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Emotional categorization: individual emotional differences and laterality effects in healthy and persons with multiple sclerosis

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ABSTRACT

A study examining affective information processing in persons with Multiple Sclerosis and healthy adults was carried out. It was hypothesized that individual characteristics could modulate participants' emotional categorization and reaction times for categorization decisions. For example, individuals with negative valenced emotional profile (e.g. anxious) should choose negative emotional alternatives faster and more frequently. Participants consisted of two different populations: 80 right-handed healthy French-speakers, and 40 right-handed French-speakers with multiple sclerosis. The results showed a positive correlation between high-level of negative emotional sensibility and emotional categorization (decision and decision speed) for affective information presented on the right-side of the screen. For all participants there were more frequent emotional choices and faster decisions for left-side presented emotional alternatives. It seems individuals' emotional differences in general and in MS populations modulate hemispheric asymmetry of processing emotional judgments.

Keywords: Emotion; Categorization; Hemispheric Asymmetry; Individual Emotional Differences; Multiple Sclerosis

1. EMOTIONAL CATEGORIZATION: INDIVIDUAL DIFFERENCES AND LATERALITY EFFECTS

There are numerous ways in which emotions and affective processes shape and organize cognitive activities. Some studies demonstrated creative, explorative behavior under positive mood and careful, error-avoidance behavior for negative mood (e.g. [1-5]; see also [6]). It has been also reported that emotional states can enhance high-level cognitive control [7], focus attentional resources, influencing encoding and organization of new information [8], and facilitating access to information previously acquired [9,10]. The influence of mental representation of affective reactions on the accessibility of concept and knowledge has been also suggested [11,6].

Individual differences seem also be related to emotional reactivity and processing information, specifically emotional-relevant information (e.g. [12-14]). Our knowledge of the ways in which individual differences and personality traits are associated with different affective and cognitive processes has grown considerably in recent years (e.g. [12-14] see also [6]). For example, it has been shown that typical happy people perceive, categorize, and retrieve pleasant information more readily, more easily than typical unhappy people, and may even interpret ambiguous stimuli more favorably [15,16]. In the same manner, an anxiety-related responses bias [17] and also an attention bias resulting in interpretation of ambiguous stimuli as threatening ones have been noticed in typical anxious individuals [18]. Therefore, researchers have proposed hypotheses about the affective- congruency [19] and trait-congruency [20].

Nevertheless, less work has been devoted to uncovering the basic factors of these influences, considering neuropsychological evidence in analyzing individual differences and affective-cognitive processes. In the last few years, however, this situation has begun to change. Considerable evidence demonstrated that individual differences, for example, in temperament are associated with differences in brain and peripheral physiological functioning (see [13,7]). Findings from some studies suggest that alexithymia (less ability to identify and communicate feelings) could be investigated as a continuous personality trait associated with either the interhemispheric transfer of information [21] or the relative development and activation of the two hemispheres in non-clinical and clinical populations ([22]; but see [23]) or as a syndrome related to some psychiatric disturbance such as Multiple Sclerosis. Therefore, individual differences in processing emotional stimuli provide a potentially rich source of information about the relationship between emotion and cognition, in normal people but also in individuals suffering from neurobiological impairment. To the extent that we understand the functions of these systems, we will be in a better position to develop more selective therapies that are targeted for the specific brain networks involved in regulation of the specific aspects of emotional psycho-pathological functions.

The present study focuses on cognitive performance in terms of emotional categorization in the general population, and also considers a clinical sample of patients suffering from multiple sclerosis. We examine the extent to which information processing depends on stable emotional-related individual differences and also lateralized nature of these processes. After reviewing some evidence concerning categorization processes of affective-relevant information, we focus on hemispheric asymmetries involved in processing of emotional categorization, and the potential role of emotion-related individual differences. Finally, we report the results of our study designed to examine these relationships.

Categorization, identification and grouping of entities into sets, is a basic cognitive process. Category learning and using depend on selective attention to category- relevant stimulus features (shape, size, etc.) inherent to objects that are perceptually similar [24,25] or share a theory of cause and effect [26-28] that serve a common goal (e.g. [29]). The idea that individual's subjective experiences and motivations could be used for grouping objects together has been also considered [30].

Distinguishing between cognitions about one’s affective reactions (its mental representations) and the affective reactions per se, it has been proposed that affect increases the accessibility in memory of semantic concepts and knowledge representations of the same valence ([8,19]; see [6]) and also increases the likelihood of thinking about information related to these concepts. This increased attention might be reflected in (a) longer time spent reading and thinking about the emotional information than neutral ones, (b) better memory for the information, and (c) therefore greater influence of the information on judgments to which it is relevant [31]. However, in spite of association between positive affect with holistic and negative affect with piecemeal processing strategies, and greater automatic allocation of attention towards negative information, it seems people are motivated to maintain their happy mood and to divest themselves of the negative events that give rise to negative feelings [32]. Consequently, compared to negative information, time spent reading and thinking about positive information could be longer.

Based on these assumptions, it has been proposed that the objects and events that elicit the same emotion in a given perceiver lead to a mental grouping of those objects and events, as instances of the same category. Research by Niedenthal and her colleagues [10,16,30,33, 34] bear on this matter. Accordingly, emotions could lead individuals to reorganize temporarily their conceptual space in function of the common evoked emotion. Thus, a category of objects and events that have elicited same emotional state (e.g. sadness) may be treated as equivalent and categorized as the same sort of the things, regardless of their perceptual, functional or theory differences. Thereby, perceivers’ understanding of the meaning of a particular category exemplar would be facilitated in terms of their own personal learning histories. This reorganization then determines how people perceive similarities and differences among objects and events. In the same way, the authors suggested that those differences in processing emotional-relevant information could be more noticeable in individuals with specific emotional trait (e.g. anxious, depressives at clinical or non-clinical level; [16]).

Nevertheless, although there is a good deal of evidence regarding affective-congruency of processing positive information, these congruency effects are not observed for negative information [35,36]. In a study Niedenthal, Halberstadt and Innes-Ker [30] used a categorization task (45 triads (a principal concept and two other concepts) of happy (9), sad (9), and neutral words (27)) in which participants were induced or not (control condition) to feel either happy or sad by having them watching a film for 12-15 minutes prior to a categorization task, so called triad task. Then while listening a music of the same valence, they performed a triad task in which a number of positively (related to happiness e.g. puppy, celebration, etc.), negatively (related to sadness e.g. cancer, divorce, etc.) valenced triads of words or neutral ones were presented. The results showed that the participants in emotional states (happy or sad) compared to those in a control condition, used more frequently the happy concepts as basis for their categorization decisions. But whatever the valence of their emotional state (happy, sad or neutral), they all responded in the same way to the sad concepts presented in the absence of happy ones (no differences related to emotional states).

According to the authors, the sad concepts, when presented in the absence of the happy ones, (a) either suggested sadness as a basis for categorization, (b) or altered the emotional state of control participants. An eventual (c) semantic priming effect has been suggested too. In this sense, according to the authors the experimental affective manipulation could prime generic knowledge about emotions [8]. Therefore, it would be the concepts or mental representations of emotion and not experience of emotion which influence emotional categorization of the negative information.

If generic knowledge about emotion is contextually (emotion induction procedure) or chronically (typical emotional reactivity) primed, it might be such a priming and not the induced emotional state itself or emotional experience which enhances the tendency for individuals to group together concepts on the basis of their emotional equivalence, specifically in the case of negative valenced information. So, it is possible to propose that negative information captures automatically the attention of perceivers [37], and is processed in a specific manner. Consistent with this idea are information-processing models of fear [involving activation of the amygdale, [38] according to which the emotional significance of incoming information is pre-consciously assessed by a threat evaluation system [39,40]. Information judged to be threatening is then treated in priority [41], and perhaps without any retrieval of emotional experience.

Indeed, one of the most promising areas in research on emotions is work on the underlying neural substrates involved in processing emotional information. More interesting, recent evidence revealed preferential use of the left or right visual hemifield affecting everyday behavior (e.g. activities such as searching for food, agonistic responses, or escape from predators) in natural environment of a variety of species (from fish to mammals; (see [42]). In human, in addition to well-established hypothesis regarding speech production as a left hemisphere task, lateralization of emotion processing is an ongoing debate. However, processing different aspects of emotional information seems to involve differential activation of the left or right hemispheres [43]. Based on comparison between right brain damaged patients and intact subjects, a number of investigators have found right hemisphere specialization for the identification of emotional words and sentences [44], especially negative ones [45]. Consistent evidence is the faster reaction times when participants were exposed to negative words presented in the left visual field. For positive words, reaction times were faster when presented in the right visual field ([46]; see also [47]).

Other studies provide some evidence for cerebral hemisphere asymmetries in categorization processes [48]. It has been shown that the typicality of instances had a large effect on categorization times in the left visual field, suggesting that the right hemisphere relies strongly on a prototypical-based comparison strategy [49]. The left hemisphere seems to be able to categorize on the basis of exemplar-based category knowledge [50,51].

Interaction between affect and cognition as two modes of psychological functioning appears, therefore, to be linked to hemispheric asymmetries of the processing of emotional-relevant information, which is according to Davidson [13] more functional than structural [13]. Nevertheless, the organization and localization of affective treatment remains to be firmly established. Within this general area, the study of cerebral lateralization and individuals' affective-based differences is of particular importance.

Some of the inconsistencies and controversies that mark the literature regarding asymmetrical processing of emotional information could be explained in terms of individual differences. Individuals' affective-based differences may influence asymmetric processing of information in different ways. For example, association of different temperamental styles with asymmetric activity of frontal cortex has been suggested (see [43]). Compared with individuals displaying higher left prefrontal activation, those with higher activation in right prefrontal regions report more dispositional negative affect. Some studies demonstrated that depression and impulsivity were associated with a decreased activation in the left-prefrontal region [52,53], whereas anxiety was associated with an increase in the right prefrontal region [54]. Experimental studies have shown that alexithymia was common among patients with a right-hemisphere lesion [55,56].

Although, alexithymia was initially identified as a syndrome for clinical patients, recent works revealed that its features might be observed in nonclinical populations, too. And in spite of increasing number of personality traits identified as being involved in processing emotional information [55,57-61], alexithymia offers the most interesting condition to analyze relation between emotional aspects of personality and asymmetrical processing of emotional information in terms of psychological functions in clinical as well as nonclinical populations.

Recent works focused on alexithymia have proposed different hypotheses to explain it in structural and functional terms (see [23]). In structural terms, one neural hypothesis suggests that alexithymia is related to poor interhemispheric transfer, in normal as well as clinical populations [21,23,62]. Another hypothesis associates it with a poor right hemisphere activity [22]. Actually, studies in psychiatric field have revealed, in patients and some normal subjects, an interhemispheric cerebral transfer deficit [63-65]. However, neuropsychological studies have shown that patients with brain damage in the right hemisphere perform worse than patients with brain damage in the left hemisphere when processing and organizing emotional experience [66,67]. In functional terms, alexithymia represents a unique personality trait that might predispose individuals to somatic and mental disorders [68]. The psychological studies have highlighted that alexithymia is correlated with both anxiety and depression [68,69]. It has also been found that alexthymic individuals use more emotional words, specifically the negative ones. These underline the possibility that alexithymia might be a coping or defense mechanism utilized for life-threathening situations [68], and thus involved in processing of negative information.

However, alexithymic features are also associated with psychopathology and certain neurological syndromes, such as multiple sclerosis (MS; demyelinating disease of the central nervous system disrupting neural transmission). The case of MS is of particular interest to researchers because of its close neurological and psychopathological correspondence to those resulted from alexithymia in general. Alexithymia is more frequently reported in MS patients (50%) compared to general population (8%) [70]. Cognitive and emotional disturbances in the early stages of MS have been frequently described in terms of high frequency of affective incontinence and lability. Although, these abnormalities are not directly related to depressive states [71], depression and anxiety are frequently reported in the case of MS (The Goldman Consensus Group, [72,73]). Explosive laughing or crying, and euphoria are also observed in individuals with MS [74]. Such variation provides a potentially rich and relatively untapped source of information enabling comparison of clinical and non-clinical populations based on relationships between emotional aspects of personality and asymmetrical processing of emotional information.

2. PRESENT STUDY

The primary aim of the present study was to examine lateralized cerebral processing in a triad task as a function of individuals' affective-based characteristics. Our second objective was to evaluate the extent to which the pathological deficits in processing emotional information might interfere in lateralized cerebral processing of emotional-relevant information. Because of their particular emotional and neurobiological characteristics, the patients suffering from multiple sclerosis were chosen for our comparative study of emotional information processing.

Many studies reported for these patients an emotional profile marked by affective lability, with high prevalence of depression (60%) [75,76] and anxiety (37%) [77]. As mentioned before, compared to general population, alexithymia is 6 times more frequent in MS patients. Some studies demonstrated dysfunction of interhemispheric transfer (callosal dysfunction) in MS patients, too [70]. In general, this kind of functional impairment is correlated to the degree of corpus callosal atrophy and the severity of diffusion of white matter changes identified by magnetic resonance imaging (MRI). Few studies suggest the potential clinical value of callosal involvement and alexithymia and its interest as a model to study interhemispheric disconnection (e.g. [23,70]), specifically in MS patients.

Usually, impaired information processing in individuals diagnosed with multiple sclerosis is mild or moderate, and mainly affects working memory and processing time, through which inhibition and interpretation capacities [78]. The causal mechanisms of these affective-cognitive impaired relationships are not well known. Neuroanatomic account suggests that both gray and white cerebral matter atrophies contribute to neuropsychological deficits in MS [79]. The role of atrophied corpus callosum leading to intra- and inter-hemispheric disconnection has been also suggested. Considering the studies published to date, which have reported specific affective and cognitive psychological impaired processes associated with this disease, and the importance of these processes in emotional categorization involving working memory, we decided to assess and compare the performance of individuals with multiple sclerosis with a non-clinical population. We believe that comparative studies of such cases might provide new perspectives on the relation between cognitive neuropsychology and social-personality psychology.

In the case of the present study we address the question: How individuals' emotional characteristics could influence their emotional response categorization (grouping together stimuli, e.g. words, related to the emotion of the same valence), and if these influences could be associated with hemispheric asymmetries. More precisely we predicted an association between higher frequencies of emotional choices and shorter time decisions for left sided presentation of negative emotional words for individuals with higher scores on anxiety, depression, and alexithymia scales. Our second hypothesis was focused on comparison of the data from non-clinical individuals to those of MS patients. Because of their psychological and neuropsychological profiles, and also their impairment in processing emotional-relevant information, we predicted higher frequencies of choices and shorter time decisions for right sided presentation of neutral words considered as emotional in MS patients compared with non-clinical individuals. However, regarding emotional words, lower frequencies of emotional choices and faster time decisions were predicted for MS patients, compared with non-clinical individuals specifically in the case of left sided presentation of negative words.

2.1. Method

2.1.1. Participants

2.1.1.1. Non-Clinical Population

Eighty right-handed (male n = 34 and female n = 46) native French-speakers aged between 20 to 59 years (*M* = 33.43 years, *SD* = 9.67 years) were recruited by announcements published in local newspapers to participate in a paid study.

Upon arrival at the laboratory, a brief description of the experimental procedure was given. The subject was then asked to complete a consent form and questionnaire concerning medications and drug use. The subjects were excluded if they were left-handed, had used drugs, or psychoactive medication within the past six months.

2.1.1.2. Clinical Population

Forty right-handed native French-speakers (male n = 15 and female n = 25) aged between 21 to 55 years (*M* = 37.84 years, *SD* = 8.38 years) with clinically relapsing-remitting multiple sclerosis less than 5 years duration (M = 3 years, SD = 1.54) were selected. They participated after providing their informed consent approved by the ethical committee. Multiple Sclerosis was diagnosed by a physician, applying the New McDonald Criteria. New diagnostic criteria from the International Panel of McDonald and colleagues incorporate MRI evidence of dissemination in time and space to allow a diagnosis of MS in patients with clinically definite and remitting syndromes with or without inflammatory dysfunction in the central nervous system (CNS). For five patients the functional scores on the Kurtzke expanded disability status scale ([80]; EDSS) were between 4.5-6.0, without any aggravation (mean follow-up 3 months). Patients with moderate and severe cognitive impairment were excluded after assessment with the BNI [81]. The selected MS participants were then compared with 40 participants (male n = 14 and female n = 26) selected among our non-clinical sample based on their autobiographical profile (gender, age, education, and socio-economical background).

2.1.2. Stimuli

The stimuli were triads (see Annex) of concepts composed of a target and two comparison concepts. In each triad, one of the two comparison concepts was related to the target concept through an emotional (positive or negative) association, whereas the other one was related to the target concept through a non-emotional, taxonomic association. Three categories of triads (negative, positive, and neutral), with nine triads per category were used. Some triads were extracted from material used by Niedenthal, Halberstadt, and Innes-Ker [30]. Other triads were created for this study following the procedure described by Niedenthal and her colleagues [30].

2.1.3. Material Check

An initial pilot test (n = 30 participants who did not participate in the main study) on a large set of potential triads (88 concepts) was conducted to ensure that participants chose a variety of responses for each triad (at least 20% and no more than 80% of pilot participants selecting each possible response).

2.1.4. Measure of Individual Characteristics: Questionnaires and Scales

In the present study, we used a battery of self-report questionnaires that measure emotion-related personality characteristics. As moderator variables, anxiety, depression, and Alexithymia have been known to be emotion-related personality traits relevant to cognitive performance, but also as characteristics of individuals with multiple sclerosis. Therefore, all participants were administered the Trait-Anxiety Inventory [82], Beck Depression Inventory [83], and Toronto Alexithymia Scale [84]. All three are self-report instruments intended to assess the existence, intensity or severity of the felt anxiety, symptoms of depression, and difficulties in identifying, describing, and communicating emotional feelings in clinical and non-clinical populations. High scores on theses scales are indicatives of anxietous, depressive and Alexithymic tendencies.

The standardized version of the Trait-Anxiety Scale contains 15 items. For each item, the respondent was asked to indicate on a 4-point scale from “never” to “always” how frequently s/he would feel in that way. The standardized version of the Beck Depression Inventory is a 21-item self-report instrument intended to assess the existence and severity of symptoms of depression. Each of the 21 items corresponding to a symptom of depression is summed to give a single score. There is a four-point scale for each item ranging from 0 to 3. On two items (16 and 18) there are seven options to indicate either an increase or decrease of appetite and sleep. The revised-version of the Toronto Alexithymia Scale consists of 20 items, and a high score on this scale corresponds to difficulty to distinguish between (identification), to describe (description), and to express (exteriorization) one's emotions. It was constructed after a literature review revealing 5 main content areas thought to reflect the construct. However, factorial analysis of the finalized 20-item version of the TAS suggested a three- factor solution. First factor consisted of items that refer to the ability to identify and describe feelings and to distinguish between bodily sensations, secondary factor reflected the ability to communicate feelings to others, and third factor represented the tendency to focus on external events over inner experiences. For each item, the respondent was asked to indicate on a 5-point scale ranging from "strongly disagree" to "strongly agree" the extent to which s/he was agreed with statement. The TAS has shown adequate internal consistency, good test- retest reliability, and good convergent and discriminant validity [85]. The TAS and TAS-20 are now the most widely used measures of alexithymia [86].

2.1.5. Apparatus and Response Measurement for the Experimental Task

The instructions, presentation of the triads, collection of subject's responses and response times were controlled by a Pentium IBM compatible computer with an IIyama 15 inch vision master 404, 50/60 hz monitor. The time between presentation of each triad and the lexical decision by subjects was recorded as decision time.

2.1.6. Experimental Task

Each trial consisted of simultaneous presentation of three concepts in an equilateral triangular shape. The centered target word was presented 8 cm from the top of the screen, with two alternative response words displayed 8 cm below the target. Two comparison concepts were presented 14.5 cm apart from each other. The concepts were presented in 24 pixel MS serif small letter. A fixed, random order of triads (positive, negative, neutral) was used. The left or right sided presentation of emotional terms was counterbalanced across trials for each category of triads.

After three practice trials, all the participants received 27 test trials. Each triad was displayed by the computer until the subject made a decision. The participants used a 9 cm × 20 cm × 4.20 cm response box with two keys placed 5.5 cm apart on the board corresponding respectively to the position of the index of right and left hands on an outstretched bras. They were seated 70 cm away from the screen, and 30 cm away from the response box. They were encouraged to keep the palm of the hand on the table, making discrete index finger movements only. The participants were asked to fixate on a central point presented at the center of the screen when each triad was removed. For each trial, the computer began to display a fixation point at the center of the screen, and after 500 ms a triad was displayed. The participants were instructed to press with their left index finger on the left key if they thought the target concept was most similar to the concept displayed on the left and with their right index finger on the right key in the other case. The next trial was initiated only after the subject responded. Responses and response times were recorded and encoded in terms of the valence (positive, negative, neutral) and presentation-side (left/right) of the emotional information. Then, mean frequencies (number of valenced emotional decisions for each presentation-side divided by total number of negative or positive triads per presentation-side) and mean time of decisions (sum of valenced emotional decision times for each presentation-side divided by number of valenced emotional decisions for each presentation-side) were computed and analyzed.

2.1.7. Procedure

Participants were told that the purpose of the experiment was to assess their decisions about different concepts. After entering a sound-attenuated room, the participants were invited, by experimenters, to sit on a chair facing a computer monitor on which a uniformly gray image was presented and to complete a questionnaire. If the subjects indicated no recent psychoactive medications they would complete a consent form and read the instructions displayed on the computer. The instructions indicated that the experiment concerned participant's perception of lexical similarity. Participants were instructed to view each triad on the screen and to use the response box by pressing the appropriate key to transmit their choice. Participants were also instructed that an initial block of three trials was designed to aid habituation to the experimental task and experimental process. After presentation of all the triads, participants completed a number of self-report scales intended to measure emotion-related individual differences (Trait-Anxiety Scale, Beck Depression Inventory, Toronto Alexithymia Scale, and autobiographic questionnaire). Finally, participants were debriefed, thanked, and paid.

3. STATISTICAL ANALYSIS

For both samples, descriptive statistics were calculated for each of the variables and Pearson's correlation coefficients were used to investigate the relationship between the individuals' differences and cognitive performances. To test the hypothesis that processing affective information could be related to hemispheric asymmetries, we conducted analyses of variance in which we examined the relationships between valence and presentation-side of the emotional information with frequency and time of categorical decisions for both non-clinical and clinical populations. Regression and variance analyses were used in order to examine the effects of age and gender on the emotional scores and cognitive performances. All data were analyzed with Statistica and SPSS for Windows.

4. RESULTS

4.1. Individual Emotional Differences

Correlations computed between different measures of individuals' emotional characteristics showed that each characteristic preserved it's specificity, at least partly, reflecting the interest of taking into account these measures for evaluation of their impact and/or relationships with cognitive performances. The results showed that the level of alexithymia was significantly and positively correlated with the level of anxiety and depression (*r anxiety* = 0.34; *r BDI* = 0.28, $p < 0.05$). These two last emotional characteristics were also significantly and positively correlated ($r = 0.71$, $p < 0.05$). Although, intercorrelations between global level of alexithymia and its components were strong (*r identification* = 0.77; *r description* = 0.78; *r externalization* = 0.58, $p < 0.05$), only its identification component was correlated significantly with the scores on anxiety and depression (*r anxiety* = 0.48; *r BDI* = 0.40, $p < 0.05$).

4.1.1. Emotional Characteristics and Cognitive Performance

Correlations were computed between individuals' emotional characteristics and categorization decision scores (frequency and reaction times). The correlations suggest relations between emotional individual differences and triad task performance. These relations vary, however, depending on the side of presentation of emotional terms of each triad suggesting a role of hemispheric organization of processing of emotional-relevant information. In our sample, the more anxious and depressive participants chose preferentially negative emotional information presented in their left visual space (*r anxiety* = 0.29, $p < 0.05$; *r BDI* = 0.24, $p < 0.05$) indicating the right hemisphere implication.

For the neutral triads, participants with the higher scores of alexithymia chose more frequently the left side concept. Correlations between measures of alexithymia and frequency of the left-sided (*r* TAS20 = 0.26, $p < 0.05$), and right-sided choices (*r* TAS20 = –0.26, $p < 0.05$) for neutral triads could be accounted for a more left-sided search than right-sided when individuals with difficulties to identify and name emotional information try to make an emotional categorical decision, corresponding to so called leftward bias in literature [87]. There were no significant correlation between individuals' emotional characteristics and categorization decision times.

Simultaneous multiple regression (see [88], for details about the regression procedure) of the emotional categorization (frequencies and decision times) on the predictors (age, gender: male = 0, female = 1, anxiety, depression, and components of alexithymia) revealed only significant contributions of the global alexithymia scores and its identification component for frequencies related to neutral triads ($R^2 = 0.12$, $F(5,74) = 1.92$, $p < 0.10$; $\beta = -0.30$, $t = -2.51$, $p < 0.02$) and for decision times relative to left-sided neutral triads ($R^2 = 0.15$, $F(7,72) = 1.79$, $p < 0.10$; $\beta = -0.42$, $t = -3.18$, $p < 0.003$).

In sum, frequencies of the categorical decisions for neutral triads were lesser and also decision times for left-sided neutral triads were longer when participants with difficulties to processing emotional information, specifically identifying them, tried to make a categorical decision. The lengthened decision times for left-sided neutral triads corresponds to the right hemisphere hypothesized-error detection function predicted by Smith and colleagues [89].

Although non-significant, the contribution of the age and gender variables on variance of the categorical decisions found to be dependent on the valence of the triads. In general, men's decision times for emotional triads were longer whatever their hand-side, but they were chosen more frequently by women when they were presented on the right side. However, negative left-sided triads were chosen by younger men, and positive ones by younger women. Regarding neutral triads, the decision times for left-sided triads were longest for older women, and shortest for men's right-sided decision. Frequencies of left-sided neutral triads chosen as emotional were highest in younger women, but frequencies of right-sided choices were highest in older men.

4.2. Non-Clinical Population

4.2.1. Emotional Characteristics

Separate analyses of individual differences for anxiety, depression, and alexithymic scores for the non-clinical sample were computed. The results showed no significant effects except for externalization involving sex of the subjects, $F(1,78) = 4.42$, $p < 0.04$; $f = 0.48$. Consistent with other published data (e.g. [90]), compared with women, men demonstrated more difficulties for expressing their emotions ($M = 2.12$, $SD = 0.52$ VS $M = 1.89$, $SD = 0.44$).

4.2.2. Emotional Categorization

4.2.2.1. Frequency of Emotional Choice[1]

A 2 × 3 × 2 (Sex of the subjects × Valence of the tri-

[1]Note: A separate analysis of variance of categorization decision and decision times was conducted for neutral triads (**Table 1**). The results showed no significant effect due to participant's sex.

ads × Hand-side) ANOVA was used in which two latter factors were treated as repeated measures.

Analysis of variance for frequency of emotional choices revealed significant main effects of sex of the subjects, $F(1,78) = 4.64$, $p < 0.04$; $f = 0.48$, valence of the triads, $F(2,156) = 17.11$, $p < 0.001$; $f = 0.66$, and hand-side, $F(1,78) = 9.44$, $p < 0.003$; $f = 0.70$. The significant main effect of valence was due to the more frequent choice of the subjects for positive rather than negative emotional responses (*M positive* = 0.598 VS *M negative* = 0.495 VS *M neutral* = 0.500). The main effect of the sex of the subjects corresponds to a more frequent emotional choice for women compared to men (*M women* = 0.550 VS *M men* = 0.510). Effect of the hand-side showed more left categorical choice than right (*M left* = 0.561 VS *M right* = 0.500).

A two-way interaction associating valence of the triads with hand-side, $F(2,156) = 3.13$, $p < 0.05$; $f = 0.28$, was found, too. Inspection of the data showed most frequent left-side emotional choice for positive triads and less for negative ones (*M positive* = 0.657 VS *M negative* = 0.505 VS *M neutral* = 0.522). For right-side emotional choice, most frequent choice was also found for positive triads, but less for neutral ones (*M positive* = 0.538 VS *M negative* = 0.484 VS *M neutral* = 0.478). Thus, emotional choices were more frequent for positive triads, particularly in the case of the left-sided presentations.

Separate analyses of the data for emotional triads showed same significant effects and revealed modulation of categorization of emotional information by valence and side of presentation of the stimuli, particularly for positive triads, $F(1,78) = 5{,}56$, $p < 0.02$; $f = 0.53$. The most frequent choice was observed for positive triad when emotional concept was presented at the left side, and the least for negative triad with emotional concept presented on the right side (see **Table 1**).

Analyses of the data taking into account subjects' differences for anxiety, depression, and alexithymic (identification and description) scores as covariable revealed the same significant effects, except for externalization. Indeed, after integration of externalization score as covariable the main significant effect of gender disappeared, without any consequence for the other effects.

Table 1. Categorization Decision Frequency and Categorization Decision Times as a function of Sex of the subjects, Triad valence, and Hand-side.

Group/ Triade-Valence	Hand-side Left	Hand-side Right
Male(n = 34)		
Neutral		
M	0.546	0.454
SD	0.156	0.156
M	2604a	2254
SD	0.205	0.588
Positive		
M	0.603a	0.500
SD	0.223	0.192
M	5835	6549
SD	0.151	0.211
Negative		
M	0.500	0.459
SD	0.222	0.194
M	4700	5333
SD	0.141	0.199
Female(n=46)		
Neutral		
M	0.498	0.502
SD	0.123	0.123
M	2221a	2327
SD	0.834	0.509
Positive		
M	0.712a	0.574
SD	0.241	0.222
M	5988	7267
SD	0.173	0.178
Negative		
M	0.511	0.509
SD	0.217	0.172
M	4619	6080
SD	0.177	0.151

Note**:** Categorization decision times are displayed in milliseconds.

4.2.2.2. Categorization Decision Time

Analyses of variance with a 2 × 3 × 2 (Sex of the subjects x Valence of the triads x Hand-side) factorial design were performed for categorization decision times in which two latter factors were treated as repeated measures. Except for main effect of sex of the subjects, analyses after logarithmic transformation of categorization decision times showed similar main effects and interactions to those found for frequency of the categorization decisions.

Significant main effects of valence of the triads, $F(2, 156) = 13.34$, $p < 0.001$; $f = 0.59$, and hand-side, $F(1,78) = 5.85$, $p < 0.02$; $f = 0.55$, were found. Careful inspection of the data for these main effects showed faster decision times for negative compared with positive triads (*M* Positive = 6440 ms VS *M Negative* = 5196 ms VS *M* Neutral = 2366 ms), and for left hand categorization decisions (*M* left = 4339 ms VS *M* right = 4996 ms).

A two way significant interaction effect was found involving valence of the triads and hand-side; $F(2,156) = 3.58$, $p < 0.03$; $f = 0.30$. The data are relevant to the hypothesis of differential processing of left- and right presentations of the emotional information. Asymmetrical processing of information seems to be related to t h e

Table 2. Categorization Decision Frequency and Categorization Decision Times as a function of Hand-side and Triad valence.

Triad valence	Hand side	
	Left	Right
Neutral	0.522a	0.478c
	2413a	2291a
Positive	0.657ab	0.538cb
	5912ab	6909abc
Negative	0.505b	0.484b
	4660ac	5707ac

Note**:** categorization decision times are displayed in milliseconds. Means that share superscripts differ at p < 0.05 in post-hoc LSD tests.

valence of emotional information. In general, as we expected, for right-handed individuals the data (see **Table 2**) showed fastest decision times in the case of neutral triads (*M left-neutral* = 2413 ms, *M right-neutral* = 2291 ms). In contrast, emotional decision times were slower for positive triads; the fastest emotional choices occurred for left-side decisions based on negative valenced information (*M left-positive* = 5912 ms VS *M right-positive* = 6909 ms; *M left-negative* = 4660 ms VS *M right- negative* = 5707 ms). The configuration of results for emotional decisions supports our hypothesis. In spite of a general deceleration of the decision times for positive triads and acceleration for negative triads which are relevant to a motivational hypothesis [32], these tendencies were more noticeable whenever positive information was more accessible to the right hemisphere and negative information to the left hemisphere.

Analyses of the data in function of subjects' differences for anxiety, depression, and alexithymic (identification, description, and externalization) scores as covariable revealed the same significant effects.

4.3. Clinical Population

4.3.1. Emotional Characteristics

Analyses of individual differences for anxiety, depression, and alexithymic scores for clinical sample showed the same significant gender effect for emotion externalization, $F(1,38) = 8.86$, $p < 0.005$; $f = 0.97$, with more difficulties of externalization for men ($M = 49.33$, $SD = 10.72$ VS $M = 66.24$, $SD = 20.29$).

4.3.2. Emotional Categorization

4.3.2.1. Frequency of Emotional Choice

Separate analysis of variance for neutral triads (**Table 3**) for participants with multiple sclerosis showed a significant interaction for categorization decision involving sex of the subjects and hand-side, $F(1,38) = 4.91$, $p <$

0.04; $f = 0.72$. Inspection of the data showed most fre

Table 3. Categorization Decision Frequency and Categorization Decision Times as a function of Group and Sex of the subjects, Triad valence, and Hand-side.

Group/Triad valence	**Hand-side**	
	Left	Right
Healthy Participants (40)		
Neutral		
Male (n=14)		
M	0.508	0.492
SD	0.188	0.188
M	2178	2219a
SD	0.232	0.184
	Positive	
M	0.571	0.571
SD	0.206	0.205
M	4890	8084
SD	0.186	0.288
	Negative	
M	0.446	0.557ab
SD	0.223	0.160
M	3926	6340
SD	0.144	0.261
Female (n=26)		
Neutral		
M	0.496	0.504
SD	0.114	0.114
M	347	2319a
SD	0.164	0.154
	Positive	
M	0.673	0.577
SD	0.262	0.206
M	5915ab	7613
SD	0.202	0.194
	Negative	
M	0.481a	0.538
SD	0.199	0.176
M	4330	6715a
SD	0.195	0.173
Participants with Multiple Sclerosis	(n=40)	
Male (n=15)		
Neutral		
M	0.422	0.578
SD	0.086	0.086
M	3034	2188a
SD	0.162	0.169
	Positive	
M	0.667	0.537
SD	0.204	0.242
M	7440a	9439
SD	0.476	0.923
Negative		
M	0.317a	0.373a

SD	0.291	0.237
M	4201	6280
SD	1.701	1.233
Female (n=25)		
Neutral		
M	0.511	0.489
SD	0.140	0.140
M	2265	2460a
SD	0.175	0.199
Positive		
M	0.640	0.640
SD	0.315	0.252
M	5635ab	9268
SD	0.931	0.191
Negative		
M	0.410	0.344ab
SD	0.269	0.147
M	4192	4820a
SD	1.376	0.720

Note**:** categorization decision times are displayed in millseconds. Means in the same row that do not share superscripts differ at p<.05 in post-hoc LSD tests.

quent right-side and less left-side choices for men (*M left-side* = 0.422 VS *M right-side* = 0.578; $p < 0.02$). Reverse tendencies were found for women (*M left-side* = 0.511 VS *M right-side* = 0.489). It seemed false alarm were significantly more frequent for men in the case of the right-sided information, whereas women did the same for left-sided ones.

Analysis of variance (Sex of the subjects 2 × Valence of the triads 3 × Hand-side 2) for frequency of emotional choices revealed significant main effects of valence of the triads, $F(2,76) = 22.72$, $p < 0.0001$; $f = 1.10$, which was due to the more frequent choices for positive or neutral rather than negative emotional responses (*M positive* = 0.621 VS *M negative* = 0.361 VS *M neutral* = 0.500).

A three-way interaction associating sex of the subjects with valence of the triads and hand-side, $F(2,76) = 3.18$, $p < 0.05$; $f = 0.41$, was found, too. Inspection of the data revealed for men most frequent left-side emotional choices for positive triads and less frequent emotional choices for negative ones (Positive: *M left-side* = 0.667 VS *M right-side* = 0.537; Negative: *M left-side* = 0.317 VS *M right-side* = 0.373. Neutral: *M left-side* = 0.422. VS *M right-side* = 0.578). For women, we did not find any differences related to hand-side for positive triads. However, women made relatively more categorical decisions for left-sided negative and neutral information (Positive: *M left-side* = 0.640 VS *M right-side* = 0.640; Negative: *M left-side* = 0.410 VS *M right-side* = 0.344. Neutral: *M left-side* = 0.511 VS *M right-side* = 0.489). Thus, emotional choices were more frequent for positive triads, particularly for men in the case of the left-sided presentations, involving right hemisphere activation. For negative triads, men's left-sided and women's right-sided were least choices.

Analyses of the data in function of subjects' differences for anxiety, depression, and alexithymic (identification, description, and externalization) scores as covariable revealed the same significant effects.

4.3.2.2. Categorization Decision Time

Analyses of variance performed for categorization decision times after logarithmic transformation of the data showed significant main effects of valence of the triads, $F(2,76) = 9.37$, $p < 0.001$; $f = 0.70$, and hand-side, $F(1,38) = 6.45$, $p < 0.02$; $f = 0.82$, and also a significant interaction effect involving same variables, $F(2,76) = 5.17$, $p < 0.01$; $f = 0.52$. Inspection of the data for these main effects showed faster decision times for negative compared with positive triads (*M Negative* = 4874 ms VS *M Positive* = 7946 ms VS *M Neutral* = 2487 ms), and for left hand compared with right hand categorization decisions (*M left* = 4461 ms VS *M right* = 5743 ms).

A significant interaction effect involving valence of the triads and hand-side was observed concerning the hypothesis of asymmetrical processing of information dependent on the valence of emotional information. In general, as we expected, for right-handed individuals the data (see **Table 4**) showed fastest decision times in the case of neutral triads (*M left-sided* = 2649 ms, *M right-sided* = 2323 ms). For emotional decision times, right-sided decision were the slowest, specifically in the case of positive triads (*M left-positive* = 6538 ms VS *M right-positive* = 9353 ms; *M left-negative* = 4197 ms VS *M right-negative* = 5550 ms). The data's directions for emotional decisions was similar to that of the general population in the present study, specifically when positive information was more accessible to the right hemisphere and negative information to the left hemisphere.

Analyses of the data in function of subjects' differences for anxiety, depression, and alexithymic (identification, description, and externalization) scores as covariable revealed the same significant effects.

4.4. Comparative Analyses

In order to compare performance of participants with multiple sclerosis with the general population, we conducted a separate analysis comparing 40 control participants matched on sex, age, and socio-economical profile with those participants with multiple sclerosis.

4.4.1. Emotional Characteristics

Analyses of individual differences for anxiety, depression, and alexithymic scores comparing healthy participants with those with multiple sclerosis showed significantly higher levels of anxiety, $F(1,76) = 8.43$, $p < 0.005$; $f = 0.67$; *M control* = 37.51 VS *M sclerosis* = 44.35, and alexithymic scores, $F(1,76) = 16.09$, $p < .0001$; $f = 0.56$; *M control* = 43.38 VS *M sclerosis* = 52.31, for the clinical group. Concerning alexithymic values, although in both groups there were no differences between men and women in terms of difficulties to identify emotions, $F(1, 76) = 20.31$, $p < 0.0001$; $f = 1.04$; *M control* = 14.01 VS *M sclerosis* = 19.25, for externalization of emotions in addition to main effects related to participants' sex and health, a significant two-way interaction involving both variables is found, $F(1,76) = 10.69$, $p < 0.002$; $f = 0.75$. Compared to women, men of the non-clinical sub-sample experience more difficulties to express their emotion (*M men* = 17.14, *SD* = 3.40 VS *M women* = 14.92, *SD* = 3.53). A reversed trend is observed for the clinical group: Women more than men find difficult to express their emotions (*M men* = 49.33, *SD* = 10.71 VS *M women* = 66.24, *SD* = 20.29). No significant main effects or interaction were found for the scores on depression.

Table 4. Categorization Decision Frequency and Categorization Decision Times as a function of Group of the subjects, Hand-side, and Triad valence.

Group/Triad valence	Hand-side	
	Left	Right
	Healthy subjects	
Neutral	0.502	0.498
	2262	2269
Positive	0.622	0.574
	5402bc	7848abc
Negative	0.464ab	0.548ab
	4128bc	6528ac
	Participants with Sclerosis	
Neutral	0.467	0.533
	2649	2324
Positive	0.653	0.588
	6538a	9354ab
Negative	0.363a	0.359b
	4197a	5550ab

Note**:** Categorization decision times are displayed in milliseconds. Means that share superscripts differ at p < 0.05 in post-hoc LSD tests.

4.4.2. Emotional Categorization

4.4.2.1. Frequency of Emotional Choice 1

For emotional triads, a 2 × 2 × 3 × 2 (Sex of the subjects × Group of the subjects × Valence of the triads × Hand-side) ANOVA was used in which two latter factors were treated as repeated measures.

Analysis of variance for frequency of emotional choices revealed significant main effects of valence of the triads, $F(2,152) = 27.41$, $p < 0.001$; $f = 0.85$, and its interaction with group of the subjects, $F(2,152) = 7.14$, $p < 0.002$; $f = 0.43$. The significant main effect of valence was due to the most frequent choices of the subjects for positive rather than negative emotional responses (*M positive* = 0.610 VS *M negative* = 0.433 VS *M neutral* = 0.500).

A two-way interaction associating valence of the triads with group of the subjects, corresponding to the most frequent emotional choices for positive triads and least for negative ones was observed in the case of the participants with multiple sclerosis (*M positive* = 0.621 VS *M negative* = 0.361 VS *M neutral* = 0.500) compared to healthy ones (*M positive* = 0.598 VS *M negative* = 0.506 VS *M neutral* = 0.500). In fact, differences between non-clinical and clinical participants were significant only for negative choices, $F(1,76) = 13.27$, $p < 0.0005$; $f = 0.82$, *M control* = 0.506 VS *M sclerosis* = 0.361.

4.4.2.2. Categorization Decision Time

A 2 × 2 × 3 × 2 (Sex of the subjects x Group of the subjects x Valence of the triads x Hand-side) factorial analysis was performed for categorization decision times in which the two latter factors were treated as repeated measures. Analyses after logarithmic transformation of categorization decision times showed in addition to the main effects of valence of the triads, $F(2,152) = 8.83$, $p < 0.0002$; $f = 0.48$, and hand-side, $F(1,76) = 7.59$, $p < 0.008$; $f = 0.63$, two two-way interactions, $F(2,152) = 9.47$, $p < 0.0001$; $f = 0.50$; $F(1,76) = 5.06$, $p < 0.03$; $f = 0.52$, and a three-way, $F(2,152) = 5.23$, $p < 0.007$; $f = 0.35$, involving group of the subjects and the two former variables. Inspection of the data showed longest time decisions for positive information (*M positive* = 7286 ms VS *M negative* = 5101 ms VS *M neutral* = 2376 ms), right-sided information (*M right-side* = 5645 ms VS *M left-side* = 4196 ms), specifically for participants with multiple sclerosis in terms of valenced information (Multiple sclerosis: *M positive* = 7946 ms VS *M negative* = 4874 ms VS *M neutral* = 2187 ms; Control: *M positive* = 6625 ms VS *M negative* = 5325 ms VS *M neutral* = 2265 ms), or its presentation side (Multiple sclerosis: *M right-side* = 5743 ms VS *M left-side* = 4461 ms; *Control*: *M right-side* = 5548 ms VS *M left-side* = 3931 ms).

A three-way interaction showed that compared with non-clinical population those from clinical sample took more time to make their decisions in the case of the positive and neutral triads, with the longest decision times for right-sided positive information (Right-side: *M* control = 7848 ms VS *M sclerosis = 9353 ms; Left-side: M* control = 5402 ms VS *M sclerosis* = 6537 ms), and the fastest time decisions for right-sided neutral ones (Right-side: *M* control = 2268 ms VS *M sclerosis* = 2323 ms*; Left-side*: *M* control = 2262 ms VS *M sclerosis* = 2649 ms). The most interesting effect was observed in the case of negative triads. Indeed, although there were no differences between healthy participants and multiple sclerosis patients when processing left-sided negative information (*M* control = 4127 ms VS *M sclerosis* = 4197 ms), in the case of the right-sided negative information participants with multiple sclerosis took less time to make their emotional decision (*M* control = 6527 ms VS *M sclerosis* = 5550 ms, see **Table 4**).

Thus, although participants with multiple sclerosis needed much more time to make their decision about categorization of emotional information, when facing negative information they were relatively rapid. This effect could be interpreted as a consequence of their disease and the worries it generates, in which case a negative correlation between anxiety or depression scores and frequencies and time decisions for negative information would be expected. Nevertheless, the results of our study reveal rather positive and non significant correlations between these variables.

5. DISCUSSION

Our data are consistent with previous studies, showing a) right hemisphere specialization for the categorization of emotional concepts (e.g. [44]), especially negative ones (e.g. [45]) in general population and in a sample of patients suffering from multiple sclerosis. In addition, our data provide b) evidence for asymmetrical processing of emotional information and bring some methodological insights related to measurement of negative-valenced information processing, suggestion correspondence between valenced information (positive/negative) and their presentation-side (left/right). As a matter of fact, the lack of differential processing of negative information in the absence of positive ones in some studies could be explained in terms of the lack of those types of correspondence (e.g. [30,35,36]). Nevertheless, they show, for both populations, c) no gender-related differences regarding individuals' emotional characteristics, specifically in terms of alexithymia features (e.g. [56]).

On the basis of these findings our hypothesis that emotion-related individual differences could modulate processing of affective information is partially supported. In accordance with previous studies, analyses show that dimensions relevant to emotional disorders are generally associated with asymmetrical categorization, with slow left-sided decisions, particularly in the case of negative information. Anxious or/and alexithymic people seemed to solicit preferentially right hemisphere resources, causing slower treatment of right-sided negative stimuli, except in the clinical sample. Indeed, participants with multiple sclerosis treated right-sided negative information faster than non-clinical participants. Two different but related explanations could be proposed to explain this effect. First, people with multiple sclerosis may rely first on left hemisphere activation for processing emotional information regardless of the valence of the information. Second, we could imagine that this preferentially activation is due to their general negative emotional state.

Our analyses of variance showed that people develop some preferential processes for categorization decisions, which result in longer decision times for preferred information (positive information, [32]). However, even though participants preferred, in general, to use positive information as the basis of their categorization, they chose more left-sided than right-sided positive emotional alternatives. At the same time, these left preferential decisions were faster than right-sided decisions. When participants had to choose between emotional or non-emotional alternatives they showed the same tendencies, more frequent and faster left-sided emotional decisions. The processing of emotional information, specifically positive information seemed to be more efficient whenever it was accessible to the right hemisphere.

This preferential processing seems to vary depending on gender of the individuals. Women compared to men chose more frequently emotional information for making categorical decisions, but they took more time to make these decisions. Regarding gender, we noticed exactly the same tendencies in clinical population investigated in present study.

The main finding of the present study was that there exists patterns of hemispheric asymmetry that vary systematically as an interactive function of the valence of emotional information involved in categorical decisions, and the spatial presentation of this information (left- or right side), resulting in more or less accessibility of information to the left or right hemisphere. Additionally, the results showed a contribution of certain individual emotional characteristics to the organization of these patterns. The central finding regarding hemispheric laterality was that the asymmetry emerged from longer processing for the right side decisions (stimuli/response) and shorter processing for left side, thus from more accessibility of the information for the right hemisphere than the left, except in the case of neutral triads. The slowest and the fastest decisions were respectively found for positive and neutral right-sided triads, supporting a motivational hypothesis, according to which people are motivated to search and preserve their positive feelings.

Taken together, the results concerning individuals' emotional differences and cognitive tasks revealed a greater implication of the right hemisphere in processing affectivo-verbal information. This observation favors a functional conception of hemispheric asymmetry [13], and provides evidence concerning the dynamic relationship between individuals' emotional differences (alexithymic features), the nature of information and the spatial context of their presentation. The participants high in emotion identification and externalization needed more time to process emotional information presented to the right visual field (left hemisphere activation).

In the present study, the emotional stimuli were presented in the both hemi-spaces, and the right hemisphere dominance was present across both positive and negative stimuli. All participants with a higher emotional sensitivity (anxiety, emotion identification and externalization) seemed to search emotional information in their left visual space (right hemisphere involvement), and process it more efficiently. However, those with multiple sclerosis processed faster but less efficiently (less than 40% of emotional categorization decisions) right-sided information (involving the left hemisphere). These findings support those of previous studies and suggest the importance of integration of individual differences in the analysis of hemispheric asymmetrical processing of emotional information. In fact, although the patterns of asymmetries favor right hemisphere processing of negative stimuli compared to left hemisphere treatment of positive stimuli (faster negative left-side decision), in the case of non-clinical participants when comparing decision times only for emotional triads, the interactive effect associating valence of triads with their side presentation disappeared. These complex dynamic relationships between dispositional and situational features in cognitive tasks require more investigation. It may be valuable for future studies on hemispheric laterality of emotional information to consider the functions of each hemisphere depending on emotional states. The present research suggests the importance of right-hemispheric activity in processing emotional information as a function of dispositional characteristics. By understanding basic processes involved in treating emotional information we should be in a better position to predict relationships between emotion and cognition.

For example, working memory involved in categorization processes seems to have two major levels of processing in terms of access to encoded information: maintenance, and manipulation. Irrespective of which of these two systems are responsible for impaired performance in working memory, another mediating variable influencing working memory performance accuracy is information processing speed [91]. Several studies have revealed significant difficulties in information processing in individuals with multiple sclerosis [92]. In fact, decreased efficiency in processing speed is a primary determinant of impaired working memory performance. However, a recent research using MRI suggested that patients, with working memory impairment, at the early stage of MS may partially compensate by a greater cognitive control [93]. Also, our results suggest that investigation of processes which underlay hemispheric specialization and interaction between emotion and cognition is warranted among subjects with multiple sclerosis and may ultimately help us to better understand and generate novel techniques to provide a better life-quality for them.

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ANNEX

Order of presentation and valence of the Triads:

French version

Target Concept	Alternative Concepts	
Neutral Triads		
1)cuisinier	serveur	artiste
3)peau	écorce	cheveux
5)muscle	os	moteur
6)patinoire	stade	miroir
12)dents	perles	gorge
13)fourchette	dard	louche
17)football	ping-pong	œuf
18)chaussure	pneu	chemise
21)moquette	parquet	fourrure
27)chapeau	chaussettes	toit (roof)
30)serpent	spaghettis	tortue
Positive triads		
2)soleil	rire	allumette
7)succès	incertitude	vacances
10)chanson	cris	barbe à papa
14)mer	liberté	plaine
15)plage	falaise	tendresse
20)repos	fleur	extinction
23)escalade	monte-charge	pique-nique
26)biberon	câlin	assiette
29)diamant	fer	étoile
31)promenade	beauté	course
Negative Triads		
4)béquilles	fauteuil roulant	jambe
8)avalanche	neige	accident
9)ruine	achats	ouleur
11)avocat	contrat	divorce
16)hôpital	hôtel	ennui
19)poubelle	odeur	sac
22)doberman	requin	caniche
24)incendie	enterrement	grille-pain
25)dentiste	souffrance	brosse
28)ambulance	fourgonnette	guerre

English version

Target Concept	Alternative Concepts	
Neutral Triads		
1)chief	waiter	artist
3)skin	bark	hair
5)muscle	bone	motor
6)skating rink	stadium	mirror
12)teeth	pearls	throat
13)fork	stinger	ladle
17)football	ping-pong	egg
18)shoe	tire	shirt
21)carpet	floor	fur
27)hat	shoes	roof
30)snake	spaghetti	turtle
Positive triads		
2)sun	laugh	matches
7)success	uncertainty	vacation
10)song	screams	cotton-candy
14)sea	freedom	plain
15)beach	cliff	tenderness
20)rest	flower	extinguish
23)climbing	hoist	picnic
26)bottle	cuddle	plate
29)diamond	iron	star
31)walk	beauty	race
Negative Triads		
4)crutch	wheelchair	leg
8)avalanche	snow	accident
9)ruin	purchases	pain
11)lawyer	contract	divorce
16)hospital	hotel	boredom
19)trash	smell	bag
22)doberman	shark	poodle
24)fire	burial	toaster
25)dentist	suffering	brush
28)ambulance	truck	war

Note: Trial 1 Neutral was used as an example triad

