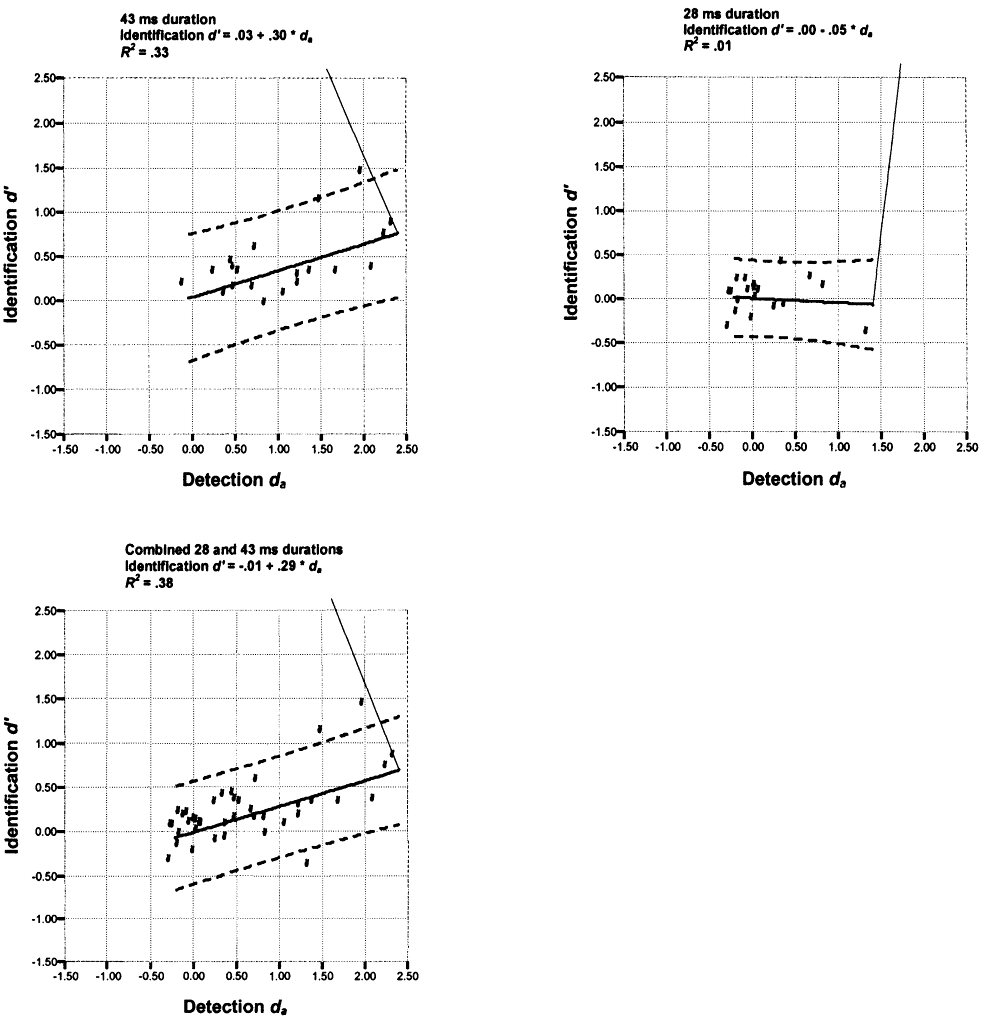

Figure 3. Regression plots for the 43-ms and 28-ms target durations of Study 1. The inner line represents the regression line, and the upper and lower dashed lines depict the 95% confidence interval

removing the $\sqrt{2}$ correction from the identification calculations does not significantly alter the aforementioned results.

DISCUSSION

These results indicate that detection performance is superior to identification when the two variables are compared with a wide range of techniques. The sensitivity of detection probably is superior because presence–absence detection decision does not entail any semantic or letter-level processing. All the participant needs to be aware of the stimulus is to note that a small change in luminance has taken place.

The pooled "no" responses in the 43-ms experiment are significantly above chance in regard to identification, which is similar to results of previous studies using subjective threshold paradigms (Merikle & Reingold, 1990). However, this dissociation is not apparent when these indices are compared via measures derived from SDT. Thus, the elevated identification at the lower detection confidence levels is likely to be mediated by some degree of stimulus awareness, which is consistent with previous findings (Haase & Fisk, 2001).

STUDY 2

Many recent studies of unconscious perception use discrimination tasks in which the signal plus noise and noise trials have similar sensory characteristics but differ in regard to meaning. This approach matches the targets and noise on low-level sensory information such as luminance, so the signal plus noise and noise trials differ only in regard to semantic properties. Study 2 was performed to assess potential dissociations that might occur when identification is compared with a discrimination indicator of awareness. This study was identical to Study 1 except that nonwords were displayed instead of blank fields on the noise trials, thereby necessitating a constrained discrimination of word stimuli from nonword stimuli. This constrained discrimination was compared with a constrained 2AFC identification task, similar to that of Study 1.

METHOD

Participants

The participants were 63 undergraduate students who did not participate in Study 1. These participants were divided into three groups that received different target durations. Two people were removed from the dataset for not following instructions, resulting in a total of 61 participants.

Protocol

The experimental protocol was the same as that of Study 1, with a few minor changes. The detection task was changed to a discrimination task in which the participants had to decide whether one of two words or nonwords were displayed. The signal plus noise trials were the same as those in Study 1. On the noise trials, participants were showed one of eight nonwords (in between the forward and backward masks) that were composed of randomly selected letters. The only constraint on the nonword noise stimuli was that these did not look like a word, a target word, or the masking stimuli. The participants were not informed that there were 64 word stimuli (32 word pairs) and 8 nonword stimuli. Three experiments were performed with target durations of 28 ms, $N = 20$; 43 ms, $N = 21$; or 57 ms, $N = 20$. The practice task was also modified so that the participants practiced distinguishing words from nonwords before the experiment began. The participants performed the identification task on all trials, regardless of whether a word or nonword was displayed. All other aspects of the experiment, including the stimulus masking, the rating scale task, and the identification task, were the same as those in Study 1.

RESULTS

As expected, identification performance varied with target duration, with the longest target durations producing the best identification performance. The overall identification means for the 57-ms and 43-ms experiments were .71, $SE = .03$, and .57, $SE = .02$, respectively. Both of these results were significantly above chance: 43 ms, $t(20) = 4.57$, $p < .01$; 57 ms, $t(19) = 7.87$, $p < .01$. However, overall identification in the 28-ms experiment was not different from chance, $M = .50$, $SE = .01$, $t(19) = .26$, $p > .05$.

The proportions of correct identifications for each experiment were examined at different levels of discrimination confidence rating (Figure 4). The relationship between discrimination confidence and identification performance in the 57-ms experiment was monotonic throughout the range of discrimination confidence levels. The identification performance for the 57-ms experiment was not above chance, .50, at the 1 rat-

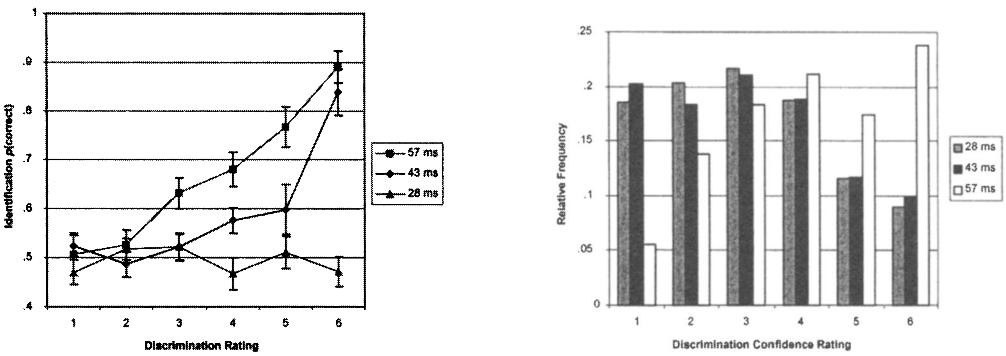

Figure 4. Identification performance as a function of discrimination confidence ratings 1–6 from Study 2. Mean identification performance is displayed at discrimination confidence ratings 1-6 for the 57-ms, 43-ms, and 28-ms experiments. Error bars depict one standard error of the mean; chance identification performance in the 2AFC task was .50

ing level, $M = .51$, $SE = .04$, $t(6) = .13$, $p > .05$, or at the 2 rating level, $M = .53$, $SE = .03$, $t(15) = .88$, $p > .05$. In contrast, identification performance was significantly greater than chance at the 3 discrimination confidence rating, $M = .63$, $SE = .03$, $t(17) = 4.18$, $p < .01$, and the higher ratings (i.e., 4–6; $ps < .01$). For the experiment with 43-ms targets, identification performance was not significantly different from chance at the lowest discrimination confidence ratings: 1, $M = .52$, $SE = .02$, $t(13) = 1.10$, $p > .05$; 2, $M = .49$, $SE = .03$, $t(19) = -.50$, $p > .05$; and 3, $M = .52$, $SE = .03$, $t(16) = .82$, $p > .05$. The 4 rating, $M = .58$, $SE = .03$, $t(16) = 2.97$, $p < .01$, and higher discrimination confidence ratings were all significantly above chance. In the 28-ms experiment, all identification means ranged from .47 to .52 for discrimination confidence ratings 1–6, with none of these ratings being significantly different from chance, $p > .05$.

As in Study 1, discrimination confidence ratings 1–3 were collapsed into a "no" category and 4–6 were collapsed into a "yes" category to approximate a yes–no discrimination task (Haase & Fisk, 2001). The 57-ms experiment had identification performance that was significantly above chance for the pooled "no" discrimination confidence rating, $M = .57$, $SE = .02$, $t(40) = 3.29$, $p < .01$. In contrast, the pooled "no" discrimination confidence rating for the 43-ms experiment was not significantly above chance, $M = .51$, $SE = .01$, $t(50) = .58$, $p > .05$. The pooled "yes" ratings produced significantly above chance identification for the 43-and 57-ms experiments, $ps < .01$. In contrast, the pooled results for the 28-ms experiment were not different from chance for both the "no" and "yes" conditions: "no," $M = .51$, $SE = .01$, $t(56) = .38$, $p > .05$; "yes," $M = .48$, $SE = .02$, $t(41) = -1.06$, $p > .05$. These results showed that dissociation between discrimination confidence and identification would have been likely in the 57-ms experiment if the discrimination variable were a simple yes–no scale, which essentially replicated earlier studies that reported evidence of stimulus processing following discrimination failure (Haase & Fisk, 2001).

The relationship between discrimination confidence and identification sensitivity was analyzed by comparing measures based on the d' statistic. Discrimination performance was best in the 57-ms experiment, with a mean of .90, overall $d_a = .84$, and a slope of .87. The identification d', $M = .82$, overall $d' = .76$, was slightly lower than discrimination d_a in this experiment, but this difference was not significant, $t(19) = 1.23$, $p > .05$. The bias, expressed as the measure c_2, was .05, suggesting a negligible amount of conservative bias. Discrimination performance showed a lower level of sensitivity in the 43-ms experiment, d_a $M = .33$, overall $d_a = .23$, slope = .81, but was still significantly above zero, $t(21) = 3.95$, $p < .01$. Identification d', $M = .25$, overall $d' = .25$, in this experiment was not statistically significant different from discrimination, $t(20) = 1.35$, $p > .05$. Bias was

$c_2 = .36$, which indicated that participants in the 43-ms experiment had a greater degree of conservative bias. For the 28-ms experiment, both discrimination and identification were at zero, d_a $M = .02$, overall $d_a = .04$, slope = .95; identification d' $M = -.02$, overall $d' = .01$, and were not significantly different, $t(19) = .46$, $p > .05$. The bias measure c_2 was .27 in the 28-ms experiment, indicating some conservative bias. To summarize, discrimination and identification performance were not meaningfully different in any of these comparisons, which indicated no dissociation between these variables.

A second SDT-based approach for examining the relationship between discrimination and identification was based on analysis of ROC and IOC curves (Figure 5). $IOC_{predicted}$ values from the 57-ms experiment showed a close correspondence between predicted and observed IOC values, with the predicted identification performance slightly exceeding the observed identification rates. In the 43- and 28-ms experiments, the predicted IOC was almost identical to the observed IOC, which demonstrated that iden-

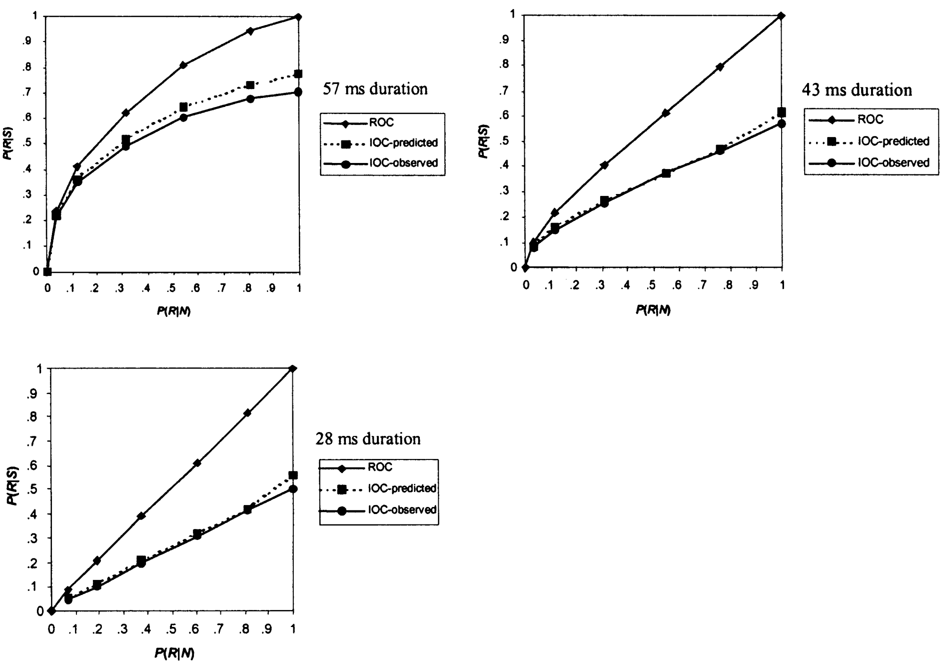

Figure 5. Plots of receiver operating characteristic (ROC), observed identification operating characteristic ($IOC_{observed}$), and predicted identification operating characteristic ($IOC_{predicted}$) for the 57-ms, 43-ms, and 28-ms target durations of Study 2

tification accuracy was, again, closely predicted by discrimination performance. These results indicated that identification performance did not have greater sensitivity than the levels that could be predicted from discrimination performance alone, consistent with an interpretation that there is no dissociation between these variables.

The relationship between discrimination confidence and identification was also compared via A_z (Macmillan & Creelman, 1991), which has been has been used successfully as a performance measure in a wide variety of detection and discrimination tasks (Swets, 1986a, 1986b). For the 57-ms experiment, $A_z = .72$, which was comparable to the overall identification performance obtained in the experiment, $M = .71$. Similarly, A_z in the 43-ms experiment, $A_z = .57$, and 28-ms experiment, $A_z = .51$, showed a close correspondence to the empirically obtained overall identification performance: 43 ms, $M = .57$; 28 ms, $M = .50$. These data illustrate a close correspondence between discrimination and identification performance, which is consistent with SDT. From an observer's perspective, these tasks might be nearly equivalent. Identification and discrimination could both be viewed as examples of multidimensional detection (i.e., simultaneous detection of multiple stimulus features). Stated differently, even though the discrimination response was given first, the participant might identify which one of the two words was shown and then rate his or her confidence that the trial displayed a word. Both decisions are based on the same information but are compared against independent decision criteria (Macmillan & Creelman, 1991).

Scatter plots and regression lines of these data from the 57-, 43-, and 28-ms experiments are shown in Figure 6. The 57-ms experiment had a regression line of $y = .69x + .19$, with a y-intercept that was significantly above zero, $t(19) = 2.03$, p (one tail) $< .05$. The 43-ms experiment also had a regression line, $y = .51x + .09$, with a y-intercept that was significantly above zero, $t(20) = 1.75$, p (one tail) $< .05$, but the y-intercept of the 28-ms experiment was not significant, $y = -.13x - .02$, $t(19) = -.35$, $p > .05$. Although the y-intercepts from the 57-ms and 43-ms experiments were significant when evaluated as directional, one-tailed tests, both of these just missed statistical significance when evaluated as a two-tailed test: 57 ms, $p < .057$; 43 ms, $p < .096$. Both the 57- and 43-ms experiments had strong relationships between discrimination and identification (57 ms, $r = .89$, $r^2 = 79$, $SE = .24$, $p < .01$; 43 ms, $r = .76$, $r^2 = .58$, $SE = .17$, $p < .01$), but there was no relationship between these variables in the 28-ms experiment ($r = .14$, $r^2 = .02$, $SE = .25$, $p > .05$). The slopes from these regression lines were also tested for significance. The slopes for the 57-ms experiment, $t(19) = 8.17$, $p < .001$, and the 43-ms experiment, $t(20) = 5.12$, $p < .001$, were both statistically significant. The slope for the 28-ms experiment, on the other hand, did not meet statistical significance, $t(19) = -.62$, $p < .54$.

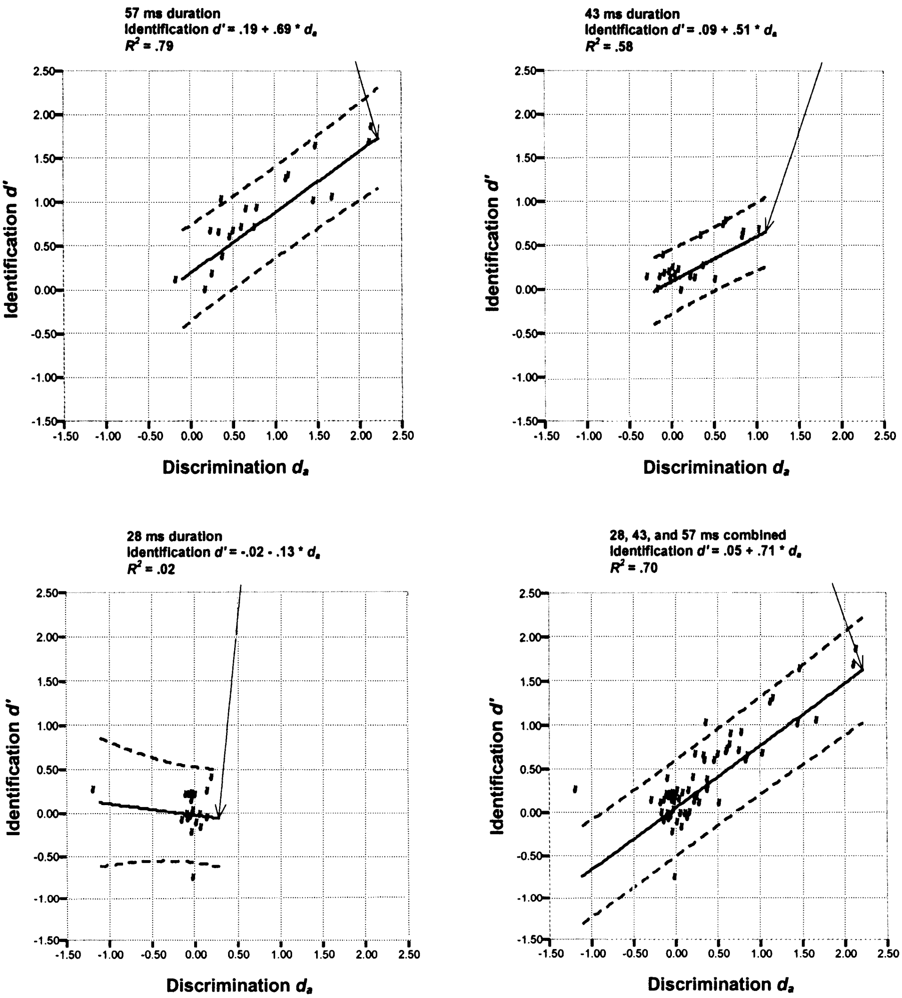

Figure 6. Regression plots for the 57-ms, 43-ms, and 28-ms target durations of Study 2 and the combined results for all three experiments. The inner line represents the regression line, and the upper and lower dashed lines depict the 95% confidence interval

The negative slope in the 28-ms experiment appears to be caused by the presence of a single outlier with a discrimination d_a of −1.1. Removing this outlier from the dataset changes the slope of the 28-ms experiment to a positive value, $y = .56x - .08$. The presence of a statistically significant, positive y-intercept in the 57-ms and 43-ms experiments was consistent with previously reported dissociation effects obtained via regression analysis (Draine & Greenwald, 1998; Greenwald et al., 1995). However, combining the results from the 57-, 43-, and 28-ms experiments yields a regression line, $y = .71x + .05$, with a y-intercept that is not significantly above zero, $t(60) = 1.26$, $p > .05$. These combined results also showed a strong correlation between discrimination and identification, $r = .84$, $r^2 = .70$, $SE = .27$, $p < .01$, and a statistically significant slope, $t(60) = 11.8$, $p < .0001$.

The data from the 43-ms and 57-ms experiments were examined further to determine influences that might contribute to a significant y-intercept in the regression analyses. Visual inspection of the scatter plots suggested that participants with the highest values of discrimination d_a did not have equally high identification d'. Based on this observation, a median split was performed on discrimination d_a for the 57- and 43-ms experiments to compare identification and discrimination of the participants with higher discrimination sensitivity and the participants with lower discrimination sensitivity. For the 57-ms experiment, participants with highest discrimination d_a values, $M = 1.41$, $SD = .54$, had significantly lower identification d' values, $M = 1.19$, $SD = .38$; $t(9) = 2.27$, $p < .02$. There was no difference between discrimination d_a and identification d' for participants with lower discrimination sensitivity in the 57-ms experiment, discrimination d_a, $M = .39$, $SD = .21$; identification d', $M = .45$, $SD = .32$; $t(9) = -.69$, $p < .25$), although a trend is present, suggesting that the lowest values of d_a were accompanied by higher identification d' in some participants. In the 43-ms experiment, once again the participants with higher discrimination d_a, $M = .65$, $SD = .27$, had lower identification d', $M = .41$, $SD = .28$; $t(9) = 3.56$, $p < .003$. In contrast, the participants with less discrimination sensitivity, $M = .03$, $SD = .12$, had higher identification sensitivity, $M = .11$, $SD = .11$, but this difference just missed statistical significance, $t(9) = -1.64$, $p < .07$.

To summarize, these data suggested that a small number of participants with the highest discrimination d_a scores did not have correspondingly high identification performance. The opposite pattern, low discrimination d_a accompanied by higher identification d', was present in a few participants with the lowest discrimination sensitivity, but this trend did not reach statistical significance. These effects appeared to be caused by regression to the mean in that extreme performance on the discrimination task tends to be accompanied by performance closer to the mean on the identification measure. These patterns seem to affect just the extreme scores, given that most participants in each experiment have approximately equal discrimination and identification sensitivity.

As in Study 1, the identification measures were made using the $\sqrt{2}$ adjustment. A reanalysis of the data without this adjustment indicated that identification d' increased slightly in the 28- and 43-ms experiments, d' $M = -.03$ and .36, respectively, but this increase was insufficient to yield a significant difference between identification and discrimination, 28 ms, $t(19) = .44$, $p > .05$; 43 ms, $t(20) = -.58$, $p > .05$, as in Study 1. However, one difference in the 57-ms experiment was that identification without the correction, d' $M = 1.15$, is more sensitive than discrimination, $t(19) = -3.38$, $p < .01$. For the regression analyses, removing the $\sqrt{2}$ correction increases the slopes and y-intercepts in the 43-ms experiment, $y = .72x + .12$, and 57-ms experiment, $y = .98x + .27$, but decreases the slopes and y-intercept of the 28-ms experiment, $y = -.18x - .03$. The absence of the correction does not change the obtained t values and statistical significance of the y-intercepts, as described in Study 1. In summary, these results showed that the presence or absence of the $\sqrt{2}$ correction has a negligible effect on d' values near zero, which is the critical outcome for demonstrating unconscious perception. The removal of this correction also has no impact on the significance of the y-intercept in the regression analyses.

DISCUSSION

As in Study 1, the comparison of discrimination and identification yields indications of dissociations that are similar to those from subjective threshold paradigms in that the pooled "no" response showed above-chance identification performance in the 57-ms experiment. Although this dissociation suggests unconscious perception, the other results are not consistent with this interpretation. For example, dissociations were not present in experiments where the d' values were closer to zero. Second, comparisons of d'-based statistics do not yield a dissociation. Third, identification performance does not exceed levels that can be predicted from discrimination sensitivity. When considered in totality, the present results do not yield compelling evidence favoring an unconscious mechanism that causes discrepancies between discrimination and identification.

The present findings suggest that subjective threshold dissociation effects depend largely on methods. First, the stimulus display parameters are important for finding above-chance identification after a missed stimulus, such as the longer target durations generally improving identification performance at the lower discrimination ratings. For example, identification was significantly above chance at the 3 discrimination rating level in the 57-ms experiment but was not significantly above chance in the 43-ms experiment, even though the stimuli were discriminated at this duration. In addition, the pooled "no" response from the 57-ms experiment had above-chance identification, whereas the pooled "no" response from the 43-ms experiment did not. From these results it logically follows that above-chance identification after discrimination failure critically depends on having stimuli with a duration that is long enough to elevate both discrimination and identification performance at the lower confidence ratings. Because conscious awareness of the target stimuli is more likely at longer stimulus durations, these results suggest that conscious processing probably is necessary for obtaining elevated identification performance after discrimination misses. Second, above-chance identification after a miss is more likely with a one-interval, yes–no discrimination scale. When the pooled 1–3 ratings in the 57-ms experiment are used to estimate results from a simple yes–no task, the results show significantly above-chance identification for the pooled "no" response. In contrast to a one-interval, yes–no scale, participants who are allowed to use a rating scale to express a wider degree of discrimination confidence do not exceed chance identification at the 1 level (i.e., no confidence that a word was presented), consistent with our previous findings (Haase & Fisk, 2001). Therefore, the dissociation effect in subjective threshold paradigms (i.e., above-chance identification after discrimination failure) is critically dependent on the experimental method: Both target display durations and the availability of a discrimination rating scale influence the degree of identification performance at low discrimination confidence. This pattern suggests that the unconscious perception measured in subjective threshold paradigms may be an experimental artifact, a point that was strongly promoted by Holender (1986) and more recently by Snodgrass et al. (2004).

Another dissociation from Study 2 is that the *y*-intercepts of the 43- and 57-ms experiments are significant when identification d' is regressed onto discrimination d_a. Although this dissociation could be interpreted as unconscious perception, another possible interpretation is that these effects may be a result of the regression technique. These data yield clues regarding how this effect might occur. Most participants with moderate discrimination sensitivity had comparable identification sensitivity. However, a small number of participants with the highest discrimination sensitivity did not have correspondingly high identification sensitivity, which is probably a result of regression to the mean. A similar but opposite pattern (i.e., the lowest discrimination values being accompanied by higher identification values) was present in the participants with the lowest discrimination performance, but this trend was not statistically significant. These differences in identification performance from the participants with the highest and lowest discrimination sensitivities flatten the slope of the regression line to a value of less than 1.0. When these flattened slopes are combined with a limited range of positive d' values (negative d' values are nonsensical and probably result from error variability), a positive *y*-intercept is almost guaranteed. Therefore, the present results suggest that the significant *y*-intercepts predicted for null awareness are artificially high estimates of perceptual processing that arise from basic statistical phenomena (restricted range and regression to the mean).

This interpretation is supported by comparing the significant *y*-intercepts of the 43-ms and 57-ms experiments with the results from the 28-ms experiment. Although the *y*-intercept from the 43- and 57-ms experiments predicts above-chance processing at discrimination $d_a = 0$, this prediction does not hold up empirically when discrimination d_a is actually at zero. In contrast to the values predicted by regression, identification d' empirically obtained at $d_a = 0$ is also about zero, which demonstrates that the significant *y*-intercepts in the other experiments are overestimates. Furthermore, combining results from the 28-, 43-, and 57-ms experiments also yields a nonsignificant *y*-intercept of zero. This results stands in contrast to Greenwald et al. (1995, p. 32, Figure 4), who found a significant *y* intercept when their Experiments 1–17 were combined.

The results from Study 2 do not provide strong evidence for or against unconscious perception when considered in totality. However, it is worth considering that even if stronger evidence of superior identification performance was obtained it still might not provide compelling evidence in support of unconscious perception. The reason why is that a participant actually needs less information to perform the 2AFC identification task than the discrimination task. For example, imagine that the word "HOUSE" was briefly displayed but the participant consciously perceives only the "H." This limited information may be insufficient to guide a response on the word–nonword discrimination task because "H" could be part of either a word or a nonword. However, if given an identification choice between "HOUSE" and "PAPER," the participant would reasonably pick "HOUSE" because it contains an "H." Because the participants need less information to guide responses on the identification task, we could expect that identification performance would be dramatically superior to word–nonword discrimination. However, this result was not consistently obtained, possibly because of influences from the display of the identification choices during the discrimination task. The presence of these words during the discrimination task might lead participants to perform the identification first internally, then make a decision about discrimination. Even though comparison of identification and discrimination favors superior identification performance, this pattern was not consistently present in these results.

GENERAL DISCUSSION

The present findings do not yield robust, unambiguous evidence of unconscious perception even though a wide range of stimulus parameters (28-, 43-, and 57-ms targets), awareness tasks (detection and discrimination), and statistical comparisons were used. Dissociations between identification and detection (Study 1) or discrimination (Study 2) are present when these variables are compared with subjective threshold approaches. However, detection sensitivity exceeds identification performance in all SDT-based comparisons made in Study 1, thereby failing to yield a dissociation and weakening the impact of the observed dissociation (i.e., above-chance identification on missed trials at the longer duration). SDT-based comparisons of constrained discrimination and identification indicate that these tasks have approximately equal sensitivity. These findings are consistent with the possibility that participants need at least some degree of stimulus awareness in order for a dissociation to occur in subjective threshold paradigms, especially given that at the 57-ms duration, discrimination confidence often was very high (see Figure 4).

The distinction between direct and indirect measures of stimulus processing is relevant to the interpretation and limitations of the present findings. The results, which are based on direct tasks of detection or discrimination and identification, do not produce compelling evidence of unconscious perceptual processes. However, it is conceivable that an appropriate indirect task might be capable of showing sensitivity to unconscious perception under comparable display parameters. Despite this possibility, it is important to consider that unconscious, neural processes must underlie both direct and indirect tasks, which suggests that it should be entirely possible to measure unconscious perception effects with direct tasks (Snodgrass et al., 1993; Van Selst & Merikle, 1993). The current findings cannot rule out the possibility that the lack of unconscious perception evidence results from the use of direct perceptual tasks. In future studies, we intend to address this issue by extending the methods derived from SDT to situations with indirect tasks, such as priming techniques.

The present results show that linear regression techniques in which two direct tasks (identification and discrimination, Study 2) are compared can yield significant *y*-intercepts, a prediction of stimulus processing occurring despite null discrimination sensitivity. This finding is not completely consistent with previous studies that propose regression of indirect variables onto direct variables is an indication of unconscious perception occurring at $d' = 0$ (the "indirect without direct" pattern, Draine & Greenwald, 1998; Greenwald et al., 1995). The present results demonstrate that indirect tasks are unnecessary to achieve this dissociation. Furthermore, the results suggest that elevated *y*-intercepts might be attributable to a combination of restricted range (i.e., d' values tend to be 0 or higher) with regression to the mean. This combination flattens the slope of the regression line and makes a positive *y*-intercept likely on purely statistical grounds. Altogether, it is unclear whether the regression approach can be considered a valid demonstration of unconscious perception if the dissociation (a significant *y*-intercept) is an outcome of the statistical procedures. Another potential problem with the regression technique concerns whether these should be conceptualized as a subjective or objective approach. The null awareness criterion is clearly objective (e.g., detection $d' = 0$), but the *y*-intercept (i.e., identification performance when detection d' is at 0) is determined from participants who are well above this level of sensitivity. Therefore, a significant *y*-intercept in this approach is essentially a subjective threshold paradigm. In support of this interpretation, significant elevations in the *y*-intercept are more likely at longer target durations (43 and 57 ms) that have significant discrimination sensitivity. However, this result is not found when discrimination sensitivity is at 0 (28–ms experiment), which suggests a subjective threshold situation. Thus, the regression approach could be considered a hybrid of the objective and subjective threshold paradigms, and the subjective elements may introduce problems in that the significant *y*-intercepts may result from participants who have some degree of stimulus awareness.

Recently, Snodgrass et al. (2004) introduced the objective threshold/strategic model (OT/S) of unconscious perception. They similarly criticized subjective threshold approaches as being weak because of the possibility that any dissociations could be caused by partially conscious information that guides responses (Snodgrass, 2002; Snodgrass et al., 2004). The present data are consistent with this assessment. The present findings are also relevant to other aspects of the OT/S model. The fundamental features of the model are evidence of stimulus processing when detection $d' = 0$ and a nonmonotonic relationship between stimulus processing and detection variables as detection d' values increase above zero (see Snodgrass et al., 2004, for details). The data from Study 1 partially support the OT/S model in that identification d' is at zero when detection d' is still greater than zero (Study 1, 28-ms duration), and the relationship between these variables appears to increase monotonically for detection d' values above this point. The critical finding of superior identification when detection d' drops to zero was not addressed in this study, so future studies will need to test this important feature of the model. However, this pattern was not indicated based on one aspect of the present data. For example, examination of the scatter plot from Study 1 (Figure 3, 28 ms) shows that most participants are clustered around 0,0, suggesting that identification sensitivity will be at zero when detection d' reaches zero. However, a full assessment of the OT/S model is beyond the scope of this article. In future work, we will address this key feature of the model to determine whether stimulus processing is still possible when detection d' is at or near zero, in addition to addressing the SDT assumptions of using $d' = 0$ as an indicator of null awareness (see Haase & Fisk, 2004).

SDT provides a robust framework for understanding identification sensitivity at low levels of detection performance. Comparisons of SDT-based measures generally show that detection and discrimination are greater than or equal to identification in sensitivity to the word stimuli. For subjective threshold situations (e.g., above-chance pooled "no" responses), the independent observation model from SDT provides an alternative explanation of situations resulting in apparent dissociation. Figure 7 displays a top-down view of the independent observation model (Macmillan & Creelman, 1991). The circles in this model represent bivariate Gaussian probability functions for the word and nonword stimuli, with some overlap between distributions present because of the difficulty of stimulus presentation (i.e., low *d'*). Decision spaces for detection and identification are independently partitioned by a detection criterion (solid line between the word and noise distributions) and an identification criterion (dashed line at a 45° angle). Misses in each word distribution are represented by the portion of each word distribution that falls below the detection criterion. This model predicts that above-chance identification will be possible on trials in which detection falls below the detection criterion yet enough information is present to raise responding on identification trials to above-chance levels. In essence, this model offers an interpretation of dissociations obtained in subjective threshold paradigms without the need to invoke additional constructs such as unconscious perception (Macmillan, 1986).

A persistent problem for studies of unconscious perception is the measurement of conscious awareness. A key feature underlying the logic of dissociation is that the awareness variable must be exhaustively sensitive

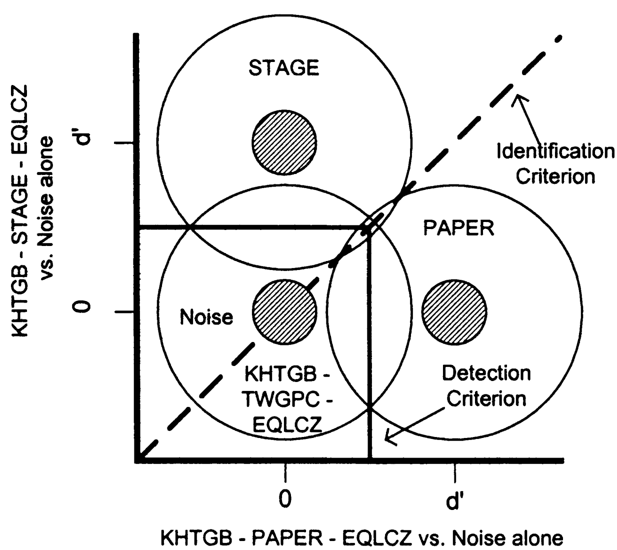

Figure 7. A diagram of the independent observation model representing a hypothetical decision space for a particular trial of the concurrent discrimination and identification task (based on Macmillan & Creelman, 1991). The gray circles represent the centers (i.e., greatest probability density) of each distribution

to conscious experience so that no residual conscious perception goes unmeasured. This is essential for ruling out the possibility that partial or weak stimulus awareness is guiding responses on the other variable of perceptual processing. Based on this criterion, detection appears to be the best choice for measuring consciousness. Presence–absence detection has great sensitivity. For example, as little as 10 quanta of light can be consciously experienced by dark-adapted participants (Bouman, 1955; Cornsweet, 1970; Hecht, Schlaer, & Pirenne, 1942). Of course, the stimuli presented under the present conditions do not approach this level of sensitivity, but this suggests that presence–absence detection might approach exhaustive sensitivity to the sensory aspects of a stimulus. In support of this possibility, detection is much more sensitive to the presence of a stimulus than discrimination (see Snodgrass et al., 2004). Another important criterion for an awareness variable is that it must be exclusive (i.e., represents only conscious perception rather than a combination of conscious and unconscious perception) in order to completely separate conscious and unconscious processes. Detection sensitivity relies on simple luminance changes that are likely to be consciously experienced rather than semantic meaning or "wordness," which have indeterminate conscious status (but see Doyle & Leach, 1988, and Marcel, 1983, for an opposing viewpoint). Detection of low-level sensory information can be done independently of assessment of stimulus features such as wordness, suggesting that detection is exclusively sensitive to the sensory aspects of the stimulus. The importance of independence between the awareness and perceptual sensitivity variables is illustrated by comparing identification and discrimination (Study 2), in which dissociation becomes much more likely when both the awareness and perceptual sensitivity variables simply assess different aspects of word processing. Although presence–absence detection appears to best fit the requirements of an awareness variable, it is important to acknowledge that detection falls short of perfectly satisfying the exhaustiveness and exclusiveness assumptions. For example, the use of detection as an indicator of awareness carries some often unaddressed assumptions, as articulated by SDT. First, the signals must be equally detectable. Word targets of unequal length (Snodgrass et al., 1993; Van Selst & Merikle, 1993) might differ in regard to identification sensitivity under certain display and masking parameters, which could be problematic. Second, the signals must be uncorrelated with the noise and masking stimuli. If these assumptions are not met, null sensitivity (i.e., overall $d' = 0$) on stimulus detection would not be a valid expression of null awareness. To our knowledge, no studies have made statements or provided supporting evidence regarding these critical assumptions. We are pursuing this area of research (Anderson, Lopohovsky, Gross, Haase, & Fisk, 2004).

On another level, we should question the logic of comparing identification or other forms of perceptual processing (e.g., priming) with tasks (e.g., discrimination, detection) that presumably reflect awareness. For example, identification and discrimination could both be considered multidimensional detection from a SDT perspective. In other words, they represent overlapping, similar processes. We cannot validly conclude that one variable represents consciousness and the other represents processing, given that they could be different expressions of the same functions. Any differences in sensitivity between these variables could simply be the result of experimental manipulations that might favor one variable over the other. For example, making the identification choices more similar probably would decrease identification performance while having little effect on detection or discrimination. Conversely, statistical manipulations such as y-intercepts from the regression analyses or the presence or absence of the $\sqrt{2}$ correction might favor the stimulus processing variable over the awareness variable under some conditions. Investigators with differing motives might be able to produce a dissociation or lack of dissociation given the experimental parameters and statistical assumptions that are used or may not realize the assumptions that are needed before null sensitivity can be accepted as a valid indication of null awareness. If there are various means to alter the sensitivity of either stimulus processing or awareness variables through stimulus manipulations, then the resulting comparisons may have little relevance to unconscious perception. Furthermore, we should question whether comparing various expressions of stimulus processing will give insight into the status of psychological processes. For example, we might conclude that identification and discrimination are different when we compare them, but this conclusion does not permit inferences about the psychological status of these items, such as whether they are conscious. We strongly believe that the attainment of "null awareness" on the detection variable must be more fully investigated to ensure that the assumptions of SDT are being met. Otherwise, it might be the case that participants were actually conscious of some of the relevant stimuli, but because of an inflated false alarm rate from things such as correlated noise, their overall performance on the task could be artifactually deflated to chance levels.

The failure of the dissociation paradigm to produce unambiguous evidence of unconscious perception should not be interpreted as evidence against unconscious perceptual processing. In fact, many aspects of stimulus processing are likely to be at least partially unconscious in all sensory systems. The important point is that attempts to isolate unconscious perception (in a cognitive sense) with the dissociation paradigm yield evidence that is weak at best. The present experimental approach indicates that discrimination and detection are, respectively, either superior or approximately equal in magnitude to identification sensitivity, which suggests that dissociations cannot be convincingly interpreted as unconscious effects. New approaches and techniques are needed to produce convincing evidence of unconscious perceptual processes. The SDT-based approach, which does not assume any special unconscious perceptual mechanisms, is sufficient by itself to explain the identification performance obtained in many of the present experiments. However, it is important to bear in mind that SDT does not take a position in regard to the status of conscious or unconscious elements of perception, even though it certainly appears to describe the pattern of data from the present experiments. The psychological status of processing in perceptual tasks (and other similar tasks using global indicators of performance such as d') may be inherently difficult to identify and separate into conscious and unconscious functioning (Uttal, 1998). One clear result from these studies that is consistent with Snodgrass et al.'s (2004) theoretical model is that subjective threshold evidence for unconscious perception is not convincing based on the aforementioned SDT interpretations. The future challenge for the SDT models will be to explain unconscious perception effects obtained at the objective, classic detection threshold. SDT predicts that, again with certain assumptions, null detection should result in null identification (or priming if a priming study is conducted). This area of research clearly deserves much attention.

Notes

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1. If the identification task had been yes–no (e.g., the participant is shown only one word on the identification task) then no downward adjustment would be necessary. If the goal were to assess the discriminability of a small set of words from each other, no adjustment would be necessary (Massaro, 1974). If the signals were unidimensional and polar opposites (e.g., identifying a stimulus as a light or dark patch against a gray background), identification should be upward adjusted by a factor of 2. In any case, more precise testing would be necessary to evaluate the downward adjustment assumption (e.g., separately estimating the detectability of each stimulus compared with noise and separately estimating the identifiability of each stimulus against the others). If each signal had equal detection d' and the signals were orthogonal, then we would expect that the identification of one signal from another would be greater than detection d' by factor of $\sqrt{2}$.

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