

How do cognition, emotion, and epileptogenesis meet? A study of emotional cognitive bias in temporal lobe epilepsy

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ABSTRACT

Emotional distress is one of the most frequently reported seizure precipitants in epilepsy, but little is known about its causes and processes. Interestingly, it is now accepted that emotional distress, such as anxiety, may be accompanied by evolutionary adaptation, or abnormal attentional vigilance toward threatening stimuli. The goal of this research was to study the link between emotional seizure precipitants and pathological attention-related biases toward threat in temporal lobe epilepsy (TLE). To this aim, patients were asked to report the extent to which seizures were elicited or not by emotional precipitants, allowing distinction of two groups: “Emo-TLE” group and “Other-TLE” group. Attentional biases were investigated by comparing patients’ emotional Stroop and dot detection paradigms with those of healthy individuals (control group). We found that the Emo-TLE group was characterized by attentional bias toward threatening stimuli compared with neutral stimuli and compared with the other two groups. We thus hypothesize that attentional biases related to threat in patients with TLE may sustain emotional vulnerability and seizure occurrence.

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1. Introduction

Temporal lobe epilepsy (TLE) is the most frequent form of partial epilepsy in the adult population, characterized by abnormal electrical changes starting from one or several regions of the temporal lobe including the amygdala [1]. Patients with TLE often present with ictal emotional disturbances such as fear and anxiety.

Additionally, these patients may disclose interictal (i.e., occurring between seizures) psychiatric modifications, such as anxiety, depression [2], and panic disorders [3]. Some data from studies in animals and humans [4,5] have provided support for the theory that electrical changes in the temporal lobe structures may induce affective modifications and potentially play a determinant role in affective disorders [3–8]. Neural circuitry, including that of the temporal lobe and amygdala, underlies expression and regulation of emotions, in particular stress and threat-related responses [9–11]. Moreover, it has been accepted that epileptic seizures may occur not completely randomly, but in response to environmental stimuli [12]. Few previous investigations have been able to confirm

the widely held perception that emotional distress and anxiety states are often reported by patients to act as seizure precipitants [13–18]. It has been suggested that pathophysiological changes in the temporal lobe, including the amygdala, may trigger these phenomena, but the underlying mechanisms are poorly known. The goal of the present study was to investigate seizure-precipitating factors in patients with TLE and to determine if this group of patients discloses specific characteristics, particularly in terms of emotional vulnerability.

From the cognitive point of view [19–23], a key factor of the emotional distress and the maintenance of anxiety disorders is the existence of nonadaptive attentional bias toward information with aversive value. One of the common paradigms used to study anxiety and attention is the probe detection task [24]. The task consists of simultaneous presentation of threatening and neutral stimuli (e.g., threatening words), one above the other, on a computer screen. After the offset of stimuli, a dot appears in the same location as one of the two items (threatening or neutral), and participants have to detect its spatial position. In comparison with normal controls, anxious people present a classic “congruency effect,” with a significant difference between reaction times (RTs) when the dot replaces the threatening stimuli (congruent trials) and RTs when the dot replaces neutral stimuli (incongruent trials)

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[24]. Several potential attentional processes may sustain the congruency effect. It was first inferred that the main mechanism was a facilitated response during congruent presentations (quicker RTs) (compared to incongruent trials) and neutral control baseline trials, resulting in a “vigilance” toward threat [25–28]. Nevertheless, it has been also proposed that the congruency effect related to anxiety may depend on a “difficulty to disengage” attentional resources from threat [29]: slower responses (longer RTs) to detect the dot during incongruent trials (compared with congruent and neutral control baseline trials) (Fig. 1). This assumption is now supported by studies using either the dot detection task [30,31] or the emotional variant of the exogenous cueing paradigm [30,32,33].

To our knowledge, only one study has investigated the impact of affective disturbance on cognitive processes in patients with epilepsy. Indeed, Zeitlin et al. [34] used the emotional Stroop paradigm to assess the influence of the so-called “fear of seizure” on attentional biases in patients with generalized or complex partial seizures. They found that participants with many seizure-related fears had slower RTs in naming the color of emotional seizure-related words than in naming the color of emotionally neutral words. The authors thus concluded that selective attention toward fear of seizure-related information contributed to maintaining interictal psychosocial difficulties and psychiatric problems, without considering the type of epilepsy. Although authors linked some epileptic-affective disorders to attentional bias for specific items, no data are currently available on attentional bias related to emotional precipitants of seizures in patients with TLE.

The present study was designed to investigate whether patients with TLE prone to epileptic seizures in the context of emotional distress disclose specific characteristics and, in particular, abnormal responses during a probe detection task and during the emotional Stroop task.

2. Materials and methods

2.1. Participants

Thirty-one adult patients (12 males and 19 females, age range = 16–50 years, mean age = 33.1, SD = 10.4 years) with drug-resistant TLE were prospectively studied in the Epilepsy Unit of

the Clinical Neurophysiology Department (Timone Hospital, Marseille, France). The experiment took place during presurgical evaluation. All patients included received detailed information and gave written informed consent for the present research. They underwent a comprehensive evaluation including detailed history and neurological examination, neuropsychological testing, high-resolution MRI, interictal/ictal single-photon computerized tomography, and video/EEG recording of seizures. In 16 patients, the epileptogenic zone was located in the left mesial temporal lobe, and in 15, in the right mesial temporal lobe. Patients with TLE were split into two groups according to the type of factors precipitating seizures: The Emo-TLE group comprised patients who self-reported that seizures were influenced by emotional factors (e.g., emotional distress, annoyance), and the Other-TLE group comprised patients who self-reported that epileptic seizures were precipitated by other factors (e.g., lack of sleep, flashing lights) or did not have a clear provoking factor. Twenty-one healthy volunteers, with no history of neurological or psychiatric impairments, were matched as closely as possible to the patients with TLE with respect to age, sex, and education (for details, see Procedure) (Table 1 and Supplementary Table 2a and b).

2.2. Stimuli

We focused on “general” threatening words (e.g., war, poison, massacre) and neutral words (e.g., face, sphere, housing) not related to epilepsy. Stimuli were selected from a large pool of 276 initial French words in the literature and several were chosen intuitively by us (e.g., see [26,32,34–43]). Words for the two final lists, in the emotional Stroop and dot detection tasks, were chosen on the basis of different parameters: arousal, valence using the Self-Assessment Manikin SAM [44], and the fact that they should not be relevant to the epilepsy as they were being evaluated by healthy individuals and patients with epilepsy.

A total of 96 words, 32 threatening and 64 neutral, were selected. Two lists were constructed, one used in the Stroop task and the other in the probe detection task. For each list, “neutral” words were chosen and matched to threatening words with respect to semantic category, length, and lexical frequency in the Brulex frequency dictionary [45]. The two lists of words are available in Supplementary Table 1a and b. The word list for the Emo-

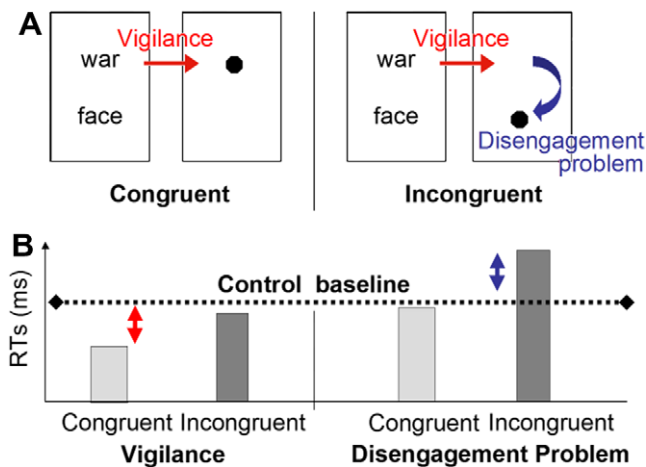


Fig. 1. (A) Illustration of “vigilance” or the “problem of disengagement” with words, during congruent and incongruent trials. Behavioral illustration in reaction times (RTs) of the two possible explanations with congruent, incongruent, and control trials: vigilance or difficulty in disengaging attention from threatening words. The bold line represents control baseline (neutral-neutral trials). Vigilance (left side) to threatening words facilitates detection of the probe on congruent trials (faster RTs) compared with incongruent and control conditions. (B) Difficulty in disengaging attention from threatening words (right side) in incongruent conditions (longer RTs), relative to congruent and control conditions (B).

Table 1
Characteristics of participants.

Characteristic	Emo-TLE group (n = 17)	Other-TLE group (n = 14)	Control group (n = 21)
Age (years)	32.4 (11.2)	34.6 (10.3)	31.7 (8.9)
Education level (years)	11.7 (2.3)	12.2 (1.9)	12.7 (2.6)
Sex (M, F)	M: 4, F: 13	M: 8, F: 6	M: 7, F: 14
State-Trait Anxiety Inventory			
State	32.2 (8.6)	32.3 (9.6)	32.8 (8.5)
Trait	41.9 (8.7)	40.5 (8.9)	39.1 (7.2)
Beck depression inventory	5.1 (3.8)	6 (4.5)	5.6 (5.3)
Side of epilepsy (R, L)	R: 8, L: 9	R: 7, L: 7	—
Ictal emotional symptoms	13	7	—
Initial emotional event	9	0	—
Epilepsy duration (years)	12.6 (9)	17.2 (13.9)	—
Seizure frequency (/month)	13.1 (19.6)	11.8 (19.6)	—
IQ	90.3 (14.3)	84.8 (9.1)	—
Total			
Verbal	88.6 (14.2)	87.1 (5.7)	—
Nonverbal	91.3 (14.8)	86.6 (14.1)	—
Stroop (classic)	39.6 (8.8)	37.6 (11.5)	—
Etiology			
Hippocampal sclerosis	6	5	—
Other lesion	8	4	—
Normal MRI	3	5	—

Note. Values represent means (SD) or numbers.

tional Stroop task contained 16 negative and 16 neutral words. Each of them was presented in three colors. The total number of trials was 96. The word list for the probe detection task contained 16 negative words matched with 16 neutral words, resulting in 16 emotional–neutral pairs. As previously mentioned, the congruency effect could be due to facilitation or difficulty in disengaging attention from threatening words. To answer this question, an additional 32 neutral words were chosen to obtain 16 pairs of neutral–neutral words, matched for length and frequency. Finally, the dot task contained 16 emotional–neutral pairs and 16 neutral–neutral pairs and a total of 128 trials. In each emotional–neutral pair, combination between the position of the words (lower/upper) and the position of the probe (lower: upper) led to four types of presentations corresponding to two types of conditions (congruent and incongruent):

- Two congruent conditions: where the dot replaces the emotional word (lower/upper).
- Two incongruent conditions: where the dot replaces the neutral word (lower/upper).

2.3. Tasks

2.3.1. The emotional Stroop task

Each trial consisted of a black fixation cross display of 500 ms followed by a cue display until the response was given. The inter trial interval was 500 ms with a black screen. The cue display consisted of either an emotional or a neutral word. The word was presented in the middle of the screen. Type of words (i.e., emotional/neutral) and type of ink color (red, blue, green) were randomly counterbalanced across trials, with a new randomized sequence for each participant. The participants were asked to fixate on the black cross. After it disappeared, they had to give the color of the presented word, by pressing the corresponding button (i.e., 'K' = red, 'L' = blue, 'M' = green) as fast as possible, without making any error and ignoring the meaning of words. The experimental trials were preceded by 20 practice trials.

2.4. The modified probe detection task

Each trial consisted of a succession of three steps: a black fixation cross display of 500 ms, a cues display of 500 ms, and a dot display until the response was given. The intertrial interval was 500 ms of a black screen. The cues consisted of either emotional word and matched neutral word or neutral word and matched neutral word. Words were vertically opposite at equal distances from the center of the computer screen (distance between words = 4 cm). The probe display consisted of a black circle that appeared in the same spatial location as one of the two words. Emotional word position (i.e., lower/upper), probe position (i.e., lower/upper), and type of word pair (i.e., emotional–neutral/neutral–neutral) were also counterbalanced with a new randomized sequence for each participant. Participants were asked to fixate on the black cross in the center of the screen and were informed that two words would appear immediately after the black cross and, finally, that a dot would appear after the words. They were asked to give the location of the probe by pressing the corresponding button as fast as possible without making an error (i.e., “enter” key = upper location, “tab” key = lower location). The experimental trials were preceded by 20 practice trials.

2.5. Procedure

The emotional Stroop and dot detection tasks were driven on Macintosh IBook G4 from the Hypercard 2.4 software. Partici-

pants were seated about 60 cm from the computer screen; they were informed that the study was being conducted to evaluate attention and reaction time. Each participant performed both tasks (i.e., emotional Stroop and dot detection tasks), and the order of presentation of tasks was counterbalanced across subjects. Trials in which participants gave the wrong color or wrong dot position or in which RT was below or above 2 SD of the subject's mean RT (the average error rate was equal to 3% for the Stroop task and 2% for the dot task) were considered error trials. After the tasks, participants completed the French version of the short form (13 items) of the Beck Depression Inventory [46] and the French version of the State–Trait Anxiety Inventory [47].

To assess emotional seizure precipitants and potential related individual differences, a face-to-face interview was carried out in which patients were questioned about several clinical features in addition to those concerning etiology (i.e., cerebral lesions) and semiology (i.e., ictal modifications). We particularly focused on seizure duration, seizure frequency (per month during the year), context of the first seizure (first psychological event: emotional or other), types of seizure precipitants, and impact of precipitants inducing seizures. Emotional precipitating factors were identified through open-ended questions: Have you noticed any factors (situations or states) which favor your epileptic seizures? Could you describe them? Can you estimate on a scale from 0 to 10 the importance to which your seizure occurrence is favored or increased by emotional factors? If participants did not report emotional precipitants, a rating of “0” on a scale of 0–10 points was given. Patients with 0 scores constituted the “Other-TLE” group. In the other cases, the impact of emotional factors ranged from 1 to 10, referring to the rating of “Emo-TLE” group (e.g., 9 score for “emotional distress strongly increases my seizure occurrence”). This measure has been named *impact of seizure precipitants*. Patients always labeled “emotional distress” and/or “annoyance” as general triggering factors and more generally negative emotions (i.e., angry, worried, sadness, anxiety). Two patients also reported both positive (i.e., “when I feel happy”) and negative affective precipitants. No participant in this study reported only positive emotional seizure precipitants. We excluded menstrual cycle, lack of sleep, and tiredness as affective components.

2.6. Statistical analysis

Comparison of the different groups (Emo-TLE, Other-TLE, and controls) employed nonparametric tests for continuous data (i.e., Kruskal–Wallis *H*-test, Mann–Whitney *U* test) and χ^2 for categorical data. A *P* value <0.05 was considered significant.

3. Results

3.1. Clinical data

No difference was observed between patients with right and left temporal lobe epilepsy and normal controls with respect to anxiety and depression scores ($P > 0.05$). In our population, 54.8% (ratio: 17/31) of patients with TLE reported having emotional precipitants (Emo-TLE). On the 10-point scale used, scores ranged from 1 to 10 (mean = 5.37, SD = 2.87) in this group.

Concerning seizure semiology in terms of subjective emotional aura (i.e., feelings of fear, anxiety, disgust during seizures), there was no difference between the Emo-TLE (76.5%, ratio: 13/17) and Other-TLE (50%, ratio: 7/14) groups ($\chi^2 = 2.35$, $P > 0.05$). As far as etiology is concerned (i.e., presence of a temporal lobe lesion, hippocampal sclerosis), we did not find differences between the Emo-TLE and Other-TLE groups ($P > 0.05$). In addition, there was no difference between the Emo-TLE and Other-TLE groups with

respect to anxiety and depression scales, seizure frequency, and seizure duration ($P > 0.05$).

A retrospective study of the patients' medical histories showed that in contrast to the Other-TLE group (0%: 0/14), 52.9% (9/17) of patients in the Emo-TLE group tended to have their first epileptic seizure in an emotional context, mainly negative ($P = 0.004$). In addition, we found a trend toward a larger proportion of females in the Emo-TLE group (76.5%, ratio: 13/17) than in the Other-TLE group (42.9%, ratio: 6/14) ($\chi^2 = 3.65$, $P = 0.06$) see Table 1, irrespective of the lateralization of the epilepsy (individual data on semiology, etiology, and the first psychological event are given in Supplementary Table 2). No difference was found between antiepileptic drugs in these two groups ($P > 0.05$), and no patient was taking an antidepressant drug at the time of the study.

In addition, no patient selected in this study manifested nonepileptic seizures during video monitoring sessions.

3.2. Behavioral tasks

3.2.1. Dot task paradigm

Because predictions have been made about differences in attentional bias and their underlying mechanisms across groups, the RTs were converted into three different indices, adapted for the dot detection design:

1. Classic index of congruency effect: RTs "incongruent" – RTs "congruent." A positive index ($I > 0$) merely revealed a detection of threat, on either congruent or incongruent trials.
2. Index of vigilance: RTs "control" – RTs "congruent." A positive index ($I > 0$) indicates an increase in attentional engagement of the emotional word, and its facilitating effect during congruent trials compared with control baseline (i.e., "neutral-neutral" pairs).
3. Index of disengagement: RTs "incongruent" – RTs "control." A positive index reveals a difficulty in disengaging attention from the threatening word.

Across all indices, negative scores ($I < 0$) reveal that participants avoid threat. RTs correspond to the "mean RTs" to detect the dot replacing either the threatening word (congruent condition) or the neutral word (incongruent and neutral conditions).

3.2.1.1. Congruency index. Statistical analysis revealed a main effect of group ($H = 26.83$, $P < 0.0001$). Patients in the Emo-TLE group had a more positive congruency index (mean = 39.12, SD = 32.52) than those in the Other-TLE group (mean = -18.28, SD = 22.14) ($U = 13.00$, $P < 0.0001$) and control group (mean = 3.05, SD = 16.60) ($U = 66.00$, $P = 0.009$). In addition, the congruency index differed from zero ($P = 0.003$): the attention of patients with emotional seizure precipitants was captured by the threatening word compared with the other two groups. Conversely, participants in the Other-TLE group had a more negative index of congruency effect compared with controls ($U = 61.00$, $P = 0.004$) and the Emo-TLE group ($U = 13.00$, $P < 0.0001$). Finally, the congruency index for the Other-TLE group tended to differ from zero ($P = 0.06$). Therefore, participants with other nonemotional precipitants of seizures tend to avoid threatening information in comparison with the other two groups (Fig. 2).

3.2.1.2. Vigilance or difficulty in disengaging attention. There was a significant difference between the Emo-TLE and control groups ($U = 102.5$, $P = 0.02$). The Emo-TLE group's vigilance index tended to be positive and differed from zero (mean = 28.41, SD = 40.66, $P = 0.07$). However, there was no difference for the attentional vigilance between Emo-TLE and Other-TLE groups ($P > 0.05$) and Other-TLE and control participants ($P > 0.05$).

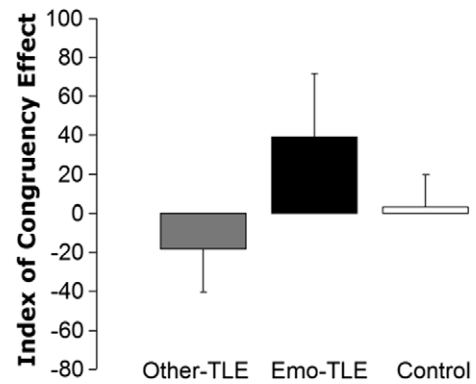


Fig. 2. Index of congruency effect (means and SD) according to the group factor (Other-TLE, Emo-TLE, control).

The main effect for the disengagement component index was observed in the Other-TLE group. Indeed, there was a difference between the Other-TLE group (mean = -25.42, SD = 31.63) and the Emo-TLE group (mean = 8.71, SD = 31.68; $U = 52.00$, $P = 0.008$), the Other-TLE and Control group ($U = 70.00$; $P = 0.009$). For the Other-TLE, the index of disengagement was slightly negative ($P = 0.05$).

3.2.2. Emotional Stroop task

An index of attentional bias was also calculated for this task: Stroop Index (I) = RTs emotional – RTs neutral. "Emotional RTs" corresponded to the mean latency to naming the color of emotional words (in milliseconds) and "neutral mean RTs" corresponded to the mean latency to naming the color of neutral words. A positive Stroop Index ($I > 0$) means that the attention of participants was captured by the meaning of emotional words and they had a longer color identification latency compared with the neutral words. A negative Stroop index ($I < 0$) revealed that participants avoided emotional information and that they took longer to name the color of neutral words.

Statistical analysis revealed a significant difference between the three groups ($H = 10.48$, $P = 0.008$). The Emo-TLE group had a positive Stroop index (mean = 28.66, SD = 34.17), differing significantly from zero ($P = 0.017$). Patients in the Emo-TLE group also manifested stronger positive Stroop interference compared with patients in the Other-TLE group (mean = -6.78, SD = 21.80) ($U = 44$, $P = 0.005$) and the control group (mean = 6.14, SD = 17.19) ($U = 105$, $P = 0.03$). Thus, patients with emotional precipitants of seizures took longer to name the color of threatening words compared with neutral words, and compared with the other two groups. Consequently, patients with epilepsy with affective precipitating seizures showed an attentional bias on the emotional Stroop task (Fig. 3).

3.3. Correlations

Correlation analysis was performed only in the Emo-TLE group. No correlation was observed between seizure frequency and scores of emotional seizure precipitants. Furthermore, the scores of emotional precipitants of seizures was positively and strongly correlated with the Stroop index (Spearman's $\rho = 0.71$, $P = 0.004$) and moderately with the congruency index (Spearman's $\rho = 0.50$, $P = 0.04$) (see Fig. 4), and tended to correlate positively with the vigilance index (Spearman's $\rho = 0.43$, $P = 0.08$). We also noted a strong positive correlation between congruency and vigilance indices (Spearman's $\rho = 0.56$, $P = 0.02$). There was no correlation between the Stroop index and the three dot detection task indices ($P > 0.05$).

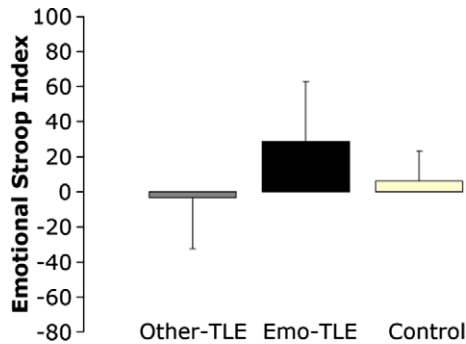


Fig. 3. Stroop index (means and SD) according to the group factor (Other-TLE, Emo-TLE, control).

4. Discussion

Epilepsy is a prevalent disorder, affecting up to 1% of the population [48]. The recurrence of seizures, particularly in patients with drug-resistant epilepsy, negatively impacts quality of life [49]. A large proportion of patients with epilepsy have seizures precipitated by stress-related factors. Through clinical and cognitive approaches, the goal of this research was to study this “emotional vulnerability” in TLE, the most frequent form of drug-resistant epilepsy in adults.

We found that a large proportion of patients with TLE (55% Emo-TLE) reported a link between emotional distress, annoyance, and seizure occurrence. This is consistent with previous findings in which emotional distress was found to be the most frequent seizure precipitant varying from 34% [16], to 53% [17], to 58.7% [50]. Nevertheless, impact of stressful events on the risk of seizures is a subjective perception and the causal relationship is speculative [13,14,18]. Self-perception of seizure precipitants can be influenced by psychological status [18]. In this context, we have therefore mainly studied attentional biases as a potential objective marker of emotional vulnerability in patients with TLE. In addition, the Emo-TLE and Other-TLE groups did not differ in terms of depression or anxiety scores, eliminating the possible influence

of these two factors. The main result of the present study was to demonstrate that the patients in the Emo-TLE group changed attentional bias across two cognitive tasks. We have found that the Emo-TLE group is characterized by attentional bias toward threatening stimuli compared with neutral ones, and compared with the other two groups. Contrary to our expectation, the Emo-TLE group changed a congruency effect that could be supported by vigilance to threat rather than by defective disengagement. However, the observed variability (i.e., SD) did not provide robust findings to definitively conclude about vigilance or disengagement effect. This result may be due to the absence of anxious “status” (i.e., trait of anxiety) in the Emo-TLE group. In addition, one limitation is also that attentional biases could be more pronounced with the use of “biologically prepared” or naturally occurring stimuli (e.g., fearful versus neutral facial expressions) and with shorter presentations [30,32]. Furthermore, the scores of emotional precipitants of seizures were positively correlated with the Stroop index and the congruency index. These findings point to a relationship between the subjective appreciation of emotionally induced seizures and the objective measurement of cognitive/emotional performance. We thus assume that the more threatening the stimulus or situation, the more the patients in the Emo-TLE group present an abnormal attentional bias, which could favor seizure occurrence. Increasing attention for visual emotional information increases neuronal activity [51,52], particularly in the amygdala and visual system. It could therefore be the case that this effect was exacerbated in the patients in the Emo-TLE group and that increasing neuronal activity could in turn precipitate seizures.

Interestingly, our results corroborate a recent prospective diary study [14] in which higher self-reported stress and anxiety levels, evaluated on a 10-point scale, were associated with seizure occurrence (i.e., “high anxiety scores (≥ 5) in the univariate analysis were associated with a doubling of the risk of seizure the next day compared to low anxiety (< 2) scores”).

Furthermore, we also found that gender and affective experience may potentially characterize the Emo-TLE group. Indeed, we observed a trend toward a larger proportion of females in this group (76.5%) and half (53%) of them had their first epileptic seizure after a first psychological event, usually with negative value (e.g., death of family member, divorce). Could the initial psychological event and gender differences play a role in the affective changes observed in these patients? Even if this relationship is still largely speculative, some support has recently been provided by data from studies in humans [53] as well as in animals [54]. A recent large population-based case-control study of all newly diagnosed unprovoked seizures [53] has shown that depression is a risk factor for developing unprovoked seizures and epilepsy. These data suggest that depression may be due to underlying neurochemical changes important in the development of epilepsy. In rats, early postnatal life stress (maternal separation) results in persisting vulnerability to TLE and limbic epileptogenesis [54]. This effect was observed only in females. The amygdala and the hippocampus are probably involved in such phenomena as a result of their influence on neuroendocrine stress responses and memory storage for arousing events [55,56]. Furthermore, gender differences could also influence neuroendocrine stress responses and sensitivity to aversive information [57,58].

In our study, it is thus tempting to speculate that an arousing emotional context reported as having occurred before the first seizure could have resulted in neurobiological effects on the temporal lobe [59], playing a role in emotional regulation and vulnerability (notably female) in combination with the epileptic condition.

In summary, the patients in the Emo-TLE group were characterized by emotional/attentional vulnerability, such as attentional bias toward aversive information, and potentially by the effect of gender and affective life experience. In some cases the initial event

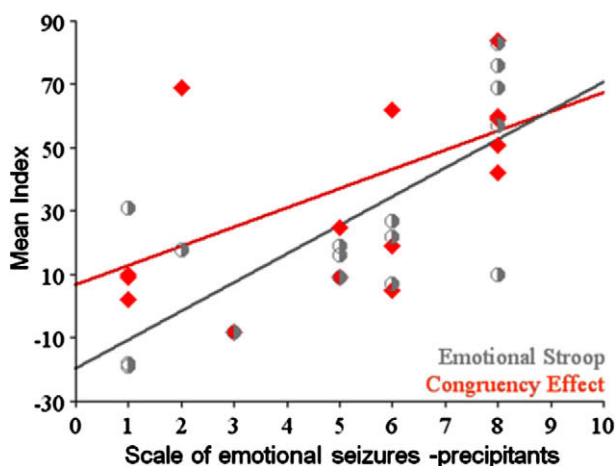


Fig. 4. Correlations between the emotional Stroop index, the congruency index, and the impact of emotional seizure precipitants reported by those in the Emo-TLE group. The figure depicts the distribution of mean index scores for the emotional Stroop (gray circles) and the congruency effect in the dot detection task (red symbols), for each patient in the Emo-TLE group. There is no correlation between the congruency index and the emotional Stroop index, whereas scores of the impact of emotional seizure precipitants correlate positively with the two indices ($P < 0.05$). The index of vigilance is not represented. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this paper.)

could induce physiological markers or modifications and promote consecutive cognitive biases by conferring a better processing of negative information. These alterations might be reinforced by the development of the epileptogenic process in the same areas. Therefore, the overlap of the abnormal chronic activation of medial temporal structures and the previous modifications induced by a psychological event might potentiate responsiveness to emotional stimuli in terms of increased vigilance to threat. However, further investigations are required to better estimate the role of gender and affective life experience in the emotional vulnerability of patients with TLE.

With respect to treatment, our results provide interesting perspectives. Indeed, the identification of specific subpopulations of patients with epilepsy who are particularly sensitive to emotional factors could be the basis for specific therapeutic strategies aimed at decreasing emotional vulnerability. Conflicting results have been reported with cognitive-behavioral therapy [reviewed in 60] in patients with epilepsy. However, these approaches could be potentially more active if applied to the group of patients with attentional bias, as proposed in patients with anxiety disorders [61,62]. In the future, further investigations are required to determine if these approaches may also be effective in this population of patients with epilepsy.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.yebeh.2009.03.034](https://doi.org/10.1016/j.yebeh.2009.03.034).

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