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Altered visual field asymmetry for lexical decision as a result of concurrent presentation of music fragments of different emotional valences

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Abstract

Sixteen right-handed male students were administered a unilateral lexical decision task in 4 conditions: a baseline condition and three sound conditions. In the sound conditions, the participants listened to noise, to music with a positive emotional valence, and to music with a negative emotional valence, while performing the visual half-field task. In the baseline condition, the noise condition, and the positive music condition, lexical decision latencies were shorter to right than to left visual field presentations. In the negative music condition, there was a selective enhancement of left visual field performance, which cancelled the visual field advantage completely. None of the concurrent sounds affected autonomic arousal as measured by heart rate. The results demonstrated that music with a negative emotional valence can alter the half-field asymmetry of a verbal task. The outcome was discussed in terms of right hemisphere priming due to negative emotional experience. (*JINS*, 1997, *3*, 473–479.)

Keywords: Divided visual field, Emotion, Music, Hemispheric asymmetry

INTRODUCTION

There are two main neuropsychological hypotheses concerning the differential representation of positive (pleasant) and negative (unpleasant) emotions in the cerebral hemispheres. These hypotheses are the *right hemisphere hypothesis* and the *valence hypothesis* (Borod, 1993). The right hemisphere hypothesis postulates that the right hemisphere is specialized for emotion, regardless of the valence of the emotion. The valence hypothesis maintains that the right hemisphere is specialized for the *perception* of emotion, irrespective of its valence, whereas the two hemispheres are differentially specialized for the *experience* and *expression* of positive and negative emotion.

Of these two hypotheses, the valence hypothesis appears to be the most plausible. Regarding the perception of emotion, clinical studies and studies with normals have demonstrated right hemisphere superiority for processing facial affect and processing emotional intonations of speech, irrespective of valence (Heilman et al., 1993). Where the experience of emotion is concerned, there is consistent experimental evidence that the left hemisphere is more engaged during positive emotional states, while the right hemisphere is more engaged during negative emotional states (for review, see Davidson, 1993).

Evidence for the valence hypothesis implies evidence for caudality. That is, the hemispheric specialization for emotion not only varies along the left *versus* right dimension, but also along the anterior *versus* posterior dimension. Differential lateralization as a function of valence occurs for anterior regions, while right hemispheric dominance for the perception of emotion, irrespective of valence, is limited to posterior regions (Davidson, 1984; Borod, 1993).

Heller (1993) pointed out that emotions can be defined by two dimensions; arousal and valence. Heller postulated that the right parietotemporal regions not only are specialized for the perception of emotion, but also modulate autonomic arousal. Measures of autonomic arousal such as heart rate, electrodermal response, and cortisol secretion are more affected by emotional stimuli presented to the right than to the left hemisphere. The frontal regions, on the other hand, are involved in modulation of emotional valence. Higher

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left than right frontal electrophysiologic activity is associated with positive valence, whereas the reverse is associated with negative valence. In Heller's view, the left and right frontal lobes are not specialized for positive and negative emotions. Rather, the relative activation of these regions with reference to each other is associated with a certain valence. According to Heller, emotional states depend on the diverse and changeable activation patterns of frontal (valence) and right parietotemporal (arousal) regions.

Heller's distinction between emotional valence and arousal is important to a discussion of the results of those studies that have demonstrated that negative emotions can prime the right hemisphere, and thus change the standard pattern of hemispheric laterality. Asbjörnsen et al. (1992) demonstrated that during a high incentive negative arousal condition (threatening participants with electric shocks), the right ear advantage for dichotic listening to consonant–vowel syllables was cancelled. The reduced ear difference was the result of both an increase in left ear performance and a decrease in right ear performance. A low incentive negative (threatening participants with noise bursts) and high and low incentive positive (monetary rewards) arousal conditions had no effect on the right ear advantage. Interestingly, their participants exhibited a significant increase in heart rate during the high negative condition only. This suggests that arousal rather than emotional valence was the critical factor for priming the right hemisphere.

Gruzelier and Phelan (1991) found that a stressful situation (testing medical students 1 or 2 days before an exam) induced a reversal of visual field asymmetry. A lexical task that required discrimination of consonants from vowels resulted in a right visual field (RVF) advantage in the neutral condition, whereas this task resulted in a left visual field (LVF) advantage in the stressful condition. Gruzelier and Phelan explained this outcome as an interplay of structural and dynamic processes that determine visual field asymmetries. Structural processes give rise to a RVF advantage for lexical stimuli (as a consequence of contralateral specialization for verbal abilities), but dynamic processes, such as the priming of the right hemisphere due to stress, reverse this asymmetry. The participants of Gruzelier and Phelan's study showed slower electrodermal habituation in the stressful condition. Again, arousal rather than emotional valence may have been the determining factor in priming the right hemisphere.

The influence of threatening information on visual field asymmetries was also demonstrated by our own research (Van Strien & Morpurgo, 1992; Van Strien & Heijt, 1995). Van Strien and Morpurgo (1992) primed the right hemisphere by presenting threatening words in the central visual field. It was expected that right hemisphere priming would provoke a leftward attentional bias (Kinsbourne, 1970) and therefore would yield a LVF performance improvement. Structural asymmetries were investigated using a unilateral letter naming task. In each trial, three consonants were presented for 100 ms to the LVF or to the RVF. In the control condition (no concurrent presentation of words), participants identified more letters correctly in the RVF than in the LVF. In the threatening concurrent word condition, each lateral three letter presentation was preceded by a threatening negative word in the central visual field. Participants had to recall the word after reporting the three letter set. Anxiety research has demonstrated that words like "injury" and "criticized" contain physically or socially threatening information (MacLeod et al., 1986). As was expected, the concurrent presentation of threatening words resulted in superior letter identification performance in the LVF. The concurrent presentation of nonthreatening, positive words (such as "harmony" or "wonderful") resulted in a selective enhancement of RVF performances. These results were replicated in the Van Strien and Heijt (1995) study. Because the threatening words did not give rise to a robust increase in arousal, we believe that the right hemisphere priming was a consequence of the negative emotional valence of the words rather than of higher autonomic arousal. Although some of the participants in our experiments felt a bit uncomfortable during the presentation of the negative words and commented that these were nasty words, they were not really anxious. In neither study however, did we measure psychophysiological responses to the words. For this reason, the possibility that arousal was the underlying cause of right hemisphere priming cannot be ruled out. To explore the relative importance of the valence and arousal dimensions to right hemisphere priming, heart rate (HR) was measured during each condition of the present study.

An unresolved issue in our previous experiments is the influence of the verbal nature of the concurrent words on the changes in asymmetry patterns. The concurrent presentation of nonthreatening words resulted in selective RVF performance improvement. It is not clear whether this is a consequence of the positive valence of the nonthreatening words or is a consequence of the verbal nature of the words (priming the verbal left hemisphere). In an earlier study (Van Strien & Bouma, 1990), we also found RVF letter-naming improvement as a consequence of the concurrent presentation of *neutral* words. Van Strien and Heijt (1995) hypothesized that, with threatening words, left hemisphere priming due to the verbal nature of the words is inhibited by right hemisphere priming due to the negative valence of the words. In this report we examined whether concurrent nonverbal stimuli with negative or positive emotional valence yielded comparable alterations in visual half-field asymmetry as did emotional words. We used a lateral lexical decision task as the visual half-field task. We choose this verbal task because it yielded a robust structural RVF advantage in a former study (Geerlings et al., 1995). We employed music fragments that are known to have a specific positive or negative emotional impact on the listeners. We expected that the concurrent presentation of the threatening, unpleasant music fragment (negative valence) would prime the right hemisphere as evidenced by selective LVF shortening of latencies for lexical decision. The impact of the joyful music fragment (positive valence) on visual asymmetry can shed some light on the positive emotion *versus* verbal nature is-

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sue of the preceding research with nonthreatening words. If the concurrent presentation of pleasant music yields a selective RVF improvement, then the left hemisphere can be primed by a stimulus with positive emotional valence without a verbal component.

METHOD

Research Participants

Sixteen strongly right-handed male students volunteered for the experiment and were paid for their participation. Participants ranged in age from 20 to 29 years, with a mean age of 24 years. Strength of hand preference was measured using a 10-item handedness questionnaire, with scores ranging from −10 (*extreme preference for the left hand*) to 10 (*extreme preference for the right hand*). All participants had a hand preference score of at least +8.

Apparatus and Stimuli

HR was recorded on an ambulatory monitoring system developed by the division for instrumentation of our faculty (for description see Willemsen et al., 1996). Interbeat intervals were stored continuously during the entire experiment. For further statistical analysis, HR data (number of heart beats per min) were averaged across six 1-min samples during each condition.

The lateral lexical decision task was presented on a NEC 5FGe monitor that was connected to a MS-DOS computer. Stimulus presentations and response registration were programmed using the Experimental Run Time System software package (Beringer, 1994). The participants were seated at a distance of 50 cm from the screen. They responded bimanually by pressing response keys for index and middle fingers. Half of the participants responded with both index fingers for *word* decisions and with both middle fingers for *nonword* decisions. The other participants responded in the opposite manner.

There were four conditions, each with a block of 48 trials. These conditions were (1) baseline, (2) concurrent presentation of noise, (3) concurrent presentation of joyful music, and (4) concurrent presentation of threatening music. In each block there were 24 word trials (12 LVF, 12 RVF) and 24 nonword trials (12 LVF, 12 RVF). For the 192 experimental trials, 48 real words (16 four-letter words, 16 five-letter words, and 16 six-letter words) and 48 nonwords were used. Nonwords were obtained by replacing one or two letters of the four-letter words, two letters of the five-letter words, and three letters of the six-letter words. Within each experimental block, a word or nonword was presented twice (in a random sequence); once to the LVF and once to the RVF. The four series were matched for word length, word frequency, and imageability.

The words and nonwords subtended 1.6° (four-letter words) to 2.6° (six-letter words) of visual angle horizontally and were presented at an angle (measured at the middle of the word) of approximately 2.7° left or right from the center of the screen.

In the noise condition, the participants listened to pink noise while performing the lateral lexical decision task. Pink noise is a random noise source, created by passing white noise (which contains equal amounts of all audible frequencies) through a 3 dB/octave rolloff filter. Because pink noise sounds richer in low frequencies than white noise, we thought it the preferred control sound in relation to the music fragments. In the joyful music condition, the participants listened to *Jupiter, the Bringer of Jollity* from *The Planets* by Gustav Holst (Philips 442 408-2, Berlin Philharmonic Orchestra conducted by Sir Colin Davis). In the threatening music condition, they listened to *Threnody for the Victims of Hiroshima* by Krysztof Penderecki (EMI 5 65077 2, Polish Radio National Symphony Orchestra conducted by Krysztof Penderecki). The two music fragments (*Jupiter* and *Threnody*) were chosen because the validity of their emotional appeal has been demonstrated by VanderArk and Ely (1992, 1993, 1994).

Noise and music fragments were recorded on analog CrO_2 tape with Dolby C noise reduction and played back with an Aiwa AD-F800 cassette player, a Sony TA-F120 stereo amplifier and a pair of Sennheiser HD250 headphones. In the noise condition, the sound pressure level was 70 dB (A-weighted). In the music conditions, the sound pressure level ranged from 40 to 91 dB. The sound pressure level was measured with a Brüel and Kjaer Type 4152 artificial ear.

Design

Within each run, trials were presented in a pseudorandomized predetermined order with no more than three successive presentations in the same visual field and no more than three successive presentations of the same word type (word or nonword). The order of conditions was counterbalanced across subjects in such a way that the two emotional conditions were always separated by either the noise or the baseline condition.

Procedure

Each condition was initiated by the experimenter. In the noise and music conditions, the participants listened to the tape for 1 min before starting with the lexical decision task. The noise or music continued during this task.

The sequence for each trial was (1) a visual warning signal (!!!!!) presented centrally for 1000 ms, (2) the 1000-ms presentation of the fixation dot, (3) the 180-ms unilateral presentation of the word or nonword, and (4) the 2000-ms presentation of the fixation dot.

Preceding the experimental run, the participants received 48 training trials with words and nonwords that were not used in the experimental run. At the end of a music condition, the participants rated, on a seven-item questionnaire, the emotional impact of the music fragment concerned.

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Results

Lexical Decision

Response latencies were averaged across hands. Incorrect responses and outliers within each participant's dataset (i.e., latencies more than 3.5 *SD*s deviations away from a participant's mean) were omitted. The overall error rate was 8.0%, and the overall rate of outliers was 0.7%. For each participant, mean reaction times were computed as a function of condition, word type, and visual field. An analysis of variance was performed on these means with Condition (baseline, noise, *Jupiter*, *Threnody*) × Word Type (word, nonword) × Visual Field (LVF, RVF) as factors within participants.

Besides a significant main effect for Word Type [$F(1,15) = 8.07$, $p < .02$], with shorter latencies to word ($M = 832$ ms) than to nonword ($M = 897$ ms) presentations, a nearly significant main effect for visual field [$F(1,15) = 3.90$, $p < .07$] was found. Across conditions, participants tended to respond faster to RVF ($M = 854$ ms) than to LVF ($M = 876$ ms) presentations. The interaction of Condition × Visual Field was significant [$F(3,45) = 2.97$, $p < .05$]. This interaction is depicted in Fig. 1.

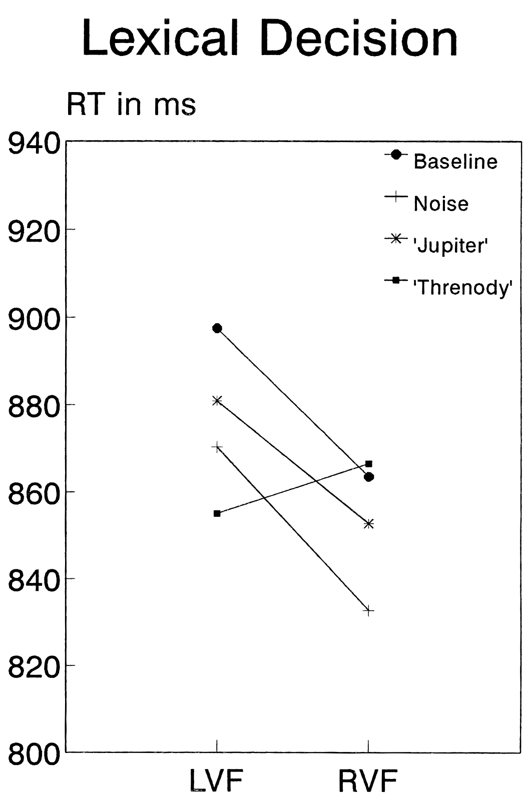

Fig. 1. Mean response times (in ms) for the lexical decision task as a function of condition and visual field (LVF = left visual field; RVF = right visual field).

Table 1. Mean response times (in ms) for the lexical decision task as a function of condition and word type

	Words		Nonwords	
Condition	*M*	(*SD*)	*M*	(*SD*)
Baseline	869	(203.4)	892	(152.9)
Noise	818	(159.0)	885	(171.3)
Jupiter	835	(165.9)	898	(175.6)
Threnody	806	(148.6)	915	(177.5)

From this figure, it can be seen that the baseline condition resulted in a RVF advantage. The noise condition and the *Jupiter* condition did not yield asymmetric performance changes. The *Threnody* condition, however, resulted in a selective LVF performance enhancement, which cancelled the RVF advantage. This was reflected by the analysis of partial interactions (i.e., for noise *vs*. baseline, *Jupiter vs*. baseline, and *Threnody vs*. baseline), which showed that the interaction of Condition × Visual Field was only significant for the *Threnody vs*. baseline comparison [$F(1,15) = 7.51$, $p < .02$].

There was also a significant interaction of Condition × Word Type [$F(3,45) = 4.22$, $p = .01$]. Table 1 shows the mean latencies as a function of condition and word type.

From this table, it can be seen that the three sound conditions, when compared to the baseline condition, resulted in shorter latencies to words but not to nonwords. Additional analyses of variance in which the three sound conditions (noise, *Jupiter*, *Threnody*) were pooled revealed that across the sound conditions ($M = 820$ ms), words were recognized significantly faster than in the baseline condition [$M = 869$ ms, $F(1,15) = 5.28$, $p < .05$]. For nonwords, there was no difference between the sound conditions ($M = 899$ ms) and the baseline condition [$M = 892$ ms), $F(1,15) = .31$, ns].

Heart Rate

An analysis of variance on the HR data revealed no significant effect for condition [$F(3,45) = 2.08$, $p < .12$]. From Table 2, it can be seen that the HR did not change as a function of the experimental conditions.

Table 2. Mean heart rate in beats per minute (BPM) as a function of condition

Condition	Mean BPM score	(*SD*)
Baseline	71.77	(10.38)
Noise	73.94	(10.85)
Jupiter	72.06	(11.21)
Threnody	72.90	(10.72)

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Emotional Impact

Figure 2 displays the participants' ratings for the three sound fragments on the seven-item questionnaire.

Threnody was rated significantly more annoying ($p < .005$, two-tailed Wilcoxon matched-pairs signed-ranks test), sad ($p < .05$), dramatic ($p < .005$), and threatening ($p < .002$) than *Jupiter*, while *Jupiter* was rated significantly more jolly ($p < .001$) and serene ($p < .005$) than *Threnody*.

DISCUSSION

In the baseline condition, the lexical decision task yielded the typical RVF advantage that can be anticipated when employing a verbal task. The absence of a main effect for condition indicates that, across visual fields and word types, music and noise did not distract our participants. The reason for this outcome may be that the lexical decision task was relatively easy to perform. Noise and music will be more distracting during complicated than during easy tasks. Furthermore, our noise source had a continuous sound level, which is much less distracting than separate noise bursts.

Across all four conditions, latencies were shorter to words than to nonwords, as was reflected by the significant main effect for word type. This is in agreement with other lexical decision studies. The faster recognition for words than for nonwords can be explained by a dual-route model of word recognition (e.g., Ellis, 1984). According to this model, existing words will be mainly processed by a rapid matching of the visual word image as a whole, whereas nonwords must be processed by a slower, sequential phonological system before they can be further processed by the semantic system. Although the sound conditions did not affect overall performance, the significant interaction of Condition $\times$ Word Type revealed that, during the sound conditions, the latencies to existing words were shorter than during the baseline condition. We can only speculate about the reason why latencies to existing words in particular shortened when concurrent sounds were heard. There may be a differential effect of sounds on the visual and phonological systems of word recognition. It is possible that the concurrent sounds interfered with the phonological system in particular. As a consequence, the rapid direct visual recognition of existing words was favored.

As was expected, the concurrent presentation of unpleasant music resulted in shorter latencies to LVF presentations, which cancelled the baseline RVF advantage. The outcome is comparable with the results of our studies with threatening words, in which also selective LVF performance improvements were found (Van Strien & Morpurgo, 1992; Van Strien & Heijt, 1995).

Like noise and joyful music, unpleasant music did not differentially affect HR in our participants. Apparently, the sound stimuli did not provoke a notable change in autonomic arousal. In the VanderArk and Ely (1992, 1993, 1994) studies, cortisol, biochemical, and electrodermal indices of arousal in biology majors were, in general, not affected by positive or negative emotional music. In music majors, by contrast, plasma cortisol levels raised significantly after listening to either *Jupiter* or *Threnody*. Also, when compared to biology majors, music majors exhibited significantly more galvanic skin response peaks during both *Jupiter* and *Threnody*. From VanderArk and Ely's studies, it can be concluded that musicians exhibit higher autonomic arousal in

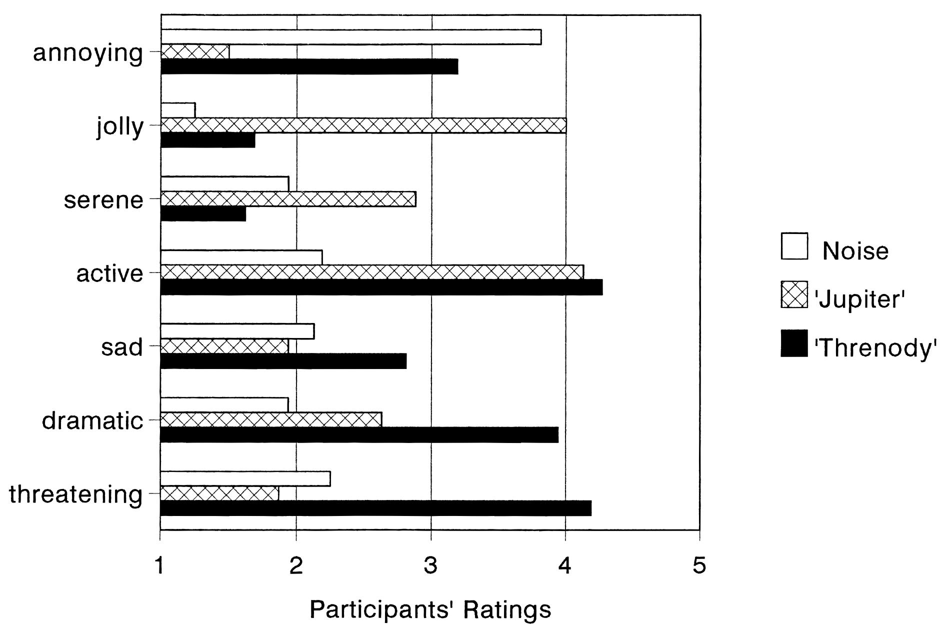

Fig. 2. Participants' ratings of the impact of the three sound fragments (1 = *not at all*; 5 = *highly*).

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response to music than do nonmusicians. Since none of our participants was a student in music, the music conditions did not affect their arousal levels.

It seems reasonable to infer that the negative emotional valence of the unpleasant music rather than a higher level of arousal provoked the altered visual field asymmetry in our participants. Given the differential specialization of the anterior regions for emotional experience as a function of valence, unpleasant music will be accompanied by right frontal activation. In our view, the priming of the right frontal regions provoked a leftward attentional bias and therefore yielded reduced latencies to LVF presentations.

The concurrent presentation of noise or joyful music did not affect the RVF advantage. According to the valence hypothesis, joyful music should be accompanied by left frontal activation. However, we did not observe significantly reduced latencies to RVF presentations during the positive music condition. It may well be that the positive emotions elicited by joyful music were only modest, resulting in marginal left frontal activation. The absence of a selective RVF performance improvement in the joyful music (positive) condition is at variance with the selective RVF improvement of letter naming performance as a consequence of concurrent presentation of nonthreatening (positive) words. Given the present results, it seems likely that, in our preceding research, the selective RVF improvement was caused by the verbal nature rather than the positive emotional content of the words.

The participants' ratings of the sound fragments confirmed the hypothesized differential impact of both pieces of music. *Jupiter* had a jolly and serene effect, whereas *Threnody* had a annoying, sad, dramatic, and threatening effect. It should be noted that in the present study, the hemispheric control of music processing was not investigated. Our subjects merely listened to the music (while performing the lexical decision task), whereas in studies concerning the lateralization of music functions, participants usually have to detect, recognize, or compare certain aspects of music, such as pitch, rhythm, harmony, or tone sequences.

Compared to *Jupiter*, *Threnody* is an unusual piece of music and is not easy on the ear. Therefore, it could be argued that unfamiliarity or novelty rather than negative emotional content caused the right hemisphere priming. Goldberg and Costa (1981) have proposed that the right hemisphere is better equipped to process novel stimuli. In our previous studies, however, threatening and nonthreatening words were matched for frequency, which makes a novelty explanation for the outcome of these studies unlikely. Concerning music perception, Gates and Bradshaw (1977) demonstrated that, in their dichotic listening study, the right ear (left hemisphere) was more sensitive in recognizing unfamiliar melodies and the left ear (right hemisphere) in recognizing familiar melodies, a result that runs contrary to the novelty model. Furthermore, LaBarba and Kingsberg (1990), using a dual-task paradigm, could not demonstrate differences in cerebral lateralization of familiar and unfamiliar music perception in nonmusicians. It therefore seems likely that the emotional valence rather than the novelty of *Threnody* primed the right hemisphere.

The outcome of the present research is in partial support of the valence hypothesis. We could demonstrate a right frontal activation under the negative emotional condition, but no left frontal activation under the positive emotional condition. Tucker (e.g., Tucker et al., 1995) has proposed an alternative hypothesis concerning emotional experience and the frontal regions. In his view, the left frontal region inhibits left hemisphere limbic and subcortical contributions to negative affect. This places a processing load on the left hemisphere, which may impair RVF processing (Tucker, 1981). Impaired RVF processing (i.e., longer latencies) as a result of negative emotions will also result in a cancellation of the lexical RVF advantage. When compared to the baseline or joyful music condition, the unpleasant condition did not result in impaired RVF processing. However, when compared to the RVF latencies under the noise condition, RVF latencies under the unpleasant music condition were longer. If neutral noise can be subtracted from unpleasant music to evaluate the impact of negative valence without sound, it follows that the negative valence interfered with left hemisphere processing. We doubt that pink noise and music differ only in emotional valence. The continuous sound level of the noise condition may have affected the lexical decision process in other ways than the dynamics of a neutral piece of music would have done. For this reason, and given the experimental evidence from our own previous research and that of others (e.g., Gruzelier & Phelan, 1991), we take the view that the altered visual field asymmetries as a result of concurrent negative emotional stimulation support the notion that negative emotional experience results in right frontal activation rather than left frontal inhibition.

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