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# Subconscious Detection of Threat as Reflected by an Enhanced Response Bias

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Neurobiological and cognitive models of unconscious information processing suggest that subconscious threat detection can lead to cognitive misinterpretations and false alarms, while conscious processing is assumed to be perceptually and conceptually accurate and unambiguous. Furthermore, clinical theories suggest that pathological anxiety results from a crude preattentive warning system predominating over more sophisticated and controlled modes of processing. We investigated the hypothesis that subconscious detection of threat in a cognitive task is reflected by enhanced ''false signal'' detection rather than by selectively enhanced discrimination of threat items in 30 patients with panic disorder and 30 healthy controls. We presented a tachistoscopic word–nonword discrimination task and a subsequent recognition task and analyzed the data by means of process-dissociation procedures. In line with our expectations, subjects of both groups showed more false signal detection to threat than to neutral stimuli as indicated by an enhanced response bias, whereas indices of discriminative sensitivity did not show this effect. In addition, patients with panic disorder showed a generally enhanced response bias in comparison to healthy controls. They also seemed to have processed the stimuli less elaborately and less differentially. Results are consistent with the assumption that subconscious threat detection can lead to misrepresentations of stimulus significance and that pathological anxiety is characterized by a hyperactive preattentive alarm system that is insufficiently controlled by higher cognitive processes.

In the following, we present a brief review of neurobiological and clinical approaches to fear and anxiety. We argue that both perspectives suggest that threat can affect behavior at a subconscious level of processing and that pathological anxiety is associated with the predominance of this subconscious threat detection mode over more elaborated and more conceptual (conscious) modes of processing. Subsequently, these issues are addressed in a psychological experiment in which recent methodological contributions from cognitive psychology are considered. We examine the question of how subconscious threat perception affects behavior in a cognitive task.

Throughout the present article, we understand consciousness as a state or process that is strongly coupled to focal attention. Thus, unconscious processes and preattentive processes are regarded as synonymous. Conscious states and processes are regarded as being principally accessible to introspection because they provide access to metacognitive and self-referential processing. Hence, declarative (explicit) memory is

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regarded as conscious memory. We are aware of the fact that this operational definition does not specifically address other aspects of consciousness such as the emergence of subjective phenomenal states (qualia).

We think that consciousness does not arise from a central site in the neocortex, but that it emerges from iterative processes in highly interconnected neural networks integrating the activity of several cortical and subcortical modules (Newman, 1995). Also, we think that neocortical processing is necessary (but not sufficient) for focal attention to occur.

## Neurobiological Approaches

Neurobiological theories of anxiety suggest that subcortical structures can detect novelty and potential threat in the perceptual environment at a preattentive level of processing and can subsequently prompt conscious processing of these stimuli (Gray, 1982; 1995). Characterizing its functions, this system has been designated an ‘‘alarm bell’’ and a ‘‘comparator’’ (Gray, 1982; 1995). It has primarily been assigned to the limbic region, especially to hippocampus and amygdala.

In his experimental work with rats, LeDoux (1992; 1995a; 1995b) has focused more specifically on the amygdala and its role in emotional responding and fear conditioning (see also Davis, 1989; 1992; and Bechara, Tranel, Damasio, Adolphs, Rockland, & Damasio, 1995, referring to humans). He found that the lateral nucleus of the amygdala receives direct input from the sensory thalamus, which enables the amygdala to detect aversive stimulation and fear-conditioned stimuli even if the sensory neocortex is disconnected, lesioned, or ablated. Hence, the amygdala can elicit autonomic, endocrine, and motor fear responses very quickly even before the organism can be aware of the triggering threat event. Simultaneously, the amygdala signals the potential threat detection to the neocortex (LeDoux, 1992; 1995a; 1995b), thereby causing the neocortex to allocate its attentional resources to the current perceptual input. Thus, the amygdala serves as a preattentive alarm system determining priority and emotional connotation of conscious processing.

However, since the thalamo-amygdala projections leave the sensory system at a very early stage of processing, they can only encode rather simple stimulus features and do not include any complex or differential information. Thus, although not required for the acquisition of simple conditioned fear responses, neocortical processing seems necessary for *discriminative* conditioning as well as for the *extinction* of conditioned fear responses (LeDoux, 1995a; 1995b; Gallagher & Chiba, 1996). LeDoux, Romanski, and Xagoraris (1989; LeDoux, 1995b) argue that in absence of primary sensory areas, potential fear information cannot be relayed to higher cortical regions such as the prefrontal cortex and/or the hippocampus, areas which are believed to be crucial for visual attention (Crick, 1994; Crick & Koch, 1995), working memory (Goldman-Rakic, 1990), and explicit memory (Bechara et al., 1995; Eichenbaum, Otto, & Cohen, 1992; Squire, 1992). Thus, without adequate control provided by more conceptual modes of (neocortical) processing, the preattentive alarm system tends to give rise to false threat alarms because it works in a crude and purely stimulus-driven mode of processing. However, as LeDoux (1986) points out, false-positive responses to potential threat have more survival value than false-negative responses, especially since unnecessary or maladaptive fear responses can normally be modified and extinguished by more detailed and more conceptual modes. LeDoux (1986) describes this as follows:

> The defensive reaction can be aborted once it is determined, on the basis of more detailed perceptual analysis (provided by the way of cortico-amygdala connections), that the threat is not real. Postponement of defense until the cortical sensory systems have analyzed the stimulus, however, could be costly (LeDoux, 1986, p. 241).

Summarizing these results, it seems that preattentive processing of threat tends to give rise to neocortical misrepresentations of threat and stimulus significance (false alarms). At the same time, it also enacts conscious experience, perhaps by activating ascending activation systems (Davis, 1989; Graeff, 1994; Newman, 1995; Newman & Baars, 1993). These neurotransmitter systems can improve the signal-to-noise ratio in the neocortex (Robbins & Everitt, 1995), thereby supporting synchronous oscillations of currently activated neurons (Munk, Roelfsema, König, Engel, & Singer, 1996). Since synchronous oscillatory neuronal activity has been proposed to be the neuronal correlate of (visual) awareness (Crick, 1994; Crick & Koch, 1990; 1995), these mechanisms may be crucial for the establishment of conscious processing allowing modification and verification of automatically evoked emotional fear responses.

## Clinical Approaches

Patients with pathological anxiety, e.g., patients with generalized anxiety disorder or patients with panic disorder, suffer from recurrent and unexpected episodes of fear including a variety of cognitive and physiological symptoms without any obvious cause. They often describe their symptoms as coming ‘‘out of the blue,’’ and as being almost completely uncontrollable and irrational (American Psychiatric Association, 1994). Thus, one could speculate that that pathological anxiety arises from unconscious and automatic processing rather than from conscious and controlled processes.

In clinical psychology, many different cognitive paradigms have been forwarded in order to elucidate the role of information processing for the origin and maintenance of anxiety disorders (see Mathews, 1990; Mathews & MacLeod, 1994; McNally, 1994a, 1994b, 1995; Williams, Mathews, & McLeod, 1996, for reviews). Theoretically, most of these investigations were based on cognitive theories proposing selectively enhanced attention for threat stimuli in subjects with enhanced anxiety (Beck, Emery, & Greenberg, 1985; Bower, 1981; Clark, 1986; Ehlers, Margraf, & Roth, 1988a). Thus, patients with anxiety disorders were presumed to display a tendency to selectively detect, focus on, interpret, store, and retrieve threat-related information. In concordance with this hypothesis, patients with panic disorder were found to show shorter response latencies to the presentation of threatening words (Asmundson, Sandler, Wilson, & Walker, 1992), to evaluate panic-related auditory information as more intense than neutral information (Amir, McNally, Rieman, & Clements, 1996), and to show enhanced implicit and explicit memory performance for bodily sensation words (Cloitre, Shear, Cancienne, & Zeitlin, 1994; but see also Rapee, 1994).

However, the assumed cognitive bias was found only for stimulus words (e.g. anxiety, attack, panic, breathless, palpitation, dizziness) or phrases (e.g. ‘‘The woman panicked in the supermarket’’) that are highly specific for the patient sample, but not for the control sample. For example, Becker, Rinck, and Margraf (1994) found the expected cognitive bias in patients with panic disorder only in panic-related, symptom-specific words, but not in generally negative words. Since panic-related concepts and representations are probably much more frequently used and enacted by patients with panic disorder (relative to healthy controls), it is possible that the reported results simply reflect a word-frequency effect (e.g., Treisman, 1974; see also Engelkamp, Zimmer, & Kurbjuweit, 1995) in the patient group resulting from use-dependent neuronal learning mechanisms (e.g. Brown, Kairis, & Keenan, 1990). In this case, the cognitive bias would merely reflect a *consequence* of the disease and must not be interpreted with respect to the origin of the disorder.

But studies on information processing in patients with anxiety disorders have also been criticized for other reasons. It has been argued that the experimental paradigms that have been applied do not differentiate appropriately between automatic and controlled processes (McNally, 1994a, p. 135; McNally, 1995; Reingold & Merikle, 1993). Therefore, McNally (1995, p. 751) recommended the application of process-dissociation procedures (Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993) in clinical studies to find out whether pathological anxiety actually results from deficits in automatic (or unconscious) processes rather than in controlled (or conscious) processes. Furthermore, it has been argued that sensitivity measures were very often inseparable from response tendencies in the paradigms that have been used so far (McNally, 1994a, p. 126f). Clinical researchers have focused on sensitivity measures only, thereby overseeing the possibility that subconscious processing might affect response tendencies rather than sensitivity scores. This issue is especially remarkable since cognitive theories of panic explicitly describe panic-related cognitions as cognitive *misinterpretations* of threat (Clark, 1986). These ‘‘misinterpretations’’ reflect *false* threat alarms to actually neutral information and should therefore be seen as resulting from a cognitive deficit to differentiate true threat from pseudo-threat, independent of the actual valence of a given stimulus or information. Thus, pathological anxiety has to be viewed as an abnormal *response tendency* when differentiating threat and nonthreat stimuli and must not be confused with a *selectively enhanced sensitivity for threat* as presumed by most clinical researchers.

In their recent psychological model of generalized anxiety, Beck and Clark (1997) express a similar view. Here, they consider pathological anxiety to result from the predominance of a relatively primitive early warning system over rational, metacognitive processing. Information processing in this early warning system is described as being rapid, involuntary, unconscious, and stimulus driven. It is characterized as being undifferentiated, stereotyped, and indiscriminative, as simply reflecting recognition of the valence or personal relevance of a given stimulus but involving only little higher level processing and semantic analysis. Beck and Clark (1997) argue that this early registration mode can result in automatic, irrational, and involuntary fear responses. They propose that these automatic fear responses can normally be countered by more elaborative, strategic processing performed by the metacognitive mode, but that patients with anxiety disorders somehow fail to make use of this modifying mechanism. Thus, the model fits perfectly to the neuroscience perspective outlined above.

Summarizing the review of the clinical literature, pathological fear responses seem to represent an inability to differentiate false from true threat preattentively. However, this assumption has never really been tested experimentally because cognitive researchers were always uncertain about how subconscious perceptual processes can actually be measured (Holender, 1986; Merikle & Reingold, 1992).

It is argued here on the basis of neuroscience evidence and clinical models of anxiety that a hyperactive preattentive threat detection mechanism should manifest cognitively as an enhanced tendency to misinterpret any stimulus input as more dangerous and more significant than it actually is. That is, patients with panic disorder should display an enhanced tendency to falsely perceive relevance and significance in any stimulus presented to them, irrespective of the actual valence of the stimulus and irrespective of conscious performance. Furthermore, they should display a lower than normal ability to modify this tendency by means of conscious and elaborated processing.

## Methodological Concerns

There have been numerous methodological debates in cognitive psychology about the valid assessment of conscious and unconscious processes (e.g. Holender, 1986; Merikle & Reingold, 1992; Reingold & Merikle, 1993). Recently, the process-dissociation procedure introduced by Jacoby (1991; Jacoby et al., 1993) has been welcomed as a suitable method for the post hoc separation of automatic (unconscious) and strategic or controlled (conscious) processes. In this procedure, subjects are first presented word lists in an incidental or an intentional learning task. This task is then followed by a subsequent memory task, e.g., a recognition task (Jacoby, 1991) or a word-stem completion task (Jacoby et al., 1993) presented with one of two different instructions (inclusion and exclusion condition). In the inclusion condition of the word-stem completion task variant, subjects are asked to complete the word stems either with old items that had been presented to them in the previous learning phase, or—if they cannot remember any—with the first word that comes to their minds. In the exclusion condition, however, they are asked to complete the word stems only with new items that had *not* been presented before. When subjects in the exclusion condition erroneously depict *old* items for the completion of the word stems, these items are considered as being unconsciously remembered due to enhanced familiarity. Conversely, old items are presumed to be *consciously* remembered when being excluded in line with the instructions. On the other hand, subjects in the inclusion condition are presumed to use old items when they either consciously or subconsciously remember them.

In the recognition task variant, subjects are shown two word lists in the learning task (list A and list B). In the subsequent test phase, they are presented test words and must judge if these had been presented before or not (yes–no). In the inclusion condition, subjects are instructed to say ‘‘yes’’ to both, words from list A and words from list B. In the exclusion condition, they are instructed to respond ‘‘yes’’ only to words from list A, and ‘‘no’’ to words from list B. Only the responses to list B items are analyzed. It is assumed that if subjects consciously remember these items, they will respond ‘‘yes’’ in the inclusion condition and ‘‘no’’ in the exclusion condition. If there is no conscious recollection but unconscious memory for the items (due to familiarity), subjects are assumed to answer ‘‘yes’’ in both conditions. Thus, when both conditions are considered simultaneously, the procedure allows one to estimate the relative proportion of conscious and unconscious processing in this memory task.

More recently, the original process-dissociation procedure has been discussed controversially for several reasons (e.g. Buchner & Erdfelder, 1996; Buchner, Erdfelder, & Vaterrodt-Plünnecke, 1995; Vaterrodt-Plünnecke, Krüger, Gerdes, & Bredenkamp, 1996). For example, the measurement model of the process-dissociation procedure is actually formally equivalent to the two-high-threshold model (see Snodgrass & Corwin, 1988). The probability of correctly responding with old words in the inclusion condition (*INCLUSION*) can be seen as the hit rate (*HIT*), and the probability of erroneously responding with an old word in the exclusion condition (*EXCLUSION*) represents the false alarm rate (*FA*) in terms of signal detection theory. Thus, Jacoby's formula (e.g., Jacoby et al., 1993, p. 141) for computing conscious recollection ($R$)

$$R = INCLUSION - EXCLUSION$$

is mathematically equivalent with the sensitivity measure $P_r$ in two-high-threshold theory (see Snodgrass & Corwin, 1988, p. 38) defined as

$$P_r = HIT - FA.$$

Correspondingly, Jacoby's parameter for automatic processes ($A$) (e.g. Jacoby et al., 1993, p. 141) computed as

$$A = EXCLUSION/(1 - R)$$

is the same as the response bias measure $B_r$ in the two-high-threshold model defined as

$$B_r = FA/(1 - P_r)$$

(see Snodgrass & Corwin, 1988, p. 38).

Thus, the process dissociation procedure actually implies the assumption that unconscious memory effects enhance the response bias for choosing old items due to familiarity, whereas conscious recollection allows correct discrimination of old and new words (see also Hay & Jacoby, 1996). This central assumption of the process dissociation approach seems to be agreed upon by most cognitive psychologists in this domain. Using distributed neural networks, some researchers have attributed this response-bias-enhancing memory effect to increased synaptic weights in the memory matrix resulting automatically from use-dependent neuronal learning mechanisms (Ratcliff & McKoon, 1996), whereas synchroneous activation of relatively loosely interconnected neurons seems to require additional neuromodulatory transmitter input enhancing the signal-to-noise ratio in neocortical processing (Durstewitz & Windmann, in press; Munk et al., 1996).

In correspondence with two-high-threshold theory, Jacoby (1991, Jacoby et al., 1993) assumed that the a priori response bias (=base rate) for depicting a word from the study list even if it had not been presented in the study phase is equal for the inclusion and the exclusion condition (see Toth, Reingold, & Jacoby, 1995). Thus, when base rates are not determined separately, the index $A$ (or $B_r$) indicating automatic recollection is actually a compound measure of both, the a priori response bias (base rate) plus the response-bias-enhancing unconscious memory effect. In the literature, the question of how these two measures should be separated from each other and from conscious performance has become a controversial issue because it seems unclear what measurement model should be applied (e.g., Buchner et al., 1995; Wainwright & Reingold, 1996; Yonelinas & Jacoby, 1996; Buchner & Erdfelder, 1996; Reingold & Wainwright, 1996; Cowan, 1996; Erdfelder & Buchner, in press). At present, it seems that the most exact and most powerful method is provided by extended process-dissociation procedures based on multinomial modeling (Hu & Batchelder, 1994; Riefer & Batchelder, 1988). Important advantages of this statistical technique are first that it provides mathematical independence of memory performance measures and the response bias measure, and second that it provides an opportunity to statistically test the appropriateness of the measurement model underlying a given data analysis. It has recently been applied to an implicit memory task requiring the discrimination of tachistoscopically presented words and nonwords (Vaterrodt-Plünnecke, 1994).

## Assumptions and Aims of the Present Study

In the present study, we investigated preattentive processing and implicit and explicit memory for threat and neutral items in patients with panic disorder and healthy controls. We selected threat items that were *generally* threatening, that is, we excluded items that are specifically related to panic symptomatology because we did not want performance of panic patients to be confounded with word-frequency effects.

For the implicit memory task, we used the same experimental procedures as Vaterrodt-Plünnecke (1994). These consisted of an incidental learning task and a subsequent lexical decision task with tachistoscopic presentation of words and nonwords for 28 ms. The task allowed assessment of conscious perceptual processes, implicit memory effects, and a priori response tendencies (=base rates). It was followed by an explicit recognition task to determine how well elaborated threat and neutral words had been studied in the acquisition phase. Here, we analyzed the proportion of conscious recollection and the response bias (reflecting unconscious memory *plus* base rates).

Our hypothesis was that subconscious threat detection would provoke an enhanced tendency to respond with false signal detections (in terms of signal detection theory) in both memory tasks, independent of conscious processes.

The rationale for our assumption is the following: When regarding neurobiological evidence of subconscious threat detection mechanisms, it is plausible to assume that any time the subconscious alarm system detects potential threat, it suggests to the cognitive system that some meaningful and relevant stimulus has been presented that must not be disregarded during ongoing cognitive activity. That is, stimuli which become subconsciously associated with potential threat appear important to conscious processing even if it is actually unable to identify them or is currently engaged in a completely different task that is not related to threat recognition. In other words, we assume the preattentive alarm system to cause ‘‘misrepresentations of significance’’ any time it detects potential threat, thereby directing subjects’ responses toward the positive response pole, irrespective of what the cognitive system is actually looking for at the moment and whether it would regard the stimulus as being relevant or not on the basis of *conscious* analysis. Just as the amygdala is known to lead to false-positive responses to potential threat rather than to false-negative responses, subconscious threat detection in the memory tasks we used should lead to false signal perceptions (indicating ‘‘important stimulus—probably relevant—deserves attention’’) rather than to false nonsignal perceptions (‘‘unimportant stimulus—probably meaningless—can be rejected’’). Interestingly, a similar phenomenon has been proposed earlier in patients with temporal lobe epilepsy in order to explain sudden increases in religiousness (Ramachandran et al., 1997). These patients were presumed to ascribe more significance to any perceived object or event because of increased connectivity between the amygdala and the temporal lobes, a condition which actually parallels cerebral abnormalities found in panic disorder in some respect (see Dantendorfer et al., 1996; George & Ballenger, 1990; Lucas, Telch, & Bigler, 1991).

Some further comments seem helpful at this point to delimit our hypothesis against assumptions that have been made in previous experiments. Since we believed discriminative processing to be a function of conscious processing rather than of unconscious processing, we did not expect panic patients to show selectively enhanced *sensitivity* for threat items. This clearly contrasts with assumptions of all previous studies known to us examining attentional or memory biases in clinical disorders using symptom-specific stimuli (e.g. Amir et al., 1996; Becker et al., 1994; Cloitre et al., 1994; Ehlers et al., 1988b; Rapee, 1994). Moreover, it is important to note that our hypothesis does not imply that patients with panic disorder show enhanced implicit *memory* performance. Even though we agree that implicit memory can be considered unconscious memory, we consider pathological anxiety to be related to subconscious threat detection processes at an early *perceptual* stage, not to any conscious or subconscious memory process. By referring to neurobiological evidence, we have a specific hypothesis about how subconscious perceptual processes might lead to misinterpretations of stimulus valence in patients with panic disorder, but we do not see any specific reason why these misinterpretations should result from a selectively enhanced implicit memory bias for threat stimuli. Nevertheless, the memory bias hypothesis has very often been proposed and supported, and we reexamined it in the present study using non-symptom-specific stimuli in order to find out whether these previous findings point to a more general cognitive abnormality that cannot simply be attributed to word-frequency effects.

Hence, with reference to subconscious perceptual processes, two predictions were derived from our hypothesis:

1. Subconscious detection of threat manifests as a tendency to build up misrepresentations of stimulus significance leading to ‘‘false alarm responses’’ unless being modified by conscious, discriminative processing. Thus, we expected subjects to automatically and involuntarily ascribe more significance to threat than to neutral items in our cognitive tasks, *irrespective of their ability to consciously perceive or recollect the stimuli.* For the word–nonword discrimination task, we hypothesized that this mechanism would lead to more false ‘‘word’’ (rather than to more false ‘‘nonword’’) responses to threat than to neutral items, irrespective of whether in fact a word or a nonword had been presented. It is important to note at this point that this procedure presumed that threat nonwords would activate semantic threat associations more than neutral ones even though they were orthographically illegal. This seemed likely because nonwords had been generated from legal words by a simple transformation of

the letter strings (e.g. RETOT for the German word ‘‘TOTER’’, meaning ‘‘dead man’’). Although these items were meaningless in a lexical sense, they did nevertheless show structural similarity to the words they were generated from. Consequently, our hypothesis that subjects would show more ‘‘word’’-responses to threat than to neutral items (irrespective of discrimination performance) referred to both, words *and* nonwords. As we defined word presentations as signals and nonword presentations as nonsignals, this tendency reflects an enhanced (=more liberal) response bias for threat items relative to neutral items.

In the recognition task requiring subjects to indicate whether the presented word stimuli had been shown previously, we were again interested in seeing whether subjects would respond differently to threat and to neutral items irrespective of their ability to discriminate whether these items are old or new. In accordance with the word–nonword discrimination task, we defined positive responses (‘‘old’’) as signal detections and negative responses (‘‘old’’) as nonsignal detections. Again, we hypothesized that subjects would show more ‘‘false signal detections’’ to threat than to neutral items indicating cognitive misinterpretation of subconscious threat detection influences. Given our definition of signals and nonsignals, this would be represented by an enhanced (=more liberal) response bias to threat items in comparison to neutral items.

2. If panic disorder is associated with a hyperactive preattentive threat detection system, this should lead to more enhanced ‘‘false signal’’ detections, that is, to an enhanced tendency to misinterpret any perceptual input as significant for current cognitive processes irrespective of whether this stimulus is actually meaningful (and maybe threatening) or not. Thus, we expected panic patients to display an abnormal (=enhanced, more liberal) response bias for threat and for neutral items in both tasks, but we did neither expect them to show increased perceptual discrimination performance nor enhanced implicit or explicit memory scores in threat items compared to controls. On the contrary, since we hypothesized the hyperactive subconscious alarm system to be associated with a *deficit* in more elaborated and more controlled modes of processing, we expected panic patients to show *lower* explicit memory scores than healthy controls.

## METHODS

### Subjects

Thirty patients (25 women, 5 men; aged 37.36 years, *SD* = 8.57) with panic disorder according to DSM IV (American Psychiatric Association, 1994) participated in the experiment. Patients were diagnosed by means of the German inventory for the diagnosis of psychiatric disorders (DIPS) (Margraf, Schneider, & Ehlers, 1994). They were contacted by the help of local psychotherapists or via local media announcements. Only one patient was hospitalized at the time of the experiment.

Thirty healthy subjects (25 women and 5 men, aged 36.0 years, *SD* = 11.36) with no history of psychiatric disorders were selected as controls. All control subjects indicated that they had never undergone psychiatric or psychotherapeutic treatment.

Three patients who had traveled more than 10 miles for participation were paid DM 15 as a representation allowance.

### Stimulus Material

Two parallel word lists (forms A and B) were made up for the incidental learning task (English translation see Appendix, Table A). Both lists contained 15 threat substantives and 15 neutral substantives consisting of 2 or 3 syllables. Words of both valences were parallelized according to number of letters and frequency using linguistic statistics provided by Meier (1967). For the word–nonword discrimination task (implicit memory task), words of list B served as distractor items for list A and vice versa. This counterbalancing procedure was meant to ensure that any observed effect of repeated presentation could not be due to any specific characteristic of one of the two word lists.

From the 30 words in both lists, nonword items were constructed in that at least two letters of each word were transposed. This was performed with the two restrictions that first, the two transposed letters had to be separated by at least one other letter, and second, the resulting letter string still had to be pronounceable. The latter strategy was meant to avoid correct identification of a nonword from three or more vowels or consonants in a row (such as ‘‘ZWG’’ or ‘‘UAE’’). For the recognition task, 30 new distractor items (15 threat words and 15 neutral words) were selected. These were also matched with the test items with respect to word length and frequency.

Thus, for both parallel test forms, the word–nonword discrimination task consisted of 120 items in total, and the recognition task involved 30 old and 30 new words.

### Experimental Tasks

All experimental procedures were run on an IBM-compatible personal computer. Items were presented in the center of the DOS screen as black text on white background.

In the *incidental learning task*, threat and neutral words were presented in randomized order for 1.5 s. Subjects were asked to read these words and to rate the ‘‘emotional threat’’ valence of each word on a 7-point rating scale by key press. In the subsequent *word–nonword discrimination task* (implicit memory test), items from the learning task plus distractor items were presented tachistoscopically for 28 ms (accomplished by directly controlling the video port), and were masked by a white XXXXXXXXX pattern on black background. Subjects had to indicate (by key press) whether they believed that the presented item was a word or a nonword. In the final *recognition task* (explicit memory task), items of the learning phase plus new distractor items were presented in randomized order. Subjects were asked to indicate whether they believed that the presented item had been presented before (in the learning phase) or not. To facilitate responding, subjects were allowed to indicate how confident they were of their response (‘‘certain’’ or ‘‘uncertain’’). However, for the data analyses, only positive (‘‘old’’) and negative (‘‘new’’) responses were differentiated.

### Procedure

All subjects gave informed consent prior to participation in writing. Experimental sessions took place in the afternoon hours between 3 and 7 p.m. to minimize possible circadian influences on vigilance and attention.

Subjects were randomly assigned to either test forms A or B with the restriction that half of the subjects from both groups received test form A and the other half test form B, each consisting of the incidental learning task, the implicit memory task, and the explicit memory task. Instructions were presented on the video screen and were also read aloud to the subjects. After task completion, subjects were given the German version of the Beck-Depression Inventory (Hautzinger, Bailer, Worall, & Keller, 1994), and the German version of the State–Trait Anxiety Inventory (Laux, Glanzmann, Schaffner, & Spielberger, 1981). In total, these procedures took about one hour. Subsequently, patients with panic disorder were interviewed more individually about their symptomatology in a nonstandardized clinical interview.

## Data Analysis

### *Rating of the Stimulus Material (Incidental Learning Task)*

Ratings of the stimulus words were analyzed using a 2 (Group) × 2 (Valence)-ANOVA with repeated measures on the second factor.

### *Word–Nonword Discrimination Task (Implicit Memory Task)*

Performance in the word–nonword discrimination task was analyzed by means of traditional two-high-threshold analyses (Snodgrass & Corwin, 1988) and, in addition, using the multinomial modeling approach (Riefer & Batchelder, 1988; Hu & Batchelder, 1994) as described by Vaterrodt-Plünnecke (1994; see also Buchner et al., 1995).

*Two-high-threshold analysis.* Two-high-threshold analysis provides the (nonparametric) sensitivity measure $P_r$ indicating the ability to discriminate words and nonwords. It is defined as

$$P_r = HIT - FA,$$

where $HIT$ = probability of a ‘‘word’’-response when in fact a word had been presented, and $FA$ = probability of a ‘‘word’’ response when in fact a nonword had been presented. The index varies between −1 (inverse sensitivity) over 0 (null sensitivity) to 1 (perfect sensitivity).

In addition, two-high-threshold analysis provides a response bias index computed as

$$B_r = FA/(1 - P_r)$$

(notation as above). The index ranges from 0 (extremely strict bias) over 0.5 (neutral bias) to 1 (extremely liberal bias = high tendency to respond with false alarms).

We computed $P_r$ and $B_r$ for old and new items separately. The difference between $P_r$ for old items and $P_r$ for new items represents the classical implicit memory effect indicating increased discrimination performance in old items due to previous presentation. Likewise, while $B_r$ for new items represents the base rate in Jacoby’s terms (Jacoby, 1991; Jacoby et al., 1993), $B_r$[old] minus $B_r$[new] represents further implicit memory effects enhancing the tendency to respond ‘‘word’’ to familiar items compared to new (unfamiliar) items.

We tested group and valence effects by a three-way ANOVA (2 Group × 2 Valence × 2 Presentation Status) with Valence (threat/neural) and Presentation Status (new/old) as repeated measures.

*Disadvantage of this procedure.* The traditional two-high-threshold analysis yielding $P_r$ and $B_r$ does not account for the fact that implicit memory effects should be independent of the a priori performance ($P_r$[new] and $B_r$[new]). For example, if a subject was able to discriminate new words and nonwords with a probability of $P_r$[new] $= .80$, the maximal profit from a prior presentation (that is, the maximal classical implicit memory effect) could be .20 because the implicit memory score is calculated as the difference between $P_r$[old] and $P_r$[new] (that is, 1 minus .80). Furthermore, the model assumes that the probability of identifying a word as a word item equals the probability of identifying a nonword as a nonword item (two-high-threshold assumption). The model itself, however, does not provide any statistical support for this assumption. Therefore, we repeated the analysis of the word–nonword discrimination data using multinomial modeling procedures. See Buchner et al. (1995), Buchner and Erdfelder (1996), Erdfelder and Buchner (1998), and Vaterrodt-Plünnecke et al. (1996) for further discussion of this and related problems.

*Multinomial modeling.* The multinomial modeling works as follows. A system of nonlinear equations is defined in which hypothetical parameters represent latent cognitive events (see Fig. 1). The parameters and their confidence intervals can be estimated from subjects' responses by means of maximum-likelihood methods (Riefer & Batchelder, 1988). Furthermore, the mathematical validity of the estimated parameter set can be tested statistically by means of goodness-of-fit tests (Hu & Batchelder, 1994). Since the same can be done with restricted variants of the model, successive parameter restrictions can be introduced into the equation system to find the most economic parameter set which predicts a given empirical data set with sufficient statistical precision. In the present study, these analyses were performed using a publicly available computer program written by Hu (1995). The program yields the goodness-of-fit statistic $G^2$ which is approximately $\chi^2$ distributed (see Hu & Batchelder, 1994; Read & Cressie, 1988).

In the present study, four submodels had to be specified, since the design involved two groups (panic patients and controls) and two item valences (threat and neutral). The structure of each one of these submodels is illustrated by Fig. 1. Each submodel contained four stimulus categories: old words, the corresponding ''old'' nonwords, new words, and the corresponding ''new'' nonwords. Subjects' responses to these four stimulus classes were assumed to reflect the probability of four latent cognitive processes represented by four free parameters. In concordance with Vaterrodt-Plünnecke (1994), these four parameters were designated

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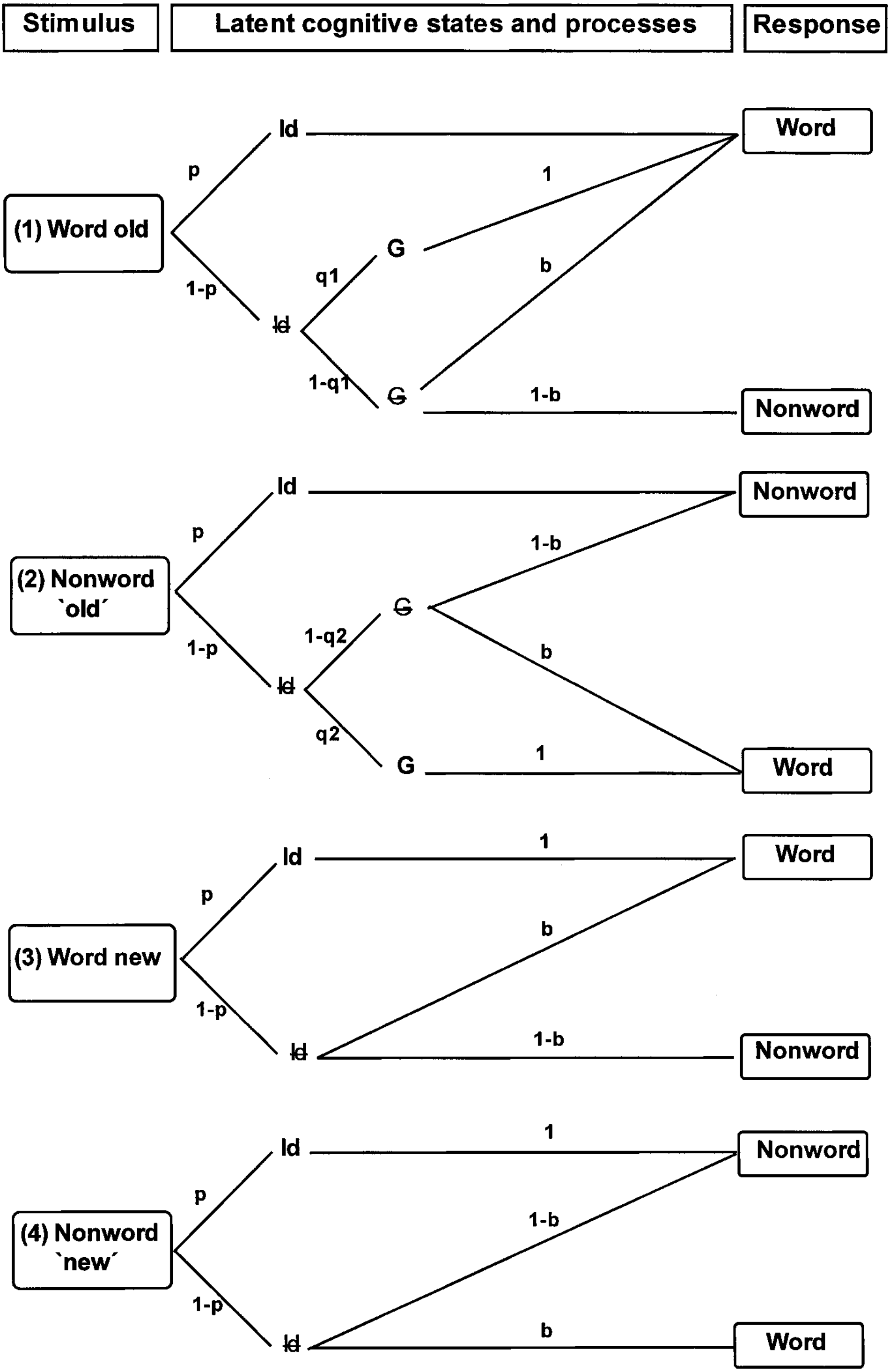
**FIG. 1.** Schematic illustration of the two-high-threshold model for the implicit memory task (word–nonword discrimination task) (see Vaterrodt-Plünnecke, 1994). Id and G denote internal states (**Id** = identification; ~~Id~~ = no identification; **G** = priming effect; ~~G~~ = no priming effect). Parameters $p$, $b$, $q1$, and $q2$ denote transitional probabilities from left to right, representing latent cognitive processes (see text). When an old word was presented, for instance, the model assumes that a correct ''word'' decision results from (1) correct discrimination (probability $p$), or (2) no discrimination ($1 - p$), but an unconscious priming effect ($q1$), or (3) no discrimination ($1 - p$), no unconscious priming effect ($1 - q1$), but a response bias for a ''word'' response ($b$). Thus, the equation for the observed frequency of ''word'' responses when old words were presented reads $[p + (1 - p) \cdot q1 + (1 - p) \cdot (1 - q1) \cdot b]$.


Stimulus
Latent cognitive states and processes
Response
(1) Word old
p
1-p
Id
~~Id~~
q1
1-q1
G
~~G~~
1
b
1-b
Word
Nonword
(2) Nonword `old´
p
1-p
Id
~~Id~~
1-q2
q2
~~G~~
G
1-b
b
1
Nonword
Word
(3) Word new
p
1-p
Id
~~Id~~
1
b
1-b
Word
Nonword
(4) Nonword `new´
p
1-p
Id
~~Id~~
1
1-b
b
Nonword
Word

- *p:* correct (conscious) discrimination of the items (as words or nonwords);
- *q*1: increased correct discrimination of old items relative to new items (classical implicit memory effect, similar to $P_r$[old] minus $P_r$[new]);
- *q*2: increased false ''word'' responding to ''old'' nonwords relative to ''new'' nonwords due to enhanced perceptual fluency (resulting from previous presentation of the corresponding words, representing a similar effect as $B_r$[old] minus $B_r$[new]);
- *b:* response bias (=base rate; tendency for ''false signal detections,'' indicating a tendency to respond ''word'' when the item had actually not been identified).

Since *p* is assumed to be equal for words and nonwords, this model also represents a two-high-threshold model for the discrimination of words and nonwords. Vaterrodt-Plünnecke (1994) had shown this assumption to be valid for the given task using concrete as well as abstract substantives. However, its validity will be tested again in the present study.

The model does not imply a special temporal order of the predefined latent processes. It is mathematically equivalent to a model assuming the priming effect to occur before identification.

To test the experimental effects for statistical significance, the original model $M_0$ (which includes all four submodels and 16 free parameters, that is, 4 in each submodel) and a restricted variant of the model ($M_{1,}$ which also includes all four submodels but less than 16 parameters) were compared by computing the difference between the $G^2$-statistics of $M_0$ and $M_{1.}$ This procedure was performed for all $M_{n+1}$ until no further restrictions could be introduced into the equation system without a significant loss of the model's fit. In our data set, these analyses were based on 60 (subjects) × 120 (items) = 7200 observations. For this sample size, maximally 3 degrees of freedom, and an $\alpha$-error-level of 5%, the program GPower (Erdfelder, Faul, & Buchner, 1996) indicates a statistical power of approximately 1 for $\chi^2$-comparisons with small effect sizes.

### *Recognition Task (Explicit Memory Task)*

Performance in the recognition task was also analyzed by applying the two-high-threshold model to hit and false alarm rates (see Snodgrass & Corwin, 1988). $P_r$ and $B_r$ were computed as above, with *HIT* = probability of an ''old''-response to an old word, and *FA* = probability of an ''old''-response to a new word (distractor item).

Formally, this analysis corresponds to the process dissociation procedure by Jacoby (1991; see Buchner et al., 1995; Vaterrodt-Plünnecke, 1994) when base rates are not determined separately. Hence, the response bias measure $B_r$ represents a compound measure for both, the a priori response bias (=base rate), and unconscious memory (=automatic recollection).[2]

[2] $B_r$ and $P_r$ usually correlate very highly (>.95) with other nonparametric measures of response bias ($B''$ and $B_H$) and sensitivity ($A'$), respectively (Windmann, 1997; cf. Snodgrass & Corwin, 1988). This was also true for the present data set. One common characteristic of all nonparametric measures of response bias ($B_{r,}$ $B''$, and $B_H$) is that false alarms make less difference to the terms the more hit rate approximates 1. Furthermore, the terms are not defined in case of perfect sensitivity ($P_r$ = 1). In our data set, $B_r$ of seven controls and one patient with panic disorder represented missing values in the ANOVA with repeated measures.

TABLE 1
Means (*SD*) of Patients and Control Subjects in the Standardized Clinical Questionnaires

| Questionnaire | Patients | Controls | *F* test |
|---|---|---|---|
| STAI: Trait anxiety | 55.30 (11.88) | 41.13 (9.61) | 25.75 *** |
| STAI: State anxiety | 46.56 (11.15) | 36.41 (10.70) | 12.89 *** |
| BDI: Depression | 17.86 (9.58) | 7.26 (6.30) | 25.59 *** |

*** $p < .005$.

Group differences in both parameters were analyzed by means of a 2 (Group) × 2 (Valence) factorial ANOVA with repeated measures on Valence.

## RESULTS

### Sample Characteristics and Clinical Questionnaires

Mean duration of panic symptomatology in the patient group was 7.78 years (*SD* = 6.11). Twenty-three patients (77%) fulfilled the DSM IV criteria of agoraphobia, the others were diagnosed as panic disorder without agoraphobia. Twenty-one patients (70%) received psychotherapy at the time of the experiment. Ten patients (33%) received pharmacological treatment on a regular basis; eight of them tricyclic antidepressants, the other two benzodiazepines.[3]

Table 1 shows the results from the standardized clinical questionnaires.

### Rating of the Stimuli

The Group × Valence ANOVA with repeated measures on Valence showed a highly significant effect for Valence ($F[1,58] = 540.29$, $p < .0001$), indicating that threat words were rated as much more threatening than neutral words. The Group factor was also significant ($F[1,58] = 25.80$, $p < .001$), since patients rated the words as more threatening than control subjects. However, there was no significant Group × Valence interaction effect ($F[1,58] = 1.77$; see Fig. 2).

### Word–Nonword Discrimination

#### *Traditional Two-High-Threshold Analysis*

Analysis of variance with repeated measures for Valence and Presentation Status showed no significant effect for Group ($F[1,58] = 0.64$) for the sensitivity measure

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[3] Medications were prescribed in very low doses and did not affect performance scores significantly. Unfortunately, we did not test our subjects for intelligence or verbal skills. Instead, we compared educational levels and found that subjects in the control group had achieved (on average) a higher academic status than panic patients. Further analyses showed, as should be expected, that educational level affected neither discrimination performance in the word–nonword discrimination task significantly, nor implicit memory performance. However, it did affect explicit recognition performance significantly. Therefore, we repeated our ANOVA analysis using three levels of academic achievement as a covariate. We found the same group effect as in the other analysis, but on a lower level of statistical significance ($p < .05$). Neither explicit recognition performance nor educational level showed any practically significant correlation (>.20) to response bias measures. Thus, intellectual differences between the two groups do

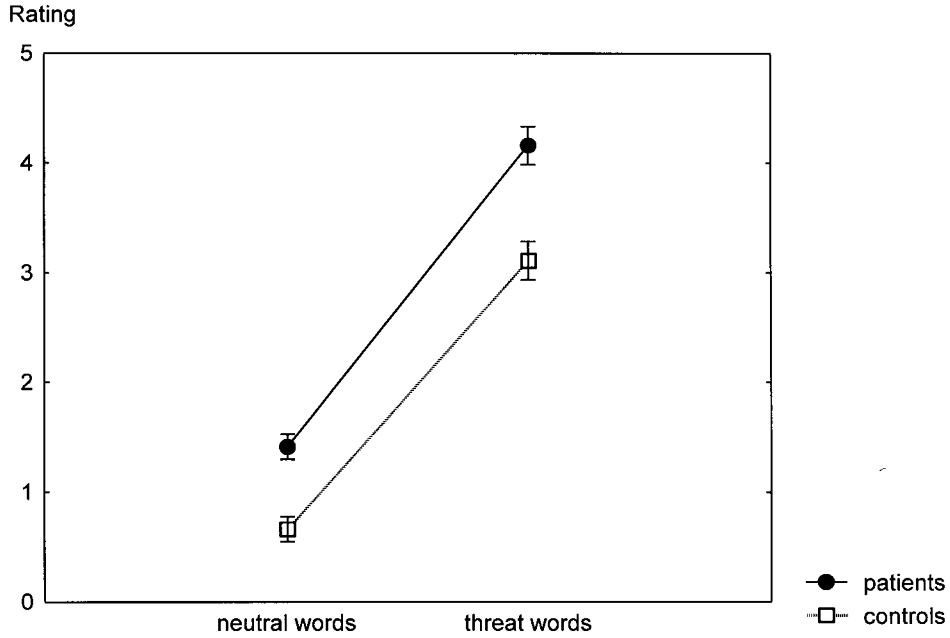

**FIG. 2.** Rating of the stimulus material on a 7-point scale ranging from 0 (absolutely not threatening) to 6 (extremely threatening).

$P_{r,}$ but a significant effect for Valence ($F[1,58] = 6.64$, $p < 0.05$), and a significant Group × Valence–interaction effect ($F[1,58] = 5.48$, $p < 0.05$). Orthogonal post hoc comparisons indicated that discrimination performance was enhanced for neutral items compared with threat items in healthy controls ($F[1,29] = 15.40$, $p < .001$), but not in panic patients ($F[1,29] = 0.02$; see Fig. 3).

In addition, there was a significant main effect for Presentation Status ($F[1,58] = 48.25$, $p < .001$) reflecting the classical implicit memory effect, as old items were discriminated better than new items. The interaction effect Valence × Presentation Status reached marginal significance ($F[1,58] = 3.36$, $p < .10$) since old neutral items were discriminated better than old threat items ($F[1,58] = 11.90$, $p < .002$), but new neutral items were not discriminated significantly better than new threat items ($F[1,58] = 0.16$). Figure 3 illustrates these results.

For the response bias measure $B_{r,}$ the ANOVA showed a significant effect for the repeated factor Valence ($F[1,58] = 32.85$, $p < .001$). Threat items were associated with a higher response bias than neutral items. The Group factor was also significant ($F[1,58] = 15.31$, $p < .001$). Panic patients showed an enhanced response bias compared with controls. In addition, the repeated factor Presentation Status was significant ($F[1,58] = 44.31$, $p < .001$), because the response bias to old items was higher than to new items. However, there was also a significant three-way interaction of

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not threaten the validity for our main results, but some caution has to be warranted regarding the effect size of Group on explicit memory performance.

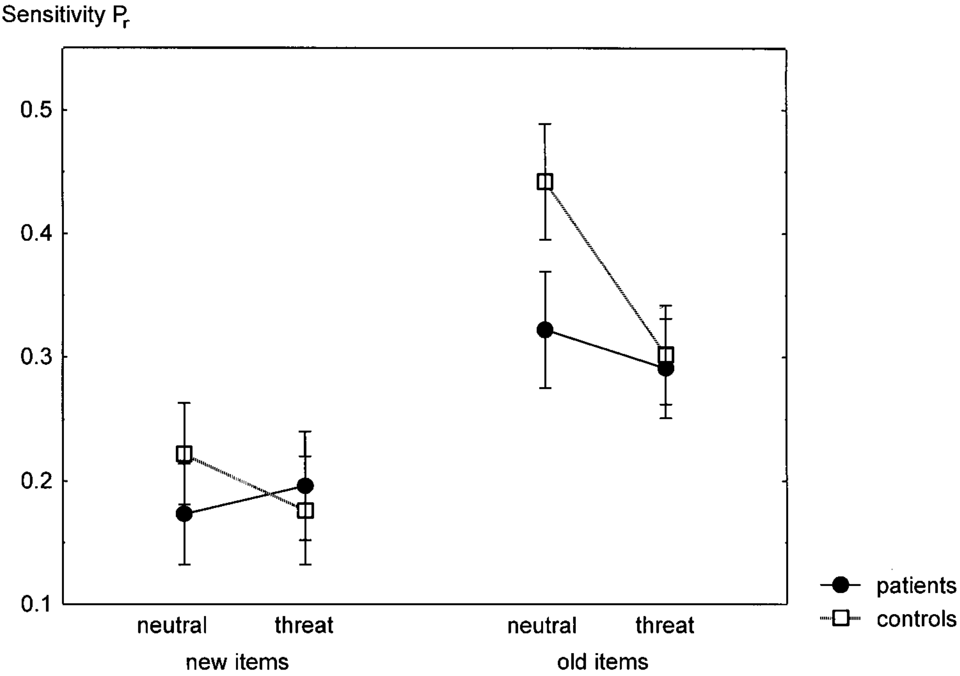

**FIG. 3.** Word–nonword discrimination performance ($P_r$) in the implicit memory task according to the two-high-threshold analysis.

Group × Valence × Presentation Status ($F[1,58] = 4.96$, $p < .05$). Orthogonal post hoc tests indicated that the response bias differed significantly between patients and controls for old neutral items ($F[1,58] = 13.23$, $p < .001$), for new neutral items ($F[1,58] = 8.38$, $p < .005$), and for new threat items ($F[1,58] = 17.42$, $p < .001$), but not for old threat items ($F[1,58] = 2.09$). That is, healthy controls showed a significantly reduced response bias compared with panic patients except in old threat items (see Fig. 4).

To summarize, both measures, sensitivity as well as response bias, showed a significant implicit memory effect. Old items were discriminated better than new ones and were designated more often as ‘‘words’’ than new ones. The sensitivity measure $P_r$ did not show any consistent significant difference between threat and neutral items and between patients and controls. However, the response bias measure $B_r$ was significantly enhanced for threat items compared to neutral ones. This difference was especially pronounced in old items presented to healthy subjects. Furthermore, panic patients showed a generally enhanced response bias compared to healthy controls.

*Intercorrelations.* Sensitivity measures of discrimination performance did not correlate more than .10 with response bias measures (Pearson correlations). This was true for neutral as well as for threat items and for old as well as for new items.

### *Multinomial Modeling of the Data*

The original model $M_0$ involving data from both groups (patients and controls) and both valences (threat and neutral) contained four parameters for the correct dis-

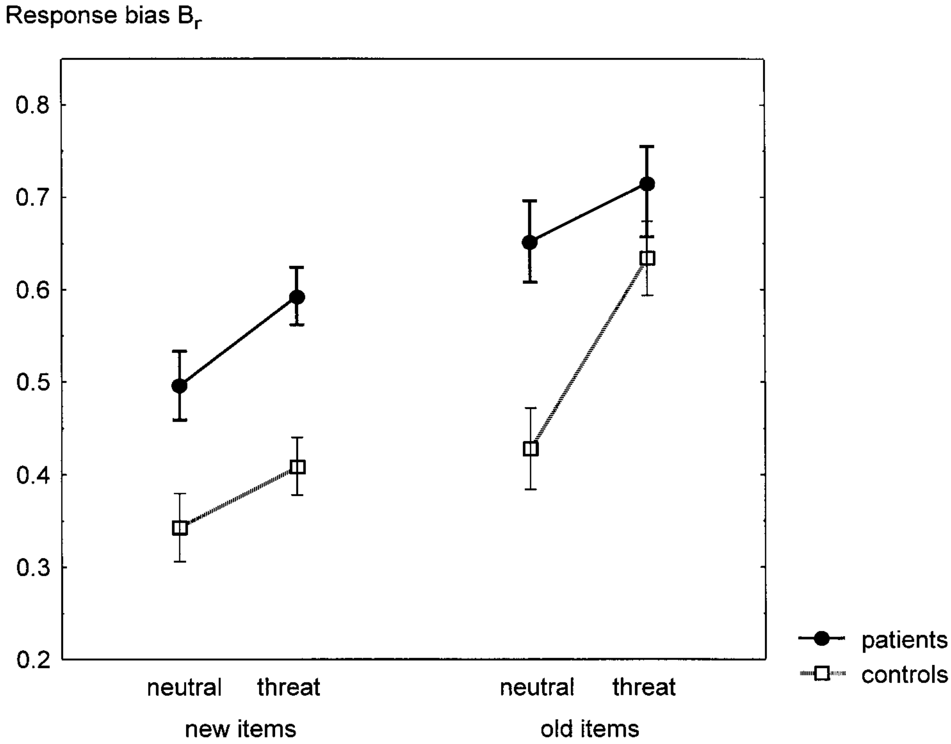

**FIG. 4.** Response bias ($B_r$) in the word–nonword discrimination task according to the two-high-threshold analysis.

crimination of words and nonwords (*p*), four parameters for the response bias (*b*), four parameters for the classical priming effect (*q*1), and four parameters for the priming of ‘‘old’’ nonwords (*q*2). Table 2 indicates the parameter configuration of this initial model before any parameter restrictions were introduced.

To reduce the number of free parameters in this model below the number of inde-

TABLE 2
Parameter Estimates for the Nonrestringent Model $M_0$

| Parameter | Patients | Controls |
|---|---|---|
| Neutral items | | |
| $p_{\text{neutral}}$—correct discrimination | .173 [.120/.227] | .230 [.179/.281] |
| $q1_{\text{neutral}}$—classical priming effect | .396 [.296/.496] | .392 [.309/.474] |
| $b_{\text{neutral}}$—response bias | .510 [.478/.543] | .322 [.289/.354] |
| $q2_{\text{neutral}}$—priming in nonwords | .028 [−.106/.162] | .001 [−.090/.088] |
| Threat items | | |
| $p_{\text{threat}}$—correct discrimination | .197 [.144/.250] | .176 [.122/.229] |
| $q1_{\text{threat}}$—classical priming effect | .322 [.197/.446] | .421 [.336/.505] |
| $b_{\text{threat}}$—response bias | .596 [.563/.629] | .404 [.372/.437] |
| $q2_{\text{threat}}$—priming in nonwords | .037 [−.131/.205] | .163 [.055/.271] |

*Note.* Values in brackets represent 95% confidence intervals.

TABLE 3
Parameter Estimates for the Final Model $M_3$

| Parameter | Patients | Both groups | Controls |
|---|---|---|---|
| $p_{\text{threat}}$, $p_{\text{neutral}}$—correct discrimination | | .197 [.170/.223] | |
| $q1_{\text{threat}}$, $q1_{\text{neutral}}$—classical priming effect | | .392 [.345/.438] | |
| $b_{\text{threat}}$—response bias (threat items) | .586 [.558/.614] | | .405 [.374/.436] |
| $b_{\text{neutral}}$—response bias (neutral items) | .509 [.480/.538] | | .323 [.293/.353] |
| $q2_{\text{threat}}$—priming in nonwords (threat items) | .058 [−.038/.154] | | .184 [.088/.279] |
| $q2_{\text{neutral}}$—priming in nonwords (neutral items) | | | .001 [−.072/.074] |

*Note.* Values in brackets represent 95% confidence intervals.

pendent equations, $p$ was held constant for both groups and valences. This resulted in a nonsignificant goodness-of-fit statistic of $G^2[3] = 2.77$. Therefore, this restriction (model $M_1$) was accepted.

Next, $q1$ for both groups and both valences were set equal (model $M_2$). This restriction also resulted in a non-significant decrease of the goodness-of-fit statistic ($G^2[3] = 1.70$), indicating that the restriction was to be accepted.

In the following step, we attempted to hold $b$ constant for both groups and valences. This resulted in a highly significant decrease of the goodness-of-fit ($G^2[3] = 142.01$, $p < .001$). Thus, we tried to hold $b$ constant only for the two valences. This also lead to a significant decrease of the model's fit ($G^2[2] = 24.33$, $p < .001$). Furthermore, the restriction that b was set equal for both groups also yielded a significant loss of the model's goodness-of-fit ($G^2[2] = 11.63$, $p < .01$).

Finally, we tried to hold $q2$ constant for both groups and valences. Since this also resulted in a significant decrease of the model's fit ($G^2[3] = 11.69$, $p < .01$), we tried to hold $q2$ constant for the two valences only. The resulting $G^2$ was acceptable only if this restriction was made within the panic group ($G^2[1] = 0.008$), but not within the control group ($G^2[1] = 11.63$, $p < .01$).

Thus, the final model $M_3$ showed a good fit to the data ($G^2[7] = 4.43$; $p > .70$). Table 3 contains its parameter estimates.

As can be seen in Table 3, $b$ was elevated in both groups for threat items in comparison to neutral items. Furthermore, patients with panic disorder displayed a higher response bias than controls, irrespective of the valence of the items.

Parameter $q2$ indicates the priming effect of ‘‘old’’ nonwords due to prior presentation of the corresponding old words. While the probability of these kinds of false signal perceptions was equal for neutral and threat items in patients with panic disorder, healthy controls restricted their false alarm responses to real threat nonwords. Thus, control subjects displayed practically no false-positive responding to neutral ‘‘old’’ nonwords.

In summary, the multinomial modeling approach confirmed the effects found in traditional analyses. There was no difference between threat and neutral items and between patients and controls in word–nonword discrimination performance (parameter $p$). However, threat items were responded to with significantly more ‘‘word’’ responses than neutral items (parameter $b$), especially in old nonwords presented to healthy subjects (parameter $q2$). In addition, patients with panic disorder showed a

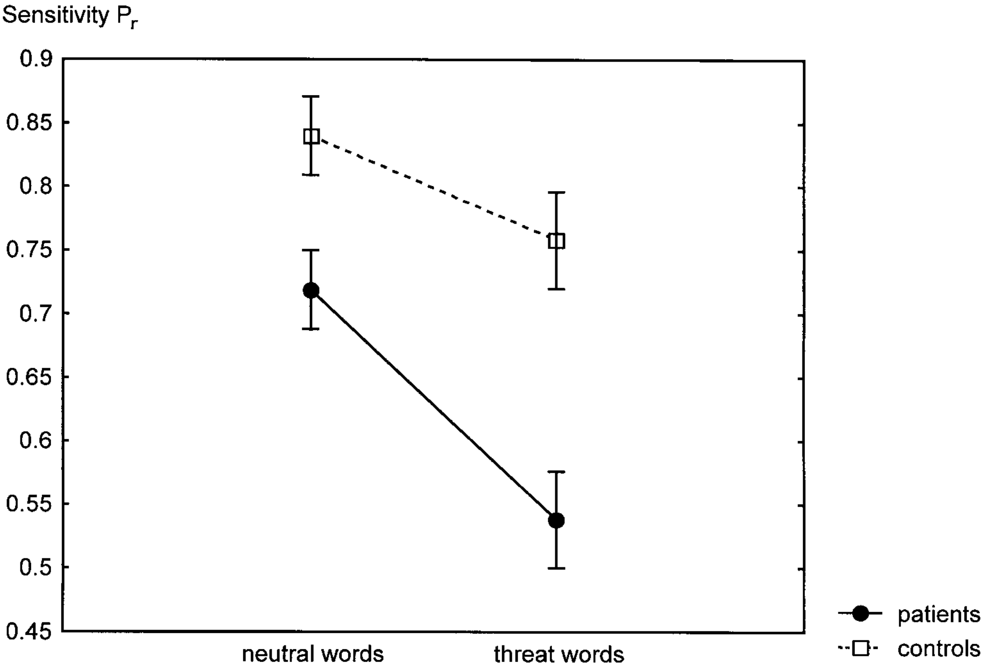

**FIG. 5.** Discrimination performance ($P_r$) in the recognition task.

generally enhanced tendency to respond ‘‘word’’ to words and nonwords in comparison to healthy controls. The significant difference between threat and neutral items in $q2$ found in healthy controls was not observed in patients with panic disorder.

## Recognition Task

The ANOVA of the sensitivity measure $P_r$ revealed a significant effect for Group ($F[1,58] = 17.14$, $p < .001$) indicating that patients achieved lower performance scores in the recognition task than controls. The repeated factor Valence was also significant ($F[1,58] = 26.22$, $p < .001$) indicating that recognition memory for neutral items was higher than recognition memory for threat items. The Group × Valence interaction effect reached marginal significance ($F[1,58] = 3.66$, $p < .10$) indicating that the valence effect on recognition performance tended to be higher in patients than in control subjects (see Fig. 5).

The ANOVA of the response bias measure $B_r$ showed no significant main effect of Group ($F[1,50] = 2.18$), but a significant main effect of Valence ($F[1,50] = 51.04$, $p < .001$), because the response bias for threat words was higher than for neutral words. The Group × Valence interaction effect was marginally significant ($F[1,50] = 3.43$, $p < .10$) (see Fig. 6). Orthogonal pairwise comparisons indicated that the response bias of patients with panic disorder was increased for neutral items ($F[1,52] = 5.45$, $p < .05$), but not for threat items ($F[1,53] = 0.21$) when compared with healthy controls (for explanation of the degrees of freedom see footnote 2).

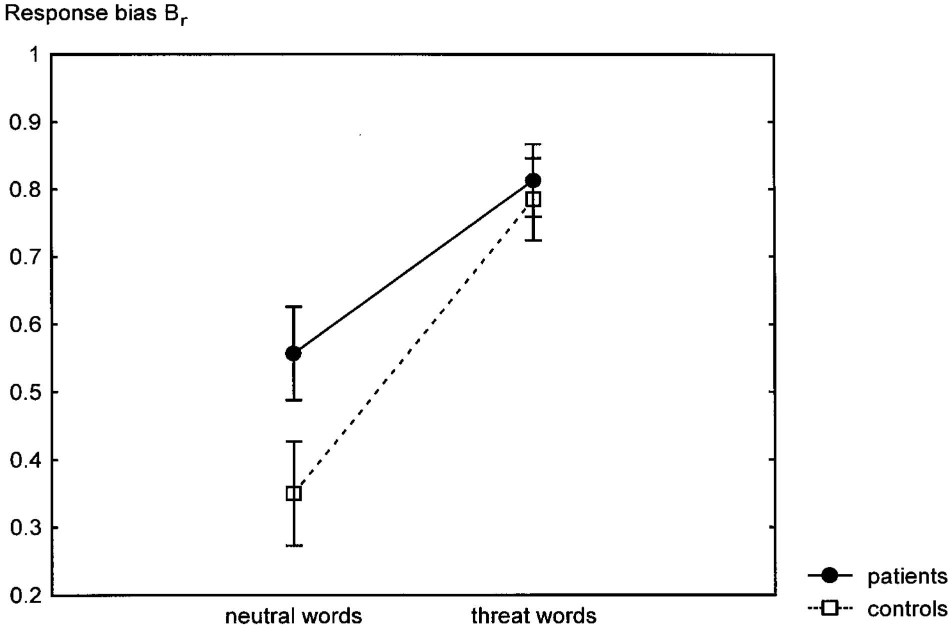

**FIG. 6.** Response bias ($B_r$) in the recognition task.

*Intercorrelations.* Recognition performance $P_r$ did not correlate more than .10 with the response bias measure $B_{r,}$ neither in neutral nor in threat items (Pearson correlations).

## DISCUSSION

In the present study we investigated the hypothesis that subconscious threat detection leads to enhanced ''false signal perceptions'' in cognitive tasks that require discrimination of signal and nonsignal events. To test this assumption, we examined the response tendency of patients with panic disorder and healthy controls to threat and neutral stimuli in an implicit memory task involving discrimination of tachistoscopically presented words and nonwords and in a subsequent explicit memory task. Referring to both tasks, the main result was a significant effect of Valence and Group on the response bias measures which was not found in the discriminative measures. In the following sections, we argue why we think that this pattern of results reflects effects of unconscious threat detection.

### Rating of the Stimuli

In the incidental learning phase, patients and controls rated threat words as much more threatening than neutral words, but threat items were not specifically related to panic symptomatology because the interaction effect of Group and Valence was not significant. However, patients with panic disorder rated items of both valences as more threatening than healthy controls, that is, they showed their typical tendency to overestimate threat in any perceived stimulus (referred to as ''cognitive misinterpretations''; Clark, 1986). On the basis of these subjective ratings alone, however, it is not possible to tell whether this difference between the two groups is driven by conscious or unconscious threat perception or both. In other words, it is unclear at this point whether this enhanced threat perception in panic patients is related to conceptual and discriminative processing or to subconsciously evoked false alarms.

## Subconscious Detection of Threat

With respect to the two memory tasks, subjects responded to threat items with a significantly higher response bias than to neutral items. This effect was observed in both groups and both memory tasks, and was not restricted to the classical two-high-threshold analysis. Furthermore, in the word–nonword discrimination task, the effect was observed in old as well as in new items. Since the response bias $B_r$ is independent of the discrimination index $P_r$ in general (Snodgrass & Corwin, 1988, p. 47) as well as in our data set, and as exact discrimination and controlled retrieval of a stimulus is presumed to be associated with conscious processing while false-positive responding is assumed to represent subconscious processes (LeDoux et al., 1989; 1995a; 1995b; Hay & Jacoby, 1996; Ratcliff & McKoon, 1996), we interpret the effect of valence on the response bias as resulting from *subconscious* processes. Obviously, subjects had perceived more stimulus significance in threat items than in neutral items irrespective of discriminative processing.

Referring more specifically to the cognitive tasks presented in our study, the effect can be described as follows. In the word–nonword discrimination task, subjects of both groups gave more ''word'' responses to threat items than to neutral items irrespective of the ability to consciously identify the items (which would be reflected by correct word–nonword discrimination rather than by false ''word'' responding). Thus, subjects seemed to respond with more ''false alarms'' (in terms of signal detection theory) to the presentation of threat items than to the presentation of neutral items even if they had not been able to identify the stimuli. This effect has been demonstrated by our data set using traditional as well as more sophisticated methods of analysis.

In the recognition task, subjects designated threat items more often as ''old'' than neutral items, even though they were actually less able to consciously remember them. Again, they displayed a stronger tendency for false signal-perceptions (representing old items in this case) to threat items than to neutral items. Here, the fact that subjects showed this tendency even though they had not at all been instructed to *attend* to the valence of the stimuli may be taken as evidence for the preattentive and automatic nature of this process.

However, with reference to the bias index $B_r$ in the recognition task alone it is actually not possible to tell for sure whether the valence effect is due to enhanced automatic recollection (unconscious memory) for threat items compared with neutral items or due to enhanced subconscious threat detection or due to both. $B_r$ in the explicit memory task is a compound measure for both of these processes since base rates for the words in the two lists were not determined separately in our study. However, since we found no evidence for a selectively enhanced unconscious memory for threat items in the word–nonword discrimination task (except in $B_r$[old] in the control group, see below), we think that the enhanced bias for threat items in the recognition task does in fact contain subconscious threat *detection* effects. In any event, our analysis shows that the valence effect on the response bias measure in both tasks is not accompanied by enhanced explicit memory for threat items, thus supporting the assumption that it is independent of how thoroughly the stimuli had been processed during the incidental learning phase and how well they can be remembered explicitly.

To summarize our findings so far, we infer that aversive stimulus valence had affected subjects' willingness to risk false-positive responses via automatic and unconscious influences. The word–nonword discrimination task shows that the effect is independent of perceptual accuracy and implicit memory effects, and the recognition task shows that it is independent of conscious (explicit) memory.

From an evolutionary point of view, the tendency to implicitly assign more significance and more relevance to threatening than to neutral stimuli even if these can actually not be identified is of adaptive value because it enables subjects to respond to potential threat quickly and efficiently, irrespective of ongoing cognitive activities, and even if the exact structure of the stimulus and its conceptual meaning cannot yet be assessed precisely (Beck & Clark, 1997; LeDoux, 1986). Thus, the mechanism enables subjects to automatically respond to environmental threat even if capacity-limited modes of processing are currently engaged in different processes (such as recollection).

## Subconscious Information Processing in Panic Disorder

The ‘‘cautiousness’’ of preattentive processing becomes maladaptive when it is hyperactive and undifferentiated (LeDoux, 1995a). In this case, the alarm system leads to frequent and unnecessary disruptions of more elaborated processing, because it repeatedly comes up with new false threat alarms demanding a shift of focal attention. Consequently, higher cognitive processing cannot fully develop, becomes less elaborated, and thus less efficient in modifying the automatic emotional responses to false threat alarms. A condition like this might be best understood as the predominance of automatic processing over metacognitive and controlled (conscious) processing. As pointed out in the introductory section, this should result in irrational fear and uncontrollable symptoms of anxiety and panic (Beck & Clark, 1997).

In the present study, there are three lines of evidence that support the notion that panic disorder is actually related to such a hyperactive subconscious threat detection mode. First, panic patients adopted a higher response bias than healthy controls in the implicit memory task and a higher response bias to neutral items in the explicit memory task. Again, this bias is independent of whether words/nonwords or old/new items had actually been presented; that is, it is independent of discriminative processing. Thus, the group effect is independent of conscious processing and must therefore reflect subconscious processing. Second, in comparison with healthy controls, patients with panic disorder displayed decreased explicit memory scores for both types of stimulus words, and this effect tended to be even more pronounced for threat items. Both findings clearly contrast with cognitive theories proposing a selectively increased *sensitivity* for threat in clinical anxiety (e.g., Amir et al., 1996; Ehlers et al., 1988a, 1988b; Cloitre et al., 1994; Rapee, 1994), at least in so far as these are not simply suggesting use-dependent modifications of the cognitive system but refer to the origins of panic and anxiety. Our findings merely suggest that patients with panic disorder tend to process threat and other information *less* conceptually and *less* elaborately than healthy controls. This interpretation corresponds to neurobiological findings of hippocampal and temporal lobe abnormalities in these patients (e.g., Dantendorfer et al., 1996, Friedman, 1992; George & Ballenger, 1992; Lucas et al., 1991; McNally, 1994a, p. 77–78), regions which are associated with higher-order perceptual analysis resulting in object recognition (van Essen & Deyoe, 1995) and conscious memory (Eichenbaum et al., 1992; Squire, 1992). Thus, we interpret the group effect in explicit recognition performance as evidence for diminished functions of more elaborated modes of processing in patients with panic disorder as suggested by the recent Beck and Clark (1997) model.

Third, in contrast to healthy controls, patients with panic disorder did not respond differentially to threat and neutral nonwords after repeated presentation of the items as indicated by parameter $q2$ in the implicit memory task. Parameter $q2$ represents false positive (‘‘word’’) responses to ‘‘old’’ nonwords (in contrast to ‘‘new’’ nonwords) which are not included in the response bias $b$. Logically (not mathematically), $q2$ corresponds to the difference between $B_r$[old] and $B_r$[new] in the traditional two-high-threshold analysis. The measure is greater than zero because ‘‘old’’ nonwords are primed to some extent because of their perceptual similarity to the corresponding words that had been presented previously in the learning phase (cf. Ratcliff & McKoon, 1996; Vaterrodt-Plünnecke, 1994). Healthy subjects responded quite often falsely to ‘‘old’’ nonwords, but only when in fact threat stimuli were presented. This is indicated by the significant valence effect on $q2$ and, accordingly, by the significant three way interaction effect on $B_{r.}$ Prior presentation of the words in the incidental learning phase had obviously increased control subjects’ capability to differentiate the actual valence of the corresponding ‘‘old’’ nonwords, even though they were still unable to identify them as nonwords. Consequently, they restricted their false alarm responding to real threat items and showed practically none to neutral items. The fact that they were still unable to correctly *identify* these stimuli as nonwords can again be taken as evidence for the unconscious nature of the underlying process. Since the rating task in the incidental learning phase allowed conscious and elaborative processing of the stimuli, the valence effect on $q2$ in healthy controls might actually represent an effect of successful *modification* of the preattentive alarm system by means of previous conscious processing. This pattern of results involving very careful responding to new stimuli and more differentiated responding to previously learned stimuli reflects highly adaptive behavior (LeDoux, 1995b, p. 224; Beck & Clark, 1997, p. 51).

However, the significant valence effect on $q2$ (and the corresponding effect in $B_r$[old] minus $B_r$[new]) was not found in patients with panic disorder in both tasks. Their tendency to respond with false alarms due to misperception of stimulus significance was generally hyperactive and much less differentiated than controls, irrespective of whether the items had been presented before or not.

A similar group difference can actually be found in the response bias measure of the explicit memory task. Healthy controls responded with as many false signal detections as patients with panic disorder when threat items were presented, but they risked less false alarms than patients with panic disorder when neutral items were presented.

Thus, false-positive responding in panic patients was enhanced in neutral items when compared to controls and did not differ between word valences, whereas it was more differentiated in healthy subjects.[4]

Thus, patients with panic disorder tended to show false-alarm responses not only more frequently, but also less differentially and less reasonably than healthy controls in both tasks. Repeated presentation of the items improved the ability to preattentively differentiate between threat and neutral stimuli in healthy subjects, but not in patients with panic disorder. This result might be interpreted as evidence that panic disorder is associated with a deficit to modify the hyperactive functioning of the preattentive alarm system by means of conscious processing, but further research addressing this specific aspect more directly is required to establish this interpretation.

To summarize the group effects, we did not find any differences between panic patients and controls in classical implicit and explicit memory scores as suggested by cognitive models of panic and anxiety, but we did find a consistently enhanced response bias in patients with panic disorder in both memory tasks and all item types (old/new, threat/neutral). We interpret this finding as evidence for enhanced subconscious threat detection in panic patients. This interpretation is warranted by the data of the word–nonword discrimination task where measures of response bias (=base rates) could clearly be separated from measures of unconscious memory, while in the recognition task, these two effects are confounded to some extent. However, since patients with panic disorder showed no enhanced unconscious memory effects in the word-nonword-discrimination task ($q1$ and $q2$), we do not find it plausible to assume that they had suddenly developed this enhanced memory performance in the recognition task. It is more likely that the group difference reflects the same cognitive abnormality that had been effective in the word–nonword discrimination task, and which we interpret as enhanced subconscious threat detection.

## Possible Alternative Explanations

An alternative explanation for our results would be the argument that group differences in the response bias might simply reflect unspecific motivational differences rather than differences in preattentive processing. While motivational differences can threaten the internal validity of practically all studies comparing performance scores of two samples drawn from different populations, we think that this argument is not convincing in the present context. First, it is questionable why motivational factors should have directed subjects' responses toward a *specific* direction, that is, toward the positive-response pole. Subjects in our study did not have any reason to believe that they would profit ( = achieve higher performance scores) from frequent ‘‘signal’’ responses, especially since they were told explicitly that the task required perceptual discrimination of words *and* nonwords (old and new words in the recognition task), not only identification of words. In contrast to this objection, our assumption that enhanced response tendencies reflect preattentive threat detection is plausible from a neurobiological, a clinical, and a cognitive perspective. Second, *both* groups displayed a selectively enhanced response tendency to threat items compared to neutral

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[4] Interestingly, Ehlers, Margraf, Davies, and Roth (1988b) reported (but did not interpret) a similar effect of valence on the response bias in a recognition task.

items, irrespective of discrimination performance. This was true for both memory tasks as well as for old *and* new items in the word–nonword discrimination task. The fact that the effect emerged so consistently in both groups and both tasks provides further support for our interpretation. In healthy subjects (not in patients with panic disorder), it was even more pronounced in items that had been presented previously compared to new items, and this also holds for both memory tasks. Thus, the observed valence effect corresponds with our interpretation of the group effects but can hardly be integrated into the assumption of differential motivational states. In general, we think that any potential explanation for the group effect must take this very consistent valence effect into account. Third, since patients with panic disorder were significantly more depressed than healthy controls, it seems unlikely that they were more motivated than controls in performing the tasks.

## CONCLUSIONS

The present study showed that threat associated stimuli affect behavior at a preattentive level of processing even if the stimuli cannot be consciously identified. Our results support the notion that preattentive detection of potential threat affects measures of response bias while leaving measures of discriminative sensitivity unaffected.

Moreover, our findings represent evidence for the existence of a hyperactive preattentive alarm system (or process) in patients with panic disorder. If this preattentive system is assumed to be associated with the amygdala, the whole bandwidth of psychological and physiological symptoms during panic attacks could be explained (cf. Davis, 1989; 1992). In our view, subjects with panic disorder engage in cognitive misinterpretations of harmless internal or external sensations (Clark, 1986) because their preattentive alarm system transmits abnormally frequent and intense false threat alarms to ascending activation systems arising from the reticular formation and thalamic structures (Graeff, 1994; Newman, 1995). Interestingly, this idea can integrate cognitive theories of panic and biological approaches postulating dysfunctional monoaminergic neurotransmission in patients with panic disorder (e.g., den Boer, Westenberg, & Verhoeven, 1990) due to the well known fact that tricyclic antidepressants affecting these transmitter systems can reduce intensity and frequency of panic attacks (see McNally, 1994a, for an extensive review of the literature). Thus, if ascending transmitter systems are activated by false threat alarms which are not related to any actual danger in the outside world, the individual will experience irrational anxiety while being ‘‘left with much room for cognitive interpretations’’ (LeDoux, 1986, p. 242) about what had caused this experience. Thus, cognitive misinterpretations of harmless sensations in patients with panic disorder (Clark, 1986) actually seem to represent the *result* of a dysfunctional mechanism that precedes conscious experience rather than being a *cause* of fear and anxiety itself as Clark’s (1986) original model suggests.

Although we referred to neurobiological evidence in the introductory section, the present study does not, of course, allow any direct conclusions with respect to the cortical mechanisms involved in performance of the two tasks. We did not intend to induce feelings of fear and symptoms of anxiety by our procedures but merely attempted to assess general information processing styles using a relatively artificial experimental setting involving verbal stimuli. It is very unlikely that threat detection in these two tasks was performed on the basis of the amygdala alone. It is more likely that a neuronal circuit involving the amygdala, occipital, hippocampal, temporal, and maybe other neocortical association areas have been involved (cf. Gallagher & Chiba, 1996; LeDoux, 1992, 1995b; Pulvermüller, 1996). However, neurobiological evidence strongly suggests that it is probably the amygdala that is responsible for cognitive misrepresentations of threat and significance. By activating ascending activation systems (Graeff, 1994; Newman, 1995), it might amplify and stabilize the current neuronal input patterns in sensory and association areas which otherwise would dissociate and decay too quickly to be grasped by consciousness. However, much more interdisciplinary work is needed to elucidate the cortical mechanisms in subconscious and conscious threat detection more directly, especially with respect to word stimuli (e.g., Taylor, 1996), but also with respect to more natural fear stimuli (e.g., Grillon, Ameli, Goddard, Woods, & Davis, 1994). We think that purely cognitive models of conscious and unconscious information processing can profit from these approaches as well because neurobiological findings can help to make psychological theories more specific and more falsifiable by providing independent external criteria these should be able to comply with.

## APPENDIX

### TABLE A
Stimulus Material (Threat and Neutral Words)

| Threat words | | Neutral words | |
|---|---|---|---|
| List A | List B | List A | List B |
| corpse | tragedy | hotel | household |
| accident | cemetery | shadow | exception |
| invalidism | casket | conception | method |
| horror | sorrow | beaker | reservation |
| shock | dead | strawberries | influence |
| weapon | injury | planet | basis |
| hazard | violence | proxy | butter |
| disgust | darkness | substitute | assumption |
| separation | insanity | globule | potato |
| evil | dread | factory | claim |
| cripple | wound | duration | argument |
| punishment | pain | machine | avalanche |
| victim | harshness | effect | motive |
| disaster | disgrace | bird | boulder |
| doom | torture | volcano | department |

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