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Dissociating Prelexical and Postlexical Processing of Affective Information in the Two Hemispheres: Effects of the Stimulus Presentation Format

Sabine Windmann,* Irene Daum,† and Onur Güntürkün*

**Department of Biopsychology, Ruhr-University Bochum, Germany; †Department of Neuropsychology, Ruhr-University Bochum, Germany*

Using a lexical decision task, the authors investigated whether brain asymmetries in the detection of emotionally negative semantic associations arise only at a perceptually discriminative stage at which lexical analysis is accurate or can already be found at crude and incomplete levels of perceptual representation at which word–nonword discrimination is based solely on guessing. Emotionally negative and neutral items were presented near perceptual threshold in the left and right visual hemifields. Word–nonword discrimination performance as well as the bias to classify a stimulus as a ''word'' (whether or not it actually is a word) were assessed for a normal, horizontal stimulus presentation format (Experiment 1) and for an unusual, vertical presentation format (Experiment 2). Results show that while the two hemispheres are equally able to detect affective semantic associations at a prelexical processing stage (both experiments), the right hemisphere is superior at a postlexical, perceptually discriminative stage (Experiment 2). Moreover, the findings suggest that only an unusual, nonoverlearned stimulus presentation format allows adequate assessment of the right hemisphere's lexical–semantic skills. © 2002 Elsevier Science (USA)

Key Words: bias; lexical decision; word recognition; prelexical; emotion; affect; hemispheres; conscious; unconscious; visual field.

INTRODUCTION

The right hemisphere shows a preference for processing affective cues relative to the left hemisphere. This is a well-established finding, at least with respect to negative emotional valence. Empirical evidence is provided by studies in which words (Bryden & MacRae, 1988; Hartley, Ireland, Arnold, & Spencer, 1991; Richards, French, & Dowd, 1995), pictures (Johnsen & Hugdahl, 1993; Moretti, Charlton, & Taylor, 1996), or film clips (Wittling, 1995) were presented lateralized to healthy subjects; by neuropsychological investigations of patients with unilateral brain damage (Mandal, Tandon, & Asthana, 1991; Schmitt, Hartje, & Willmes, 1997); by psy-

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Address correspondence and reprint requests to Sabine Windmann, Ruhr-University, Bochum, Faculty of Psychology, Biopsychology, GAFO 05, 44780 Bochum, Germany. Fax: +49 234 321 4377. E-mail: Sabine.Windmann@ruhr-uni-bochum.de.

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chophysiological studies using electrophysiological recordings (Laurian, Bader, Lanares, & Oros, 1991; Pihan, Altenmüller, & Ackermann, 1997; Spence, Shapiro, & Zaidel, 1996) or positron emission tomography measuring regional brain activation (George et al., 1996; Gur, Skolnick, & Gur, 1994; Lane et al., 1997); and by neurological investigations with the intracarotid sodium amytal test (Ahern et al., 1991).

Most of these studies investigated attentional processing of affective valence and arousal; that is, they allowed subjects to accurately identify and consciously analyze the stimuli. The question of whether hemispheric asymmetries for emotion perception can also be found under conditions that prevent subjects from resolving the physical structure of the stimuli so that the emotive value of the items can be processed only incidentally has rarely been addressed. This leaves open the question at what stage of perceptual processing hemispheric asymmetries for emotional information come into play. Does an emotional stimulus have to be fully and accurately identified before hemispheric differences in the semantic analysis of this stimulus manifest? Or is some form of brain asymmetry for the affective value of a stimulus independent of whether or not the sensory systems can accurately resolve that stimulus? The former would suggest that hemispheric asymmetries in emotion perception emerge only at a stage at which discriminative object recognition is performed, whereas the latter would suggest that they might exist already at an early, perhaps unconscious stage of processing (cf. Anderson & Phelps, 2001; Zajonc, 1980). With regard to lexical stimuli, this possibility may be considered unlikely because language has developed only recently in human evolution, hence it could be argued that both hemispheres may be unable to extract the semantics of language without prior lexical analysis (White, 1996). On the other hand, some researchers have in fact reported brain asymmetries in the processing of emotional words that were presented below the subjective identification threshold (Làvadas, Cimatti, Del Pesce, & Tuozzi, 1993; Wexler, Warrenburg, Schwartz, & Janer, 1992). However, methodological problems associated with subliminal stimulation (Holender, 1986; Reingold & Merikle, 1993) and subjective (as opposed to *objective*) identification thresholds (Cheesman & Merikle, 1986) prohibit any firm conclusions being drawn from these findings.

To address the question of whether hemispheric asymmetries in the processing of emotional meaning require prior stimulus identification, the sensitivity of the two hemispheres to the *semantic* meaning of emotional stimuli, as compared to neutral stimuli, would have to be measured independently of the two hemispheres' *perceptual* sensitivity for the same stimuli (Làvadas et al., 1993, p. 96; Greenwald, Draine, & Abrams, 1996). Ideally, effects of emotion that depend on (or are linked to) discriminative perception would have to be *process dissociated* (Debner & Jacoby, 1994; Jacoby, 1991) from acuity-independent effects of emotion (cf. LeDoux, 1993). The response bias (the ‘‘guessing tendency'') in two-alternative forced-choice tasks is a measure that might actually allow such process dissociation, as it has been found to be sensitive to the emotional meaning of verbal stimuli in lexical decision tasks as well as in yes/no recognition tasks (Cross, 1999; Ehlers, Margraf, Davies, & Roth, 1988, p. 210; Leiphart, Rosenfeld, & Gabrieli, 1993, Maratos, Allan, & Rugg, 2000; Windmann & Krüger, 1998; Windmann & Kutas, 2001) while being independent of correct discrimination performance (Snodgrass & Corwin, 1988).

The response bias is defined as the probability to guess that a particular stimulus has been presented when there is uncertainty as to which stimulus has actually been presented. Figure 1 shows how response bias (B_r) and discrimination performance (P_r) can be computed from binary responses in a lexical decision task according to the two-high-threshold theory (see Snodgrass & Corwin, 1998), the measurement model that also underlies the process dissociation procedure (Buchner, Erdfelder, & Vaterrodt-Plünnecke, 1995; Jacoby, 1991; Windmann & Krüger, 1998) and that

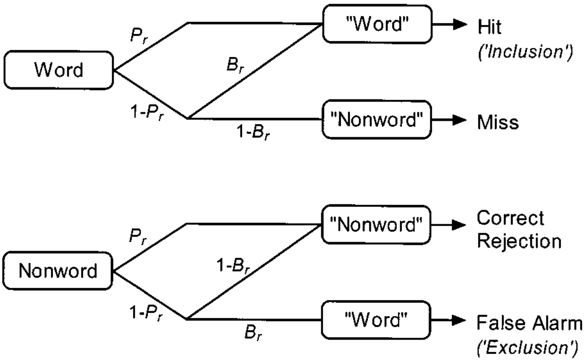

FIG. 1. Assessment of discrimination performance P_r and the response bias B_r in a lexical decision task according to two-high-threshold theory. P_r and B_r can be regarded as transitional probabilities from left to right (the index *r* being simply a relic from former applications in recognition tasks). The figure depicts only one cell out of eight in the 2 × 2 × 2 design of the two experiments reported in this article (e.g., new neutral stimuli presented to the left visual hemifield). As seen in the top panel, when a word is presented, subjects identify it and correctly respond ''word'' with a probability of P_r. When they do not identify it (probability $1 - P_r$), they are forced to guess. They can guess either that the stimulus is a word (probability B_r) or that it is a nonword ($1 - B_r$). Thus, the probability of correctly responding ''word'' when a word had actually been presented (= hit rate) equals $P_r + (1 - P_r)B_r$. Likewise, the probability of falsely responding ''word'' when in fact a nonword had been presented (false alarm rate) can be computed as $(1 - P_r)B_r$. ''Inclusion'' and ''exclusion'' refers to the terminology of the process dissociation procedure by Jacoby (1991), where the same logic is applied to estimate conscious and unconscious processing (cf. Debner & Jacoby, 1994; Windmann & Krüger, 1998).

has empirically been found to be appropriate for lexical decision tasks (Vaterrodt-Plünnecke, 1994; Windmann & Krüger, 1998).

Because P_r and B_r are independent mathematically (Snodgrass & Corwin, 1988, p. 47) as well as empirically (for lexical decision tasks, see Vaterrodt-Plünnecke, 1994, and Windmann & Krüger, 1998; for yes/no recognition memory tasks, see Windmann & Kutas, 2001), they can be dissociated experimentally. Variables facilitating correct stimulus identification (e.g., increased presentation time, higher stimulus contrast, enhanced attention) will increase the probability of correct identification of words and nonwords, thereby increasing the discrimination performance measure P_r while leaving the bias B_r unaffected.[1] Conversely, variables affecting subjects' willingness to guess ''word'' as opposed to ''nonword'' when they were unable to identify the stimulus will increase B_r while leaving P_r unaffected. The latter implies that any stimulus-bound variable that influences the response bias does so ''outside of'' or ''independent of'' lexical accuracy and can thus be linked to ''prelexical'' or perhaps even ''preattentive'' processes (cf. Windmann & Krüger, 1998; Windmann & Kutas, 2001; Windmann, Zakharat, & Kutas, in press).

In the current study, we made use of this logic to investigate whether brain asymmetries in the semantic processing of emotional stimuli arise at a prelexical stage at which lexical decisions are solely based on guessing (as would be reflected in B_r) as opposed to a postlexical stage at which lexical decisions are accurate (as would

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[1] For example, suppose that under facilitated perceptual conditions, the probability of correctly identifying an item as a word or a nonword increases by 20%, implying that hit rates and correct rejection rates both increase by .2. As can be seen from Fig. 1, this would increase P_r by .2. B_r would not be changed because B_r increases with enhanced correct ''word'' recognition rates (hits) as much as it *de*creases with enhanced correct ''nonword'' recognition rates (correct rejections).

be reflected in P_r).[2] In addition, we investigated whether the memory trace left behind by the perceptual processing of emotional verbal stimuli, as opposed to nonemotional verbal stimuli, will be asymmetrically distributed in the brain (cf. Van Strien & Heijt, 1995; Van Strien & Morpurgo, 1992). Perceptual memory is usually referred to as implicit memory or repetition priming and has been shown to affect both measures of bias as well as measures of accurate performance (Hay & Jacoby, 1994; Ratcliff & McKoon, 1996; Windmann & Krüger, 1998). However, it has never before been investigated whether these different effects of repetition priming result from different contributions of the lexically accurate left hemisphere, as compared to the right hemisphere, or how far they interact with the emotional meaning of the stimuli at either the pre- or postlexical stage.

In using a process dissociation approach to examine these questions, we introduce a novel approach to the study of hemispheric asymmetries. Although some studies on brain lateralization are available in which signal detection theory or variants thereof have been applied to the data (e.g., Chiarello, Nuding, & Pollock, 1988; Chiarello, MacMahon, & Chaefer, 1989; Funnell, Corballis, & Gazzaniga, 1999; Glosser, Deutsch, Cole, Corwin, & Saykin, 1998; Madden, Nebes, & Berg, 1981), these methods have never before been used to dissociate *semantic* processing at different perceptual stages in the two hemispheres. If we can demonstrate such dissociation, we might help to establish a paradigm for disentangling hemispheric *preferences* (bias) from hemispheric *skills* (accuracy). This may prove useful not only for lexical tasks but for all cognitive tasks in which hemispheric differences have been observed.

EXPERIMENT 1

We closely followed the procedures of an earlier study that demonstrated the effects of emotional stimulus meaning and repetition priming on measures of response bias and accuracy in a lexical decision task with foveal stimulus presentations (Windmann & Krüger, 1998). However, we used new word lists to replicate these effects independently. Emotionally negative (threat-related) words and emotionally neutral words were first presented centrally in an incidental study task while subjects rated the affective intensity of these stimuli. Subsequently, these words plus new words plus orthographically legal nonwords derived from these words (by permutation of some letters) were presented lateralized in a lexical decision task. Hence, this task involved presentation of emotionally negative words and nonwords as well as emotionally neutral words and nonwords in a divided visual field paradigm. Although the nonwords were meaningless in a lexical sense, we assumed that they would nonetheless activate semantic associations, as demonstrated earlier (Windmann & Krüger, 1998). Stimuli were presented near perceptual threshold so that perfect word–nonword discrimination was virtually impossible, and a substantial amount of guessing had to occur. We then assessed word–nonword discrimination performance P_r and the response bias B_r (indicating the likelihood to respond ‘‘word’’ when the stimulus has not been identified) separately for negative/neutral stimuli, the two hemifields, and old/new items. Repetition priming effects on P_r and B_r were defined as the difference between old items (presented previously in the rating task) and new items (not presented previously).

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[2] The division into ‘‘preperceptual’’ (prelexical) and ‘‘postperceptual’’ (postlexical) processing stages may seem simplified on theoretical grounds. Note, however, that we are referring to two *experimentally defined* distinct processing stages throughout this article (cf. Vogel, Luck, & Shapiro, 1998, p. 1657).

Methods

Subjects. A total of 40 healthy subjects (20 males and 20 females, mean age 26.35 years, $SD = 4.57$) participated in the experiment. All subjects had normal or corrected-to-normal vision and were right-handed with a laterality quotient of at least 33 (indicating a right-to-left ratio of 2 : 1) in the Edinburgh Handedness Inventory (Oldfield, 1971). Approximately half of the subjects received course credits for participation, and 14 subjects received compensation of DM 15 for participation.

Stimuli. For word list A, 40 neutral German nouns consisting of 4 to 10 letters and 40 German substantives with a negative, threat-related emotional meaning (for English translations, see Appendix) were carefully matched for number of letters, number of syllables, and frequency using the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995).

Orthographically legal nonwords were then created from the words by permutation of at least two letters per word (but the first letter was never changed) while maintaining pronounceability.[3] Negative words were treated exactly the same way as neutral words. If possible, all vowels were interchanged within a word while most of the consonants were left at their place (e.g., PINAK for PANIK). This proceeding differed from the one of Windmann and Krüger (1998), who had rearranged the letter strings much more drastically (including the first letter).

A second word list, list B, was set up the same way as list A, resulting in a total of 80 words in both lists plus the corresponding 80 nonwords. Items from list B served as new items in the lexical decision task for subjects who had been presented list A in the rating task and vice versa.

In summary, lexical decisions were performed on 320 items, 40 at each experimental factor level (Visual Half Field [right/left] × Valence [negative/neutral] × Familiarity [old/new]).

Apparatus. Experimental procedures were controlled by an IBM personal computer. Stimuli were presented on a 15-inch monitor in black against a white background in a sans serif font (mean word size approximately 3.5 cm, letter height 0.5-1 cm). Responses were made via specially designated keys on a normal PC keyboard.

Procedures. Participants were tested in individual sessions. In the rating task, negative and neutral words (either list A or list B) were presented for 2000 ms in the center of the screen in randomized order with the restriction that no more than 4 words of the same valence were presented on successive trials. Subjects were asked to read the words aloud and to rate the emotional valence of each stimulus on a 7-item scale on the keyboard (ranging from 0 = *neutral* to 6 = *extremely negative and threatening*). They were given five practice trials prior to performing.

In the subsequent lexical decision task, subjects viewed the monitor while resting their heads on a wooden chin rest with a forehead fixation device placed at a distance of 40 cm from the screen. They were asked to focus on the central fixation cross on the screen (approximately 1 cm × 1 cm in size) presented for 2000 ms. A word or a nonword was then presented tachistoscopically in the periphery of the screen (adjusted to the vertical midline) for 160 ms with a subtending visual angle of at least 2.0° measured between the inner edge of the stimulus and the center of the fixation cross (the average angle measured from the *center* of the stimuli to the center of the fixation cross was ~6°). These parameters were similar to (or exceeded) those successfully employed by Marsolek and colleagues (Marsolek, Kosslyn, & Squire, 1992; Marsolek, Squire, Kosslyn, & Lulenski, 1994; Marsolek, Schacter, & Nicholas, 1996). Stimulus displays were masked immediately by a noisy pattern of small white dots. After the response was given, the next trial began as indicated by the reappearance of the fixation cross.

In a mixed speed and accuracy instruction, participants were asked to decide whether the presented item was a word or a nonword by pressing either the ← key or the → key of the keyboard (balanced across subjects) with the index or the middle finger, respectively, as quickly as possible. Subjects were instructed to guess if they had not been able to identify the item.

The 320 test items were presented in four successive blocks in randomized order, with the restriction that all experimental variations (visual field location [right/left], item type [word/nonword], familiarity [old/new], and stimulus valence [negative/neutral]) were balanced across the four blocks and that maximally 4 items of the same experimental condition were presented on successive trials. After each block, subjects were asked to change the response hand. Half of the subjects began by using the right hand in the first block, whereas the other half began by using the left hand in the first block.

Each word and its corresponding nonword were presented into the same visual field. That is, if the word PANIK was presented into the left hemifield, then the nonword PINAK was also presented into the left hemifield (counterbalanced across subjects). This was done to strengthen priming effects for

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[3] Examples of the original stimuli are as follows: *negative*—Kamo (Koma), Arzbust (Absturz), Niza (Nazi), Daktutir (Diktatur), Atonmet (Atemnot), Feltor (Folter), Memui (Mumie), Geraun (Grauen), Legü (Lüge); *neutral*—Umgahn (Umhang), Anbehma (Abnahme), Pestor (Poster), Surip (Sirup), Baleng (Belang), Vurschob (Vorschub), Restar (Raster), Hinog (Honig), Charol (Choral).

every item within one hemisphere. Note that these procedures were the same for all experimental conditions (negative/neutral stimuli and left/right visual fields).

Subjects were given 16 practice trials (8 for each hand) prior to performing. In a 5- to 10-min break between blocks 2 and 3, the Edinburgh Handedness Inventory was filled out.

Data analysis. We analyzed participants' ratings of negative and neutral words obtained in the rating task using a one-factorial analysis of variance (ANOVA) with valence as repeated measure.

For the lexical decision task, we determined hit rates (Hit = probability of correct ''word'' responses when a word was presented) and false alarm rates (FA = probability of ''word'' responses when a nonword was presented). We then computed word–nonword discrimination performance $P_r = Hit - FA$, and the response bias $B_r = FA/(1 - P_r)$ (cf. Fig. 1). The formal equivalence of this analysis with the process dissociation approach put forward by Jacoby and coworkers (e.g., Jacoby, 1991), which attributes variations of the accuracy measure to conscious processes and variations of the bias to unconscious effects, is discussed in Windmann & Krüger (1998). The measurement model is based on the assumption that the threshold for identifying a word is the same as the threshold for identifying a nonword. This presumption has been empirically tested and confirmed for lexical decision tasks like the present one (Vaterrodt-Plünnecke, 1994; Windmann & Krüger, 1998).

For statistical tests of significance, we performed 2 × 2 × 2 design ANOVAs for P_r and B_r, with Visual Half Field (left/right), Familiarity (old/new), and Emotional Valence (negative/neutral) as within-subjects factors. We excluded outliers and erroneous trials (which had sometimes occurred due to misunderstandings or interruptions of the procedures) as defined by reaction times exceeding 3 standard deviations above the mean (~1.85% of the data). Reaction times were taken but are not discussed because they were not particularly informative with regard to the effects of emotional valence. Responses to primed items were faster than those to new ones, and the right visual field was faster than the left visual field, but reaction times were nearly identical for emotionally negative ($M = 842$, $SD = 157$) and neutral items ($M = 843$, $SD = 171$), with no significant interactions involving Familiarity or Hemisphere.

Results

Statistical analysis of the stimulus ratings showed a highly significant effect of Valence, $F(1, 39) = 789$, $p < .00001$, as negative words ($M = 3.79$, $SD = 0.85$) were evaluated as much more negative and threatening than neutral words ($M = 0.78$, $SD = 0.70$).

Analysis of P_r in the lexical decision task, indicating accurate identification of words and nonwords, showed a highly significant effect of Visual Field, $F(1, 39) = 78.76$, $p < .001$, as the right hemifield was associated with higher discrimination performance than the left hemisphere (see Fig. 2). It also showed a significant effect of Familiarity, $F(1, 39) = 4.53$, $p < .05$, reflecting a repetition priming effect as old items were discriminated better than new items (see Fig. 2). Furthermore, a significant effect of Valence was observed, $F(1, 39) = 9.62$, $p < .005$, as negative items were discriminated better than neutral items.

Analysis of B_r reflecting the tendency to guess ''word'' when the item was not identified revealed a significant effect of Visual Field, $F(1, 39) = 48.85$, $p < .001$. As Fig. 3 illustrates, the bias was much higher for the right visual field than for the left visual field. The factor Valence was also significant, $F(1, 39) = 28.93$, $p < .001$, as the bias was higher for negative items than for neutral items. Furthermore, a significant effect of Familiarity was observed, $F(1, 39) = 108.70$, $p < .001$, indicating that old items were associated with a higher bias than were new items (see Fig. 3). The Visual Field × Familiarity interaction effect was also significant, $F(1, 39) = 10.71$, $p < .005$. Post hoc tests indicated that old items were associated with a higher response bias in both the left visual field, $F(1, 39) = 54.13$, $p < .001$, and the right visual field, $F(1, 39) = 72.88$, $p < .001$, indicating that the significant interaction had resulted from the fact that priming effects were stronger in the right visual field than in the left visual field (see Fig. 3). No other effects were found (all F's < 2.0).

A correlational analysis of the relationship between P_r and B_r yielded no significant

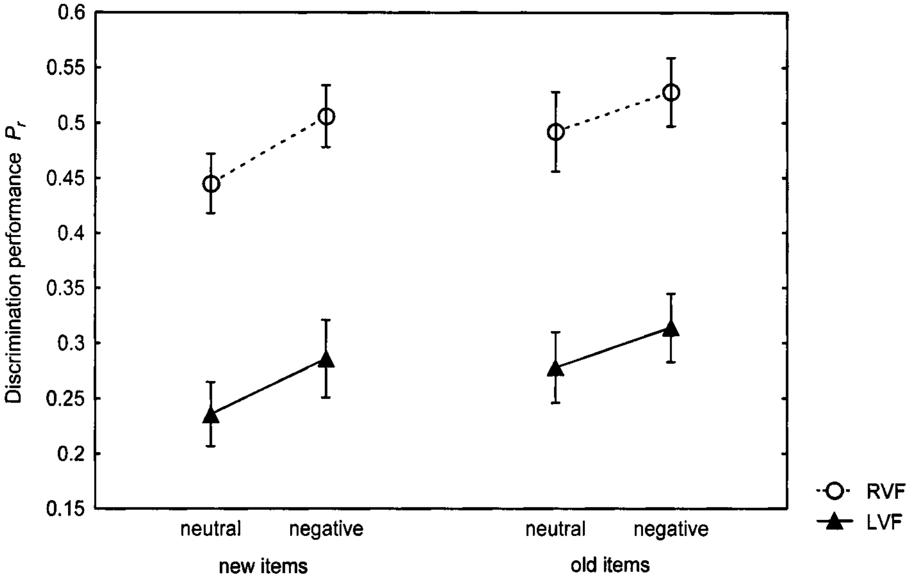

FIG. 2. Word–nonword discrimination performance for stimuli presented in the left (LVF) and right (RVF) visual fields, horizontal stimulus presentation format.

results for either the left ($r = .12$) or the right ($r = .03$) visual field, thus confirming the assumption of statistical independence of P_r and B_r.

Discussion

Participants rated the emotionally negative words as much more negative and threat related than the neutral words, suggesting that the materials we used for studying hemispheric asymmetries in the processing of negative affect were appropriate.

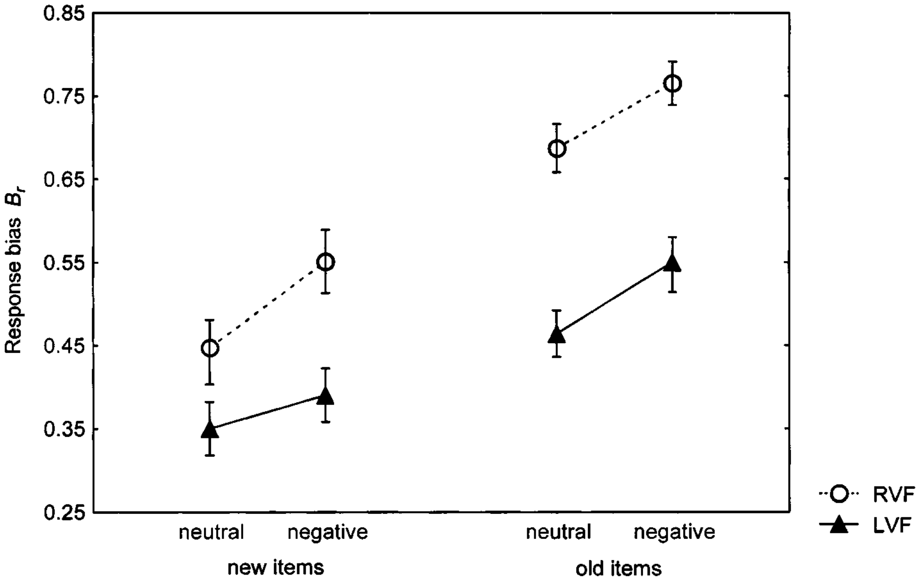

FIG. 3. Bias for responding ‘‘word’’ to stimuli presented in the left (LVF) and right (RVF) visual fields, horizontal stimulus presentation format.

In the lexical decision task, we found a clear superiority of the left hemisphere compared to the right hemisphere in the accuracy measure P_r, as expected (e.g., Chiarello et al., 1988, 1989), suggesting that the lateralization procedure worked as intended. However, we did not find any evidence for brain asymmetries in emotion perception at either discriminative or nondiscriminative levels of stimulus perception, contrary to our expectations. Although emotional valence did have significant effects on both word–nonword discrimination performance and the bias to respond ‘‘word,’’ in some correspondence with previous findings (Eviatar & Zaidel, 1991; Robinson, 1998; Windmann & Krüger, 1998), these effects were symmetrical for the two visual fields. Likewise, although repetition priming effects were clearly present in both visual fields, these were not significantly influenced by the emotional meaning of the items. Both findings seem inconsistent with previous reports suggesting enhanced sensitivity of the right hemisphere for affective information (Hartley et al., 1991; Richards et al., 1995; Van Strien & Morpurgo, 1992).

However, we made another observation that may account for this inconsistency. Surprisingly, the left hemisphere showed a much more liberal response bias than the right as well as stronger repetition priming effects on the response bias. This means that the left hemisphere generated ‘‘word’’ responses much more often than did the right hemisphere when it was unable to identify the stimulus, especially to old (= primed) stimuli. Similar observations have been reported by Chiarello and coworkers (1988, 1989). As a preliminary account for this result, we suggest that it may be related to automatic pattern completion processes due to extensive training and overlearning (Eichenbaum et al., 1999; Ratcliff & McKoon, 1996). Based on Hebbian learning, these processes serve to strengthen the connections within a neural representation, thereby increasing its coherence and retrievability (= accessibility/fluency) (cf. Kelley & Jacoby, 1998; Vaterrodt-Plünnecke, 1994). As the verbally skilled left hemisphere presumably dominates over the right hemisphere during normal left-to-right reading, it may have established much more coherent visual representations of horizontally oriented words than the right. As a consequence, its thresholds for activating these representations might be lower. In a lexical decision task like the current one in which the visually presented verbal input is weak and fragmentary, this would result in more correct identifications of actual words as ‘‘words’’ (hits) but also in more erroneous representations of actual nonwords as ‘‘words’’ (false alarms) (cf. Wallace, Stewart, Shaffer, & Wilson, 1998; White, 1996, p. 207), which is exactly what we found. If this process truly depends on differentially well established visual word representations in the two hemispheres acquired during normal left-to-right reading, then presenting the stimuli in an unusual format that is less overlearned should reduce or abolish the effect and perhaps allow a more adequate comparison of the lexical–semantic capabilities of the two hemispheres. The second experiment was carried out to test this hypothesis.

EXPERIMENT 2

Some evidence for the assumption that the usual horizontal stimulus display might favor lexical analysis in the right visual hemifield compared to the left can be found in the earlier literature on visual half field differences. Mishkin and Forgays (1952, Experiment II) were the first who found that Hebrew words (spelled right to left) were associated with a slight advantage for the *left* visual field, suggesting verbal superiority of the right hemisphere. Because the spatial resolution of the retinal image decreases toward the periphery of the visual field, and because lexical access is thought to depend crucially on the beginning of a word more than on its ending

(Bryden, 1986; Schwartz & Kirsner, 1986), the horizontal format may facilitate lexical analysis in the right visual field where the beginning of the word is nearer to the central fixation point relative to the left visual field (Kirsner & Schwartz, 1986).

On the other hand, some studies wherein Hebrew or English words were presented in a *vertical* format still found a right visual field advantage (e.g., Barton, Goodglass, & Shai, 1965; Boles, 1985; Faust, Kravetz, & Babkoff, 1993), although the effect tended to be weaker than in the horizontal case and was sometimes not significant (Howell & Bryden, 1987). Reviewing the topic, Bradshaw, Nettleton, and Taylor (1981) concluded that word orientation does not seem to have much impact on visual field differences when single-syllable words are used (cf. Bryden, 1986; Lavidor, Babkoff, & Faust, 2001). Thus, most visual half field studies still use the horizontal display, presumably because it is more convenient for both the subject and the experimenter controlling the computer-aided test procedures.

However, the experiments of Young and Ellis (1985) point to the possibility that this may be a mistake when words of more than four letters are involved, as in the current study. Discussing their finding of absent word length effects in the right visual field as opposed to the left visual field, these authors suggested that the verbally skilled left hemisphere usually makes use of a ‘‘whole word’’ access to the mental lexicon, whereas the right hemisphere needs to encode graphemic information on a letter-by-letter basis (Lavidor et al., 2001). Presenting verbal stimuli in an unusual format (Young & Ellis, 1985, Experiments 7 and 8) made these differences between the two hemispheres disappear; although the left hemisphere was still superior in terms of overall lexical performance, it was no longer immune to the effects of word length as it had been before (see also Bruyer & Janlin, 1989; Lavidor et al., 2001).

This interpretation corresponds well with our finding of a markedly enhanced response bias of the left hemisphere relative to the right hemisphere. If the left hemisphere makes use of a whole-word access to the mental lexicon and the right hemisphere does not, then the left hemisphere will show a higher bias than the right hemisphere to (mis)represent any ambiguous letter string as a legitimate word, whether or not it actually is a word (cf. Adams, 1979). If this bias is in fact based on overlearned visual representations of horizontally oriented words, then it should be reduced substantially when stimuli are presented in an unusual format (Lavidor et al., 2001). This hypothesis has not been tested before because previous studies examining the effects of word orientation on visual field differences have (a) used only relatively short words and (b) focused solely on hit rates and/or reaction times as opposed to separate measures of accuracy and bias. Moreover, the question of whether the presentation format influences hemispheric differences in the *semantic* analysis of lexical items has never before been explored.

In summary, we hypothesized that an unusual presentation format might give rise to the expected hemispheric asymmetries in the processing of negative affect that may have been absent in Experiment 1 because the horizontal stimulus display was inappropriate for assessing the lexical–semantic skills of the right hemisphere. Therefore, we repeated Experiment 1 using the same stimuli and the exact same procedures, but with items presented in a vertical format.

Methods

Participants. A total of 37 subjects (23 females and 14 males, mean age 28.34 years, *SD* = 7.52) who did not take part in the other experiment participated in Experiment 2. All participants had normal or corrected-to-normal vision. Most of them were undergraduate students and received course credits for participation. All were right-handed with a minimum laterality quotient of 33 (indicating a right-to-left ratio of at least 2:1) in the Edinburgh Handedness Inventory (Oldfield, 1971).

Stimuli, apparatus, and procedures. Materials and procedures were identical to those employed in Experiment 1 except that stimuli were presented in capital letters and in a vertical orientation in both the rating task and the subsequent lexical decision task. Letter size was approximately 0.7 × 0.5 cm, and word length varied from approximately 3.5 to 7.0 cm. Stimulus presentations were centered to the vertical midline. The items were presented for 175 ms with a minimum visual angle of 2.44° measured between the center of the fixation cross and the inner edge of the letter H (one of the widest letters), thus exceeding the angles used in other studies that had successfully demonstrated visual half field differences in lexical decision with vertical item orientations (Barton et al., 1965; Boles, 1985). Data analysis was performed as in Experiment 1. Reaction times are again not reported in detail because they showed only a significant effect of Familiarity (old items were again responded to faster than new items) and no significant main or interaction effects involving Valence or Hemisphere. Reaction times were again almost identical for negative ($M = 1033$, $SD = 221$) and neutral ($M = 1034$, $SD = 223$) items.

Results

Analysis of the rating task yielded a highly significant effect of Emotional Valence, $F(1, 36) = 1335$, $p < .00001$, indicating that negative words ($M = 3.98$, $SD = 0.66$) were rated as much more negative and threatening than neutral words ($M = 0.73$, $SD = 0.49$).

Accurate identification of words and nonwords in the lexical decision task, as indicated by P_r, showed a significant effect of Visual Field, $F(1, 36) = 6.43$, $p < .05$, indicating higher accuracy of the right visual field relative to the left visual field. It also showed a significant effect of Familiarity, $F(1, 36) = 26.63$, $p < .001$, with old items being discriminated more accurately than new items. Furthermore, a significant effect of Valence was found, $F(1, 36) = 12.83$, $p < .005$, as negative items were discriminated better than neutral items. Finally, the Visual Field × Valence interaction effect was significant, $F(1, 36) = 4.42$, $p < .05$. Post hoc tests indicated a significant difference between the two visual fields for neutral items, $F(1, 36) = 10.35$, $p < .005$, but not for negative items (F's < 0.01). As can be seen in Fig. 4, discrimination performances were nearly equal for the two visual fields for negative items. By contrast, neutral items presented in the right visual field were analyzed

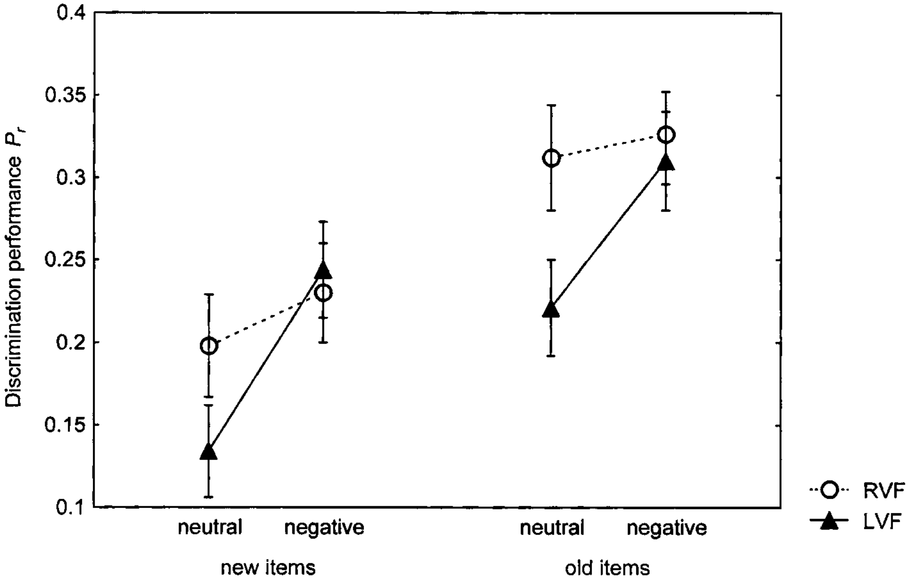

FIG. 4. Word–nonword discrimination performance for stimuli presented in the left (LVF) and right (RVF) visual fields, vertical stimulus presentation format.

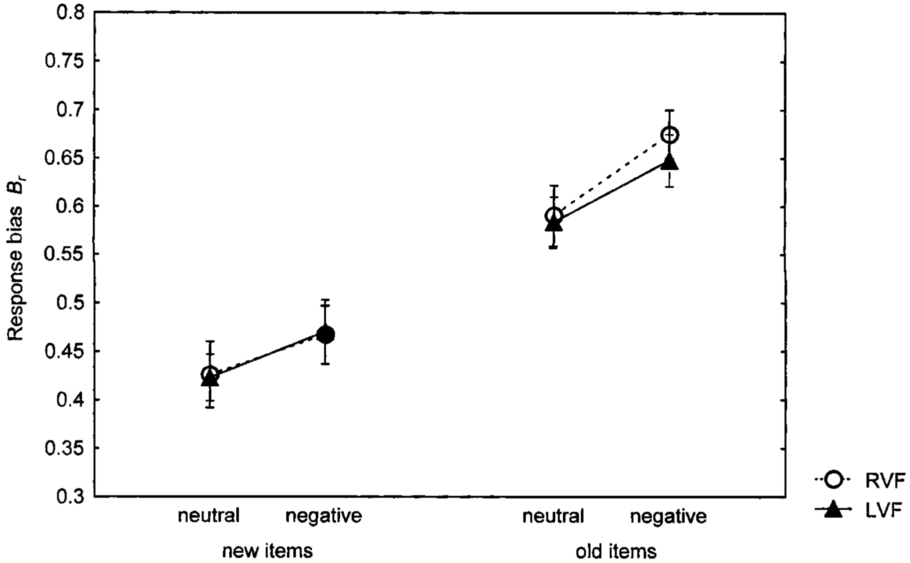

FIG. 5. Bias for responding ''word'' to stimuli presented in the left (LVF) and right (RVF) visual fields, vertical stimulus presentation format.

more accurately than those in the left visual field. No further main or interaction effects were significant or marginally significant.

The response bias B_r showed a highly significant effect of Familiarity, $F(1, 36) = 126.23$, $p < .0001$, indicating strong repetition priming effects, and a significant effect of Valence, $F(1, 36) = 16.02$, $p < .001$, as negative items were associated with a higher response bias than were neutral items (see Fig. 5). No further main or interaction effects were significant. As Fig. 5 shows, the response biases of the two hemifields were nearly identical. This holds for both negative and neutral items as well as for both old and new items.

Correlational analyses suggested again that P_r and B_r were statistically independent for the left ($r = -.20$) and right ($r = .09$) hemifields.

Discussion

Results of this experiment replicated the main findings of Experiment 1 but also yielded two important differences. The concordance was fourfold. First, strong repetition priming effects were observed in word–nonword discrimination performance (P_r) as well as in the response bias measure (B_r). Second, word–nonword discrimination for the right hemifield was superior to that for the left hemifield, suggesting that the lateralization procedure was again successful. However, this difference was considerably weaker than in Experiment 1, where stimuli were presented horizontally (cf. Barton et al., 1965; Howell & Bryden, 1987; Lavidor et al., 2001; Mishkin & Forgays, 1952).

Third, the significant effect of negative emotional valence on the response bias was replicated. Items with negative connotations again evoked more ''word'' responses than neutral items, whether or not these items were in fact words. This suggests that emotionally negative associations were activated by both words and nonwords that were not identified correctly (for further interpretation, see Windmann & Krüger, 1998; Windmann & Kutas, 2001). Fourth, there was again no evidence for differential prelexical processing of emotional information in the two hemispheres, as indicated by the absence of any Visual Field × Valence interaction effects on the response bias. In fact, both hemispheres showed practically the same effects of emotion on the bias, suggesting bilateral distribution of this (presumably preattentive) affective function. Likewise, there was no differential effect of emotional valence on repetition priming in the two hemispheres, as indicated by the absence of any significant Visual Field × Valence × Familiarity interaction.

However, turning to the differences between the current results pattern and the one observed in Experiment 1, the overall response bias of the left hemisphere was no longer different from that of the right hemisphere. In fact, the overall response biases were now nearly identical for both visual fields across all experimental conditions and variations. This finding suggests that the vertical presentation format successfully prevented differentially well-established perceptual pattern completion processes in the two hemispheres from driving the experimental effects. The superiority of the left hemisphere was now restricted to the accuracy measure P_r, as it should be if it is supposed to reflect lexical skills as opposed to the retrievability (or ‘‘fluency’’) of specifically formatted visual word representations.

At the same time, however, a new effect of emotional valence emerged that was not observed before. The right hemisphere was now no longer inferior to the left hemisphere in analyzing emotionally negative items. Although the left hemisphere was still superior in the discrimination of *neutral* words and nonwords (after all, it is the language-dominant hemisphere), the two hemispheres did not differ anymore in their ability to lexically analyze emotionally negative items. This holds for both new items and old (= primed) items.

This finding is consistent with the results of previous studies on the effects of emotions on attentional lexical processing. For example, Asbjörnsen, Hugdahl, & Bryden (1992) showed that the right ear advantage usually observed in dichotic listening tasks was abolished when subjects expected negative consequences of incorrect answers (i.e., electric shock). Similarly, Richards et al. (1995) reported right but not left hemispheric interference to fear-related stimuli for healthy subjects performing on an emotional Stroop task in a visual half field paradigm with vertically oriented words. Furthermore, Van Strien and Boon (1997) reported that the usual advantage of the left hemisphere in lexical decision was canceled out when subjects listened to aversive music sequences while performing on the task. While these studies demonstrate that functional brain asymmetries in lexical analysis change under the influence of negative affect, our study extends these findings by showing that these emotion-related changes are *restricted* to relatively sophisticated levels of perceptual–lexical analysis.

In summary, the results of Experiment 2 suggest that the right hemisphere shows an advantage for the semantic analysis of emotionally negative lexical items, as compared to emotionally neutral lexical items, only at a discriminative perceptual level allowing for accurate lexical analysis, not at a level at which words and nonwords cannot be correctly discriminated and lexical decisions are based on guessing. Thus, we infer that brain asymmetries in the processing of negative emotional words, as compared to neutral emotional words, do require (or are linked to) accurate stimulus identification. By contrast, at the prelexical processing stage, both hemispheres were equally able to detect the emotional meaning of the negative stimuli.[4] This conclusion is in conflict with prior work attributing the higher affective sensitivity of the right hemisphere to unconscious and prelexical processes (Dawson & Schell, 1982; Làvadas et al., 1993; Wexler et al., 1992). However, these studies cannot be compared

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[4] Note that this interpretation is highly unlikely to be a Type II error because the differences between the two visual fields were close to zero in all experimental conditions.

directly with the current one because they employed masking or subliminal stimulation paradigms, procedures that have long been questioned and that have been replaced by process dissociation procedures in the more recent literature (Debner & Jacoby, 1994; Greenwald et al., 1996; Holender, 1986; Reingold & Merikle, 1993).

GENERAL DISCUSSION

The experiments reported herein successfully dissociated lexical accuracy and decision bias of the two hemispheres as a function of affective value and repetition priming. Specifically, two dissociations were found to depend on the display format of the lexical stimuli. First, a highly significant hemispheric difference in the bias to classify a lexical stimulus as a ''word'' was found when the items were oriented horizontally but not when they were oriented vertically. Second, asymmetric effects of emotional valence on lexical accuracy were found for vertically oriented stimuli but not for horizontally oriented stimuli.

The first dissociation suggests not only that horizontally oriented visual word representations are more well established in the left hemisphere than vertical ones but also that they are systematically *under*represented in the right hemisphere (more than vertical ones). Presumably, the left hemisphere leaves the right hemisphere little opportunity to acquire these representations because it usually dominates over the right hemisphere during normal left-to-right reading (cf. Lavidor et al., 2001). In any event, it is important to note that the different presentation formats affected the *bias* of the two hemispheres much more than their *accuracy* scores. Because a higher bias enhances hit rates as well as response speed (cf. Windmann, Urbach, & Kutas, 2001), this results pattern implies that taking these measures in visual half field studies with horizontal stimulus displays as performance indexes will inevitably lead to a dramatic overestimation of the lexical skills of the left hemisphere. For example, in the current data set, the left-to-right visual field difference in the hit rate was nearly 10 times higher for the horizontal display ($M = .210$) than for the vertical display ($M = .026$), $t(75) = 6.65$, $p < .00001$.

Moreover, the second dissociation shows for the first time that word orientation affects not only lexical but also *semantic* processes in the two hemispheres differentially. As the stimulus presentation format was changed from usual to unusual, the right hemisphere (but not the left) showed a *valence-specific* increase in lexical accuracy. As a result, it was now equally able as the left to lexically analyze emotionally negative items and remained inferior only in the analysis of *neutral* stimuli (albeit to a much lesser extent than in Experiment 1). While this finding demonstrates the empirical dissociability of the two measures accuracy and bias, it also warns against the use of horizontal word displays in studies on brain lateralization. Although it is certainly true that the vertical presentation formats places higher demands on visuospatial skills (Howell & Bryden, 1987), it does so for *both* hemispheres (Lavidor et al., 2001); hence, it eliminates the effects of Western reading habits while maintaining the lexical nature and the experimental validity of the task. Therefore, contrary to the opinions expressed by Bradshaw et al. (1981) and Bryden (1986), we conclude that vertical or otherwise unusual/nonstandard item displays are to be preferred for divided visual field studies in which words of more than four letters are used.

As for the effects of emotion, we conclude that any visually presented verbal stimulus is first evaluated for its emotional significance at a prelexical level, regardless of its location in the visual field and its perceptual format. If the stimulus does in fact have negative emotional associations, then these serve to enhance the bias to respond ''word,'' presumably as a means to ensure that any potentially threat-related stimuli are not missed or ignored (LeDoux, 1995; Windmann & Krüger, 1998; Windmann & Kutas, 2001). Because this bias is independent of accurate performance (Snodgrass & Corwin, 1988, p. 47), as confirmed by our correlational analyses, we think that this phenomenon demonstrates semantic activation in the absence of (conscious) stimulus identification in both hemispheres (cf. Greenwald et al., 1996; Holender, 1986; Windmann & Krüger, 1998; Zajonc, 1980).

When presented in a nonoverlearned perceptual format, stimuli evaluated as potentially *negative* during this early processing are then lexically analyzed equally well by *both* hemispheres (as indicated by the symmetric P_r values for negative items), whereas items without this emotional connotation are analyzed more accurately by the verbally skilled *left* hemisphere than by the right hemisphere. Presuming that threat-related lexical stimuli can activate the same fight-and-flight responses as other threat-related stimuli, we suggest that bilateral perceptual analysis of potentially threatening stimuli might entail higher survival value because it allows for immediate planning of bilaterally controlled coarse motor responses (e.g., running). In the case of neutral words, however, lexical analysis might be performed in a more efficient way unilaterally by the verbally highly skilled left hemisphere. The same seems to hold for horizontally oriented words for which the visual system of the left hemisphere has developed strong automatic pattern completion mechanisms, whether or not these words are emotional.

APPENDIX

Word list A		Word list B	
Neutral	Negative	Neutral	Negative
Steering wheel	Insanity	Apple tree	Burglary
Airing	Gallows	Poodle	Raving madness
Dialect	Deformed baby	Grandchild	Inflammation
Chat	Graveyard	Biology	Tumor
Grid	Gall	Door handle	Nausea
Vertex	Skeleton	Interest	Freak
Plug	Coma	Overflow	Infection
Calorie	Earthquake	Tenor	Snake
Liability	Coursing	Resting place	Torture
Heirloom	Carnage	Steamer	Eradication
Magazine	Exploitation	Assistance	Wheelchair
Food	Vampire	Factory	Degeneration
Corn cob	Chaos	Presence	Poverty
Sweden	Mummy	Temple	Shortness of breath
Signal	Misery	Snail	Ghost
Plaited work	Dictatorship	Extract	Accusation
Folding-screen	Spy	Content	Case of death
Approach	Abyss	Palate	Urn
Equalization	Slaying	Direction	Vomiting
Millet gruel	Whip	Syrup	Stab with a dagger
Unity	Revolver	Iron	Poisoning
Associate	Suffocation	Precision	Gun
Bracelet	Assassination	Move	Slaughter
Project	Ambush	Cloud	Melancholy
Combine	Crash	Unicorn	Assault
Cape	Killer	Rubric	Divorce
Sound	Lie	Forearm	Massacre
Chorus	Monster	Building	Suffering
Standardization	Prosthesis	Left turn	Corpse
Honey	Deafness	Turpentine	Avalanche
Angle	Harpoon	Sweepings	Horror
Potassium	Terror	Watch-maker	Running amuck
Painting	Suspicion	Birch-tree	Skull
Nail	Paralysis	Edge	Ghetto
Branch	Deathbed	Formation	Murderer
Pearl	Projectile	Taking off	Nightmare
Cover	Crying fit	Charm	Panic
Recording tape	Drought	Poster	Executioner
Midwife	Riot	Payload	Perjury
Apparatus	Nazi	Poem	Explosion

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