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AFFECTIVE WORD PRIMING IN THE LEFT AND RIGHT VISUAL FIELDS IN YOUNG AND OLDER INDIVIDUALS

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Summary

While the right hemisphere and valence hypotheses have long been used to explain the results of research on emotional nonverbal and verbal stimuli processing, the literature on emotional word processing is highly inconsistent with both hypotheses, but appear to converge with the time course hypothesis. The time course hypothesis holds that in the processing of some parts of the semantic system the time course of activation is slower in the right hemisphere compared to the left hemisphere. The goal of this thesis was to find insight into the ways in which words with emotional words are processed in the cerebral hemispheres in young and older individuals. To this end, the first study investigated the time course hypothesis looking at the activation pattern of emotional words in the left and right hemispheres, using the priming paradigm and an evaluation task. Consistent with the time course hypothesis, the results in males revealed an early and later priming in the left and right hemispheres, respectively. The results for females, however, were consistent with the valence hypothesis, since positive and negative words were optimally primed in the left and right hemispheres, respectively. As females are considered more emotional than males, their results may be due to the nature of the task, which required an explicit decision concerning the target. The second study looked at the possibility that the preservation with age of the ability to process emotional words would follow the compensatory role of bilateral activation in high performing older individuals known as the HAROLD phenomenon (Hemispheric Asymmetry Reduction in OLDer adults). Comparing the pattern of emotional word priming in a group of equally high performing older and younger, it was shown that while priming occurred unilaterally in young participants, the pattern of priming in older participants appeared to be bilateral. The occurrence of priming in older adults occurred with a tiny delay, though, that may be due to an increase in sensory thresholds that causes older adults to need more time to encode stimuli and start activation through the semantic network. Thus, the bilateral pattern of priming and the equivalent level of performance in older adults provide behavioral evidence supporting the compensatory role of the HAROLD phenomenon.

Key words: emotional words, cerebral hemispheres, time course hypothesis, HAROLD phenomenon, priming paradigm

Résumé

Alors que les hypothèses de valence et de dominance hémisphérique droite ont longtemps été utilisées afin d'expliquer les résultats de recherches portant sur le traitement émotionnel de stimuli verbaux et non-verbaux, la littérature sur le traitement de mots émotionnels est généralement en désaccord avec ces deux hypothèses et semble converger vers celle du décours temporel. Cette dernière hypothèse stipule que le décours temporal lors du traitement de certains aspects du système sémantique est plus lent pour l'hémisphère droit que pour l'hémisphère gauche. L'objectif de cette thèse est d'examiner la façon dont les mots émotionnels sont traités par les hémisphères cérébraux chez des individus jeunes et âgés. À cet effet, la première étude a pour objectif d'évaluer l'hypothèse du décours temporel en examinant les patrons d'activations relatif au traitement de mots émotionnels par les hémisphères gauche et droit en utilisant un paradigme d'amorçage sémantique et une tâche d'évaluation. En accord avec l'hypothèse du décours temporel, les résultats obtenus pour les hommes montrent que l'amorçage débute plus tôt dans l'hémisphère gauche et plus tard dans l'hémisphère droit. Par contre, les résultats obtenus pour les femmes sont plutôt en accord avec l'hypothèse de valence, car les mots à valence positive sont principalement amorcés dans l'hémisphère gauche, alors que les mots à valence négative sont principalement amorcés dans l'hémisphère droit. Puisque les femmes sont considérées plus « émotives » que les hommes, les résultats ainsi obtenus peuvent être la conséquence des effets de la tâche, qui exige une décision explicite au sujet de la cible. La deuxième étude a pour objectif d'examiner la possibilité que la préservation avec l'âge de l'habileté à traiter des mots émotionnels s'exprime par un phénomène compensatoire d'activations bilatérales fréquemment observées chez des individus âgés et maintenant un haut niveau de performance, ce qui est également connu sous le terme de phénomène HAROLD (Hemispheric Asymmetry Reduction in OLDer adults). En comparant les patrons d'amorçages de mots émotionnels auprès de jeunes adultes et d'adultes âgés performants à des niveaux élevés sur le plan comportemental, les résultats révèlent que l'amorçage se manifeste unilatéralement chez les jeunes participants et bilatéralement chez les participants âgés. Par ailleurs, l'amorçage se produit chez les participants âgés avec un léger délai, ce qui peut résulter d'une augmentation des seuils sensoriels chez les participants âgés, qui nécessiteraient alors davantage de temps pour encoder les stimuli et entamer l'activation à travers le réseau sémantique. Ainsi, la performance équivalente au niveau de la précision retrouvée chez les deux groupes de participants et l'amorçage bilatéral observé chez les participants âgés sont en accord avec l'hypothèse de compensation du phénomène HAROLD.

Mots clés : mots émotionnels, hémisphères cérébraux, hypothèse du décours temporel, phénomène HAROLD, paradigme d'amorçage.

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List of abbreviations

DVF	Divided Visual Field
EPN	Early Posterior Negativity
ERP	Event Related Potentials
fMRI	function Magnetic Resonance Imaging
HAROLD	Hemispheric Asymmetry Reduction in OLDer (adults)
LD	Lexical Decision
LH	Left Hemisphere
LPC	Late Positive Component
LVF	Left Visual Field
PET	Positron Emission Tomography
RH	Right Hemisphere
RT	Response Time
RVF	Right Visual Field
SOA	Stimulus Onset Asynchrony
VF	Visual Field

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Chapter 1

INTRODUCTION

This chapter presents basic concepts and hypotheses related to this research project, including emotion hypotheses, semantic lateralization hypotheses, central findings in the affective priming literature, compensatory mechanism in gaing, and general objectives of the research.

1.1. Emotion Hypotheses

Communication involves not only the sharing of ideas or knowledge, but also the expression of emotions—and the understanding of emotions conveyed in the utterances of others. A large majority of studies on the neural bases of language have focused on the way the brain is functionally organized to process meanings. Yet, proportionally very few studies have looked at how the brain conveys and processes the emotional value of words. The topic of this dissertation is emotional words and the way in which these words are processed in the cerebral hemispheres. Emotional words are characterized by two features: *valence* and *arousal*. *Valence*—or *evaluation*—varies from negative to positive and is defined as a measure of how pleasant or unpleasant a stimulus is, whereas *arousal*—or *activation*—ranges from calming to highly arousing and is a measure of how intensely a person would want to approach or flee from a stimulus (Bradley, Greenwald, Prety, & Lang, 1992).

Over the last one and a half centuries, there has been growing interest in the role played by each cerebral hemisphere in the processing of emotional stimuli such as emotional words. Hughlings Jackson (1880) was one of the first to observe that some aphasic individuals were able to use emotional speech, implying that the right hemisphere (RH) plays a role in this function. In a more direct manner, Mills (1912) linked impairments in emotional processing to RH pathology, providing convergent findings that drew researchers' attention to the role of the RH in emotional processing. In the 1950s and 1960s, researchers studying behavioral modifications by injecting sodium amytal into the left and right carotid arteries encountered the unexpected results of depressive and euphoric reactions in the left hemisphere (LH) and RH, respectively. They attributed these opposite emotional behaviors to the inactivation of two distinct neurophysiological mechanisms devoted to the positive and negative aspects of emotions, with the former located in the LH and the latter in the RH (*valence effect*) (as cited in Gainotti, Caltagirone, & Zoccolotti, 1993).

Later, Gainotti (1972) observed the clinical profiles of individuals with LH and RH damage and suggested a different interpretation of the hemispheres' ability to process emotions: He interpreted the emotional reaction of the individuals with damage to their RH as an *indifference* reaction, in contrast to the *euphoric* reaction described by previous studies. That is, individuals with RH damage tended to be inappropriately indifferent to their clinical deficits and thus, due to a lack of empathy regarding their impairments, treated them with cheerful acceptance. By contrast, individuals with LH pathology tended to be appropriately depressed because of difficulties expressing themselves verbally and a paralyzed right hand. Accordingly, Gainotti hypothesized that the RH plays a critical role in the processing of emotions. Specifically, when the RH is intact, emotional behavior is appropriate, whereas abnormal emotional behavior results when the RH is damaged (*RH effect*).

Since Gainotti's (1972) hypothesis, most studies on the processing of emotional stimuli, both verbal and nonverbal, have attempted to interpret their findings in light of either the *RH hypothesis* (e.g., Borod, 1992; Borod & Koff, 1989; Bryden & Ley, 1983; Buchanan et al., 2000; Buck, 1984; Ley & Bryden, 1979; Schmitt, Hartje, & Willmes, 1997; Sim & Martinez, 2005) or the *valence hypothesis* (e.g., Ahern & Schwartz, 1985; Davidson, 1992; Silberman & Weingartner, 1986; Sutton & Davidson, 1997; Van Strien & Morpurgo, 1992). In general, the RH hypothesis holds that the RH is specialized for the processing of emotional stimuli, irrespective of valence. By contrast, the valence hypothesis proposes differential hemispheric specialization for emotional processing, where the LH is more involved in the processing of positive emotions and the RH is primarily responsible for the processing of negative emotions.

1.2. Studies of Brain-damaged and Normal Individuals

A review of the behavioral literature shows that, though limited in number, most studies related to the processing of emotional words in the cerebral hemispheres recruited neurologically normal individuals in investigating hemispheric lateralization in the processing of emotional words. A few studies that studied the role of the cerebral hemispheres in this type of processing did examine brain-damaged individuals (Borod, 1992; Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Borod et al., 1998; Cicero et al., 1999), and their findings seem to support the RH hypothesis. Yet, studies of neurologically normal and those of brain-damaged individuals actually measure two different underlying processes. Namely, studies of normal participants measure each hemisphere's specific *capacity* for a given performance, whereas studies of brain damage highlight the *actual contribution* of each hemisphere to that performance (see Kahlaoui, Scherer, & Joanette, 2008, for a review).

In addition, the major methodological differences across investigations can make it difficult to compare the results of studies of brain damage with those of studies on neurologically normal individuals and to formulate a unified account of the emotional word abilities of the two hemispheres. The following study exemplifies the methodology of such studies of brain-damaged individuals.

To compare individuals with RH damage (RHD), those with LH damage (LHD), and normal control participants in terms of their perception of emotional words and sentences, Borod et al. (1992) devised three tasks—word identification, word discrimination, and sentence identification—that evaluated three positive (*happiness*, *pleasant surprise*, *interest*) and four negative (*sadness*, *anger*, *fear*, *disgust*) emotions. Parallel neutral tasks (word discrimination, word identification, and sentence identification) were also developed to control for cognitive and linguistic factors.

For the emotional word identification task, clusters of three emotional words (e.g., *stimulate*, *motivated*, *fascinated*) were presented individually to participants, who were asked to name or point to the emotion best represented by each cluster on a seven-option (*happiness*, *pleasant surprise*, *interest*, *sadness*, *anger*, *fear*, *disgust*) multiple-choice response card. For the emotional word discrimination task, word pairs (e.g., *terror-dread*, *lucky-gloomy*) were presented to participants, who indicated orally whether the two words represented the same or two different emotions. For the emotional sentence identification task, participants viewed seven-word declarative sentences (e.g., *I was furious at what he said.*) containing a key word associated with one of the seven emotions printed on the response card and then named or pointed to the emotion best represented by the sentence. The neutral tasks used the category *characteristics of people*, which included seven neutral characteristics (*beauty*, *strength*, *intelligence*, *fatness*, *weakness*, *stupidity*, *hair color*). In all tasks, participants were allowed to view each experimental item for as long as they needed.

The results indicated that individuals with RHD were significantly more impaired than those with LHD and normal controls in the emotional tasks. For individuals with LHD and normal controls, there was no significant difference between their performances on the emotional and neutral tasks, whereas individuals with RHD showed a significant difference between their performances on the two types of tasks. The results were not affected by the valence of the stimuli. Borod et al. (1992) concluded that individuals with RHD have difficulty on a variety of emotional tasks involving identification and discrimination for both types of stimuli: single words and sentences.

By contrast, when studying neurologically normal individuals with the aim of identifying the roles of the LH and RH, researchers have tended to use the divided visual field (DVF) paradigm (e.g., Ali & Cimino, 1997; Brody, Goodman, Halm, Krinzman, & Sebrechts, 1987; Eviatar & Zaidel, 1991; Graves, Landis, & Goodglass, 1981; Strauss, 1983). In the DVF paradigm, stimuli are presented for a brief duration (typically less than 200 ms) to the right visual field (RVF) or the left visual field (LVF) and are considered to be processed primarily by the LH and RH, respectively (Atchley, Ilardi, & Enloe, 2003). The logic underlying this technique is based on the main feature of the visual system: The primary pathways from each visual field are crossed and reach the opposite hemisphere.

Given the specific aim of this research program, because of the relatively higher number of studies on neurologically normal individuals and the benefits of having access to a greater amount of electrophysiological and neuroimaging data, I decided to focus on these studies.

1.3. In Search of a Different Theoretical Framework

Generally, neither the RH hypothesis nor the valence hypothesis adequately explains what occurs in emotional word processing. (This claim will be discussed in more detail in the following two chapters.) Basically, depending on the study, emotional word processing is attributed to the RH, the LH, or even equally to both hemispheres (e.g., Collins & Cooke, 2005; Eviatar & Zaidel, 1991; Graves et al., 1981; Nagae & Moscovitch, 2002; Smith & Bulman-Fleming, 2005, 2006; Strauss, 1983). Support for the valence hypothesis is similarly ambiguous (Ali & Cimino, 1997). Even recent studies have attempted to show that the LH and RH are involved in two separate levels of the processing (e.g., *perception* vs. *memory*), yet their results do not support their predictions (Collins & Cooke, 2005; Nagae & Moscovitch, 2002).

Since emotional words are part of the semantic system, research findings in the field of semantics may provide some insight into the role of each hemisphere in emotional word processing. According to semantic research, instead of the two hemispheres sharing one semantic system, each hemisphere has its own lexico-semantic system that is activated in different circumstances (see Chiarello, 1991, 1998, for a review). If each hemisphere does, in fact, have its own semantic system, then this may be why current hypotheses of emotional processing, which attribute the processing of emotional words to one of the two hemispheres, are inadequate to explain the results of studies on emotional word processing. Thus, to resolve the discrepancies, it is necessary to consider a comprehensive model that reflects different profiles of the two hemispheres during emotional word processing.

1.4. Hypotheses Suggested by Lateralized Semantic Research

Lateralized semantic research suggests that the LH and RH represent parallel and distinct information processing systems, each of which contributes in some way to nearly all linguistic behaviors (see Chiarello, 2003, for a review). The most compelling evidence supporting this idea comes from the study of split-brain patients (Sperry, Gazzaniga, & Bogen, 1969). The real breakthrough supported by studies of split-brain patients was the conclusive demonstration that each isolated hemisphere represents a complete information processing system. Namely, each hemisphere was shown to have its own perceptual experiences, memories, lexico-semantic system, and ability to select appropriate behavioral responses (Sperry et al., 1969; Sperry, Zaidel, & Zaidel, 1979).

Likewise, numerous studies of normal participants that used the DVF priming paradigm have demonstrated that semantic information is accessed within each hemisphere, but not necessarily in the same way (see Chiarello, 1991, 1998, for a review). In the DVF priming paradigm, two successive stimuli of the prime and the target are presented to the LVF or RVF, and priming consists in accelerated processing of the target when prime and target are related. A great advantage of this paradigm lies in the *Stimulus Onset Asynchrony* (SOA; the delay between the onset of the prime and that of the target). By manipulating the SOA, the burden of processing can be tracked from one hemisphere to the other.

According to Chiarello (2003), at least two factors underlie the differences between the LH and RH in semantic processing: (1) the scope of word meaning activated within each hemisphere, which yields the *depth of activation hypothesis* (e.g., Chiarello, Burgess, Richards, & Pollock, 1990; Chiarello & Richards, 1992; Richards & Chiarello, 1995), and (2) how the availability of word meaning changes over time, which is captured by the *time course hypothesis* (e.g., Burgess & Simpson, 1988; Koivisto, 1997, 1998; Nakagawa, 1991).

According to the depth of activation hypothesis, the difference between the two hemispheres reflects the fact that a larger set of word meanings is activated in the RH than in the LH. Beeman (1993) proposed that, during semantic processing, the LH uses relatively *fine semantic coding* to quickly select a single relevant meaning or a few features of a word for further processing, whereas the RH employs relatively *coarse semantic coding* to weakly activate several meanings or features of a word. Thus, words activate broader semantic fields in the RH than in the LH, and the actual interpretation of a word can differ somewhat between hemispheres. On the other hand, the time course hypothesis holds that activation of semantic information occurs more slowly in the RH than in the LH. Therefore, semantic information becomes available early in processing in the LH and only later in the RH.

Despite their differences, the semantic literature suggests that these two hypotheses are not counterintuitive. For some groups of words, such as the dominant meaning of ambiguous words (e.g., *money* as the dominant meaning of *bank*) and closely related category words (e.g., *cat* as a close exemplar from the category of animals to *dog*), priming of both hemispheres at both short and long SOAs has been reported (e.g., Burgess & Simpson, 1988; Chiarello, Liu, Shears, Quan, & Kacinik, 2003). Yet, for other groups, such as the subordinate meaning of ambiguous words (e.g., *river* as the subordinate meaning of *bank*) and distantly related category words (e.g., *pony* as a distant exemplar from the category of animals to *deer*), priming probably shifts from the LH at a short SOA to the RH at a long SOA (e.g., Burgess & Simpson, 1988; Koivisto, 1997). That is, for the latter group of words, SOA is likely an important factor revealing a result in favor of either hemisphere. Therefore, when a short SOA is employed, the LH shows superiority in priming, and, when a longer SOA is used, priming is observed in the RH. Findings related to this tendency are presented below.

Burgess and Simpson's (1988) study was among the first conducted in the field. They explored the availability of the dominant meaning (e.g., *money* as target) and subordinate meaning (e.g., *river* as target) of ambiguous words (e.g., *bank* as prime) in the LH and RH by using two SOAs: 35 ms and 750 ms. Although equal priming of dominant meanings was found across hemispheres at both SOAs, subordinate meanings were primed only in the LH at the 35 ms SOA and only in the RH at the 750 ms SOA. According to Burgess and Simpson (1988), both subordinate and dominant meanings of ambiguous words are initially activated in the LH. Over time, and in the absence of context, the LH maintains activation only for dominant meanings and suppresses subordinate meanings. On the other hand, the RH activates subordinate meanings later during processing because the RH is slower at activating semantic information.

Research has indicated a comparable type of conceptual relation for the processing of closely related category words (e.g., *dog – cat*) and distantly related category words (e.g., *deer – pony*) in the cerebral hemispheres. In the study by Chiarello et al. (1990) on the processing of these pairs using an SOA of 575 ms, closely related category words were primed similarly in the LH and RH, whereas only the RH was capable of priming distantly related category words at the same SOA. Chiarello et al. (1990) attributed the results for distantly related category words to the activation of a larger, but diffuse, set of word meanings within the RH. They argued that, when a word is recognized by the LH, only its closely related words are activated, whereas a broader set of meanings becomes available in the RH (i.e., depth of processing hypothesis).

Later, to pinpoint the role of the cerebral hemispheres in accessing category words, Chiarello and Richards (1992), using almost the same SOA (600 ms), examined the effect of category dominance as an instrument in influencing the direction and magnitude of priming in the LH and RH. While the above-mentioned results (i.e., Chiarello et al., 1990) showed that the RH is capable of activating all category words, whether closely or distantly related, Chiarello and Richards (1992) thought that a highly typical category exemplar presented to the LH might facilitate access to other exemplars of that category. Thus, high dominant primes (e.g., *apple – grape*, *robin – crow*) and low dominant primes (e.g., *lime – grape*, *duck – crow*) served as priming stimuli, with all word pairs in the experiment being distantly related category pairs.

The results showed reliable priming only in the RH. Moreover, no effect of category dominance was discovered in the RH: The amount of priming was equivalent for both sets of pairs. That is, not even high dominant primes could facilitate the priming of distantly related category words in the LH. This finding demonstrates the ability of the RH to access all category members (though at a relatively long SOA). These data were interpreted by the authors as consistent with the depth of activation hypothesis. That is, the RH is capable of maintaining a larger set of meanings over time, whereas the LH maintains only closely related meanings.

In contrast to the two above-mentioned studies, Abernethy and Coney (1993) found a different pattern of priming for distantly related category words at two SOAs: 250 ms and 450 ms. In their study, priming occurred in the LH at the SOA of 250 ms. At the SOA of 450 ms, the amount of priming was equivalent across the hemispheres.

Therefore, it seems likely that a conclusive comparison with regard to the processing capabilities of the LH and RH is possible through manipulation of the pattern of activation of words over time. Accordingly, although research corroborates similar priming patterns of closely related category words in the LH and RH at a variety of short and long SOAs, namely, 150 ms (Audet, Driessen, & Burgess, 1998), 225 ms, 300 ms, 500 ms, and 800 ms (Chiarello et al., 2003), for distantly related category words, a different pattern of priming should be anticipated.

In an attempt to explain the inconsistent results of studies that investigated the processing of distantly related category words (i.e., Abernethy & Coney, 1993; Chiarello & Richards, 1992; Chiarello et al., 1990), Koivisto (1997) examined the priming of these words in the LH and RH using four different SOAs: 165 ms, 250 ms, 500 ms, and 750 ms. The results revealed a decrease in the amount of priming in the LH, while the onset of priming occurred much later in the RH. That is, priming occurred only in the LH at the 165 ms SOA and only in the RH at the 750 ms SOA. At the SOA of 250 ms, there was nonsignificant priming in the LH and no priming in the RH, and, at the SOA of 500 ms, there was less priming in the LH than in the RH.

The findings, thus, suggested that the time course of activation may be different in the two hemispheres, with the onset of semantic activation being slower in the RH than in the LH. This pattern of priming, which is similar to that shown by Burgess and Simpson (1988), has been formulated as the time course hypothesis.

The results of a cross-hemispheric study conducted by Abernethy and Coney (1996) seem to corroborate the time course hypothesis. According to this hypothesis, in the processing of some semantic information such as distantly related category words, the LH is initially capable of activating this information, whereas the RH takes longer to activate the same information when it is no longer available in the LH. Therefore, it is likely that early availability of a word prime in the LH facilitates responses to a word target subsequently presented not only to the LH (i.e., within-hemispheric priming), but also to the RH (i.e., cross-hemispheric priming). On the other hand, because, early in processing, a distantly related category word prime is not yet available in the RH, no facilitation is likely for a word target subsequently presented to the LH or RH.

Consequently, when Abernethy and Coney (1996) compared cross-hemispheric and within-hemispheric priming of distantly related category words at the short SOA of 250 ms, priming of these words occurred not only in the LH, but also in the RH. However, presentation of a category word prime at the same SOA (250 ms) to the RH did not cause priming in either hemisphere. This outcome likely corroborates the unavailability of distantly related category words in the RH at a short SOA because these words are activated slowly in the RH.

It is likely that the LH superiority in language processing, for the above-mentioned words, is the cause of early activation in the LH. This activation, which is suppressed over time, is followed by a later activation in the RH. This shift of activation from the LH to the RH conceivably arises from two cognitive processes, one automatic and one controlled, respectively. Automatic processing refers to that component of information processing where a stimulus automatically activates its internal representation in semantic memory and this activation spreads to related representations in memory. This process is fast acting and occurs without intention or conscious awareness. By contrast, controlled processing places demand on attention and comes into play when using, for instance, a long SOA and when the participant is put in an experimental condition such that expectations about the relationship between prime and target are encouraged (Collins & Loftus, 1975; Neely, 1991).

Research findings from studies that used emotional words as stimuli seem to suggest that the time course hypothesis also governs the processing of emotional words in the LH and RH. Recently, after reviewing studies on the emotional verbal abilities of aphasic patients as well as findings from DVF and neuroimaging studies, Landis (2006) proposed a model of emotional word processing that implicates the involvement of both hemispheres, but in a way comparable to the predictions of the time course hypothesis. According to this model, the left amygdala is activated by emotional visual information projected to the opposite visual field (i.e., RVF). The amygdala modulates the left and right visual cortex asymmetrically, thereby reducing the emotional sensitivity of the left visual cortex, while enhancing that of the right visual cortex. According to Landis (2006), this method of distributing emotional verbal information causes the information to be analyzed differently in the LH and RH.

In chapter 2, I present information that supports the dichotomy of automatic and controlled activation of emotional words in the LH and RH, respectively. In addition, chapter 3 presents results related to the predictions of the time course hypothesis with regard to the processing of emotional words.

1.5. Affective Priming and Attitude Words in Cognitive Social Psychology

One field of research whose findings, though nonlateralized, intensify the applicability of the predictions of the time course hypothesis for emotional word processing is cognitive social psychology. Evidence from cognitive social psychology that focuses on the influence of *attitudes* (i.e., positive or negative views of a person, place, thing, or event) on attention, judgment, and behavior suggests that the emotional value of stimuli is evaluated quickly and automatically, without bearing on attention. This effect has been reported repeatedly with the use of the *affective priming paradigm* and a short SOA condition (e.g., Bargh, Chaiken, Govender, & Pratto, 1992; Bargh, Chaiken, Raymond, & Hymes, 1996; Fazio, Sanbonmatsu, Powell, & Kardes, 1986). In the affective priming paradigm, a variant of the semantic priming paradigm, an emotional target (e.g., *crime*) is preceded by an emotional prime (e.g., *gift*), and affective priming is indicated when the time needed to evaluate the target as pleasant or unpleasant (e.g., Fazio et al., 1986) or to make a lexical decision (LD) about the target (e.g., Kemp-Wheeler & Hill, 1992) is significantly shorter when the prime and target share the same (as opposed to opposite) valence.

The affective priming paradigm was first introduced by Fazio et al. (1986) to show that the emotional value of attitudes is activated from memory automatically upon presentation. In Fazio et al.'s (1986) study, a prime word presented for 200 ms was followed by a target word after a delay of 100 ms (i.e., SOA of 300 ms). Participants were required to indicate whether the target was *good* or *bad* in meaning. The results showed shorter reaction times (RTs) to congruent pairs (i.e., negative prime – negative target, positive prime – positive target) than incongruent pairs (i.e., negative prime – positive target, positive prime – negative target). Given that the SOA of 300 ms was too brief to permit participants to develop expectancy about the target, the resulting priming was attributed to the automatic activation of attitude (emotional) words.

Subsequent studies in the field have provided support for the automatic nature of affective priming (e.g., Bargh et al., 1992; Bargh et al., 1996); they have also suggested that the effect is short lived (e.g., Hermans, De Houwer, & Eelen, 2001; Klauer, Rossnagel, & Musch, 1997). Hermans et al. (2001) examined the time course of affective priming by using five different SOAs: −150 ms, 0 ms, 150 ms, 300 ms, and 450 ms. Thus, the prime could either precede, follow, or be presented simultaneously with the target. At all SOAs, the prime was presented for 200 ms, and the target stayed on the screen until the participant responded. Hence, at the 150 ms SOA, the prime was presented for 150 ms, followed by simultaneous presentation of the prime and target for 50 ms, after which the prime was disappeared. At the 0 ms SOA, the prime and target appeared simultaneously, and, after 200 ms, the prime disappeared. At the SOA of −150 ms, the target was presented first for 150 ms, after which the prime appeared for 200 ms. To differentiate between the prime and target at the SOAs for which there was an overlap in their presentation, the target was underlined.

The results demonstrated significant priming at the SOAs of 0 ms and 150 ms, but not at the longer SOAs. No priming emerged at the SOA of −150 ms likely because the affective value of the prime had not been fully processed by the time the participant evaluated the target. As affective priming has been reported at a 300 ms SOA in previous studies (e.g., Bargh et al., 1992; Bargh et al., 1996; Fazio et al., 1986), Hermans et al. (2001) argued that the activation curve of valence has a very quick onset at a 0 ms SOA; the activation, however, quickly diminishes such that an SOA of 300 ms is likely located at the end of the activation curve. Nevertheless, similar to semantic research and because it developed later, the affective priming research introduces findings that show the possibility of reviving the activation at long SOAs (Klauer et al., 1997).

To explain the underlying mechanism of the affective priming effects, some researchers (e.g., Fazio et al., 1986; Bargh et al., 1996) have drawn on the similarity between the semantic and affective priming paradigms and proposed a *spread of activation account* (Collins & Loftus, 1975) for the affective priming effects. By this account, the valence of the prime activates a general purpose valence node in semantic memory, either one specific to a positive valence or one specific to a negative valence. The activation of the valence node spreads to the words with the same valence and accelerates the encoding of targets with the same valence. Consequently, targets with a negative valence, for instance, become more accessible after presentation of a negative prime than after a positive prime.

By contrast, because of the large number of positive and negative concepts in semantic memory and the limited amount of activation in the network, some researchers (e.g., Klauer & Musch, 2001; Wentura, 1999, 2000) have claimed that the spread of activation account encounters difficulties, at least as an exclusive explanation of the affective priming effects. Accordingly, Wentura (1999) proposed a *response competition account* for the affective priming effects in the evaluation task. He argued that, in an LD task—on which the spread of activation account was modeled—neither a related nor an unrelated prime favors a response to a higher degree than the target because both related and unrelated primes are real words. On the other hand, in the evaluation task, the prime can also be evaluated. Consequently, when the prime is congruent with the target (e.g., *crime – death*), its valence (negative) matches the response (negative), but, when the prime is incongruent with the target (e.g., *gift – death*), its valence (positive) mismatches the response (negative). Thus, response facilitation might occur for congruent pairs, whereas, for incongruent pairs, the resulting interference might slow down responses.

On the other hand, a reverse pattern has also been introduced in the affective priming literature for the affective priming effects, namely, that incongruent pairs are responded to faster than congruent pairs. One affective priming study conducted by Glaser and Banaji (1999) clearly demonstrates this pattern. Glaser and Banaji (1999) were interested in assessing the automatic effect of prejudicial words with African-American and European-American associations. They adapted a pronunciation task wherein participants simply read the target word aloud, which is claimed to provide a stricter condition of automaticity than the evaluation task. An SOA of 150 ms was also employed to ensure an automatic processing condition. Words associated with African Americans (Black; e.g., *Harlem, basketball*), words associated with European Americans (White; e.g., *Nazi*, *aerobics*), race-neutral food words (e.g., *sweet*, *bitter*), and race-neutral nonfood words (e.g., *agony*, *baby*) served as target words and race-neutral food and nonfood words were used as primes. Thus, food and nonfood words served as both prime and target words.

The results showed the anticipated pattern of priming when food words served as primes: Congruent pairs were responded to faster than incongruent pairs. However, when nonfood words served as primes, an unexpected pattern occurred: Incongruent pairs were responded to faster than congruent pairs; this pattern of reverse priming was stronger when race-related words served as targets. Therefore, with negative and positive food words serving as primes, faster responses were given to negative-Black and positive-White pairs, whereas with nonfood negative and positive words serving as primes, negative-White and positive-Black pairs were responded to faster than negative-Black and positive-White pairs.

To explain this unexpected pattern, Glaser and Banaji argued that food words (e.g., *turnip*, *pear*) were mildly valenced, whereas nonfood words (*cancer*, *paradise*) were extremely valenced.[1] They believed that accuracy motivation was the factor that caused participants to be vigilant for any biasing influence of the prime and to attempt to counteract it; this process likely occurred automatically. Thus, they hypothesized that the reverse priming effects occur when the prime becomes salient and causes the participant to counteract its biasing impact.

To examine this hypothesis, in a second experiment, Glaser and Banaji (1999) used only race-unrelated nonfood words as primes. By varying the saliency of these words, they used moderately valenced words (*hammer*, *horse*) and extremely valenced words (*crash*, *glory*) as primes while maintaining all other features of their first experiment. Thus, targets were Black-associated, White-associated, moderately valenced, and extremely valenced words. The results confirmed the hypothesis that the saliency of the prime determines the direction of priming: With moderate primes, responses were faster to targets preceded by congruent primes, whereas, with extreme primes, faster responses were given to incongruent pairs. Namely, priming effects were different for moderate and extreme primes, suggesting that the saliency of the prime influences the affective priming effects.

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[1] Although Glaser and Banaji (1999) mentioned nothing about the arousal dimension of the words, it seems that nonfood words were highly arousing. According to the authors, on an 11-point scale from −5 to +5, negative and positive food words had average ratings of −1.0 and +1.03, respectively, whereas, on the same scale, negative and positive nonfood words had average ratings of −3.7 and +3.85.

Again, when Black-associated and White-associated words served as targets, the pattern of reverse priming was stronger than when targets were race-unrelated words.

According to Glaser and Banaji (1999), the reverse priming pattern occurs when the saliency of the prime increases and the participant, who is given an accuracy goal, automatically recognizes the biasing influence of the prime and attempts to correct the process. Because it is easier to distinguish the source of valence information when the prime and target are incongruent, faster responses are given to incongruent pairs. By contrast, for congruent pairs, a double-check to ensure that the response is coming from the right source (the target) increases the response time (i.e., *overcorrection effect*).

Thus, the explanation of the reverse pattern of affective priming relies on the response competition account. We encountered a similar effect, which is described in chapter 3.

In semantic research, in addition to the SOA, another factor that may be manipulated to contrast automatic and controlled processing is *related proportion* (i.e., the proportion of related pairs compared with unrelated pairs). When a low related proportion such as 25% (i.e., 25% related pairs vs. 75% unrelated pairs) is used, the experiment is assumed to measure the automatic spreading of activation in the semantic network, whereas, with a high related proportion, the possibility of controlled processing increases (Koivisto, 1998). This difference results because, in the latter condition, the prime is used to generate an expectancy set that includes potential targets. Therefore, if the subsequent target is a member of the expectancy set, lexical decision (LD) is speeded. By contrast, when the target is not included in the expectancy set, the speed of LD is slowed down (Neely, 1991).

To test whether the affective priming paradigm follows the same laws as the semantic priming paradigm, Klauer et al. (1997) manipulated *congruency proportion*[2] (CP; the proportion of congruent pairs to incongruent pairs) and SOA in an evaluation task. In the first experiment, the pattern of affective priming was examined at six SOAs: −100 ms, 0 ms, 100 ms, 200 ms, 600 ms, and 1200 ms. To increase the possibility of priming at long SOAs, a high CP level, 75%, was used. This experiment showed no effect of CP: Priming was found at the two short SOAs, 0 ms and 100 ms, but not at the others. Thus, a rapid decay of activation (after 100 ms) and lack of priming at the SOA of 1200 ms, despite the use of a high CP, were discovered. The authors considered the results consistent with the automatic spreading of activation account, wherein activation is assumed to be an automatic and fast-acting process (Neely, 1977).

To further examine the CP effect, in a second experiment, Klauer et al. (1997) compared three CPs, 25%, 50%, and 75%, at three SOAs: 0 ms, 200 ms, and 1200 ms. The results indicated an anticipated pattern of priming at 0 ms SOA at the CPs of 50% and 75%, whereas, at the SOA of 1200 ms, a pattern of reverse priming occurred only at the CP of 50%. Priming at the 200 ms SOA was not reliable at any CP. Hence, in contast to semantic priming studies, which found that an increase in the related proportion leads to an increase in priming at long SOAs (e.g., Koivisto, 1998), the CP effect was more applicable at the 0 ms SOA. Considering that, at the 0 ms SOA, the prime and target are presented simultaneously, the authors argued that expectancy-based processing cannot occur in this condition; that is, some other mechanism must be involved in the effect discovered at 0 ms

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[2] As in affective priming, stimuli are emotional. Related proportion used in semantic studies is replaced with congruency proportion.

SOA. In addition, they explained the pattern of reverse priming in light of the overcorrection effect mentioned previously.

According to Klauer et al. (1997), the spreading of activation account is not sufficient for explaining the pattern of findings in the affective priming paradigm; namely, the response competition account should also be taken into account.

In the present research project, an affective priming paradigm wherein stimuli were presented laterally was used to examine the pattern of emotional word processing in the LH and RH. The results described in the third and fourth chapters suggest that affective priming can be understood by considering both spreading of activation and response competition accounts.

1.6. Aging, Semantic Processing, and Compensatory Mechanism

Another area of research that has explored access to semantic information is aging. Cognitive research on aging claims that semantic memory (knowledge of word meanings and related concepts) is relatively intact in older individuals (e.g., Park et al., 2002; Salthouse, 1993; see also Light, 1992, for a review). However, the results of some studies suggest that aging is accompanied by deficits in access to semantic information (Birren, Woods, & Williams, 1980; Giaquinto, Ranghi, & Butler, 2007; Hertzog, Raskind, & Cannon, 1986; Karayanidis, Andrews, Ward, McConaghy, 1993; Salthouse, 1982).

While one line of evidence proposes that every stage of information processing diminishes with age, as a result of a *general speed deficit* (Cerella, 1985; Mayerson, Hale, Wagstaff, Poon, Smith, 1990; Salthouse, 1982; see also Salthouse, 1996, for a review), another line of research suggests that aging is associated with a reduction in the amount of attentional resources; that is, automatic processes are relatively spared by the process of aging (e.g., Burke, White, & Diaz, 1987; Hasher & Zacks, 1979; Jennings & Jacoby, 1993). Nevertheless, in the literature on aging, there are reports that show the same pattern of access to semantic information in older and young individuals (e.g., Chiarello, Church, & Hoyer, 1985; Saxton et al., 2001; Stern, Prather, Swinney, & Zurif, 1991).

Some degree of performance variability is conceivable within a normal aging population. Indeed, recent neuroimaging evidence related to possible age-related changes in brain activity has suggested that a pattern of neurofunctional reorganization, namely, Hemispheric Asymmetry Reduction in OLDer Adults (the HAROLD phenomenon; Cabeza et al., 1997) might occur in older individuals with higher levels of education (high-performing older adults). This phenomenon is defined by a more bilateral pattern of activation associated with a given task that occurs in high-performing older individuals compared with young adults.

Cabeza, Anderson, Locantore, and McIntosh (2002) used positron emission tomography technology to examine recall and source memory in three groups of participants: high-performing older, low-performing older, and young adults. Recall and source memory tasks were selected because a previous study in young adults had shown a clear recruitment of the left prefrontal cortex (PFC) in recall and of the right PFC in source memory. The results of the source memory task showed significant activation in the right PFC for young and low-performing older adults, whereas, for high-performing older adults, enhanced activation occurred both in the right and left PFC.

Similarly, in the recall task, enhanced activation occurred unilaterally (left-lateralized) for young and low-performing older adults and bilaterally for high-performing older adults. Given that high-performing older adults performed as well as young participants in the two tasks, the HAROLD phenomenon was considered to have a compensatory function. Therefore, some older individuals were able to improve their performance on a task by recruiting homologous areas of the brain in the opposite hemisphere, in addition to the areas of the hemisphere normally recruited by young adults in that task.

Several studies comparing the performance of young and high-performing older adults on functions such as semantic memory, episodic memory, working memory, and perception have reported data compatible with the HAROLD phenomenon (see Cabeza, 2002, for a review). These studies suggest that a bilateral pattern of activation assists high-performing older adults in improving their performance to the level observed in young individuals. In the second part of this research project, we investigated the possibility that the HAROLD phenomenon is present in the access to emotional word meanings in high-performing older adults. The results are reported in chapter 4.

1.7. General Objectives and Research Program

The purpose of this research program was to gain insight into the ways in which words with emotional meanings are processed in the cerebral hemispheres in young and high-performing older adults. To this end, two studies were conducted. The first study aimed to examine the time course hypothesis in the processing of emotional words in young individuals. To be precise, the first study was designed to determine whether the activation pattern of emotional words in the cerebral hemispheres of young individuals involves early and later activation in the LH and RH, respectively.

The purpose of the second study was to investigate whether compensatory mechanisms occur during access to emotional word meanings in high-performing older adults. While the first study made a prediction that involved a unilateral pattern of activation early and later in the LH and RH, respectively, of young individuals, the second study aimed to determine whether a bilateral pattern of activation would occur both early and later during the course of processing in high-performing older adults. The bilateral pattern of activation was expected to assist high-performing older adults in improving their performance to the level of young individuals.

Because an appropriate account of the differential roles of the LH and RH in emotional word processing using a behavioral methodology was still lacking, this research program employed a behavioral paradigm. Given the results of semantic research that used the priming paradigm, this study used the affective priming paradigm along with an evaluation task in which targets were judged as pleasant or unpleasant. The DVF paradigm was employed to compare priming effects in the LH and RH. Moreover, by recruiting four different SOAs, 0 ms, 150 ms, 300 ms, and 750 ms, priming effects were tracked at different times during the course of processing in the two hemispheres.

The dissertation is organized as follows. The second chapter presents a comprehensive, critical, and synthesized review article that amalgamates the current knowledge about the neurocognitive and neurofunctional bases of emotional word processing. The third chapter consists of an article that reports and discusses the theoretical background, methodology, and results of a study that examined the time course hypothesis in the processing of emotional words in young individuals. The fourth chapter presents a third article discussing the theoretical background, methodology and results of a second study on likelihood that the HAROLD phenomenon occurs in the access to emotional word meanings in high-performing older individuals. Finally, the fifth chapter, after providing an integrated discussion of the results of the first and second studies, discusses the likely nature of emotional word processing and presents possible reasons for the different time course of activation of emotional words in the LH and RH. The fifth chapter also explores future directions, strengths, and limitations of the research.

Chapter 2

This chapter consists of an article that presents data from a large body of research based on behavioral, electrophysiological, and neuroimaging methodologies related to the processing of emotional words in neurologically normal individuals. The data support the dual-process model of automatic versus controlled processing in the LH and RH, respectively.

Processing the Emotions in Words:

The Complementary Contributions of the Left and Right Hemispheres

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Abstract

A dual-process model is suggested for the processing of words with emotional meaning in the cerebral hemispheres. While the “right hemisphere” and “valence” hypotheses have long been used to explain the results of research on emotional stimulus processing including nonverbal and verbal stimuli, data on emotional word processing are mostly inconsistent with both hypotheses. Three complementary lines of research data from behavioral, electrophysiological, and neuroimaging studies seem to suggest that both hemispheres have access to the meanings of emotional words although their time course of activation may be different. The left hemisphere activates these words automatically early in processing, whereas the right hemisphere gains access to emotional words slowly when attention is recruited by the meaning of these words in a controlled manner. This processing dichotomy probably corroborates the complementary roles the two hemispheres play in data processing.

Key words: emotional words, cerebral hemispheres, time course, automatic/controlled

2.1. Introduction

In everyday life, we are constantly surrounded by words conveying emotions. The information conveyed about internal states, beliefs, attitudes, motivations, values, and behaviors makes us feel satisfied or causes us to feel tension or resentment. Words such as *thrifty* vs. *cheap, traditional* vs. *old-fashioned,* or *eccentric* vs. *strange* have similar definitions but carry somewhat opposite emotional meanings. The choice of emotional words completes communication since it expresses the speaker's opinions and feelings, which adds to the semantic referent of a given word, making communication more human. Sometimes, these words capture our attention and move us from one opinion to another. The two features that characterize emotional words are *valence* and *arousal*. *Valence*—or *evaluation*—varies from negative to positive and is defined as a measure of how pleasant or unpleasant a stimulus is,[3] whereas *arousal*—or *activation*—ranges from calm to highly arousing and is defined as a measure of how intensely a person would want to approach or flee from a stimulus[4] (Bradley, Greenwald, Prety, & Lang, 1992; Osgood, Suci, & Tannenbaum, 1957). Research suggests some differences in the processing of emotional words compared to neutral words. Taking into consideration the fact that the left hemisphere (LH) is more efficient at language processing and the right hemisphere (RH) is often reported to be involved in the processing of emotions, the question addressed in this paper is: How do the cerebral hemispheres contribute to the processing of emotional

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[3] Sample words with negative valence: *lonely, poverty, neglect.*
Sample words with positive valence: *bless, reward, elegant.*

[4] Sample high-arousal words that are negative in valence: *assault, betray, horror.*
Sample high-arousal words that are positive in valence: *miracle, thrill, passion.*
Sample low-arousal words that are negative in valence: *bored, gloom, obesity.*
Sample low-arousal words that are positive in valence: *secure, wise, cozy.*

words, which have the attributes both of being a part of language and of being emotional? If both hemispheres are involved in the processing of emotional words, what is the role of each one, assuming they make complementary contributions?

Since the role of the cerebral hemispheres in the processing of emotional words as part of the semantic system is still unclear and disputable in many respects, the present review will summarize existing behavioral, electrophysiological, and neuroimaging studies related to the processing of emotional words in neurologically intact individuals, with an emphasis on identifying the contributions of the LH and RH to this type of processing. To this end, the first section reviews behavioral data in the field of emotional word processing, followed by the findings of semantic studies that suggest the possibility of a different time course of activation for some parts of the semantic system due to the automatic vs. controlled nature of processing governed by the LH and RH. In the next two sections, electrophysiological data that tend to support the dual-process model of automatic vs. controlled and neuroimaging data that appear to clarify the role of the hemispheres in this dichotomy are reported.

2.2. Behavioral Data on Emotional Word Processing

In the past decades, there has been a growing interest in the role that channels for conveying emotions (i.e., facial, prosodic, and verbal) play in human communication. Reviewing literature on the lateralized effect of these channels indicates that research results in almost all three areas have been compared with the two hypotheses of the RH and the valence. The RH hypothesis which has been supported especially in the studies that compared the performance of brain-damaged individuals to that of normal controls suggest that the RH has a greater role in the processing of emotional information than the LH (e.g., Adolphs, Damasio, Tranel, & Damasio, 1996; Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Cicero et al., 1999; Sim & Martinez, 2005; Windmann, Daum, & Gunturkun, 2002; see also Borod, 1992, for review) whereas the valence hypothesis states that hemispheric biases in the processing of emotional information may depend on the valence of the emotion conveyed by that information (e.g., Davidson, 1992; Jansari, Tranel, & Adolps, 2000; Silberman & Weingartner, 1986; Sutton & Davidson, 1997; Van Strien & Morpurgo, 1992). In general, while the RH hypothesis attributes comprehension, experience, and expression of emotions to the RH irrespective of valence, the valence hypothesis holds that there is differential hemispheric specialization for these processes, with the LH being more involved in positive emotions and the RH in negative emotions.

It needs to be mentioned here that more recent emotion research introduces a synthesis theory of emotion which has sometimes been referred to as circumplex theory. The main feature of this theory is that it considers not only the effect of valence but also the level of arousal that an emotional stimulus can raise (Russell, 1980, 2003). Researchers investigating this view to map neural systems involved in emotions, by employing other methodologies than behavioral such as electrophysiological, have proposed that frontal regions of both hemispheres and parietotemporal region of the RH constitute a system involved in the *experience* of, respectively, valence and arousal aspects of emotions (e.g., Heller, 1993). The anterior regions are also involved in the *expression* of emotions according to valence; this theory attributes the *comprehension* of emotions to the posterior part of the RH (Davidson, 2003).

While the two hypotheses of the RH and the valence appear to provide a good framework for explaining the results regarding the nonverbal components of emotional communication (i.e., facial expressions and prosody) (e.g., Adolphs et al., 1996; Bryson, McLaren, Wadden, & McLean, 1991; Carmon & Nachshon, 1973; Etcoff, 1989; Kimura, 1964; Ley & Bryden, 1979; Mahoney, & Sainsbury, 1987), they do not seem to adequately explain what occurs in the area of emotional word processing (e.g., Collins & Cooke, 2005; Eviatar & Zaidel, 1991; Graves, Landis, & Goodglass, 1981; Nagae & Moscovitch, 2002; Strauss, 1983).

The first attempt to study the lateralized processing of emotional words was made by Graves et al. (1981) in the early 1980s. These researchers addressed the processing of emotional words in neurological intact individuals using the *divided visual field (DVF) paradigm*. In the DVF paradigm, stimuli are presented for a brief duration (normally less than 200 ms) to the right visual field (RVF) or the left visual field (LVF) and are considered to be initially processed by the LH and the RH, respectively. The logic underlying this technique is based on the main feature of the visual system: the primary pathways from each visual field are crossed and reach the opposite hemisphere. In Graves et al.'s (1981) study, emotional words (e.g., *fear*, *love*) presented for 150 ms in the RVF (LH) or in the LVF (RH) were processed more accurately than neutral words in the LVF.

Strauss (1983) examined the two hemispheres' contributions to the processing of emotional words in two experiments. Because the preliminary data showed better results with shorter exposure durations, Strauss decreased the exposure duration to 25 ms in the first experiment and 50 ms in the second experiment. In both experiments, emotional and neutral words were recognized more accurately when presented to the RVF. Strauss interpreted this finding as supporting the view that the LH plays a greater role in the processing of verbal information, regardless of the emotional content.

In contrast to the two above-mentioned studies, Eviatar and Zaidel (1991) failed to demonstrate a significant difference in processing in favor of either hemisphere with an exposure duration of 80 ms. Thus, the results of the latter two studies fitted neither the RH hypothesis nor the valence hypothesis. Supposedly, relatively short exposure durations (25 ms and 50 ms) showed an LH role (Strauss, 1983), while a relatively longer exposure duration (150 ms) yielded an RH effect (Graves et al., 1981); with an intermediate duration (80 ms), the effect of the hemispheres was balanced (Eviatar & Zaidel, 1991).

Similarly, a study carried out by Ali and Cimino (1997) yielded results that were not completely consistent with either hypothesis. In a lexical decision task, emotional words (positive and negative), neutral words, and nonwords were presented for 150 ms to either visual field (i.e., perception task); after a 20-minute delay, participants were asked to recall as many real words as they could (i.e., recall task). After that, participants were given a list of all the real words intermixed with the same number of new words and were asked to circle the words that they had seen previously (i.e., recognition task).

The results of the perception task indicated greater accuracy only for positive words in the RVF but not for negative words in the LVF. Analysis of the correct responses to the recall task also showed greater recall of positive words in the RVF but not of negative words in the LVF. In the recognition task, however, accuracy for positive words was higher in the RVF and accuracy for negative words was higher in the LVF. Since only the results of the recognition task were consistent with the valence hypothesis, the authors suggested caution when interpreting the results in favor of this hypothesis.

In the past decade, in order to explain the inconsistent results of behavioral research, researchers attempted to demonstrate that both hemispheres are involved in emotional word processing but in varying ways (Nagae & Moscovitch, 2002; Collins & Cooke, 2005). Accordingly, Nagae and Moscovitch (2002) argued that *memory* of emotional words emerges in the RH whereas *perception* of these words occurs in the LH. They believed that lateralization studies based on the most common method for implementing the DVF paradigm, in which participants respond to each stimulus immediately after it is presented, examine primarily the perception of these words. This methodology would obscure the RH's contribution to the memory of emotional words.

In an attempt to separate the effects of memory from those of perception, Nagae and Moscovitch (2002) employed a DVF task in which a number of words were presented successively for 180 ms to participants in each block; at the end of the block, participants were asked to recall the words (experiment 1). This method was compared with a more standard DVF paradigm in which stimuli were presented for 40 ms to each visual field (experiment 2). The results of experiment 1 revealed the same accuracy rate for emotional words across visual fields, along with a larger difference between the accuracy of emotional and neutral words in the LVF. The results of experiment 2 demonstrated better performance in the RVF for both emotional and neutral words. Hence, the modified methodology yielded only a larger emotional/neutral accuracy difference in the LVF, which was due to the worse recall of neutral words presented in the LVF.

Following Nagae and Moscovitch's (2002) idea that the LH and RH contribute to emotional word processing at two different levels, Collins and Cooke (2005) aimed to separate the effect of *conceptual processing* of emotional words, occurring in the RH, from that of *perceptual processing,* emerging in the LH. After encoding the surface features (experiment 1) and semantic features (experiment 2) of emotional words, participants completed a lexical decision task incorporating words from the encoding task along with some new words. Thus, for the perceptual encoding task, participants first counted the number of long straight-lined strokes in each word and then performed a lexical decision task in which emotional and neutral words that had been presented in the encoding task and an equal number of unprimed words were presented to each visual field.

For the conceptual encoding task, participants first generated a word from the cues provided in a sentence that described that word (e.g., *jail*) and then performed a lexical decision task in which reaction times to the associates of the encoded words (e.g., *prison*) were contrasted with reaction times to an equal number of new words. The results of the perceptual experiment indicated an overall RVF advantage in reaction times to primed emotional words relative to unprimed words. In the conceptual experiment, however, there was a processing advantage only for primed positive, but not negative, words in the LVF. The latter result, therefore, did not support the role of the RH in the conceptual processing of emotional words, as hypothesized by the authors.

A review of behavioral research does not identify any further DVF studies that sought to clarify cerebral contributions to the processing of emotional words. Although the idea of Nagae and Moscovitch (2002) on the contribution of the two hemispheres is relatively innovative, a distinction between *perception* and *memory* or *perceptual processing* and *conceptual processing* do not seem to effectively capture the differential roles of the two hemispheres in emotional word processing. Yet, one implication of their idea is that the RH comes into play later than the LH. It means that the *time*, itself, may be a factor that differentiates the role of the cerebral hemispheres in emotional word processing. As comes in the next section, semantic literature provides evidence for the slow activation of the RH.

Since emotional words are part of the semantic system, research findings in the field of semantics may offer some insight into the role of each hemisphere in emotional word processing. According to the results of semantic research, instead of one semantic system shared by the two hemispheres, each hemisphere has its own semantic system which is activated in different circumstances (Chiarello, 1991, 1998, for review). If it is the case that each hemisphere has its own semantic system, then this may be the reason why the RH and the valence hypotheses, which attribute the processing of emotional words to one of the two hemispheres, are inadequate in explaining the results of this line of research. Therefore, to resolve the discrepancies in the research results, it may be necessary to consider a different theoretical perspective that reflects different profiles of the two hemispheres during emotional word processing. A review of semantic research should guide us to the right path.

2.3. Hemispheric Asymmetries in Semantic Processing

Lateralized semantic research suggests the idea that the LH and RH represent parallel and distinct information processing systems, each contributing in some way to nearly all linguistic behaviors (Chiarello, 2003, for review). The most compelling evidence supporting this idea comes from the study of split-brain patients (Sperry, Gazzaniga, & Bogen, 1969). The real breakthrough supported by these studies was to conclusively demonstrate that each isolated hemisphere represents a complete information processing system; that is, each isolated hemisphere has its own perceptual experiences, memories, semantic system, and the ability to select appropriate behavioral responses (Sperry et al. 1969; Sperry, Zaidel, & Zaidel, 1979).

Likewise, numerous studies with normal participants using *the DVF priming paradigm* have demonstrated that word meanings are accessed within each hemisphere, but not necessarily in the same way (see Chiarello, 1991; 1998, for review). In the DVF priming paradigm a prime and a target word are presented to visual fields and priming effects consist in speedier processing of the target when it is related to the prime. The main feature of this paradigm is that, by manipulating the time elapsed between the presentation of the prime and the target, namely the *Stimulus Onset Asynchrony or SOA,* information on the activation of the target at different times during processing can be extracted. This line of research seems to suggest for some part of the semantic system time is a factor that differentiates activation pattern of words in the cerebral hemispheres.

To explore the availability of the dominant meaning (e.g., *money* as target) and subordinate meaning (e.g., *river* as target) of ambiguous words (e.g., *bank* as prime) in the cerebral hemispheres, Burgess and Simpson (1988) used SOAs of 35 and 750 ms. Although they found equal priming of dominant meanings at both SOAs across hemispheres, subordinate meanings were primed at the 35-ms SOA only in the LH and at the 750-ms SOA only in the RH. Burgess and Simpson described this pattern of data based on the dual-process model of word processing that differentiates between *automatic and controlled processing* (Collins & Loftus 1975; Posner & Snyder 1975). That is, subordinate meanings become activated in the LH automatically, but this activation is suppressed over time. After that, activation occurs in the RH, probably because some time is required to allocate attention to meanings for which the RH is responsible.

Later research revealed a similar pattern of activation for the processing of distantly related category pairs (e.g., *deer – pony*). First, Chiarello, Burgess, Richards, and Pollock, (1990) using a relatively long SOA (575 ms), found priming effects only in the RH. Conversely, in the study carried out by Abernethy and Coney (1993), priming of such pairs occurred only in the LH at an SOA of 250 ms. In their study, a bilateral pattern of priming effects was observed when an intermediate SOA of 450 ms was employed. When Abernethy and Coney (1996) further examined their results with the 250-ms SOA (Abernethy & Coney, 1993) through cross-hemispheric presentation of stimuli, they found that presentation of a prime to the LH facilitated processing of a target subsequently presented to the RH, whereas presentation of a prime to the RH did not facilitate processing of a target subsequently presented to the LH. This finding indicated that the RH is slow at activating distantly related category pairs.

The observed pattern of priming at the 450-ms SOA added to the previous data on the possibility of shifting activation from the LH to the RH over the course of processing. Nevertheless, a conclusive comparison of short, intermediate, and long time courses was presented in the study carried out by Koivisto (1997), which employed four different SOAs: 165 ms, 250 ms, 500 ms, and 750 ms. This study found priming effects only in the LH at the shortest SOA (165 ms) and only in the RH at the longest SOA (750 ms). Moreover, at the 250-ms SOA, there was nonsignificant priming in the LH and no priming in the RH, while at the 500-ms SOA, there was less priming in the LH than in the RH.

Koivisto interpreted the results as indicating a difference between the time courses of activation in the cerebral hemispheres for distantly related category pairs.

The above-mentioned pattern of priming has been described in the *time course hypothesis* (e.g., Koivisto, 1997, 1998); it seems to have implications for emotional word processing. Namely, semantic research suggests that, in the processing of some parts of the semantic system, the time course of activation is a determining factor that differentiates automatic processing in the LH from controlled processing in the RH. As a piece of evidence, the *automatic evaluation hypothesis* suggests that the emotional value of words is extracted quickly and automatically (Fazio, Sanbonmatsu, Powell, & Kardes, 1986); this automatic stage is probably followed by a later stage in which attention is directed to the emotional content to guarantee an adaptive behavior (Naumann, Bartussek, Diedrich, & Laufer, 1992).

Thus, it is possible that the dual-process nature of automatic vs. controlled governs emotional word processing in the cerebral hemispheres. To be clearer about the two key concepts, automatic processing which likely occurs in the LH (Koivisto, 1997, 1998) activates nodes in memory, but does not modify long-term memory. Hence, it does not place much demands on processing resources (Fisk & Schneider, 1984). In contrast, controlled processing, which probably takes place in the RH (Koivisto, 1997, 1998), is slow and sensitive to a task difficulty. Thus, it includes effortful memory search and is under one's active control (Schneider & Shiffrin, 1977). Due to the depth of processing and contribution of processing resources, the concepts of early and later stages of processing are also used for automatic and controlled processing, respectively (Posner & Peterson, 1990).

It should also be noted that recent emotion research has differentiated between two notions related to automatic processing, namely, *strongly automatic* and *weakly or partially automatic*. Strongly automatic implies independence from top-down factors, for example, as is assumed to occur during subconscious processing. There is some evidence suggesting that this type of automatic processing is supported by subcortical pathways. By contrast, weakly or partially automatic refers to task-irrelevant or involuntary processing in which some amount of processing is obligatory, but still modifiable by attention (e.g., see Pessoa, 2005, for a review). The type of automatic processing considered in this review is mostly equivalent to the latter definition of automaticity.

In the next two sections, we present electrophysiological and neuroimaging data of emotional word processing that seem to offer insight into the dichotomy of automatic vs. controlled processing and the hemisphere where each process likely takes place.

2.4. Electrophysiological Bases of the Emotional Processing of Words

ERPs constitute valuable tools to assess how fast the emotional content of words is processed (e.g., Bernat, Bunce, & Shevrin, 2001; Scott, O'Donnell, Leuthold, & Sereno, 2009). This technique is capable of reflecting different stages of processing in real time as fast as in milliseconds. Presumably, ERP studies that have used emotional words as their stimuli have not sought evidence supporting the two hypotheses of emotions. They have not mostly intended to reveal lateralized effects either (see Kissler, Assadollahi, & Herbert, 2006, for review). The reason ERP studies use emotional words is likely due to the speed of their processing and also the different way that these stimuli attract participants' attention. To be explicit, the most significant contribution of ERP findings is to provide evidence for the dual-process model of automatic vs. controlled in emotional word processing (Franken, Gootjes, & Strien, 2009; Van Hooff, Dietz, Sharma, & Bowman, 2008). Moreover, while in this method stimuli are mostly presented centrally, this line of research seems to attribute lateralized effects of automatic vs. controlled processing, when available, to the left and right scalp regions, respectively.

Most ERP deflections are referred to by the preceding letters of P and N, which indicate polarity and are followed by a number that indicates either a peak's position within a waveform (e.g., P3) or its latency in milliseconds (e.g., P300). ERP components of emotional words can be categorized into: a) early components that appear within 300 ms of the stimulus onset, and b) later components that appear more than 300 ms from the stimulus onset.

The P300 is a component that has also been reported in ERP studies of emotional words. This component, which is greater along the midline centroparietal scalp region, typically emerges when participants attend to and discriminate stimuli, whether emotional or neutral, which are different in some aspect (e.g., De Pascalis, Strioppoli, Riccardi, & Vergari, 2004; Isreal, Chesney, Wickens, & Donchin, 1980; Naumann, Maier, Diedrich, Becker, & Bartussek, 1997; Naumann et al., 1992;).

Related to the P300 component is the late positive component (LPC), which appears during the processing of emotional words around 500 ms after the stimulus onset; for instance, it is seen when a negative word is embedded in a sequence of positive words, but not when a positive word is embedded in a sequence of positive words, and the stimuli are presented one by one to the participant. The participant's task is to respond to the emotional feature of stimuli by, for instance, counting the number of negative words (e.g., Cacioppo, Crites, Gardner, & Berntson, 1994). The distribution of the LPC has been shown to be more extensive over the right scalp regions (Cacioppo, Crites, Gardner, 1996). Attention recruited by the emotional feature (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000), mental imagery activated by emotional words (Kanske & Kotz, 2007) and semantic cohesion of the category of emotional words (Dillon, Cooper, Grent-'t-Jong, Woldorff, & LaBar, 2006) have been suggested to contribute to producing the LPC effect. The differential effect of the LPC, as compared to the P300, supposedly demonstrates that emotional words recruit attention differently from neutral words (Compton et al., 2003).

The N400 is also a later ERP correlate but with a negative deflection that is generally greater over centroparietal regions of the RH (e.g., Kutas & Hillyard 1980, 1984). Although the N400 is an appropriate ERP correlate to assess semantic processing, it has not been widely reported in the processing of emotional words. That is probably because the N400 emerges when new semantic information is integrated into a memory context. Where a smaller amplitude means facilitation of a process, decreased amplitude of the N400 likely indicates facilitated processing of emotional words due to their emotional content (Kanske & Kotz, 2007). It is reasonable, however, to think that incongruency of emotional valence, such as what occurs in the affective priming paradigm, would result in the N400 component.

The *affective priming paradigm* is a variant of the semantic priming paradigm in which a target word with emotional meaning is preceded by an emotional prime word. Behaviorally, affective priming is indicated if the time needed to evaluate the target is significantly shorter when the prime and the target share the same valence (i.e., congruent pairs: *crime – death*) than when prime and target are of opposite valence (i.e., incongruent pairs: *crime – reward*) (Fazio et al., 1986). Similar to the LPC effect, ERP evidence from the affective priming paradigm has taken the form of an extended latency of the N400 (around 600 ms) in RH electrode sites in response to incongruent pairs (Zhang, Lawson, Guo, & Jiang, 2006). This observation suggests the more intense effect of the violation of expectations in the affective priming paradigm compared to the semantic priming paradigm (e.g., Holcomb, 1988).

Research suggests that late ERP effects are subject to interference from task demands (e.g., Fischler & Bradley 2006; Naumann et al., 1992, 1997). This characteristic is considered to be evidence of the controlled nature of the later components. For instance, Fischler and Bradley (2006) contrasted the effects of different encoding tasks in a series of five experiments and observed a different pattern of ERP effects for each one. When the task was the evaluation task (i.e., identifying whether the word was unpleasant or pleasant), the LPC emerged in response to both negative and positive words. When an emotional decision task was employed (i.e., identifying whether the word was emotional or not), the N400 and the LPC were observed in response to both negative and positive words.

When the task was changed to a silent reading task, the magnitude of the LPC decreased but it was still significant in response to both negative and positive words. With a semantic category task (i.e., the emotionality of stimuli was not the focus), the LPC was found only for negative words, and with a lexical decision task no ERP effect was detected for any of the stimuli. According to Fischler and Bradley (2006), the semantic task probably yielded the ERP effect for negative words because it taps a rather deeper level of stimulus analysis and therefore the negative words' greater ability to attract attention was retained. In contrast, in the lexical decision task, in which a relatively superficial level of semantic analysis is required, the effect of emotionality was undetected.

On the other hand, ERP studies of emotional words have also reported components that occur within 100 ms of stimulus onset (e.g., Bernat et al., 2001; Scott et al., 2009; Van Hooff et al., 2008). In fact, a traditional view in the ERP literature holds that no meaning-related deflection appears within the first 200 ms after word onset (see Kissler et al., 2006, for review). Accordingly, some researchers argue that the ERP effects of emotional words that appear within the first 100 ms of stimulus onset, that is, the P1 and N1, are particularly controversial (e.g., Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Winkler, & Junghofer, 2009). Kissler et al. (2006) believe that the earliest effects are more pronounced in clinical populations such as depressed individuals, who are more sensitive to unpleasant materials.

Yet, in studies of emotional words, there are reports that the ERP correlates appear even within the first 100 ms post-stimulus onset in healthy individuals (e.g., Bernat et al., 2001; Scott et al., 2009; Van Hooff et al., 2008). A combination of high arousal, negative valence, and high frequency causes the earliest effects to appear readily in a non-demanding task such as a lexical decision task. Supposedly, high-arousal stimuli that are frequent are processed faster than low-arousal frequent stimuli, and valence gives priority to negative stimuli, probably because of the unpleasant consequences that negative material tends to have in the real world (Scott et al., 2009). This finding also supports the automatic evaluation hypothesis that states emotional words are processed early and automatically (Fazio et al., 1986).

One more ERP effect that demonstrates the early activation of emotional words is the early posterior negativity (EPN) which has recently been reported by several studies (e.g., Franken et al., 2009; Herbert et al., 2008; Kissler et al., 2009; Kissler, Herbert, Peyk, & Junghofer, 2007; Scott et al., 2009). This negative potential occurs in posterior scalp regions, 200 to 300 ms after word onset for both negative and positive high-arousal words. It has been attributed to the arousal feature of emotional words and appears predominantly in the left occipitotemporal region, (Kissler et al., 2007). In most of the studies, the EPN occurred during silent reading, that is, when emotional words were viewed passively without any explicit instruction to attend to their emotional content, which suggests that this component is automatic. That is to say, the emotional attribute of words are processed automatically upon presentation.

A stronger piece of evidence for the automatic processing of emotional words, as indicated by the appearance of early components such as P1, N1, and EPN, seems to be provided by the emotional Stroop task[5], which primarily taps an attentional process (Franken et al., 2009; Van Hooff et al., 2008). In the emotional Stroop task, naming the color of an emotional word takes longer than naming the color of a neutral word which reflects the fact that attention is captured by the emotional content of words (Williams, Mathews, & MacLeod, 1996). Thus, in such a task in which the emergence of the later components is the anticipated outcome, the appearance of the early, along with the later,

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[5] The emotional Stroop task is a version of the standard Stroop task (Stroop, 1935) in which participants are required to respond to the ink color of a color word while ignoring its meaning (e.g., the word *green* written in red ink). Since reading is an automatic process, naming the color in which a word is written requires the allocation of attention and, hence, causes longer naming times (the Stroop effect). Similarly, in the emotional Stroop task, naming the color of an emotional word takes longer than naming the color of a neutral word (the emotional Stroop effect). This effect reflects the fact that attention is captured by the emotional content of words (Williams et al., 1996).

ERP components validates the dual-process nature of emotional word processing: both automatic and controlled processes are involved in this process.

Among the ERP data on emotional words, there are also clues to a shift of activation from the LH to the RH (Bernat et al., 2001; Ortigue et al. 2004). One study that offers spatiotemporal evidence for such a shift was conducted by Ortigue et al. (2004); it employed a DVF technique along with a go/no-go lexical detection task. A word (either emotional or neutral) and a nonword, or else two nonwords, were presented to the visual fields and participants were asked to respond when they saw a word in either visual field. Overall, performance with emotional words presented in the RVF was better than emotional words presented in the LVF or neutral words presented in either visual field. Early differentiation of emotional vs. neutral word processing occurred over the 100- to 140-ms post-stimulus period when the scalp topography of emotional words presented to the RVF demonstrated bilateral activity of lateral-occipital substrates with more activation in the RH. The scalp topography of other conditions, however, revealed activity in similar substrates but mainly in the LH. This finding seems compatible with the predictions of the time course hypothesis, which implies a shift of activation from the LH to the RH while semantic information is processed (e.g., Burgess & Simpson 1988; Koivisto, 1997, 1998).

In summary, ERP studies that use emotional words as stimuli suggest the involvement of an early automatic and a later attention-demanding stage in the course of emotional word processing. While later components that are mostly the hallmark of attention to the content of emotional words are subject to interference from task demands, earlier components appear automatically upon presentation of these words. This processing pattern is consistent with the dual-process model mentioned in the time course hypothesis, namely early automatic vs. later controlled processing. Although the lateralized data provided by ERP methodology mostly show that the earlier and later components can be linked to the left and right electrode sites, respectively, neuroimaging data provided by techniques such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) should offer further insight into the locations where the automatic and controlled processes might take place.

2.5. Neuroimaging Data on Emotional Word Processing

Neuroimaging techniques detect metabolic/hemodynamic changes in the brain and, consequently, localize the regions involved in a neural process. In this method, the brain can not be scanned faster than once every 2 to 3 seconds. However, taking into account the role that the type of task (e.g., implicit tasks such as silent reading vs. attention-capturing tasks such as the emotional Stroop) plays in instigating a particular level of processing, imaging data may be able to differentiate between the structures that are involved in the automatic vs. controlled stages of processing and whether the enhanced activation is lateralized to the LH or RH. In reality, the basic idea is that implicit tasks discourage the analysis of word meanings and therefore if, in this condition, increased activation is obtained, it is likely derived from automatic activation of word meanings. Explicit tasks, in contrast, encourage a deep level of processing which involves the processing of the semantic aspects of presented words (Chwilla, Brown, & Hagoort, 1995).

In general, increased neural activity in an extensive part of the brain is a normal outcome when words, including emotional words, are presented. One observation in neuroimaging studies that compare the neural substrates involved in the processing of emotional and neutral words is enhanced activation in the areas of the LH that are primarily associated with the semantic properties of words. The inferior frontal gyrus (i.e., Brodmann areas 44 and 45) is an example of the regions that respond to almost all words (Nakic, Smith, Busis, Vythilingam, & Blair, 2006). Enhanced activation in the left temporal and occipital regions is also an inseparable part of word recognition (Beauregard et al., 1997). This is especially important because the LH is dominant in word processing and emotional words like neutral words are part of the semantic system. This observation, hence, challenges the idea that the RH is solely responsible for emotional word processing (i.e., the RH hypothesis).

However, emotional words trigger activation in other areas of the LH such as the amygdala, orbitofrontal cortex and posterior cingulate gyrus, as well. These regions have been claimed to be part of the limbic system (see Fig. 2.1), which plays a key role in emotion processing (Beauregard et al., 1997). In view of this fact, imaging studies of

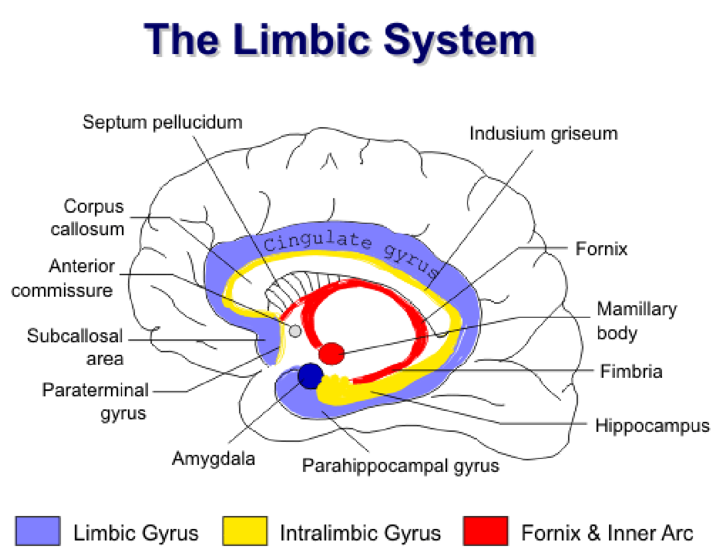

Figure 2.1. The structure of limbic system in the brain. Adapted from *Clinical Magnetic Resonance Imaging* (p. 1370), by R. R. Edelman, J. R. Hesselink, M.B. Zlatkin, & J. Crues, 2006 (Eds.), Philadelphia: Elsevier-Saunders. Copyright 2010 by E. Abbassi. Adapted with permission.

emotional word processing probably demonstrate intercorrelation between neural structures whose activation is caused by semantic features of emotional words and neural structures whose activation is triggered primarily in response to these words' emotional attributes. These structures appear to come into play earlier in processing with less demanding tasks and their activation is most likely lateralized to the LH (e.g., Costafreda, Brammer, David, & Fu, 2008; Luo et al, 2004; Kuchinke et al. 2005).

Among the structures of the limbic system, the amygdala is the most-studied structure that plays a pivotal role in the processing of emotional stimuli. Since studies that examined the processing of nonverbal emotional stimuli (e.g., facial expressions, pictures) have repeatedly claimed a central role for the amygdala in negative emotions such as fear (e.g., LeDoux, 2000), some emotional word studies have simply focused on the neural activity changes in the amygdala in response to words with negative meanings (e.g., Isenberg et al., 1999; Strange et al., 2000; Tabert et al., 2001). However, the association between the amygdala and negative words may not be exclusive, as indicated by studies that have reported reliable activation of the amygdala in response to positive words (Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; Hamann, & Mao, 2002; Herbert et al., 2009). This finding probably corroborates the role of the arousal dimension in engaging activation in the amygdala (Elliott, Rubinsztein, Sahakian, Dollan, 2000). The disproportionately high response to negative stimuli probably occurs because negative and positive stimuli differ in their functional significance; in other words, a fast reaction to negative stimuli has vital consequences for the organism (Smith, Cacioppo, Larsen, & Chartrand, 2003).

The available data most likely suggest that this structure becomes activated upon presentation of emotional words. As one proof for this claim, research has shown a strong correlation between the pattern of activation in the amygdala and the occipital cortex during silent reading (Tabert et al., 2001). This observation probably supports the notion that the amygdala modulates the processing of visual information in the occipital cortex via feedback projections. Indeed, some researchers believe that the amygdala influences emotional processes via projections back to all levels of the visual cortex that exceed the effects of the emotional input received by the visual cortex. These connections may have the advantage of making the visual cortex more sensitive to emotional stimuli (Amarel, Price, Pitkanen, & Carmichael, 1992).

Further evidence suggesting that activation in the amygdala occurs without placing much demand on processing resources comes from studies that did not report activation in this structure when attention-demanding tasks were performed. For example, during a go/no-go evaluation task in which participants responded to, for instance, positive words and inhibited their responses to negative words, activation in the amygdala was reported to be negligible (e.g., Elliott et al., 2000). In a similar vein, in a meta-analysis study carried out by Costafreda et al. (2008) implicit tasks were associated with a higher probability of activation in the amygdala than explicit tasks, suggesting the role of this structure in early processing of emotional stimuli.

Concerning the amygdala's laterality, although a right-lateralized pattern of activation (Maddock, Garrett, & Buonocore, 2003) and also a bilateral pattern (Isenberg et al., 1999) have been reported, what has been mostly detected is a left-lateralized effect (e.g., Hamann & Mao, 2002; Maratos, Dolan, Morris, Henson, & Rugg, 2001; Strange et al., 2000). Two recent meta-analyses of emotional stimuli processing have also provided support for a pattern of left-lateralized activation in the amygdala (Bass, Aleman, & Kahn, 2004; Wager, Phan, Liberzon, Taylor, 2003). Since a pattern of increased activation in the left amygdala has also been observed in nonverbal emotional studies (e.g., Hamann, 2001), Hamann and Mao (2002) argue that the left-lateralized effect of the amygdala during emotional word processing is more likely due to an advantage for the processing of emotional stimuli, in general, rather than the verbal aspect of emotional words. Costafreda et al.'s (2008) meta-analysis, in contrast, poses the possibility that the left-sided advantage of the amygdala is due to the verbal nature of emotional words. This discrepancy can be an open question for future research.

The likely role of the *left* amygdala in automatic processing of emotional words can also be deduced from the way high-frequency, high-arousal words are processed. As mentioned above, enhanced activation in the left inferior frontal lobe has been observed in response to almost all words. The exception is high-frequency, high-arousal words. That is, the left inferior frontal region responds to low-frequency, high-arousal words but not high-frequency, high-arousal words. This finding suggests that the semantic representations of high-frequency, high-arousal words receive sufficient augmentation from the amygdala that additional augmentation by the inferior frontal lobe is unnecessary (Nakic et al., 2006). Bearing in mind from the ERP findings that high-frequency negative-arousal words are responded to within 100 ms after word onset (Scott et al., 2009), the role of the left amygdala in the automatic stage of processing, in which activation occurs rapidly and without much effort, becomes more likely.

On the other hand, the privileged processing status of emotional words, such as the role that their meanings play in boosting memory (e.g., Kensinger & Corkin, 2003), seems to call on more structures. Indeed, the limbic system, which forms the inner border of the cortex, includes portions of all the lobes of the cerebral hemispheres. If this system contributes to various functions, including interpreting emotional responses, recruiting attention, storing memories and learning, it is probably due to some additional connections that serve to regulate emotional and cognitive processes (see Bush, Luu, & Posner, 2000, for review). These connections may conceivably receive their activation later in processing via controlled attention when the role of the RH becomes more prominent (Strange, Henson, Friston, & Dolan, 2000).

Presumably, a connection between emotion-related structures of the limbic system such as the amygdala, on one side, and attention-related structures such as anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (DLPFC), on the other side, is essential in the elaborated processing of emotional words. Accordingly, the ACC and DLPFC are considered as part of the cognitive system (see Vuilleumier, 2002, for a review). For instance, the ACC is part of the prefrontal cortex and has two subdivisions: cognitive and affective. Recent research demonstrates that cognitive and emotional information are processed in this structure separately but interdependently. The cognitive subdivision is part of a distributed attentional network that has reciprocal connections with the lateral prefrontal cortex, parietal cortex, and supplementary motor cortex and plays a role in the modulation of attention. In contrast, the affective subdivision (i.e., posterior cingulate cortex) contributes to the detection of the emotional features of input. Thus, the type of arrangement of the two parts of the ACC implies, to some extent, a neural basis for the interaction between emotion and attention (see Bush et al., 2000, for a review).

By attention, we mean *active* attention which is a controlled process and is guided by concentration, interest and needs. This type of attention obviously involves effort and includes selecting what we should be attending to and ignoring what we don't want to attend to (Gaddes & Edgell, 1994). Accordingly, it is likely that in emotional word processing, the role of attention is to encourage a later stage of processing by enhancing the effect of an earlier stage (Lane, Chua, & Dolan, 1999). It can be the reason why the activation shifts from the LH to the RH (Koivisto, 1997, 1998).

As previously mentioned, the interaction between emotion and attention has generally been studied by using the emotional Stroop task (Williams et al., 1996). Imaging studies have reported enhanced activation of the right ACC during performance of this task (Casey et al., 1997; Pardo, Pardo, Janer, & Raichle, 1990). This finding is also consistent with the right-lateralized effect of the emotional Stroop task indicated by the behavioral methodology (Compton, Heller, Banich, Palmier, & Miller, 2000). Research has even demonstrated the engagement of a common system in the RH for maintaining attention to the color of emotional words and incongruent color words in the emotional Stroop task and the standard Stroop task, respectively. This finding seems to support the role of the RH in attention-demanding tasks in general (Compton et al., 2003).

Likewise, there are extensive data in the literature concerning the right-lateralized effect of attention-demanding tasks. For instance, research demonstrates improved levels of activity in structures such as the right prefrontal and superior parietal regions when participants focus and maintain their attention on sensory signals that are input into the brain (e.g., Anderer, Saletu, Semlitsch, & Pascual-Marqui, 2003; Molina et al., 2005; Pardo, Fox, & Raichle, 1991; Strange et al., 2000). In addition, neglect that is claimed to be the result of damage to the attentional system in the brain occurs primarily after lesions to the RH (e.g., Driver, & Vuilleumier, 2001; Heilman & Van den Abell, 1980; Heilman, Watson, & Valenstein, 1985). These findings are not only consistent with the notion that components of human attention are right lateralized (e.g., Whitehead, 1991) but also raise the possibility of a correlation between the RH's role in the processing of emotions repeatedly reported in literature (i.e., the RH hypothesis) and its role in attention-demanding processes (e.g., Casey et al., 1997; Compton et al., 2000, 2003).

Taken together, the enhanced brain activation over the course of processing of emotional words demonstrated by neuroimaging methodology appears to occur in both the LH and RH. In the LH, the processing of emotional words not only creates activation in the semantic areas but also in the structures of the limbic system such as the amygdala for which there is more number of reports in favor of the LH. This level of activation is probably automatic because it is instigated primarily by implicit tasks. On the other hand, explicit processing of emotional words is likely along with enhanced activation in some other structures such as ACC and DLPFC which are considered as part of the attention system in the brain. The activation in these structures seems to be right-lateralized and occurs when attention is directed to the content of emotional words. Overall, the left- vs. right-lateralized processing of emotional words seems consistent with the predictions of the time course hypothesis that assigns automatic processing of semantic information to the LH and controlled processing to the RH.

2.6. Conclusion

The purpose of this paper was to provide a comprehensive and critical synthesis of current knowledge of the neurocognitive and neurofunctional bases of the processing of emotional words. The data from a large body of research based on behavioral, electrophysiological, and neuroimaging methodologies appear to converge in indicating that both hemispheres are involved in the processing of words with emotional meaning, albeit in different, and probably complementary, ways. Consistent with the time course hypothesis, this is probably due to the fact that the two hemispheres do not react similarly and at the same "micropace" to the processing of emotional words. Thus, emotional words appear first to be processed automatically in the LH and only later in a controlled manner in the RH. This distinctive, but complementary, processing in the LH and RH is also compatible with evidence provided by research on the processing of facial expressions (see Vuilleumier, 2002, for review). Taking into consideration the dominant role of the LH in language processing, the semantic feature of emotional words is probably one factor triggering the left-lateralized activation. However, the processing advantage of emotional words is also due to, on one hand, emotion-related structures of the limbic system that become activated automatically earlier in processing and whose activation is likely left-lateralized and, on the other hand, attention-related structures that likely come into play later in processing and whose activation is presumably right-lateralized. The attention-capturing quality of emotional words is perhaps the factor that causes activation to shift from the LH to the RH. Accordingly, the dual-process model of automatic vs. controlled processing of emotional words corroborates the complementary roles of the two hemispheres of the brain in data processing.

Perhaps the greatest challenge to the area of emotional word processing in the upcoming decades will be to determine whether the attention-capturing quality of emotional words is the underlying mechanism for the role of the RH in emotional word processing. This area of research also needs to determine to what extent the role of the LH depends upon each of the semantic and emotional features of these words. The use of words with different degrees of emotionality may guide research in this direction. Also, lateralized presentation of emotional words in ERP and imaging studies along with instructions that stimulate superficial vs. deep processing of the stimuli should be helpful in differentiating automatic and controlled level of processing in the cerebral hemispheres.

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Chapter 3

This chapter consists of an article in which the theoretical background, methodology, and results of the first study are reported and discussed. The aim of the study was to examine whether the pattern of activation of emotional words in the cerebral hemispheres in young individuals involves early, or automatic, and late, or controlled, activation in the LH and RH, respectively.

Hemispheric Lateralization and the Time Course of Activation of Emotional Words in the Cerebral Hemispheres

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Abstract

The visual half-field priming paradigm and an evaluation task were used to examine the time course of priming of emotional words in the left and right hemispheres across four SOAs: 0, 150, 300, and 750 ms. Twenty-eight males and 24 females participated in the study. Consistent with the time course hypothesis (Koivisto, 1997), the results in males revealed early priming at 0 and 150 ms only in the left hemisphere; priming shifted to the right hemisphere at the longest SOA (750 ms). Priming was not detected at the 300-ms SOA in either hemisphere. The results for females, however, were consistent with the valence hypothesis, in that positive and negative words were primed mainly in the left and right hemispheres, respectively. As females are considered to be more responsive to emotions than males, their results may be due to the effect of the task, which required an explicit decision concerning the target. The results suggest that the time course of emotional word activation differs in the two cerebral hemispheres: the right hemisphere activates such words more slowly than the left hemisphere.

Key words: emotional words, cerebral hemispheres, time course, priming

3.1. Introduction

In the past few decades, almost all studies of the processing of emotional stimuli (i.e., facial, prosodic, and words) in the cerebral hemispheres have attempted to interpret their findings in light of either the right hemisphere (RH) hypothesis (e.g., Borod, 1992; Borod & Koff, 1989; Bryden & Ley, 1983; Buchanan et al., 2000; Buck, 1984; Ley & Bryden, 1979; Schmitt, Hartje, & Willmes, 1997; Sim & Martinez, 2005) or the valence hypothesis (e.g., Ahern & Schwartz, 1985; Davidson, 1992; Silberman & Weingartner, 1986; Sutton & Davidson, 1997; Van Strien & Morpurgo, 1992). In general, the RH hypothesis holds that the RH specializes in the processing of emotional stimuli irrespective of valence, whereas the valence hypothesis proposes that there is differential hemispheric specialization for emotion processing, with the left hemisphere (LH) being more involved in the processing of positive emotions and the RH primarily processing negative emotions. The purpose of this study was to gain insight into the ways in which words with emotional meanings are processed in the cerebral hemispheres.

Although the findings of a few brain lesion studies somewhat support the RH hypothesis (Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Borod et al., 1998; Cicero et al., 1999; see also Borod, 1992, for a review), the results of studies in normal participants are inconsistent with both hypotheses (e.g., Ali & Cimino, 1997; Collins & Cooke, 2005; Eviatar & Zaidel, 1991; Graves, Landis, & Goodglass, 1981; Nagae & Moscovitch, 2002; Smith & Bulman-Fleming, 2005, 2006; Strauss, 1983). Graves et al.'s (1981) study was the first in this area to employ a divided visual field (DVF) paradigm, with an exposure duration of stimuli for 150 ms; in the results of that study favored the RH hypothesis in males but found no difference between the hemispheres in females. Later, Strauss (1983), in two DVF experiments with exposure durations of 25 and 50 ms, found that the LH played a primary role in the processing of emotional words. On the other hand, Eviatar and Zaidel (1991), using an exposure duration of 80 ms, failed to demonstrate a result in favor of either hemisphere. Results supporting the valence hypothesis are also equivocal in this field (Ali & Cimino, 1997).

To explain the inconsistent results, recent research has attempted to demonstrate that both hemispheres are involved in the processing of emotional words but in varying ways (Collins & Cooke, 2005; Nagae & Moscovitch, 2002). Nagae and Moscovitch (2002) argued that the common method for applying the DVF paradigm measures the dominant role of the LH in the perception of emotional words. This method obscures the role of the RH, which is responsible for the memory of these words and comes into play later in processing. In order to prevent the LH effect from emerging, they used a DVF task that tapped the recall of emotional words. A number of words were presented to participants successively in each block; at the end of the block, participants were asked to recall the words. This method showed enhanced recall of emotional words in both hemispheres, along with a larger difference between recall of emotional and neutral words in the left visual field [LVF (RH)], due to the worse recall of neutral words in the RH. Consequently, although the idea that the RH becomes involved later in the process seemed rather innovative, the methodology did not differentiate between the roles of each hemisphere.

Following Nagae and Moscovitch's (2002) line of thought, Collins and Cooke (2005) attempted to separate two levels of implicit memory of emotional words: perceptual memory (in the LH) and conceptual memory (in the RH). To tap the LH's role, participants encoded surface features (counting the number of straight-lined strokes) of emotional words; then, in a lexical decision (LD) task, the response times (RTs) for these words were compared with RTs for an equal number of new words. To examine the RH's role, after participants generated words through semantic features (e.g., *jail*), RTs for the associates of the encoded words (e.g., *prison*) were contrasted with RTs for an equal number of new words. Although the results indicated a right visual field [RVF (LH)] advantage in the perceptual processing of emotional words, in the LVF there was evidence of conceptual processing only for positive words.

A review of the semantic literature finds evidence for the slow activation of the RH. Indeed, semantic research using the DVF priming paradigm has demonstrated that, in the processing of some parts of the semantic system, word meanings are accessed within each hemisphere but the activation time is slower in the RH (see Chiarello, 2003, for a review). This pattern of activation has been described in the time course hypothesis, which states that the important factor underlying the difference between the two hemispheres is how the availability of word meanings changes over time. Research data on the processing of subordinate meanings of ambiguous words (e.g., *bank – river*) and distantly related category pairs (e.g., *deer – pony*) match this pattern of activation (e.g., Abernethy & Coney, 1993, 1996; Burgess & Simpson, 1988; Chiarello, Burgess, Richards, & Pollock, 1990; Koivisto, 1997, 1998; Nakagawa, 1991).

In a DVF priming paradigm, two successive stimuli—the prime and the target—presented to the RVF or LVF; the priming is manifested in speedier processing of the target when the prime is related to the target. A great advantage of this paradigm is the period between the onset of the prime and the target, or SOA (i.e., Stimulus Onset Asynchrony). By manipulating the SOA, one can track the burden of processing from one hemisphere to the other. A study carried out by Koivisto on the processing of distantly related category pairs shows this advantage. In order to examine priming of these pairs, Koivisto (1997) used four different SOAs. By varying the SOA from 165 to 750 ms, he found a decrease in the amount of priming in the LH with longer SOAs, while the onset of priming occurred much later in the RH. Specifically, priming effects occurred only in the RVF at the 165-ms SOA and only in the LVF at the 750-ms SOA. At the 250-ms SOA, nonsignificant priming in the RVF and no priming in the LVF was detected, and at the 500-ms SOA there was less priming in the RVF than in the LVF. Koivisto's findings, therefore, suggested that the time course of activation may differ in the two cerebral hemispheres, with the onset of semantic activation being slower in the RH than in the LH.

For this part of the semantic system, an early meaning activation in the LH, which is likely suppressed over time, is followed by a later meaning activation in the RH. This shift in meaning accessibility from the LH to the RH may arise from two kinds of cognitive processing: of automatic vs. controlled (Collins & Loftus, 1975; Posner & Snyder, 1975). Automatic processing refers to that component of information processing in which a stimulus automatically activates its internal representation and this activation spreads to related representations in memory. This process is fast-acting and occurs without intention or conscious awareness. In contrast, controlled processing places demands on attention and comes into play when, for instance, a long SOA encourages the formation of expectations about the relations between the prime and the target (Neely, 1977, 1991).

Electrophysiological studies that used emotional words as stimuli also seem to suggest the existence of an early vs. a later stage in the processing of such words.

Researchers classify ERP correlates of emotional words into two groups: early components that appear within 300 ms of stimulus onset and later components that emerge more than 300 ms after stimulus onset (see Kissler, Assadollahi, & Herbert, 2006, for a review). While the early components such as P1 and N1 have been attributed to the automatic activation of emotional words (e.g., Kissler, Herbert, Peyk, & Junghofer, 2007; Kissler, Herbert, Winkler, & Junghofer, 2009; Scott, O'Donnell, Leuthold, & Sereno, 2009), the later components such as the P300 and LPC (i.e., late positive component) have been suggested to reflect increased attentional resources devoted to the emotional content (e.g., Cacioppo, Crites, Gardner, & Berntson, 1994; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; De Pascalis, Strioppoli, Riccardi, & Vergari, 2004).

Responses to task demands are considered to be evidence for the automatic vs. controlled nature of the early and later ERP components, as research suggests that the early and later components respond differently. While late ERP effects are more subject to interference from task demands (e.g., Fischler & Bradley, 2006; Naumann, Maier, Diedrich, Becker, & Bartussek, 1997), the type of task seems to have no bearing on the appearance of the early components (e.g., Kissler et al., 2009). Among the ERP data on emotional words, some data indicate left-lateralized scalp distribution for early components and bilateral distribution (Bernat, Bunce, & Shevrin, 2001) or bilateral distribution with more activation in the RH (Ortigue et al., 2004) for later components. These findings likely support the claim that emotional words are activated slowly in the RH.

In neuroimaging studies that used emotional words as their stimuli it seems to be possible to differentiate the involvement of LH regions from that of RH regions based on the type of task. Typically, when the emotional attribute is not the focus of the task or the task is not demanding, the contribution of LH regions is more salient. In contrast, in demanding tasks where the emotional meaning needs to be suppressed or attended to, RH regions appear to be involved in processing. The left amygdala (e.g., Hamann & Mao, 2002; Maratos, Dolan, Morris, Henson, & Rugg, 2001; Strange, Henson, Friston, & Dolan, 2000), the left posterior cingulate cortex (Maddock, Garrett, & Buonocore, 2003), the left orbitofrontal cortex (Beauregard et al., 1997), and the left fusiform gyrus (Luo et al., 2004) are structures that have shown activation during less demanding tasks in this field.

For instance, research has shown a strong correlation between the pattern of activation of emotional words in the amygdala and in the occipital cortex during silent viewing of these words (e.g., Tabert et al., 2001). Accordingly, some researchers believe that the amygdala influences emotional processes via projections back to all levels of the visual cortex that exceed the effects of the emotional input received by the visual cortex (Amarel, Price, Pitkanen, & Carmichael, 1992). This finding suggests the early involvement of the amygdala in emotional word processing.

Another finding that suggests that activation in the amygdala occurs automatically, without placing much demand on processing resources, is the outcome of research that demonstrates the insensitivity of the amygdala when attention is recruited by a task. During a go/no-go task in which participants respond, for instance, to positive words and inhibit their responses to negative words, activation in the amygdala is negligible (e.g., Elliott, Rubinsztein, Sahakian, & Dollan, 2000). In contrast, in attention-demanding tasks such as the emotional Stroop task, in which participants respond to the ink color of emotional words while ignoring their meaning, RH regions such as the right anterior cingulate cortex and the right prefrontal cortex have been reported to be activated (Compton et al., 2003; Strange et al., 2000).

Overall, the above-mentioned ERP and imaging data seem to suggest the existence of an early automatic stage vs. a later attention-demanding stage in emotional word processing; these two stages probably require greater contributions from the LH and the RH, respectively. These data seem to fit the time course hypothesis, which predicts the later activation of semantic information in the RH (Koivisto, 1997). In view of the fact that some structures associated with the emotional meanings of words, such as the left amygdala, become activated in the LH upon presentation of these words, one can postulate that emotional word processing has a quick onset in the LH. The verbal nature of emotional words as part of the semantic system makes this prediction more reasonable. In the next stage, when the attention-capturing quality of these words comes into play, the activation shifts to the RH and the role of structures such as the right cingulate and prefrontal cortex becomes critical.

Therefore, the main purpose of this study was to examine the time course hypothesis in the processing of emotional words in the LH and RH. We expected the pattern of activation to show a shift from early activation in the LH to later activation in the RH. Since an appropriate account for the differential role of the LH and RH using a behavioral methodology was still lacking, this study employed a behavioral paradigm. Taking into consideration the results of semantic research that used the priming paradigm, this study was carried out by means of the affective priming paradigm, along with an evaluation task in which an emotional target word (e.g., *crime, happy*) is preceded by an emotional prime word (e.g., *gift, death*); an affective priming effect is indicated when the time needed to evaluate the target as pleasant or unpleasant is shorter when the prime and target share the same valence than when they are of opposite valence (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). The DVF method of presentation was employed in order to compare priming effects in the LH and the RH (Atchley, Ilardi, & Enloe, 2003). Moreover, by using four different SOAs—0, 150, 300, and 750 ms—priming effects were tracked at different times during the course of processing in the hemispheres.

3.2. Method

3.2.1. Participants

A total of 62 students from English-language universities in Montreal between the ages of 20 and 35 participated on a voluntary basis (with compensation)[6]. Data from 10 participants were discarded as 7 showed an overall error rate of more than 25% or their accuracy rate at least in one SOA condition was at a chance level, and 3 had PANAS (i.e., Positive and Negative Affect Scale: Watson, Clark, & Tellegen, 1988) scores that implied a depressed mood at the time of the experiment. Thus, 28 male and 24 female participants remained; their mean age was 24.7 years (SD = 3.6) for males and 24.0 years (SD = 3.3) for females. All were right-handed native English speakers, with normal or corrected to normal vision, and without any past history of neurological or psychiatric disease. Their handedness scores, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), were 92 (SD = 10) for males and 96 (SD = 6) for females. With the aim of controlling for the possible impact of hormonal fluctuations (i.e., the possible effect of a decrease in LH activation in the premenstrual phase: Alexander, Altemus, Peterson, & Wexler, 2002),

[6] The participants were recruited by posting an ad text on the intenet or flyers in social settings in Montreal. The ad text and the flyer are available in the Appendix E.

female participants were tested in the postmenstrual phase of their menstrual cycles (days 5–17, with a mean of 11). In addition, females who were taking estrogen for birth control were excluded from the study. All participants signed a consent form[7] before taking part in the study as required by the Comité d'éthique de la recherché de l'IUGM.

3.2.2. Stimuli

The stimuli[8] were selected from the Affective Norms for English Word (ANEW) list (Bradley & Lang, 1999), which is a standard set of 1,034 English words that have been characterized along the dimensions of valence (from negative to positive, with a range of from 1 to 9), arousal (from low to high, with a range of from 1 to 9), and dominance. In this study, 48 positive and 48 negative words with higher arousal ratings (5–9) were selected from the words with valence ratings of 1 to 3 (negative words) and 7 to 9 (positive words), and 48 congruent prime-target pairs [i.e., positive-positive (P-P) and negative-negative (N-N)] were constructed. The prime and target of each congruent pair belonged to the same category but were not semantically related. The lack of semantic relatedness was confirmed by performing *the word association task* [9] in that we asked 21 of the participants at the end of their experimental session to list three words that they immediately associated with each prime word. Thus, a total of about 63 associations was received for each prime and the target was never among them.

The positive and negative prime sets and target sets were carefully matched according to grammatical category, imageability, concreteness, and word length (Medical

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[7] The consent form is available in the Appendixe D.
[8] All word stimuli and their specifications are listed in the Appendix A.
[9] The task sheet and its consent form are available in the Appendix C and D, respectively.

Research Council psycholinguistic database: Coltheart, 1981). Stimuli were used in English either as nouns or as both nouns and verbs. All words were 3 to 7 letters long, with the mean length of prime and target sets being 5.415 and 5.29, respectively. Frequency ratings, however, were slightly different, with mean ratings for P-P pairs and N-N pairs being 72.67 and 40.25, respectively. Although this could potentially pose a problem because frequency affects speed of lexical access, it could not be avoided since we did not have a large enough pool of emotional words from which to choose a frequency-balanced subset. Nevertheless, this difference is a normal attribute of language: positive words are more frequent than negative words and an imbalance is unavoidable in studies that use a larger stimulus set (e.g., Scott et al., 2009; Wurm & Vakoch, 1996).

The congruent prime-target pairs were re-paired to form 48 incongruent positive-negative (P-N) and negative-positive (N-P) pairs. To counterbalance for congruency and visual field of presentation, the congruent and incongruent pairs were divided into two sublists, each including 24 congruent pairs (12 in each visual field) and 24 incongruent pairs (12 in each visual field). Mirror-image versions of these sublists were created by reversing the visual field of presentation, resulting in four different test lists. Within each test list, every prime-target pair was unique. Assignment of SOAs to the test lists was counterbalanced. Therefore, there was a total of 48 prime-target pairs in each test list and each participant received all four test lists, one for each SOA condition (i.e., 0, 150, 300, and 750 ms), for a total of 192 pairs for the four SOA conditions. The trials in each block were preceded by three buffer trials. In each block, half of the pairs were presented in the RVF and half in the LVF (i.e., RVF prime – RVF target, LVF prime – LVF target). A practice set consisted of four blocks of 16 trials, one for each SOA, which introduced the

SOAs that would be presented in the following blocks. Stimuli were presented in white uppercase against a black background, subtending 1.6°–4° and .9° of horizontal and vertical visual angles, respectively.

3.2.3. Procedure

Before running the practice trials, participants completed three paper-and-pencil questionnaires: a participant information form[10], the PANAS (Watson et al., 1988), and the Edinburgh Handedness Questionnaire (Oldfield, 1971). When this was done, the participant sat 60 cm away from the computer screen. A chin rest was used to maintain a constant viewing distance. All instructions were explained to the participant by the experimenter, who also monitored eye movements using a video camera during testing and reminded the participant if any deviation from the fixation point was noted. Stimulus presentation, timing and data collection were controlled by E-Prime 1.0 software. The session began with practice trials, followed by one of the experimental blocks. The presentation order of the four blocks was counterbalanced across participants. Participants were allowed to rest briefly between blocks.

Throughout the trials, there was a central fixation point at the center of the screen. Each trial began with an alerting tone after a 700-ms period, the prime was displayed in the RVF or LVF for 150 ms. The participant's SOA group determined whether 0, 150, 300, or 750 ms elapsed between the onset of the prime and the onset of the target. The target was always presented for 180 ms. The next trial was initiated 1 s after the participant's response. Alternatively, if the participant did not respond within 1600 ms, an error was

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[10] The participant information form is available in the Appendix B.

registered by the computer and the next trial was initiated after 1 s. The prime and target of each pair always appeared in the same visual field. Trials were presented in pseudo-randomized order with no more than three successive trials in the same visual field. To ensure that the prime was processed, it was displayed above or below the location of the target. The target was always underlined. This was important, especially at the 0-ms SOA, for which the presentation of the two stimuli overlapped. Participants were informed that the underlined word would either be presented simultaneously with another word or follow it.

Participants were asked to maintain their gaze on the central fixation point. They were instructed to read both words but respond only to the underlined word. They were required to decide as quickly and accurately as possible whether the target word was pleasant or unpleasant. Responses were registered by simultaneously pressing the “c” and “m” keys of a keyboard placed symmetrically at the midline for pleasant words and the “d” and “k” keys for unpleasant words. The faster of the two responses was taken as the RT for that trial. In addition to RT, accuracy was measured.

3.3. Results

In screening the RT data, pairs with RTs greater than 1.5 SD of each participant’s mean (per condition) (8% of the correctly answered pairs: about .9 pairs per condition) were removed from the analyses. Preliminary analyses showed a significant effect of gender [$F(1, 50) = 8.711$, $p < .01$]: females’ overall RTs were faster than males’ (524 ms vs. 577 ms). As there was an interaction between gender and congruency [$F(1, 50) = 5.646$, $p < .05$], a trend toward an interaction between gender and visual field (VF) [F (1,

50) = 2.956, .05 < p < .10], and above all an interaction of gender and all the factors involved (i.e., Congruency x VF x SOA x Gender) [F (3, 150) = 3.344, p < .05], two separate 2 x 2 x 4 repeated measures ANOVAs with congruency (Congruent vs. Incongruent), VF (RVF vs. LVF), and SOA (0 vs. 150 vs. 300 vs. 750 ms) as factors were performed on the RT data and percent accuracy scores of male and female participants. No gender effect was observed on the accuracy data, however. Thus, further analyses concentrated on the RT data as they were more normally distributed and had the most variance. The results of male participants including RT and percent accuracy data will be presented first, followed by females' results.

3.3.1. Data from Male Participants

Male participants' mean RTs for correct responses and percent accuracy scores for congruent and incongruent pairs, along with priming effects at each SOA in the RVF and LVF, are shown in table 3.1.

According to the ANOVA for RTs, the difference between RTs for stimuli in the RVF vs. LVF did not reach significance (575 ms in the RVF vs. 580 ms in the LVF: F (1, 27) = 1.085, p > .05). There was a significant main effect of SOA [F (3, 81) = 10.540, p < .001], with RTs being 618, 569, 552, and 570 ms at the 0-, 150-, 300-, and 750-ms SOAs, respectively. A trend toward faster RTs for incongruent pairs (574 ms) vs. congruent pairs (580 ms) was shown [F (1, 27) = 3.533, .05 < p < .10]. The two-way interactions were not significant (Fs < 1.6). However, the most important finding was a significant three-way interaction of Congruency x VF x SOA [F (3, 81) = 4.404, p < .01], which indicates that the pattern of responses to congruent vs. incongruent pairs in the two VFs was modulated by SOA.

Table 3.1. *Mean Response Times (ms) and Accuracy (Percent Correct) for Congruent and Incongruent Pairs in each Visual Field as a Function of SOA (SD) in Male Participants*

	SOA							
	0 ms		150 ms		300 ms		750 ms	
	RT	Accuracy	RT	Accuracy	RT	Accuracy	RT	Accuracy
RVF								
Congruent	627 (98)	85 (11)	554 (73)	88 (11)	552 (86)	89 (10)	574 (97)	90 (9)
Incongruent	598 (92)	87 (12)	575 (88)	87 (11)	545 (94)	86 (14)	572 (95)	91 (9)
Priming	–29**	2	21**	–1	–7	–3	–2	1
LVF								
Congruent	618 (92)	81 (11)	580 (95)	83 (13)	554 (94)	85 (13)	582 (92)	92 (11)
Incongruent	629 (106)	80 (16)	568 (80)	84 (13)	557 (83)	88 (11)	551 (74)	88 (10)
Priming	11	–1	–12	1	3	3	–31**	–4

** indicates significant priming effects ($p < .05$).

Then the processing of congruent vs. incongruent pairs in the RVF and LVF at four SOA conditions was tracked by examining the simple effects of congruency at each SOA within the RVF and LVF. This analysis demonstrated a 29-ms reverse priming effect (i.e., faster RTs for incongruent pairs than congruent pairs) at the 0-ms SOA in the RVF [F (1, 27) = 10.921, $p < .01$], whereas in the LVF the 11-ms faster RTs for congruent vs. incongruent pairs did not reach significance ($1 < F < 2$). On the other hand, in the same VF in which a pattern of reverse priming emerged (i.e., the RVF), a reliable 21-ms priming effect was revealed at the 150-ms SOA [F (1, 27) = 4.857, $p < .05$], whereas in the LVF the 12-ms faster RTs for incongruent vs. congruent pairs fell short of significance ($F < 1.3$). At the 300-ms SOA, no priming effects were detected in either VF ($Fs < 1$). Finally, at 750 ms, a reverse priming pattern again occurred but this time in the LVF [F (1, 27) = 7.987, $p < .01$], whereas no priming was observed in the RVF ($F < 1$).

Separating the effect of pairs with negative targets (i.e., N-N, P-N) from pairs with positive targets (i.e., P-P, N-P) by adding a valence variable (Negative vs. Positive) to the design and running a 2 (Valence) x 2 (Congruency) x 2 (VF) x 4 (SOA) ANOVA indicated a trend toward an effect of valence [F (1, 27) = 3.653, $.05 < p < .10$]. Hence, due to the theoretical significance of valence, two separate 2 (Congruency) x 2 (VF) x 4 (SOA) ANOVAs were run on the RTs for pairs with negative targets and with positive targets. Male participants' mean RTs for correct responses to pairs with negative targets and pairs with positive targets, along with priming effects at each SOA in the RVF and LVF, are shown in table 3.2.

Table 3.2. *Mean Response Times (ms) to Pairs with Negative Targets (N-N, P-N) and Pairs with Positive Targets (P-P, N-P) in Each Visual Field as a Function of SOA (SD) in Male Participants*

	RVF (LH)				LVF (RH)			
	SOA				SOA			
	0 ms	150 ms	300 ms	750 ms	0 ms	150 ms	300 ms	750 ms
N-N	651 (114)	569 (96)	569 (116)	586 (133)	645 (105)	601 (97)	564 (113)	590 (107)
P-N	634 (91)	598 (107)	550 (128)	597 (109)	647 (119)	578 (83)	564 (80)	570 (88)
Priming	–17	29**	–19	11	2	–23	0	–20
P-P	644 (137)	551 (88)	558 (101)	576 (114)	621 (108)	591 (126)	561 (99)	581 (108)
N-P	575 (107)	558 (116)	557 (115)	551 (98)	633 (124)	565 (102)	565 (109)	554 (99)
Priming	–69**	7	–1	–25	12	–26	4	–27

** indicates significant priming effects ($p < .05$).

Analyses of the RTs for pairs with negative targets showed that the priming that occurred at the 150-ms SOA in the RVF was mainly the effect of these pairs [$F(1, 27) = 4.154$, $p = .05$], and not of pairs with positive targets ($F < 1$). On the other hand, analyses of the RTs for pairs with positive targets revealed that the pattern of reverse priming that occurred at the 0-ms SOA in the RVF was principally due to these pairs [$F(1, 27) = 11.372$, $p < .01$], and not to pairs with negative targets ($F < 1.2$). Indeed, in the data on pairs with positive targets, the main effect of congruency (i.e., comparison between RTs to P-P pairs and RTs to N-P pairs) reached significance (570 ms for N-P pairs vs. 585 ms for P-P pairs: $F(1, 27) = 5.194$, $p < .05$). However, this effect was modulated by a significant three-way interaction of Congruency x VF x SOA [$F(3, 81) = 3.874$, $p < .05$], showing that N-P pairs were responded to significantly faster than P-P pairs at the 0-ms SOA in the RVF [575 vs. 644 ms: $F(1, 27) = 11.372$, $p < .01$]. Presumably, in both visual fields, RTs for all pairs at 0 ms were slower than the other three SOA conditions, except for RTs to N-P pairs presented in the RVF at 0 ms, which were responded to about as fast as in the other three SOA conditions. Nevertheless, at the 750-ms SOA, both pairs with negative targets and pairs with positive targets seemed to yield reverse priming effects since the 20-ms RT advantage for P-N pairs over N-N pairs and the 27-ms faster RTs for N-P pairs compared to P-P pairs failed to reach significance by themselves ($Fs < 2.5$).

Regarding accuracy scores, the percentage of correct responses entered into a 2 (Congruency) x 2 (VF) x 4 (SOA) ANOVA revealed a main effect of visual field [$F(1, 27) = 6.835$, $p < .05$], showing that responses were more accurate to the RVF stimuli (88%) than to the LVF stimuli (84%). Congruency did not have a statistically significant effect ($F < 1$), but the main effect of SOA was significant [$F(3, 81) = 8.237$, $p < .01$]. Post hoc comparisons showed significant differences at an alpha level of 5% between percent accuracy scores at the 0-ms SOA (83.4%) and the 300-ms (86.9%) and 750-ms (88.9%) SOAs, whereas the difference between the percent accuracy scores at 0 ms and 150 ms (83.4% vs. 85.5%) failed to reach significance. The two-way and three-way interactions did not show reliable effects in the accuracy data analysis. Hence, the similarity between RT and accuracy results, particularly with regard to SOA (e.g., slower RTs and decreased accuracy at 0 ms) and VF (e.g., faster RTs and higher accuracy for RVF stimuli than for LVF stimuli) makes the possibility of a speed-accuracy trade-off in the data from male participants trivial.

3.3.2. Data from Female Participants

Female participants' mean RTs for correct responses and percent accuracy scores for congruent and incongruent pairs, along with priming effects at each SOA condition in the RVF and LVF, are shown in table 3.3. Figure 3.1 compares RTs for congruent vs. incongruent pairs in the RVF and LVF as a function of SOA in female and male participants.

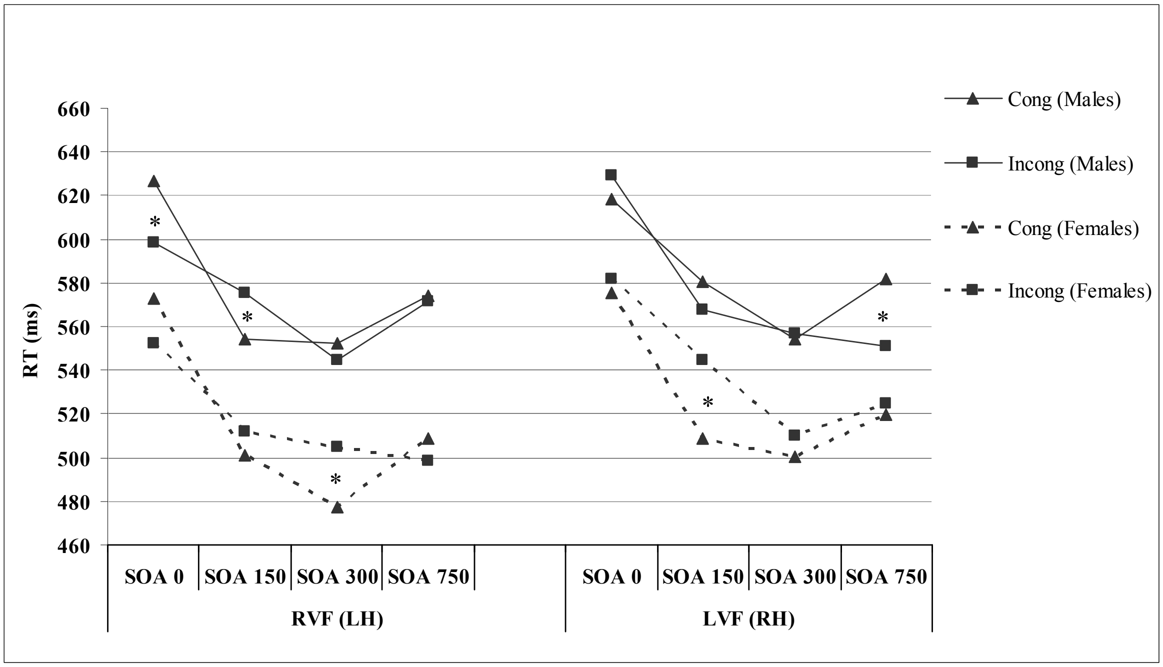
In the ANOVA for RTs, the main effect of congruency was not significant; that is, the 8-ms faster overall RTs for congruent pairs compared to incongruent pairs (521 vs. 529 ms) did not reach significance [$F(1, 23) = 2.412$, $p > .05$)]. The RTs for the RVF stimuli were significantly faster than RTs for the LVF stimuli (516 vs. 533 ms) [$F(1, 23) = 14.447$, $p = .001$)]. The main effect of SOA was significant [$F(3, 69) = 12.366$, $p < .001$], showing that overall RTs were slower at the shortest SOA (571 ms) than in the other SOA

Table 3.3. *Mean Response Times (ms) and Accuracy (Percent Correct) for Congruent and Incongruent Pairs in Each Visual Field as a Function of SOA (SD) in Female Participants*

	SOA							
	0 ms		150 ms		300 ms		750 ms	
	RT	Accuracy	RT	Accuracy	RT	Accuracy	RT	Accuracy
RVF								
Congruent	573 (81)	85 (11)	501 (72)	89 (12)	478 (62)	91 (9)	509 (76)	90 (9)
Incongruent	552 (75)	84 (17)	512 (72)	85 (15)	505 (78)	90 (9)	498 (74)	91 (11)
Priming	–21	–1	11	–4	27**	–1	–11	1
LVF								
Congruent	575 (80)	83 (14)	509 (73)	89 (10)	500 (77)	91 (8)	520 (59)	88 (10)
Incongruent	582 (84)	83 (15)	544 (90)	86 (10)	510 (69)	89 (13)	525 (66)	88 (15)
Priming	7	0	35**	–3	10	–2	5	0

** indicates significant priming effects (p < .5).

Figure 3.1. Response times (ms) to congruent and incongruent trials in each visual field as a function of SOA in male and female participants



* indicates significant priming effects (p < .05).

conditions (516, 498, 513 ms at 150, 300, and 750 ms, respectively), which did not differ from one another significantly. The two-way Congruency x SOA interaction was significant [F (3, 69) = 3.782, p < .05]. Examining the simple effects of congruency within each SOA condition showed 23 ms of reliable priming at the 150-ms SOA [F (1, 23) = 6.877, p < .05] and 19 ms of marginally significant priming at the 300-ms SOA [F (1, 23) = 3.795, .05 < p < .10], whereas the priming that emerged at the SOAs of 0 ms and 750 ms was negligible (Fs <1).

Tracking the processing of congruent vs. incongruent pairs at each SOA condition in the RVF and LVF revealed 27 ms of priming in the RVF at the 300-ms SOA [F (1, 23) =

5.049, $p < .05$] and 35 ms of priming at the 150-ms SOA in the LVF [$F(1, 23) = 6.992$, $p < .05$]. Although at the 0-ms SOA in the RVF, incongruent pairs were responded to 21 ms faster than congruent pairs, the difference between the RTs for the incongruent and incongruent pairs was not significant [$F(1, 23) = 2.87$, $p > .05$].

When we separated the effect of pairs with negative targets (i.e., N-N, P-N) from pairs with positive targets (i.e., P-P, N-P) by adding a valence variable to the design of the experiment and running a 2 (Valence) x 2 (Congruency) x 2 (VF) x 4 (SOA) ANOVA, we found no significant effect of valence ($p > .10$). Nevertheless, due to the theoretical significance of valence, two additional ANOVAs were performed: one for the RTs of pairs with negative targets and the other for the RTs of pairs with positive targets. Female participants' mean RTs for correct responses to pairs with negative targets and pairs with positive targets, along with the priming effects at each SOA in the RVF and LVF are shown in table 3.4.

Analyses of RTs for pairs with negative targets indicated that the priming in the LVF at the 150-ms SOA was mainly due to the effect of these pairs [$F(1, 23) = 9.612$, $p < .01$]. On the other hand, priming of pairs with positive targets occurred mainly at the 300-ms SOA in the RVF [$F(1, 23) = 4.582$, $p < .05$]. In other words, the priming at 300 ms in the RVF was because of the pairs with positive targets whereas the effect of pairs with negative targets at this SOA and in this VF was trivial ($F < 1$).

Regarding accuracy scores, a 2 (Congruency) x 2 (VF) x 4 (SOA) ANOVA for the percentage of correct responses showed only a main effect of SOA [$F(3, 69) = 7.209$, $p < .001$]. Post hoc comparisons at an alpha level of 5% revealed that percent accuracy scores at the 0-ms SOA (84%) were significantly lower than those at the 300-ms (90%) and 750-

Table 3.4. *Mean Response Times (ms) to Pairs with Negative Targets (N-N, P-N) and Pairs with Positive Targets (P-P, N-P) in Each Visual Field as a Function of SOA (SD) in Female Participants*

	RVF (LH)				LVF (RH)			
	SOA				SOA			
	0 ms	150 ms	300 ms	750 ms	0 ms	150 ms	300 ms	750 ms
N-N	600 (105)	519 (89)	514 (103)	517 (72)	581 (93)	504 (76)	504 (94)	565 (103)
P-N	576 (95)	532 (77)	511 (88)	515 (84)	595 (103)	556 (110)	519 (90)	537 (64)
Priming	–24	13	–3	–2	14	52**	15	–28
P-P	549 (85)	490 (69)	474 (75)	512 (95)	579 (87)	513 (82)	507 (98)	524 (78)
N-P	566 (76)	508 (104)	511 (105)	500 (93)	583 (79)	548 (92)	514 (102)	535 (108)
Priming	17	18	37**	–12	4	35	7	11

** indicates significant priming effects ($p < .05$).

ms (89%) SOAs. The difference between the percent accuracy scores at 150 ms (87%) and 300 ms was also significant, whereas the other pairwise comparisons fell short of significance. Congruent and incongruent pairs were responded to with similar levels of accuracy (88% vs. 87%) ($1 < F < 2$), and the difference between percent accuracy scores in the RVF (88%) and the LVF (87%) was not significant ($F < 1$). The RT and accuracy results are similar, in particular with regard to the SOA conditions. That is, female participants tended to be less accurate at the 0-ms SOA, which was also characterized by slower RTs, and they were more accurate at the 300-ms SOA in which they also demonstrated faster RTs. This outcome makes the possibility of a speed-accuracy trade-off in the female participants' data negligible.

3.4. Discussion

In this study, in order to investigate potential hemispheric asymmetries in the time course of activation of emotional words, the priming of congruent and incongruent emotional word pairs in the LH and RH was compared across four SOAs: 0, 150, 300, and 750 ms. The results showed different patterns of priming effects in male and female participants. In males, consistent with our prediction, priming occurred at the two short SOAs (0 and 150 ms) in the LH and at the long SOA (750 ms) in the RH. No priming was detected at the 300-ms SOA in either hemisphere. In females, no reliable priming was detected at the shortest and longest SOAs employed in the experiment (0 and 750 ms). However, priming of negative words occurred in the RH at the 150-ms SOA ms and priming of positive words emerged in the LH at the 300-ms SOA. This pattern is consistent with the valence hypothesis of emotion processing. A discussion of the results observed in males will be followed by examination of the observed pattern of priming in females, possible reasons for the different results in the two groups, and the likely difference between processing modes of the LH and RH.

3.4.1. Pattern of Priming Effects in Male Participants

In males, projections of an emotional prime word to the LH at the SOAs of 0 and 150 ms activated responses to an emotional target word subsequently projected to the LH, whereas no such effect was observed in the RH. The absence of priming in the RH in the short SOA conditions likely shows that the RH is not sensitive to the emotional relationships between words early in processing. The priming in the LH decreased over time: at the 300-ms SOA, no reliable priming was detected in this hemisphere. On the other hand, the onset of activation occurred later in the RH, where priming emerged at 750 ms. Thus, priming effects that were restricted to the LH at the short SOAs shifted to the RH at a longer SOA. This pattern seems to be compatible with the time course hypothesis, for which evidence has been found in some parts of the semantic system such as subordinate meanings of ambiguous words and remotely related category pairs (Abernethy & Coney, 1993, 1996; Burgess & Simpson, 1988; Chiarello et al., 1990; Koivisto, 1997, 1998).

Presumably, the LH has automatic access to the emotional content of words earlier in the course of processing. This is likely consistent with the automatic evaluation hypothesis, which holds that emotional stimuli are processed quickly and without intent (Fazio et al., 1986). In contrast, the delayed activation of emotional words in the RH at the 750-ms SOA, in conjunction with the lack of priming in the LH at the same SOA, seems to suggest that emotional word activation can be revisited in a controlled mode in the RH by directing attention to the content of these words. So, when sufficient time has elapsed and the meaning is suppressed in the LH, access is possible through the RH. This may imply that the hemisphere that is dominant over automatic aspects of emotional word processing is not dominant over controlled aspects. That may be the reason why hemispheric dominance alters over the course of processing (Burgess & Simpson, 1988).

Nevertheless, the pattern of priming at the 0- and 750-ms SOAs represented a type of reverse priming (i.e., shorter RTs for incongruent pairs than for congruent pairs), whereas at 150 ms the pattern was a type of anticipated priming (i.e., shorter RTs for congruent pairs than for incongruent pairs). A convincing explanation of the delayed response to congruent pairs, as opposed to incongruent pairs, could call upon the underlying mechanisms that have been suggested for affective priming effects. In fact, some researchers (e.g., Bargh, Chaiken, Govender, & Pratto, 1992; Bargh, Chaiken, Raymond, & Hymes, 1996; Fazio et al., 1986), drawing on the similarity of the semantic and affective priming paradigms, have proposed a spread of activation mechanism (Collins & Loftus, 1975) for affective priming effects whereby the valence of the prime activates a general purpose valence node in semantic memory. The activation of the valence node spreads to words with the same valence and speeds up encoding of targets with the same valence. Consequently, targets with negative valence, for instance, become more accessible after projection of a negative prime than a positive prime.

On the other hand, since the number of positive or negative concepts in semantic memory is large and the quantity of activation in the network is limited, some researchers (e.g., Klauer & Musch, 2001; Wentura, 1999, 2000) believe that the spread of activation account faces difficulties, at least as an exclusive explanation for affective priming effects. Accordingly, Wentura (1999, 2000) proposes a response competition account for affective priming effects in evaluation tasks. He argues that, in an LD task—on which the spread of activation account was modeled—neither a related prime nor an unrelated prime favors a response to a higher degree than the target because both related and unrelated primes are real words. On the other hand, in the evaluation task, the prime can also be evaluated. Consequently, when the prime is congruent with the target, its valence matches the response but when the prime is incongruent with the target, its valence mismatches the response. Thus, response facilitation might occur for congruent pairs, whereas for incongruent pairs the resulting interference might slow down responses.

For that reason, the mechanism underlying priming effects when the prime and target are presented at the same time is probably response competition. Presumably, at an SOA of 0 ms the valence of the target and the prime are first activated simultaneously and then compared with regard to their being pleasant or unpleasant. This serial process would result in longer RTs than when there is a delay between the presentation of the prime and the target (Hermans, De Houwer, & Eelen, 2001). And in fact, in our study, we obtained the slowest RTs at the 0-ms SOA.

Research suggests that, when the prime becomes salient, such as when it is highly arousing or highly frequent, reverse priming is more likely to occur (Glaser & Banaji, 1999). Giving the participant an accuracy goal may reinforce the saliency of the prime: when participants strive for accuracy, they automatically recognize the prime's potential to bias their judgment regarding the target and consequently attempt to ensure that they respond to the right item, namely the target. As it is easier to distinguish the target from the prime in the case of incongruent pairs, participants respond to them faster. In contrast, a double check will result in extended RTs for congruent pairs (Wentura, 2000). In our study, the stimuli were high-arousal words and their frequency could not be categorized as low (Scott et al., 2009). As well, the fact that at the start of the experiment participants were asked to be both quick and accurate probably automatically set them the goal of avoiding or counteracting any influence from the irrelevant stimuli (i.e., primes) during the experiment. This process probably occurred automatically, as participants could not deliberately slow down their RTs by an average of 50 to 60 ms when primes were followed by congruent targets (Glaser & Banaji, 1999).

However, the reverse priming at the 0-ms SOA occurred for pairs with positive targets (N-P pairs vs. P-P pairs) and not pairs with negative targets (P-N pairs vs. N-N pairs). To explain this result, the effect of valence should be considered first. In the present study, positive targets were responded to faster on average than negative targets (Kanske & Kotz, 2007; Kuchinke et al., 2005; Kuchinke, Vo, Hofmann, & Jacobs, 2007). This advantage may occur because positive stimuli facilitate approach responses, whereas negative stimuli are followed by withdrawal responses. In a lab setting, where no immediate threat is expected, the approach system is more likely to be activated, and that normally leads to faster RTs for positive stimuli (Ito & Cacioppo, 2005). The verbal nature of emotional words is another factor biasing the situation in favor of activating the approach system (Kanske & Kotz, 2007). Moreover, positive stimuli seem to demand fewer cognitive processing resources than negative stimuli (Ferre, 2003; Isen & Daubman, 1984).

In contrast, processing negative stimuli is likely associated with a disparate pattern of effects: processing resources are rapidly recruited, followed by a slowing of responses (Dahl, 2001; Taylor, 1991). This pattern was described by Taylor (1991) in the mobilization-minimization hypothesis. Specifically, mobilization occurs in the initial stages of processing of negative stimuli and evokes strong and rapid physiological and cognitive changes in the organism. This stage is followed by a minimization stage in which additional physiological and cognitive responses are employed to diminish the impact of the negative stimulus. One possible explanation for the mobilization might be sensitivity to the threatening impact of negative stimuli (McKenna & Sharma, 1995; Pratto & John, 1991).

Accordingly, RTs for N-P pairs were much lower than RTs for P-P pairs at the 0-ms SOA because of the effect of the negative prime. If the prime had been disregarded, we would not have seen any differential effect of N-P vs. P-P pairs, which share positive targets; their difference must be due to their primes. ERP data demonstrate an extremely rapid differentiation (i.e., the P1) of negative words with high ratings for arousal and frequency from positive words that are also high-arousal and frequent (Scott et al., 2009). Hence, the processing advantage of N-P pairs over P-P pairs was perhaps due to participants' high sensitivity to the negative stimuli which served as the primes in the N-P pairs, on the one hand, combined with a response advantage for positive targets directed by the approach system, on the other hand. As far as response competition goes, the above-mentioned features of negative vs. positive stimuli do not provide such an advantage for P-N pairs over N-N pairs.

Moreover, it is unlikely that frequency of positive vs. negative words accounts for the effects observed at 0 ms. In fact, while there was a slight difference between the frequency of negative and positive pairs, the difference between frequency of N-P vs. P-P pairs (56 vs. 73, respectively), and of P-N vs. N-N pairs (57 vs. 40, respectively) was not significant. Indeed, although the frequency of N-P and P-N pairs was almost the same (56 vs. 57, respectively), an analysis of the data for the 0-ms SOA showed a significant difference between RTs for these two kinds of pairs, but not between RTs for P-P and N-N pairs. Besides, if the processing advantage for pairs with positive targets at this SOA was due to their frequency, the fastest RTs should have been for P-P pairs rather than N-P pairs.

On the other hand, at the 150-ms SOA participants did respond to congruent pairs more quickly than incongruent pairs. At this SOA, spreading of activation was probably the mechanism underlying the priming effects. Presumably, at 150 ms, the delay between presentation of the prime and the target caused the participant to get ahead in accessing the representation of the prime; consequently, spreading of activation to words with a congruent valence facilitated responses to these pairs. However, at this SOA, priming was mainly due to pairs with negative targets, namely faster RTs for N-N pairs than P-N pairs.

As mentioned previously, ERP research shows very early differentiation of negative from positive words (Scott et al., 2009). Thus, when the SOA condition encourages spreading of activation, priority is given to N-N pairs, which are responded to faster than their counterparts (i.e., P-N), and not to P-P pairs. Seemingly, the dominant role of the LH makes the automatic spread of activation more achievable (Koivisto, 1997, 1998).

Conversely, at the 300-ms SOA, we found no evidence of priming (Hermans et al., 2001) in the LH, perhaps because of the narrowing of meaning availability at this SOA. In reality, when the lexical representation of the prime is activated, certain thresholds must be reached for activation to spread to the words with the same valence. Our results do show that the activation at 300 ms had already dissipated so that the required threshold to activate words of congruent valence could not be reached. As well, the delay between the prime and target was not sufficient for controlled processes; participants had no time to develop strategies regarding the valence of the target (Koivisto, 1998).

At 750 ms, however, priming shifted to the RH and no priming was detected in the LH. The time course hypothesis maintains that the RH is slow at activating semantic information (Burgess & Simpson, 1988; Koivisto, 1997, 1998). As with the 0-ms SOA, the priming at this SOA was a reverse type. Most likely, at 750 ms, two successive decisions are made by the participant, the first concerning the prime and the second the target. This is because the participant has sufficient time to identify the valence of the prime before the target appears. Accordingly, reverse priming occurs because, when the prime is encoded with different information, distinguishing it from the target becomes easier. Thus, discrepancy speeds up the decision, whereas in the case of identical valences for prime and target, the need for a double check results in longer RTs. However, unlike the 0-ms SOA, no processing advantage was detected for either valence set. Seemingly, the long delay between prime and target neutralizes the mobilization stage expected for negative but not positive primes (Taylor, 1991).

Overall, with regard to the RT data at the different SOAs, the decrease in RTs from 150 to 300 ms, followed by an increase in RTs at 750 ms, is consistent with RT data from the study carried out by de Groot, Thomassen, and Hudson (1986). In their study, while a decrease in RTs occurred from 100 ms to 400 ms, SOAs of 600 ms and over were associated with an increase in RTs.

In Brody, Goodman, Halm, Krinzman, and Sebrechts' (1987) priming study, which employed the evaluation task with word stimuli and a short SOA, the reported RT data are consistent with ours. In that study, the authors compared the increase in RTs for emotional targets presented to the LH with the decrease in RTs for emotional targets presented to the RH following emotional primes (whether positive or negative) and neutral primes. They concluded that the RH was superior at processing emotional stimuli. However, an inspection of their data reveals the occurrence of reverse vs. anticipated priming for pairs with positive and negative targets in the LH. RTs for N-P pairs were 27 ms faster than RTs for P-P pairs, representing a reverse pattern of priming for pairs with positive targets. In contrast, RTs for N-N pairs were 45 ms faster than for P-N pairs, indicating an anticipated pattern of priming for negative targets.

On the other hand, although the time course hypothesis accepts the involvement of both cerebral hemispheres in the processing of emotional words, the priming paradigm utilized in this study argues against the idea that part of emotional word processing occurs in the LH and the other part in the RH, as proposed by Nagae and Moscovitch (2002) and Collins and Cooke (2005). This is because priming occurs at a processing stage equivalent to or later than lexical access, rather than at an earlier stage such as perceptual encoding. In addition, the results of this study challenge the idea that the mechanism underlying affective priming effects is specific to the nature of the task utilized (Pecchinenda, Ganteaume, & Banse, 2006). In the evaluation task used in the present study, we see the involvement of both the spreading activation and response competition mechanisms in yielding the effects. Our results seem to suggest that the role of SOA in affective priming is more important than the task itself.

3.4.2. Pattern of Priming Effects in Females and Similarities to Data for Males

The observed pattern of priming in females seems to differ from our prediction. In this group, priming effects centered on the two SOAs—150 and 300 ms—that are located in the range that causes automatic priming (Neely, 1977, 1991). Thus, both hemispheres shared the automatic activation of emotional words; their differentiation was due to valence: consistent with the valence hypothesis, the LH responded primarily to pairs with positive targets, whereas the RH was superior in responding to pairs with negative targets.

A number of studies of the processing of facial expressions have reported data consistent with the valence hypothesis in female participants (e.g., Burton & Levy, 1989; Rodway, Wright, & Hardie, 2003; Van Strien & Van Beek, 2000). In fact, in the circumplex theory of emotion, while comprehension of emotions is attributed to the RH, the experience and expression of emotions is claimed to be mediated by the anterior parts of both hemispheres depending on valence (Davidson, 1992, 1993; Davidson & Hugdahl, 1995). Van Strien and Van Beek (2000) argued that, when a task requires evaluation of the intensity of an emotional stimulus or a comparison between two emotional expressions, the activation of the anterior regions of each hemisphere yields a valence pattern. In this condition, participants may use their own affective responses to reach a decision about stimuli (Jansari, Tranel, & Adolphs, 2000).

In the domain of language lateralization, a gender effect has not typically been claimed (e.g., Jancke, Staiger, Schlaug, Huang, & Steinmetz, 1997; Price, Moore, & Friston, 1996; Simon & Sussman, 1987); nevertheless, it is possible that the valence effect we found for females in the present study is due to the task we used, which required an explicit decision concerning the target. Females are generally considered to be "more responsive [than males] to emotions" (Gard & Kring, 2007). Research findings indicate that females, for instance, integrate emotional prosody into ongoing semantic processing more effectively than males (Schirmer & Kotz, 2003; Schirmer, Kotz, & Friederici, 2002). In addition, in imaging studies females have shown an increase in the level of activation of the limbic system while rating words with negative connotations concerning body image. Such changes have not been detected in males, suggesting that females probably process these words as being more frightening than males do (Shirao, Okamoto, Mantani, Okamoto, & Yamawaki, 2005). Likewise, performing emotional decision tasks about negative words associated with interpersonal relationships (e.g., *alone, melancholy, anger*) has been shown to trigger an increase in the level of activation of structures such as the caudate bodies, putamen and parahippocampal gyrus in females, whereas in males no difference in the level of activation of any structure was reported (Shirao, Okamoto, Okada, Ueda, & Yamawaki, 2005).

Accordingly, we speculate that the results we found for females may be the effect of our task. It is possible that with this task, in which participants decided on the pleasant/unpleasant features of the target, the experience of the related affect instigated by emotional stimuli was the mechanism that caused females to reach a decision regarding the target (Wild, Erb, & Bartels, 2001). As this process activates the anterior regions of the LH and RH for positive and negative emotions, respectively, the valence pattern for the priming effects emerged (see Davidson, 1992, 1993, for a review). The task effect can be further examined by employing an implicit task, such as one involving LD.

Despite the differences between the patterns of priming in males and females, some similarities still exist. In particular, in both genders both hemispheres proved to be involved in the processing of emotional words: in females their differentiation was valence-based, whereas in males their differentiation was due to the time course of activation. Moreover, in both patterns the leading role of the LH in the processing of semantic information is implicated (e.g., Chiarello, Liu, Shears, Quan, & Kacinik, 2003; Chiarello & Richards, 1992; Yochim, Kender, Abeare, Gustafson, & Whitman, 2005). In males, early activation of stimuli occurred in the LH and in females the LH was faster than the RH. In the data from females, the appearance of priming for negative targets earlier in the time course than for positive targets (i.e., at the 150-ms SOA), in conjunction with the slow RTs for negative targets, presumably matches the mobilization-minimization hypothesis (Taylor, 1991). Moreover, the occurrence of priming for positive targets at the 300-ms SOA, together with faster RTs for these stimuli, validates the position that positive stimuli are less cognitively demanding (Ferre, 2003; Isen & Daubman, 1984).

3.5. Processing Modes of the LH and RH

How do the processing modes of the LH and RH differ during emotional word processing? As the basic components of language, *words* function as substitutes for objects, actions, associations, events, and so forth and are represented by *concepts* in the mind (Luria, 1982). That is, a concept is formed when all the related information about an object, including emotions, and a symbol (word) are combined. This information can create an *image* in the mind and help a concept be simulated effectively (Barsalou, 1999). Research suggests a causal relationship between imagery and emotions, which has been attributed to a link between the use of imagery and the activation of autobiographical episodes (Holmes, Mathews, Mackintosch, & Dalgleish, 2008).

It has been shown that a concept can be simulated to different degrees while performing different tasks, depending on time, the participant's motivation, and the task instructions (Niedenthal, Rohmann, & Dalle, 2003). This variation means that a concept can be processed superficially such that not many of its properties become simulated or as deeply embedded as when most of its properties are activated. One outcome of this processing hierarchy is that we can access an emotional concept, but not necessarily the associated feeling (Innes-Ker & Niedenthal, 2002).

As far as the role of the hemispheres, as mentioned above, one factor that determines the degree of simulation of a concept is time. Hence, if an emotional word is presented for a brief duration, it is likely that very little activation of its related concept occurs. This is expected to occur in the LH, where it is likely that only semantic features of emotional words are activated. Such quickly occurring processing should be sufficient for language processing to proceed and for meaning to merge into the context.

On the other hand, when an emotional word is presented for a longer duration, processing likely enters another stage through the reliving of a greater number of properties associated with a concept—and the RH is likely more capable of such activity. That is not to say that processing in the RH ends with an emotional state, but the level of emotional word processing in the RH is likely deeper than that in the LH. Indeed, the semantic literature has attributed such processing to the RH: Beeman (1993) proposed that, during semantic processing, the LH uses relatively fine semantic coding to quickly select a few features of a word for further processing, whereas the RH has the ability to activate several features of a word simultaneously. Therefore, the actual interpretation of a word can differ between hemispheres.

Here, the role of attention that has mostly been attributed to the RH (e.g., Anderer, Saletu, Semlitsch, & Pascual-Marqui, 2003; Pardo, Fox, & Raichle, 1991; Strange et al., 2000) is likely crucial in entering emotional word processing to a later stage. This stage, which can accompany imagery, for which there is evidence of RH involvement (e.g., Gasparini et al., 2008), raises the possibility of a correlation between the role of the RH in the processing of emotions as reported repeatedly in the literature (the RH hypothesis) and its role in attention-demanding processes (e.g., Casey et al., 1997; Compton et al., 2003; Compton, Heller, Banich, Palmieri, & Miller, 2000).

Thus, not only does the time course hypothesis *not* challenge the dominant role of the LH in the processing of semantic information, but it also suggests that the processing abilities of both hemispheres combine for part of the semantic system—the same part for which the RH has repeatedly been claimed to play a critical role. In this respect, it is conceivable that the slow mode of processing in the RH adds some qualities to the output.

3.6. Conclusion

In conclusion, this was the first lateralized study to demonstrate a moderating effect of SOA on affective priming effects. Emotional words seem to be represented within both hemispheres but the time course of their activation is different. Presumably, the LH has access to emotional words automatically earlier in the processing sequence, whereas the activation of emotional words is slower in the RH and probably involves directing attention to their content. These findings may show how the LH's superior capabilities in language processing and the RH's focus on attention-capturing stimuli are reflected in the automatic and controlled activation of the emotional lexicon. This interhemispheric cooperation is probably the reason why hemispheric dominance alters across the course of processing. Moreover, this study is the first to raise the possibility that both spreading activation and response competition are involved as the mechanisms underlying affective priming effects. In addition, the data further support the claim that evaluation is an automatic process that occurs at a very early stage of information processing. The different pattern of findings in females is probably due to the effect of the task, which required explicit judgments concerning the targets. Future studies employing an implicit task should clarify this position.

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Chapter 4

This chapter consists of an article in which the theoretical background, methodology, and results of the second study are reported and discussed. The aim of the study was to examine whether compensatory mechanisms in the form of bilateral activation, in comparison to unilateral activation as shown in the results for young males in the first study, occur in high-performing older individuals during access to the meanings of emotional words.

The Time Course of Access to Semantic Information in High-Performing Older Adults: Behavioral Evidence for the Hemispheric Asymmetry Reduction in Older Individuals

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Abstract

The possibility that the HAROLD phenomenon (i.e., Hemispheric Asymmetry Reduction in OLDer adults) is manifested in the course of access to semantic information, in particular the meaning of emotional words, was investigated using the visual half-field priming paradigm. Twenty-eight older and 28 young adults were tested. The time course of priming was tracked in the cerebral hemispheres across three SOAs: 150, 300, and 750 ms. The results showed older and younger adults had the same level of accuracy. While priming occurred unilaterally in young participants, the pattern of priming in older participants appeared to be bilateral whenever it was present, that is, at the 300- and 750-ms SOAs. The delay in the appearance of priming in older adults may be due to an increase in sensory thresholds that causes older adults to need more time to encode stimuli and fully activate their semantic network. It is concluded that the bilateral pattern of priming in the presence of an equivalent level of performance in older adults provides behavioral evidence supporting the compensatory role of the HAROLD phenomenon for this particular task.

Key words: HAROLD phenomenon, semantic processing, priming, high-performing older adults

4.1. Introduction

Over the past few decades, a substantial body of research has concentrated on the changes in cognitive processes as a result of normal aging. One outcome of this research is the discovery that semantic memory (knowledge of word meanings and related concepts) is relatively intact in older individuals (e.g., Park et al., 2002; Salthouse, 1993; see Light, 1992, for a review). Although some studies suggest that aging is accompanied by deficits affecting access to semantic information (Birren, Woods, & Williams, 1980; Giaquinto, Ranghi, & Butler, 2007; Hertzog, Raskind, & Cannon, 1986; Karayanidis, Andrews, Ward, & McConaghy, 1993; Salthouse, 1982), many older individuals seem to perform as well as young adults on a variety of tasks including semantic tasks (see Cabeza, 2002, for a review). In the present study, in order to examine this view, we compared a group of older and younger adults' behavioral performance over the time course of access to semantic information in the cerebral hemispheres by using a visual half-field priming paradigm.

The time-course analysis is motivated by the spreading activation theoretical framework. According to this framework, semantic memory is conceptualized in terms of a network in which processing is accomplished through the spread of activation between connected nodes (Neely, 1977). The strength of the links between the nodes allows for a more rapid and efficient spread of activation; thus, the related areas of the network more available and access to the lexicon is facilitated. A paradigm that is widely used to assess the spread of activation is the priming paradigm. In such a paradigm, responses to a target word can typically be made more rapidly and accurately when the target (e.g., *chair*) is preceded by a related prime (e.g., *table*) than when an unrelated prime (e.g., *river*) is used. The presentation of a prime automatically activates its node in memory, and then this activation spreads to highly related nodes and increases their accessibility. This process occurs automatically as an inherent part of word recognition; in this condition, the participant does not make an explicit judgment about the link between the prime and the target (Collins & Loftus, 1975). In contrast, controlled processes come into play when a participant is placed in experimental conditions in which expectations about relations between the prime and the target are encouraged. Thus, when the time elapsed between the presentation of a prime and of a target (i.e., Stimulus Onset Asynchrony or SOA) is short, the resulting priming effect is assumed to occur via passive spread of activation in semantic memory, whereas with a long SOA the participant actively looks for relations between the prime and the target (Neely, 1977, 1991).

One line of aging research claims that every stage of information processing diminishes with age as a result of what is called the "general speed deficit" (see Salthouse, 1996, for a review; Cerella, 1985; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1982). However, another line of evidence suggests that aging is associated with a reduction in the amount of attentional resources which are particularly required for controlled processes, whereas automatic processes are relatively spared (e.g., Burke, White, & Diaz, 1987; Hasher & Zacks, 1979; Jennings & Jacoby, 1993). Yet, in the literature on aging, there are reports that show the same pattern of lexical access in older and young individuals (e.g., Chiarello, Church, & Hoyer, 1985; Saxton et al., 2001; Stern, Prather, Swinney, & Zurif, 1991).

For example, Stern et al. (1991) explored the activation pattern of closely-related category pairs (e.g., *cabbage – lettuce*) in elderly individuals using a priming paradigm.

Since a prime and its target were presented in a list form, where one stimulus from each pair is displayed and lexical decisions are required for each stimulus, interstimulus intervals (ISI) were manipulated, rather than SOAs. Using five different ISIs—300, 500, 800, 1100, and 1500 ms—the results indicated a similar pattern of lexical access for older and younger participants in that priming was reliable only at the 500-ms ISI. Stern et al. (1991) argued that "wherever the locus of age related slowing may be, it is not in the early, language-specific processing devices that mediate lexical access" (p. 359).

Chiarello et al.'s (1985) study of the processing of category words (e.g., *inch – yard*) also found comparable priming effects in older and younger individuals. In their study, 600 ms elapsed between the onset of the prime and the target (i.e., SOA of 600 ms). Accordingly, Chiarello et al. proposed that semantic priming mechanisms remain intact with age. Nevertheless, the priming study conducted by Howard, Shaw, and Heisey (1986) showed a delay in the time course of lexical access in older individuals. To compare the priming of category words (e.g., *bird – robin*) in older and younger adults, Howard et al. used three SOAs: 150, 450, and 1000 ms. Their study found significant priming effects at all three SOA conditions for young participants, whereas in older individuals priming did not occur at the 150-ms SOA. This pattern likely shows a delay in early access to semantic information in older adults.

Measures of electrical brain activity (ERPs: event-related potentials) have also been used to enhance our understanding of lexical access in older individuals. ERPs with a resolution of milliseconds provide detailed information about the size and timing of semantic effects, in particular the N400, which occurs during semantic processing (Kutas & Hillyard, 1980, 1984). The results gained by employing this methodology also seem to show inconsistent results regarding a change in semantic processing in older adults (e.g., Federmeier, Van Petten, Schwartz, & Kutas, 2003; Giaquinto et al., 2007; Karayanidis et al., 1993). For example, while no difference was detected between older and younger adults in the onset latency and duration of N400, the peak latency of this component appeared later in older individuals during a task in which participants had to look for words belonging to a pre-assigned category embedded in a sequence of words from other categories (Giaquinto et al., 2007). On the other hand, with a similar task, there is a report that the N400 lasts longer in older adults (Karayanidis et al., 1993). At the same time, some findings in the field of aging indicate no difference in the features of the N400 for older and younger individuals (Federmeier et al., 2003).

While cognitive changes in older individuals reflect an age-related change in the functions of the brain (see Cabeza, 2001, for a review), equivalent levels of performance in some older individuals as in young adults may be attributed to the possibility that compensatory mechanisms occur in older individuals. Indeed, neuroimaging evidence related to possible age-related changes in brain activity has suggested that a pattern of neurofunctional reorganization, the Hemispheric Asymmetry Reduction in OLDer Adults (HAROLD) phenomenon (Cabeza et al., 1997), may occur in older individuals with higher levels of education, known as high-performing older adults. This phenomenon corresponds to a more bilateral pattern of activation associated with a given task that occurs in high-performing older individuals than in young adults, who show unilateral activation for the same task.

In order to examine the HAROLD phenomenon, Cabeza, Anderson, Locantore, and McIntosh (2002) used positron emission tomography to examine recall and source memory in three groups: high-performing older, low-performing older, and young participants. Recall and source memory tasks were selected because a previous study with young adults had shown a clear recruitment of the left prefrontal cortex (i.e., PFC) for recall and of the right PFC for source memory (Cabeza, Locantore, Anderson, 2003). The results for source memory showed significant activation in the right PFC for young and low-performing older participants, whereas for high-performing older participants activation occurred not only in the right PFC but also in the left PFC. Likewise, for the recall task activation was unilateral (i.e., left-lateralized) in young and low-performing older participants and bilateral in high-performing older participants. Because the accuracy of the high-performing older adults was shown as well as young participants on both tasks, the significance of the HAROLD pattern was considered to be compensatory. Thus, some older individuals seem to maintain high performance on tasks that usually depend on one of the hemispheres by recruiting homologous areas of the brain in the opposite hemisphere.

To date, the HAROLD phenomenon has been supported by several studies that compared the performance of younger and older adults on functions such as episodic memory, working memory, semantic memory, and perception (see Cabeza, 2002, for a review). In the aging literature, data from ERP studies (Friedman, 2003) and behavioral studies (Reuter-Lorenz, Stanczak, & Miller, 1999) also indicate the advantageous impact of bilateral recruitment on older adults' performance.

The results of one study in our lab that investigated the time course of access to emotional words (as part of the semantic system) using a priming paradigm showed unilateral pattern of priming effects at short SOAs of 0 and 150 ms in the LH and at a long SOA of 750 ms in the RH of young individuals (Abbassi & Joanette, in press). Given the compensatory function of bilateral activation in high-performing older individuals (i.e., HAROLD phenomenon), the present study was designed to investigate the possibility that bilateral pattern of priming effects would occur in high-performing older individuals while they process emotional words and to compare their results with those of young individuals.

The study was carried out by employing the affective priming paradigm along with an evaluation task (Fazio, Sanbonmatsu, Powell, & Kardes, 1986) in which an emotional target word (e.g., *crime*) is preceded by an emotional prime word (e.g., *death*), and affective priming is indicated when the time needed to evaluate the target is shorter when the prime and the target are congruent (i.e., negative prime – negative target, positive prime – positive target) compared to when the prime and target are incongruent (i.e., negative prime – positive target, positive prime – negative target). Targets were to be judged as pleasant or unpleasant. A divided visual field (DVF) method of presentation was employed in which stimuli that are presented for a brief duration (less than 200 ms) to the right visual field (RVF) or to the left visual field (LVF) are considered to be processed primarily by the left hemisphere (LH) and right hemisphere (RH), respectively (Atchley, Ilardi, & Enloe, 2003). In addition, by manipulating SOA, we could track access to emotional words at different times over the course of processing in the LH and RH.

In young participants, we expected unilateral pattern of priming effects: at short SOAs in the LH and at the long SOA in the RH. Because the same task tends to be more demanding for older adults, the HAROLD phenomenon predicts that in older participants the same level of performance (accuracy and response time) as young participants should be associated with bilateral pattern of priming effects at short and long SOAs. It is the prediction that the present study addresses.

4.2. Method

4.2.1. Participants

Older participants were recruited on a voluntary basis (with compensation) by posting flyers in social settings or seniors' centers in Montreal and were excluded from the study if their performance on the screening tests and the experiment was below the age-appropriate range. Accordingly, from 33 older individuals tested, 28 remained in the study: 12 males and 16 females between the ages of 60 and 78, with a mean age of 67 (SD = 6). This group was compared to a group of 28 male[11] students between the ages of 20 and 35, with a mean age of 24.7 (SD = 3.6). As level of education is a criterion for matching older individuals considered to be high-performing with young individuals (Springer, McIntosh, Winocur, & Grady, 2005), only older adults with higher levels of education were recruited and matched in terms of years of formal education with the group of young participants. The average number of years of education was 14.7 (SD = 2.7) for older and 16.5 (SD = 2.7) for young participants. All participants were right-handed, native English speakers, with normal or corrected to normal vision and without any past history of neurological or psychiatric disease. Handedness scores, which were assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), were 98 (SD = 4) for

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[11] The rationale to restrict our young sample to male participants was to avoid the possible impact of hormonal fluctuations in females (i.e., the possible effect of a decrease in LH activation in the premenstrual phase: Alexander, Altemus, Peterson, & Wexler, 2002; Altemus, Wexler, & Boulis, 1989).

older and 92 (SD = 10) for young participants. To screen participants for depressed mood, the PANAS questionnaire (i.e., the Positive and Negative Affect Scale: Watson, Clark, & Tellegen, 1988) was administered. Of the 34 young individuals who participated, the data from one participant were removed from analyses because he was in a depressed mood at the time of the experiment; the older participants' PANAS scores were in the normal range. As well, the data from five additional young participants and five older participants were excluded because they had overall error rates of more than 25% or an accuracy rate at the chance level in at least one SOA condition. Older participants were also screened for cognitive impairments using the Montreal Cognitive Assessment (MoCA) test (Nasreddine et al., 2004). All participants signed a consent form before taking part in the study, as required by the *Comité d'éthique de la recherche de l'IUGM*.

4.2.2. Stimuli

The stimuli were 48 positive and 48 negative words with high arousal ratings selected from ANEW (Affective Norms for English Words: Bradley & Lang, 1999) and used to construct 48 congruent pairs (i.e., 24 positive-positive, 24 negative-negative) and 48 incongruent pairs (24 positive-negative, 24 negative-positive). The prime and target in congruent pairs were not semantically related; this was confirmed by asking 21 of the young participants to list three words that they immediately associated with each prime at the end of their experimental session; the target was never among them. The positive and negative prime sets and target sets were carefully matched according to grammatical category, imageability, concreteness, and word length (Medical Research Council psycholinguistic database; Coltheart, 1981). Stimuli could be used in English either as nouns or as both nouns and verbs and were 3 to 7 letters long. Mean frequency ratings for positive pairs and negative pairs were slightly different, which is a normal characteristic of English and is unavoidable in studies that use a larger stimulus set (Scott, O'Donnell, Leuthold, & Sereno, 2009; Wurm & Vakoch, 1996).

The congruent and incongruent pairs were divided into two sublists, each including 24 congruent and 24 incongruent pairs (12 from each category presented in each visual field). Reversing the visual field of presentation created four test lists; no stimulus was repeated within any such list. Each participant received all four test lists, one for each SOA (0, 150, 300, and 750 ms). The assignment of SOAs to the test lists was counterbalanced. Within each test list, half of the pairs were presented in the RVF and half in the LVF. Block order was also counterbalanced across participants. Pairs in each block were preceded by three buffer pairs. A practice set consisted of four blocks of 16 pairs, one for each SOA. Stimuli were presented in white uppercase against a black background, subtending 1.6°–4° and .9° of horizontal and vertical visual angles, respectively.

4.2.3. Procedure

Before running the practice pairs, participants completed three paper-and-pencil questionnaires: a participant information questionnaire, the PANAS (Watson et al., 1988), and the Edinburgh Handedness Inventory (Oldfield, 1971). When this was done, participants sat 60 cm away from the computer screen. A chin rest was used to maintain a constant viewing distance. The experimenter monitored eye movements using a video camera during testing and reminded the participant if any deviation from the fixation point was noted. Stimulus presentation, timing and data collection were controlled by E-Prime 1.0 software. Participants were allowed to rest briefly between blocks.

The session began with practice pairs followed by one of the experimental blocks. Throughout the pairs, there was a central fixation point at the center of the screen. Each pair began with an alerting tone; after 700 ms, the prime was displayed in the RVF or the LVF for 150 ms. The SOA group determined whether 0, 150, 300, or 750 ms elapsed between the onset of the prime and the onset of the target. The target was always presented for 180 ms. The next pair was initiated 1 s after the participant's response. Alternatively, if the participant did not respond within 1600 ms, an error was registered and the next pair was initiated after 1 s. Pairs were presented in pseudo-randomized order, with no more than three successive pairs in the same visual field. To ensure of the processing of the prime, it was displayed above or below the location of the target. The target was always underlined.

Participants were asked to maintain their gaze on the central fixation point. They were instructed to read both words but respond only to the underscored word. They were required to decide as quickly and accurately as possible whether the target was pleasant or unpleasant. Responses were registered by simultaneously pressing the "c" and "m" keys of a keyboard placed symmetrically at the midline for pleasant words and the "d" and "k" keys for unpleasant words. The faster of the two responses was taken as the response time (RT) for that pair (Collins & Cooke, 2005; Weems, & Zaidel, 2005). In addition to RT, accuracy was measured. The testing session was concluded by performing the MoCA test.

4.3. Results

To screen RT data, pairs with RTs greater than 1.5 SD away from each participants' mean (per condition) (8.6% and 8.8% of the correctly answered pairs in older and young participants, respectively; about .9 pairs per condition) were removed from the analyses. The mean RTs for correct responses and percent accuracy scores for congruent and incongruent pairs and priming effects at each SOA condition in the RVF and LVF for both age groups are shown in table 4.1. Figure 4.1 compares RTs for congruent vs. incongruent pairs in the two visual fields (VFs) as a function of SOA in the two groups of participants.

As preliminary analyses showed that the percent accuracy scores of about 40% of older participants at the 0-ms SOA were at the chance level and for the rest of the group the variance of the RTs at this SOA was greater than in the other three SOA conditions, the 0-ms SOA was eliminated and data analysis continued with the three SOAs of 150 ms, 300 ms, and 750 ms for both groups of participants. In addition, the preliminary analyses investigated the possibility of a valence effect in the data of both groups and of gender differences in the RTs of older adult participants. Since no such effects were found, we did not consider these variables further in the analyses. Therefore, a 2 x 2 x 3 x 2 mixed ANOVA was performed on RTs and on percent accuracy scores with congruency (Congruent vs. Incongruent), VF (RVF vs. LVF) and SOA (150 ms vs. 300 ms vs. 750 ms) as within-participant variables and age group (Older vs. Young) as a between-participant variable.

Table 4.1. *Response Times (ms) and Accuracy (Percent Accurate) for Congruent and Incongruent Pairs in Each Visual Field as a Function of SOA (SD) in Older and Younger Participants*

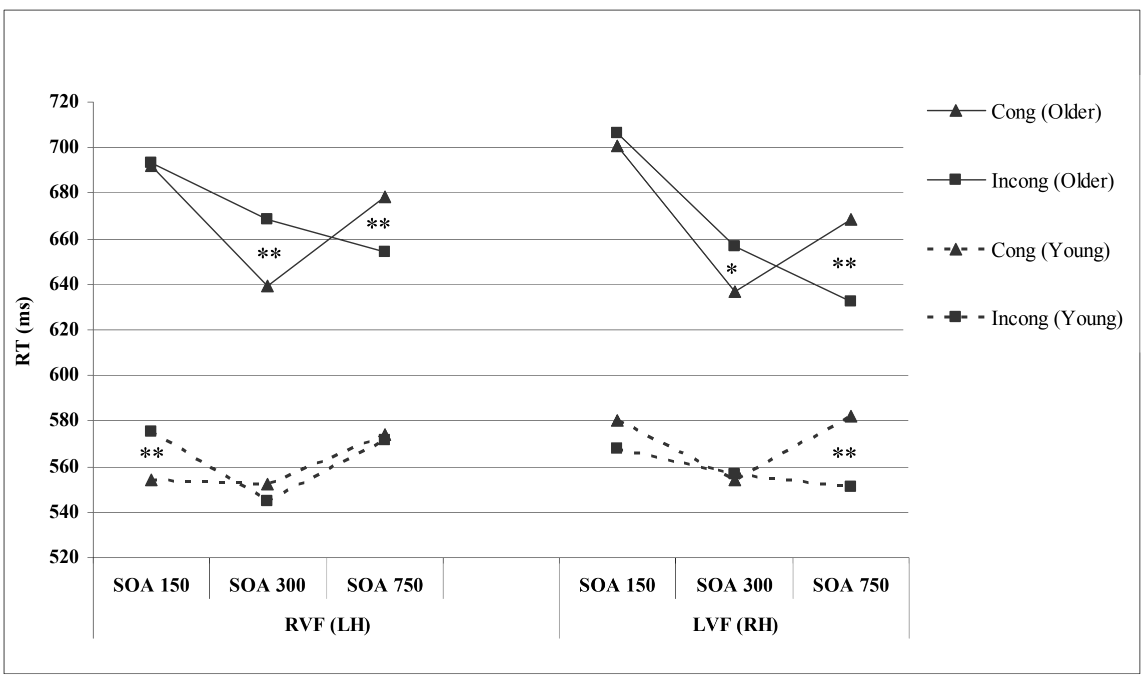
	SOA					
	150 ms		300 ms		750 ms	
	RT	Accuracy	RT	Accuracy	RT	Accuracy
Older adults:						
RVF						
Congruent	692 (103)	91 (10)	639 (112)	91 (11)	678 (121)	90 (12)
Incongruent	693 (96)	90 (10)	669 (122)	93 (7)	654 (122)	92 (10)
Priming	1	–1	30**	2	–24**	2
LVF						
Congruent	701 (114)	89 (10)	636 (100)	90 (10)	668 (111)	90 (11)
Incongruent	707 (111)	89 (9)	657 (115)	93 (8)	633 (97)	90 (13)
Priming	6	0	21*	3	–35**	0
Younger adults:						
RVF						
Congruent	554 (73)	88 (11)	552 (86)	89 (10)	574 (97)	90 (9)
Incongruent	575 (88)	87 (11)	545 (94)	86 (14)	572 (95)	91 (9)
Priming	21**	–1	–7	–3	–2	1
LVF						
Congruent	580 (95)	83 (13)	554 (94)	85 (13)	582 (92)	92 (11)
Incongruent	568 (80)	84 (13)	557 (83)	88 (11)	551 (74)	88 (10)
Priming	–12	1	3	3	–31**	–4

** and * indicate significant and marginally significant effects ($p < .05$), respectively.

In the ANOVA for RT data, the main effect of age group was significant: overall RTs in young participants were faster than overall RTs in older participants (564 vs. 669 ms) [F

(1, 54) = 22.467, p < .001]. Congruency and VF did not interact with age [Fs < 1] but there was a trend toward a significant interaction between SOA and age [F (2, 108) = 2.590, 05 < p < .10)]. An examination of the simple effects of SOA for each age group showed that in young participants the difference between overall RTs at the SOAs of 150, 300, and 750 ms (569, 552, 570 ms, respectively) was not significant [F (2, 26) = 1.435, p > .20], whereas in older participants SOA had a significant main effect [F (2, 26) = 6.792, p < .01]. Post hoc comparisons at an alpha level of 5% showed that the older participants were slower at the150-ms SOA (698 ms) than the 300-ms (650 ms) and 750-ms (658 ms) SOAs, which did not differ from one another.

Figure 4.1. Response times (ms) to congruent and incongruent trials in each visual field as a function of SOA in older and young participants



** and * indicate significant and marginally significant effects (p < .05), respectively.

Four-way interaction of Age group x Congruency x VF x SOA was not significant [F (2, 108) = 1.365, p = .260]. As well, three-way interactions of Age group x VF x SOA and of Age group x Congruency x VF were not significant (F < 1.1). However, age group interacted with Congruency x SOA (i.e., Age group x Congruency x SOA: F (2, 108) = 3.315, p < .05).

In order to investigate the occurrence of unilateral vs. bilateral priming effects in young vs. older groups, we tracked the processing of congruent vs. incongruent pairs at each SOA in the RVF and LVF by performing two separate 2 x 2 x 3 ANOVAs with factors of congruency (Congruent vs. Incongruent), VF (RVF vs. LVF), and SOA (150 vs. 300 vs. 750 ms) on the RT data from older and young participants.

In young participants, a 21-ms priming effect was observed at the 150-ms SOA in the RVF [F (1, 27) = 4.857, p < .05], whereas at the 300-ms SOA no priming emerged in either VF (F < 1). At the 750-ms SOA, 31 ms of reverse priming effects (i.e., faster RTs for incongruent pairs than for congruent pairs) occurred in the LVF [F (1, 27) = 7.987, p < .01]. On the other hand, the results in older participants revealed no priming effects at the 150-ms SOA in either VF (Fs < 1). At 300 ms, however, a 30-ms significant priming effect occurred in the RVF [F (1, 27) = 4.296, p < .05], while the amount of priming in the LVF (21 ms) was almost significant [F (1, 27) = 2.897, p = .10]. Finally, what occurred at the 750-ms SOA was a pattern of reliable reverse priming effects in both VFs: 24 ms in the RVF [F (1, 27) = 4.242, p < .05] and 35 ms in the LVF [F (1, 27) = 11.575, p < .01].

It should be mentioned that, before the RT data were analyzed, the mean RT distribution for each condition in each group of older and young participants was examined separately. The assumption of normal distribution was considered to be met. Moreover, aging studies suggest a relatively high probability of finding spurious overadditive interactions, in which the slower group (i.e., older group) produces a large effect. Considering that the RTs of older and young individuals have been claimed to be linearly related, in order to isolate group differences in information processing and augment the analyses of raw RTs, z-score transformations of RTs were performed (Faust, Balota, Spieler, & Ferraro, 1999). The results of the analyses of both transformed RTs and raw RTs were similar: although in both groups of data a trend toward an interaction of age and SOA was shown, the most important finding was three-way interaction of age group x congruency x SOA, which also accounted for the largest part of the variance. Consequently, further analysis was performed on the raw RT data.

Regarding the accuracy data, the percent correct scores were entered in a 2 (Congruency) x 2 (VF) x 3 (SOA) x 2 (Age group) ANOVA with congruency, VF and SOA as within-participant variables and age group as between-participant variable. The main effect of age group failed to reach significance [$F (1, 54) = 3.577$, $.05 > p$], indicating that the overall percent correct scores of older and young participants did not differ (91% vs. 88%). Age group did not interact with any of the variables involved in the experiment or with their interactions ($p > .05$). However, two separate 2 (Congruency) x 2 (VF) x 3 (SOA) ANOVAs were conducted for the percent accuracy scores of each age group in order to pinpoint the possibility of a speed-accuracy trade-off in the data of each group of participants. In the results of older participants, none of the main effects including Congruency, VF, and SOA or of the interactions achieved significance ($Fs < 2$). Although the difference between the percent accuracy scores in the three SOA conditions

(89.6%, 91.8%, 90.4% at 150, 300, and 750 ms, respectively) was not significant [F (2, 54) = .975, p > .30], in post hoc comparisons at an alpha level of 5% a trend toward less accurate responses at the 150-ms SOA than at the 300-ms SOA was indicated. Taking the above-mentioned RT results into consideration—namely, slower RTs at 150 ms than at 300 ms—the RTs and percent correct scores in the older participants seem to be similar. This outcome makes the possibility of a speed-accuracy trade-off in the older participants' data trivial.

Regarding the results of young participants, none of the main effects of congruency and VF or two-way and three-way interactions reached significance. Although accuracy scores at the 750-ms SOA (90%) were higher than at the 150-ms (86%) and 300-ms (87%) SOAs [F (2, 54) = 5.878, p < .01), considering that the young participants' RT data showed no difference between RTs at the three SOAs, it seems that the higher accuracy level at 750 ms did not lead to better RTs at this SOA. This outcome makes the possibility of speed-accuracy trade-off in the young participants' data negligible.

4.4. Discussion

In light of the compensatory function of bilateral activation in high-performing older individuals during cognitive tasks, this study compared the time course of access to the meanings of emotional words in the LH and RH across three SOAs—150, 300, and 750 ms—in high-performing older and young adults. The results showed the same level of accuracy in older and young participants. However, older adults responded to the stimuli slower than young participants. While, in young adults, priming appeared to be unilateral in the LH at 150 ms and in the RH at 750 ms, in older participants the pattern of priming was bilateral whenever it was present: a reliable amount of priming in the LH and an almost significant priming in the RH at the 300-ms SOA were followed by a pattern of bilateral priming at the 750-ms SOA. No priming was detected in either hemisphere at the 150-ms SOA in older adults or at the 300-ms SOA in young individuals.

The first piece of evidence to be noted in this study has to do with the evolution of the laterality of the priming effect in older adults. While the stimuli were presented equally to the RVF (LH) and LVF (RH) at each SOA in both groups, whenever priming appeared in young participants, only one hemisphere was involved, whereas in older adults both hemispheres contributed to the appearance of priming whenever it occurred. This bilateral pattern of priming seems to be consistent with the HAROLD phenomenon.

Although the four-way interaction which implied the differentiating effect of VF in young participants' results was not significance, we suspect this might be because of eliminating the 0-SOA condition from the analysis that caused a shortage in the power of the experiment. Indeed, separate analysis of the data from young participants[12] with all four SOAs indicated a three-way interaction of all factors involved in the study, with 29 ms significant priming effect at the 0-SOA in the LH. Namely, the SOA of 0 ms showed to be even more effective than the 150-SOA in the appearance of priming in the LH.

Yet, the results obtained in young adults showed a unilateral pattern of priming whenever it occurred: at a short SOA in the LH and at a long SOA in the RH. Thus, the left-lateralized pattern of priming that occurred at the 150-ms SOA in the LH eventually

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[12] The complete results of the young participants including the 0-SOA condition have been reported in a paper by the same authors (Abbassi & Joanette, in press).

decreased such that no priming was detected in this hemisphere at 300 ms. In contrast, priming emerged in the RH later, at the long SOA of 750 ms. This pattern of priming has also been shown in the processing of distantly-related category words (Koivisto, 1997, 1998) and subordinate meaning of ambiguous words (Burgess & Simpson, 1988).

Taking the data of young participants into consideration, the exploration the principal vs. supplementary roles of each hemisphere seems to be possible by simply looking at the amount of priming in the data from older adults. That is, the larger amount of priming in the LH than the RH (i.e., 30 vs. 21 ms) at the 300-ms SOA and in the RH than the LH (i.e., 35 vs. 24 ms) at the 750-ms SOA can probably be considered in line with the time course hypothesis that the LH plays a principal role earlier in processing and the RH later on (Koivisto, 1997). The marginally significant priming in the RH at the 300-ms SOA (21 ms) is still in this direction because the time course of activation in the RH is typically slower than in the LH.

In a priming paradigm, the priming that appears at short SOAs is considered to be the product of automatic activation of stimuli, whereas the priming that comes into play at long SOAs is attributed to the participant's use of strategies (Neely, 1977, 1991). For that reason, the absence of priming at the 300-ms SOA in young adults and at the 150-ms SOA in older adults should be due to different underlying mechanisms. In young participants, after the appearance of priming at the short SOA of 150 ms, automatic activation is shown to decline to a negligible amount at 300 ms. Because activation can be stimulated again by directing attention to the relationship between the prime and the target at a long SOA, priming reappeared at 750 ms. Thus, the pattern of priming in young adults suggests that the 300-ms SOA stands between the two processing modes:

automatic activation has decreased but strategies concerning the relationship between the prime and target have not yet been applied.

In older participants, there was no priming at the 150-ms SOA, and priming was first detected at 300 ms. Despite the delay in the appearance of priming, the nature of the priming at the 300-ms SOA is likely automatic. There are at least two kinds of evidence supporting this conclusion. First, the 300-ms SOA is not within the range that can cause controlled priming to emerge. The priming literature evidences the appearance of controlled priming at least 400 to 500 ms after the onset of the prime (Neely, 1991). Second, even in the pattern of priming shown by young participants, the 300-ms SOA occurs at a point where controlled processes are only about to develop.

The fact that there was a great deal of variability in priming effects among older adults at the 0-ms SOA, causing us to eliminate this condition from analysis, and the additional fact that no priming was detected at the 150-ms SOA probably suggest that the minimum SOA at which priming occurs in older individuals is different from in young adults. This result is consistent with Howard et al.'s (1986) finding of absence of priming at an SOA of 150 ms in older adults. Thus, our study suggests that automatic activation of semantic information occurs in older adults but probably with a delay as compared to young individuals. In this respect, a closer look at the studies conducted by Chiarello et al. (1985) and Stern et al. (1991) indicates that they reported priming at SOAs or ISIs of more than 300 ms (600 ms: Chiarello et al., 1985; 500 ms: Stern et al., 1991). The priming observed at these SOAs cannot easily be judged to be automatic, since these conditions are likely in the range at which strategies are developed.

On the other hand, priming at the 750-ms SOA occurred in both groups of participants. This finding in older adults suggests that the delay that may occur earlier in the course of processing does not carry over to later stages (e.g., Federmeier et al., 2003). The similar pattern of reverse priming (i.e., shorter RTs for incongruent pairs than congruent pairs) for young and older adults seems to validate this conclusion. The literature on affective priming provides an explanation for this reverse effect. Indeed, for the evaluation task, in addition to the spread of activation account as the mechanism underlying priming effects, another explanation has also been proposed (Wentura, 1999, 2000). In the so-called response competition account, the prime can be evaluated as being the target. Hence, when the prime is congruent to the target, its valence matches the response, but when the prime is incongruent to the target, its valence mismatches the response. Consequently, when prime and target are congruent, response facilitation might occur, whereas when they are incongruent, the resulting interference might slow down responses.

Research suggests that, when the prime becomes salient, such as when it is highly arousing, reverse priming is more likely to occur (Glaser & Banaji, 1999). Giving the participant an accuracy goal may reinforce the saliency of the prime. When participants have an accuracy goal, they probably recognize the potential effect of the prime to bias their judgment regarding the target and consequently attempt to ensure that the response comes to the right item: the target. As it is easier to distinguish the target from the prime in the case of incongruent pairs, participants respond faster to incongruent pairs. In contrast, a double check will result in extended RTs for congruent pairs (Wentura, 2000).

Furthermore, the appearance of priming at 750 ms in the present study does not support the possibility that attentional processes are deficient in older adults (e.g., Burke et al., 1987; Hasher & Zacks, 1979; Jennings & Jacoby, 1993). Rather, the incidence of priming at the 300-ms SOA suggests that the kind of relationship in which attention is directed to the emotional meaning of words does not change with age.

What could be the possible reason for the delay in the appearance of priming effects in older adults? In the aging literature, there has been debate over whether the slow RTs reported in aging research represent a generalized speed deficit or whether some aspects of processing are affected more than others (Salthouse, 1996, for a review). Consistent with the latter view, there is evidence that suggests that aging affects peripheral aspects of semantic processing such as word encoding more than central aspects, for instance, lexical access and decision making (Allen, Madden, Weber, & Groth, 1993). This evidence is consistent with the sensory deficit theory of aging, which attributes age-related cognitive decline to deficits in elderly people's sensory functioning; that is, sensory thresholds increase in older adults such that the analysis of a sensory stream is likely to slow down with aging (Lindenberger & Baltes, 1994).

The present study's finding that there was an age difference in the appearance of automatic priming together with the emergence of priming at the SOAs of 300 and 750 ms suggests that elderly people require more time to encode stimuli and start activation through the semantic network. Evidence from behavioral, electrophysiological, and imaging studies supports this claim.

For instance, behavioral research indicates that, in a lexical decision task, elderly participants' RTs are affected by word length more than those of young individuals, as elderly participants require more time to respond to longer words, whereas the influence of word frequency on lexical decisions is similar in young and older adults (e.g., Whiting et al., 2003). Likewise, ERP evidence of word comprehension in the elderly indicates a delay in the appearance of early ERP components such as P1 and N1 that indexes sensory analysis of stimuli. This delay, however, has not been shown to carry over to later component of the N400, which indexes semantic processing (Federmeier et al., 2003). Neuroimaging research shows less activation in the visual cortex coupled with enhanced activation in the frontal areas during cognitive tasks in elderly participants (e.g., Davis, Dennis, Daselaar, Fleck, & Cabeza, 2007); this evidence fits well with the sensory deficit theory of cognitive aging (Baltes & Lindenberger, 1997).

In addition, a number of neuroimaging studies of cognitive aging have reported the recruitment of additional brain areas in conjunction with slow speed and a similar accuracy level in older and younger adults (e.g., Cabeza et al., 2004; Davis et al., 2007; Grady et al., 1992, 1994). Those studies seem to explain our results: the recruitment of additional brain areas means that additional time is necessary for the process carried out by these areas. According to Grady et al. (1992, 1994), the age-related change in brain recruitment enhances accuracy at the expense of slowing RTs.

It is also possible, however, that the early slowing in RTs is not a characteristic of high-performing older adults. We selected the older participants only by their results on the MoCA test in addition to taking their level of education into consideration. Employing a few more screening tests (e.g., Wechsler Adult Intelligence Scale – Revised: Wechsler, 1981) could be helpful in selecting a better sample of high-performing older adults. As well, further research is needed to pinpoint the time at which automatic activation diminishes in the elderly and, hence, attentional strategies start to affect processing.

In conclusion, our study seems to provide some behavioral evidence for the HAROLD phenomenon in the processing of semantic information, in particular, emotional words. Our data show that in high performing older adults, both hemispheres contribute to the same level of accuracy that young adults reach by recruiting essentially one hemisphere. This outcome seems to be in favor of the compensation view of the HAROLD phenomenon which suggests increased bilaterality could help older adults counteract age-related neurocognitive deficits (Cabeza, 2002, for a review; Cabeza et al., 2002; Rosen et al., 2002). Our findings also indicate that in high-performing older individuals automatic and controlled access to semantic information is relatively intact and is made possible through the involvement of both hemispheres. However, sensory deficit is a factor that may limit the efficiency of semantic processing in this group and cause them to access semantic information with a tiny delay in earlier stages of processing.

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Chapter 5

General Discussion

This chapter first presents a summary of the results obtained in this research project for each group of young male, young female, and high-performing older adults. Then, the likely nature of emotional word processing in the cerebral hemispheres and also the gender effect shown in the first study are discussed. The chapter concludes with future directions, strengths, and limitations of the research.

5.1. Introduction

The purpose of this research project was to gain insight into the ways in which words with emotional meanings are processed in the cerebral hemispheres of young and high-performing older adults. To this end, two studies were conducted. In the first study, in order to investigate potential hemispheric asymmetries in the time course of activation of emotional words, the priming of congruent and incongruent emotional word pairs in the LH and RH was compared in young individuals across four SOAs: 0 ms, 150 ms, 300 ms, and 750 ms. In the second study, in light of the compensatory function of bilateral activation in high-performing older adults during cognitive tasks, the time course of access to the meanings of emotional words in the LH and RH was compared in young and high-performing older adults across three SOAs: 150 ms, 300 ms, and 750 ms.

This chapter provides a summary of the results obtained in this research project for young and older individuals, followed by a discussion of the likely nature of emotional word processing, possible reasons for the different time course of activation of emotional words in the LH and RH, and the obtained gender effect. The chapter concludes with future directions, strengths, and limitations of the research, and suggestions for future work.

5.2. Emotional Word Processing in Young and Older Adults

The results of the first study (see chapter 3) showed different patterns of processing in males and females.

5.2.1. Emotional Word Processing in Males

In males, the pattern of priming seems to be compatible with the time course hypothesis (Abernethy & Coney, 1993, 1996; Burgess & Simpson, 1988; Chiarello et al., 1990; Koivisto, 1997, 1998). Namely, priming of emotional words occurred at the SOAs of 0 ms and 150 ms in the LH, whereas no such effect was observed in the RH at these two SOAs. Priming in the LH decreased over time such that no reliable priming was detected at the 300 ms SOA possibly because of a narrowing of meaning availability at this SOA in the LH. Similarly, no priming occurred at the 300 ms SOA in the RH, which suggests that the delay between prime and target was not sufficient for controlled processes to start in the RH at this SOA. On the other hand, the onset of activation occurred later in the RH, and priming emerged at the 750 ms SOA. Thus, priming that was restricted to the LH at the short SOAs shifted to the RH at the longer SOA.

Presumably, the LH has automatic access to the emotional words earlier in the course of processing, whereas the type of processing in the RH should likely be controlled. Therefore, the appearance of priming in the RH at the 750 ms SOA, in conjunction with the lack of priming in the LH at the same SOA, suggests that emotional word processing can be revisited in a controlled mode in the RH by directing attention to the content of these words. That is, it appears that, when sufficient time has elapsed and the meaning is suppressed in the LH, access is possible in the RH. This process implies that the hemisphere that is dominant over automatic aspects of emotional word processing is not dominant over controlled aspects. That may be the reason hemispheric dominance is altered over the course of processing (Burgess & Simpson, 1988). These findings support the notion that the superior ability of the LH in language processing and the focus of the RH on attention-capturing stimuli are reflected in the automatic and controlled activation of the emotional lexicon.

5.2.2. Emotional Word Processing in Females

In females, we found an unexpected pattern of priming consistent with the valence hypothesis. That is, priming of negative words occurred in the RH at the 150 ms SOA, and priming of positive words emerged in the LH at the 300 ms SOA. Since the hemispheres likely shared the automatic activation of emotional words, their differentiation was due to valence.

We speculate that the results obtained for females are related to the nature of the task used in the experiment. Some studies have suggested that, when a task requires evaluation of the emotional stimuli or a comparison between two emotional expressions, it is possible that participants use their own affective responses to reach a decision about the stimuli (e.g., Van Strien & Van Beek, 2000). In other words, the task causes the participant to experience the emotion conveyed by the stimuli (Jansari, Tranel, & Adolphs, 2000). As the experience of emotion is claimed to be mediated by the anterior parts of both hemispheres depending on valence (Davidson, 1992, 1993; Davidson & Hugdahl, 1995), a pattern consistent with valence emerges. In accordance with the claim that females are more responsive to emotions (Gard & Kring, 2007), we saw this effect only in this group.

5.2.3. Emotional Word Processing in Older Adults

The group of high-performing older adults showed no difference in their accuracy data from the groups of young male participants. While, in both groups, the stimuli were presented equally to the RVF (LH) and LVF (RH) at the SOAs of 150 ms, 300 ms, and 750 ms, in older adults, both hemispheres contributed to the same level of accuracy that the young male participants reached by recruiting only one hemisphere. In particular, in young male adults, priming appeared to be unilateral at the SOAs of 150 ms and 750 ms in the LH and RH, respectively, whereas, in older participants, the pattern of priming was bilateral whenever it was present, that is, at the two SOAs of 300 ms and 750 ms. The bilateral pattern of priming in older adults is consistent with the HAROLD phenomenon, which has been suggested to compensate for the age-related decline in performance (Cabeza et al., 2002; Rosen et al., 2002; see also Cabeza, 2002, for a review).

However, older adults responded to the stimuli more slowly than did young male participants (Howard, Shaw, & Heisey, 1986). Namely, there was no priming at the 150 ms SOA, and priming was first detected at 300 ms in older participants. Yet, despite the delay in the appearance of priming, the nature of the priming at the 300 ms SOA is likely automatic because the 300 ms is not within the range that can cause controlled priming (Neely, 1991). An age difference in the appearance of automatic priming, together with the emergence of priming at the SOAs of 300 ms and 750 ms, suggests that older adults require more time to encode stimuli and start activation through the semantic network. Therefore, our study shows that, in high-performing older adults, automatic and controlled access to semantic information is relatively intact and is made possible through the involvement of both hemispheres.

5.3. The Nature of Emotional Word Processing

Emotion, cognition, and motivation are the three components of mental life (Hilgard, 1980). Emotion and cognition are so intercorrelated that, at times, drawing a clear-cut distinction between their influences on behavior is next to impossible. In cognitive social psychology, for instance, a positive (happy) or negative (sad) emotional state is induced in participants, who then engage in a cognitive task such as LD that incorporates words that are congruent and incongruent with the induced emotion. Such research typically shows that participants with positive feelings make faster LDs to positive over negative words, and participants with negative feelings make faster LDs to negative over positive words (Niedenthal, Halberstadt, & Setterlund, 1997; Olafson & Ferraro, 2001). These findings direct our question from emotional words to emotional states: Does the processing of words with emotional meanings result in emotional feelings?

The present research program was about words with emotional meaning and the way in which these words are processed in the LH and RH. Our results show that both hemispheres contribute to the processing of emotional words, although the RH activates these words more slowly than the LH does. In light of these findings, we can reword the above-mentioned question: What is the difference between the processing modes of the LH and RH during emotional word processing? Do these words create emotional feelings whenever they are processed? Research suggests that the processing of emotional words, despite involving emotional component, does not necessarily result in emotional states (Phelps et al., 1998). Even though emotional words can be used to communicate feelings, this should not be the main purpose of using such words because we have other channels (i.e., prosody, facial expression, and body language) to communicate emotions. Language is likely a tool with which we can control emotions (see Niedenthal, Rohmann, & Dalle, 2003, for a review). Hence, there should be a more complex relationship between language, as a component of cognition, and emotion.

5.3.1. From Words to Concepts and Concepts to Images

The development of language was a huge step from animal forms of communication and cognition to the unique form of exchanging thoughts among humans. According to Luria (1982), the *word* is the basic element of language. Words codify our experiences in the world and function as substitutes for objects, actions, associations, events, and so forth. Words double our world. In the absence of words, we deal with only those things that we perceive directly, but, with words, we can talk, think, and judge things that are not perceived directly. Indeed, words help us create *concepts* in our mind.

Concepts are representations of words in the mind and are formed when sensory experiences and symbols (words) are combined. For a concept to be formed, all related information including emotions, if applicable, is stored in the mind. This information can create an *image* in the mind and help a concept be simulated effectively. Thus, a concept is not only the mental representation of a word, but also a perceptual image and, in reality, a replay of the perceptual properties referred to by a word in the mind (Barsalou, 1999).

Images evoke stronger emotional responses than do words by themselves. Research suggests a causal relationship between imagery and emotion. This effect has been attributed to a link between the use of imagery and the activation of autobiographical episodes (Holmes, Mathews, Mackintosch, & Dalgleish, 2008). Images appear to share properties with perceptual representations derived directly from sensory experiences. Consequently, images are responded to as if they are real events (Kosslyn, Ganis, & Thompson, 2001).

Two indicators that seem to support the notion that people make mental images of concepts in their mind are *perceptual effort* and *instructional equivalence*. In perceptual effort, when participants are asked to generate the properties of a concept, observable properties are more likely to be produced because they are parts of an image in the mind. By contrast, hidden properties are less likely to be mentioned because they are not likely to be a part of an image. In instructional equivalence, when one group of participants is asked to create an image of a concept in their mind and another group is required only to think about that concept without instructions to create an image, the two groups produce similar results (Barsalou, Solomon, & Wu, 1999).

5.3.2. Degree of Simulation of Concepts

Concepts are simulated to different degrees while different tasks are being performed. According to Niedenthal et al. (2003), the degree of simulation of a concept depends on time, the participant's motivation, and the task instructions. In fact, these factors determine the degree of the involvement of a concept's perceptual properties in the resulting output. Accordingly, a concept can be either processed superficially such that not many of its properties become simulated or processed deeply such that most of its perceptual properties become activated. This means that the simulation of many properties of an emotional concept can evoke the related emotional state.

One outcome of this processing hierarchy is that we can access an emotional concept, but not necessarily the associated feeling. To test this possibility, Innes-Ker and Niedenthal (2002) used a *sentence unscrambling task*. In such a task, participants are presented with a series of words in random order and asked to construct grammatically correct sentences out of a subset of words. Critical sentences are intended to prime a specific positive or negative concept. Innes-Ker and Niedenthal (2002) used 30 four-word sentences that described behaviors, situations, and reactions associated with happy or sad feelings. A fifth word was added to each sentence to create groups of five scrambled words. The connotation of this word was the same as the sentence (e.g., *the guest felt satisfied* as the sentence and *ease* as the filler). Fifteen sentences with neutral content were also added to each list to control the bias in favor of the intended emotional concept.

Participants were asked to construct a four-word sentence out of each subset. After performing the task, they completed a self-report measure of emotional state. The results indicated that unscrambling emotional sentences did not affect participants' emotional state. However, performing the task was effective in priming semantically related words. That is, participants made faster LDs about words congruent with the activated concept than about incongruent words. Thus, we can construct sentences associated with an emotional concept, but without having imagery of that concept.

Creating an emotional state requires that the perceptual properties of an emotional concept are experienced; it is not possible unless imagery is created. Reliving the semantic aspects of an emotional concept cannot recall the associated emotional state. Therefore, emotional words have the ability of triggering processing in the mind at different levels; in the extreme, they likely evoke the associated emotional state (Holmes et al., 2008). The order of activation is as follows: emotional words, emotional concepts, imagery of perceptual properties associated with a concept, and, finally, experience of an emotional state.

5.4. Emotional Word Processing in the LH and RH

As mentioned above, one factor that determines a concept's degree of simulation is time. Our results demonstrate the differentiating role of time on the activation of emotional words in the LH and RH. Namely, if an emotional word is presented for a brief duration, very little activation of the related concept occurs. This likely describes what occurs in the LH, where, as our results suggest, only semantic features of emotional words are activated. Such processing should be sufficient for language processing to proceed and for meaning to merge into the context. This stage, which occurs quickly and is not associated with imagery, fits well with the dominant role of the LH in language processing.

On the other hand, when an emotional word is presented for a longer duration, processing likely enters another stage through the reliving of a greater number of properties associated with the concept. Seemingly, extensive processing of a concept requires a longer stimulus duration, and the RH is more capable of this type of processing. That is not to say that processing in the RH ends with an emotional state, but the level of emotional word processing in the RH should be deeper than that in the LH. Indeed, the semantic literature has attributed such processing to the RH: Beeman (1993) proposed that, during semantic processing, the LH uses relatively fine semantic coding to quickly select a few features of a word for further processing, whereas the RH has the ability to activate several features of a word simultaneously. Therefore, the actual interpretation of a word can differ between hemispheres.

The role of attention that has mostly been attributed to the RH (e.g., Anderer, Saletu, Semlitsch, & Pascual-Marqui, 2003; Pardo, Fox, & Raichle, 1991; Strange, Henson, Friston, & Dolan, 2000) is likely crucial in emotional word processing progressing to a later stage. Attention is a process that directs those centers of the brain that are responsible for cognitive processes to relevant stimuli or features of the environment and, therefore, decreases the effect of irrelevant stimuli, in accordance with goal-directed processing (Allport, 1989). Thus, in emotional word processing, the role of attention should be to encourage a later stage of processing by limiting the number of incoming stimuli and consequently enhancing the effect of an earlier stage. This stage which can accompany imagery, for which there is evidence of RH involvement (e.g., Gasparini et al., 2008), raise the possibility of a correlation between the role of the RH in the processing of emotions as reported repeatedly in the literature (the RH hypothesis) and its role in attention-demanding processes (e.g., Casey et al., 1997; Compton et al., 2000, 2003).

Accordingly, the inconsistent results of studies of emotional words may be due to the complex nature of emotional *word* processing. Presumably, in some studies, exposure duration was the factor that led to equivocal results (Eviatar & Zaidel, 1991; Graves et al., 1981; Strauss, 1983). On the other hand, as suggested by Davidson (1992, 1993; Davidson & Hugdahl, 1995), in the studies that reported results consistent with the valence hypothesis, participants' experiences of the related emotion might be involved (e.g., Ali & Cimino, 1997; Van Strien & Morpurgo, 1992). In the study conducted by Ali and Cimino (1997), the stimuli were presented to participants three times. This repeated exposure may have caused participants to become more sensitive to the emotional properties of the stimuli.

Thus, not only do the results of this research, which seem to be consistent with the time course hypothesis, *not* challenge the dominant role of the LH in the processing of semantic information, but they also suggest that the processing abilities of the LH and RH are combined for the part of the semantic system for which the RH has repeatedly been claimed to play a critical role. In this respect, it is conceivable that the slow mode of processing in the RH adds some qualities to the output.

5.5. Unexpected Pattern of Processing in Females

The suggested framework also seems to explain the results that we obtained in our female participants. Our results suggest that females are more responsive to emotional words than males are, as females were significantly faster than males at responding to emotional words. This responsiveness, which was probably intensified by the evaluation task, might have caused the processing to advance to another level and females to respond to stimuli while experiencing the related emotion.

According to the circumplex theory of emotion, which is a synthesis of the RH and valence hypotheses, while the RH is responsible for the comprehension of emotions, the experience of emotions is a function of the anterior regions of the LH and RH in accordance with valence (Davidson, 1993). One implication of this view may be that the valence pattern is observed in tasks that cause participants to experience emotions conveyed by emotional stimuli. Indeed, this is the idea suggested by Ley and Strauss

(1986), who reviewed the literature on the processing of emotional facial expressions and reported that the valence pattern emerges when emotional stimuli are evaluated in terms of being positive and negative. Notably, a large number of reports in favor of the valence hypothesis come from studies that investigated emotional face processing (e.g., Asthana & Mandal, 2001; Davidson, Mednick, Moss, Saron, & Schaffer, 1987; Jansari et al., 2000; Reuter-Lorenz & Davidson, 1981). Among emotional face processing studies, some have reported the valence pattern only in females (e.g., Burton & Levy, 1989; Rodway, Wright, & Hardie, 2003; Van Strien & Van Beek, 2000). Thus, it is possible that participants experience emotions in studies in which stimuli display emotions (i.e., emotional pictures) and are evaluated by participants.

Obviously, our stimuli were a specific type of word, namely, emotional. They were also highly arousing. In addition, our task was an evaluation task in which participants were required to indicate whether a target word was pleasant or unpleasant. This task caused a valence pattern in female participants, which likely means that only females experienced the emotion conveyed by emotional targets. As this process activates anterior regions of the LH and RH according to valence (e.g., Jansari et al., 2000), only females showed the valence pattern.

What underlying mechanism causes females to be more responsive than males to emotional stimuli? At present, emotion research provides very little insight into gender differences in terms of responding to emotions. Although there are rare cases of reports of gender-related hemispheric differences in the nonverbal domain (see Cahill, 2006, for a review), there is virtually nothing in the verbal field. Responses to emotional words have been studied less frequently than responses to emotional faces or pictures perhaps because emotional words are considered less potent as emotional stimuli. Even meta-analyses have not, for the most part, found gender differences in emotional processing (e.g., Baas, Aleman, Kahn, 2004; Costafreda, Brammer, David, & Fu, 2008); few studies targeted gender as a focus of hypotheses, and some studies restricted their participants to males (e.g., Asthana & Mandal, 2001; Beauregard et al., 1997; Hamann & Mao, 2002; Wright, 2001). Hence, we discuss the gender difference observed in our study in consideration of mostly nonverbal emotion studies.

One potential cause of gender differences may be related to hormonal fluctuations over the course of the menstrual cycle (e.g., Alexander, Altemus, Peterson, & Wexler, 2002; Altemus, Wexler, & Boulis, 1989). However, we strived to control this factor by performing the experiment when the fluctuations were at their minimum level. We also checked participants' mood at the time of the experiment by performing the PANAS questionnaire to ensure that participants' mood was in a normal range. Yet, we still encountered a different pattern of emotional word processing in females.

Some studies have attributed such gender differences to a difference in the neural substrates, for example, the dorsolateral area, which is claimed to be significantly larger in females (when adjusted for total brain size) than in males (e.g., Goldstein et al., 2001). Some data also indicate a gender difference in the lateralization of neural activity; for instance, enhanced memory of emotional films in males has been shown to be associated with increased activity in the right amygdala, whereas, in females, lateralization of the amygdala for this function was left-sided (Cahill et al., 2001). Nevertheless, our findings for older adults suggest that caution should be used when considering such possible causes of gender differences.

In fact, although in high-performing older adults, consistent with the HAROLD phenomenon, a bilateral pattern of priming was shown, it is still possible to distinguish the principal hemisphere from the supplementary one (e.g., Cabeza et al., 2002). Accordingly, the data of older adults showed that the principal hemispheres at the SOAs of 300 ms and 750 ms were the LH and RH, respectively, and this finding is consistent with the pattern of processing identified by the time course hypothesis. On the other hand, we know that this pattern was obtained by a group of 28 older adults, of whom 16 (57%) were females.

Hence, it seems that the role of sex hormones in females is multifaceted; namely, the effect of sex hormones may be mediated through interaction with some other hormones (see Cahill, 2006, for a review). Thus, emotional processing research must begin to seriously take into account the neurobiological mechanisms at work in females.

Therefore, we think that the time course hypothesis also merits consideration as a pattern governing the comprehension of emotional words in females. Employing a nonevaluative task such as an LD task may be a way to further investigate the pattern exhibited by females. Moreover, it can be combined with ERP methodology that is suited to measuring the time course of activation of stimuli and introduces a particular component for perceiving semantic information (N400) (e.g., Kutas & Hillyard 1980, 1984).

5.6. Future Directions

A number of potential future research directions deserve more attention. To identify the time course in which an emotional state is instigated in the participant, adopting the following conditions might prove effective: employing a range of long-exposure durations, presenting emotional words of either positive or negative valence to each participant, and then performing a self-report measure of emotional state.

Further research with SOAs between 300 ms and 750 ms is also required to pinpoint the SOA condition at which automatic activation diminishes in older adults and, hence, attentional strategies start to influence their processing.

To examine the processing of emotional words in the LH and RH, we used an evaluation task. Further research incorporating other tasks, particularly the LD task, is especially important to gain insight into the results that we obtained in females.

Event-related potentials may be the best measure with which to study the time course of activation of neural events. Although this methodology has been claimed not to be spatially precise in disclosing the regions involved in producing a neural correlate, the use of dense electrode arrays should fix this shortcoming and provide information about the time course of the events involved as well as the hemisphere in which each stage of processing occurs. To gain further insight into the results we obtained in this research, designing an experiment aimed at eliciting the N400 would be highly informative. Although the N400 (Kutas, 1980, 1984) has been shown to be an appropriate ERP component to assess semantic processing, it has not been widely used in emotional word processing. A priming paradigm seems to be the appropriate paradigm to elicit this component. The appearance of earlier components attributable to automatic processing, along with the N400, would provide strong support for the results of this research.

Event-related potentials may also be helpful in disclosing the nature of the delay (encoding vs. semantic) that we encountered in the results of older adults.

5.7. Strengths, Limitations, and Suggestions

The results of this research program show that carefully manipulating experimental parameters such as the SOA might contribute to resolving some of the controversies in literature regarding the processing of emotional words. In our research, only 48 pairs were presented in each block. Presenting a larger number of trials in each block can increase the power of an experiment. However, because we intended to avoid repetition in each block, we did not increase the number of trials presented.

Another limitation to this research results from the presentation of the same words in each block. Undoubtedly, presenting a unique group of stimuli in each block requires an extensive number of stimuli that would be practically impossible to find given that the stimuli need to be controlled in terms of different characteristics. Yet, by using each word in either a congruent or an incongruent pair and presenting it to either the RVF or LVF, we attempted to give each word a unique placement within the whole stimulus set.

In addition, we did not include cross-hemispheric presentation conditions (i.e., RVF prime – LVF target, LVF prime – RVF target) and presented stimulus pairs only in within-hemispheric conditions. The cross-hemispheric mode of presentation not only underscores the significance of interhemispheric communication, but is also another way of examining the results of within-hemispheric conditions.

It is likely that the purpose of presenting the prime was not clear for participants. That is, participants were not provided with any justification for why the prime was present in each trial. This ambiguous circumstance could be one reason to overcome the biasing influence of the prime in case of response competition and, therefore, reinforce the reverse priming effects. As suggested by Fazio (2001), primes can be presented as memory words that need to be recited at the end of each trial or stimuli that should be learned for a later recognition task.

The occurrence of reverse and anticipated priming in the same experiment likely suggests that the response competition account deserves more attention in lateralized studies of emotional words.

Finally, in studies on high-performing older adults, performing more screening tests such as the Wechsler Adult Intelligence Scale – Revised (Wechsler, 1981) in addition to the MOCA test may be helpful in selecting a better representative group of participants.

In conclusion, this research program was designed to explore the manner in which words with emotional meaning are processed in the cerebral hemispheres in young and high-performing older adults. Consistent with our hypothesis, the results in males seem to suggest a novel framework for emotional word processing, namely, that the automatic processing that occurs in the LH earlier in the time course can be relived later on in the RH in a controlled manner. In high-performing older adults, likely due to the occurrence of compensatory mechanisms, both automatic and controlled processing are associated with a bilateral pattern of activation in the hemispheres. Thus, our results add to the existing literature and expand our comprehension of how emotional word processing takes place in young and older adults and what mechanisms are involved in the process.

The different pattern of priming effects obtained in females raises some other questions: Did the explicit task used in the study cause processing in females to proceed to the stage of experiencing the emotions conveyed by stimuli and to respond accordingly? Was the tiny delay that occurred in the appearance of priming effects in older adults the result of an age-related increase in sensory thresholds? Would using ERPs that can reflect different stages of processing in real time help answer these questions? Can lateralized presentation of stimuli in an ERP methodology lead to more precise data on the role of the hemispheres in emotional processing? To answer most questions in the field of emotional word processing, one absolutely necessary resource is a larger bank of available stimuli—to adequately control stimuli and effectively employ emotional words without repetition. Ultimately, it is hoped that future research will provide a clearer picture of emotional word processing in the cerebral hemispheres.

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APPENDICES

Appendix A. Stimuli

Table A1: Mean ANEW Valence (VAL) and Arousal (AR) Ratings, Frequency (FR), Concreteness (CON), Part of Speech (PS), Imagability (IMG, And Number of Letters (NL), for Negative Primes in the stimulus list 1 & 2

	Negative Primes	VAL	AR	FR	CON	PS	IMG	NL
	List 1							
1	Horror	2,76	7,21	17	341	N	545	6
2	Burn	2,73	6,22	15	490	N/V	541	4
3	Fraud	2,67	5,75	8	304	N	381	5
4	Victim	2,18	6,06	27	467	N	521	6
5	Insult	2,29	6	7	375	N/V	477	6
6	Debt	2,22	5,68	13	416	N	384	4
7	Sin	2,8	5,78	53	273	N/V	441	3
8	Poison	1,98	6,05	10	527	N/V	513	6
9	Robber	2,61	5,62	2	545	N	549	6
10	Cancer	1,5	6,42	25	615	N	567	6
11	Quarrel	2,93	6,29	20	379	N/V	479	7
12	Injury	2,49	5,69	27	497	N	551	6
		2,43	6,06	18,67	435,75		495,75	5,42
	List 2							
1	Prison	2,05	5,7	42	570	N	593	6
2	Anger	2,34	7,63	48	315	N/V	488	5
3	Ulcer	1,78	6,12	5	558	N	516	5
4	Ache	2,46	5	4	443	N/V	443	4
5	Deceit	2,9	5,68	2	257	N	338	6
6	Tragedy	1,78	6,24	49	331	N	478	7
7	Tornado	2,55	6,83	1	644	N	591	7
8	Hate	2,12	6,95	42	335	N/V	462	4
9	Coffin	2,56	5,03	7	595	N/V	606	6
10	Malice	2,69	5,86	2	284	N	365	6
11	Filth	2,47	5,12	2	467	N	517	5
12	Hurt	1,9	5,85	37	368	N/V	465	4
		2,3	6,00	20,08	430,58		488,5	5,42

Table A2: Mean ANEW Valence (VAL) and Arousal (AR) Ratings, Frequency (FR), Concreteness (CON), Part of Speech (PS), Imagability (IMG), And Number of Letters (NL), for Negative Targets in the stimulus list 1 & 2

	Negative Targets	VAL	AR	FR	CON	PS	IMG	NL
	List 1							
1	Riot	2,96	6,39	7	414	N/V	548	4
2	Traitor	2,22	5,78	2	467	N	447	7
3	Jail	1,95	5,49	21	590	N	608	4
4	Bomb	2,1	7,15	36	595	N/V	606	4
5	Crisis	2,74	5,44	82	319	N	375	6
6	Lice	2,31	5	2	543	N	532	4
7	Hatred	1,98	6,66	20	239	N	417	6
8	Menace	2,88	5,52	9	377	N/V	398	6
9	Misery	1,93	5,17	15	297	N	444	6
10	Slave	1,84	6,21	30	539	N/V	564	5
11	Devil	2,21	6,07	25	274	N/V	546	5
12	Venom	2,68	6,08	2	476	N	456	5
		2,317	5,91	20,92	427,5		495,08	5,17
	List 2							
1	Slime	2,68	5,36	1	545	N/V	558	5
2	Torture	1,56	6,1	3	437	N/V	533	7
3	Assault	2,03	7,51	15	410	N/V	481	7
4	Thief	2,13	6,89	8	519	N	529	5
5	Agony	2,43	6,06	9	348	N	491	5
6	Hell	2,24	5,38	95	355	N	519	4
7	Crime	2,89	5,41	34	387	N	471	5
8	Scorn	2,84	5,48	4	290	N/V	364	5
9	Measles	2,74	5,06	2	568	N	582	7
10	Demon	2,11	6,76	9	302	N	474	5
11	Burial	2,05	5,08	11	477	N	544	6
12	Lie	2,79	5,96	59	357	N/V	385	3
		2,37	5,92	20,83	416,25		494,25	5,33

Table A3: Mean ANEW Valence (VAL) and Arousal (AR) Ratings, Frequency (FR) , Concreteness (CON), Part of Speech (PS), Imagability (IMG), And Number of Letters (NL), for Positive Primes in the stimulus list 1 & 2

	Positive Primes	VAL	AR	FR	CON	PS	IMG	NL
	List 1							
1	Treat	7,36	5,62	26	399	N/V	360	5
2	Leader	7,63	6,27	74	487	N	502	6
3	Holiday	7,55	6,59	17	439	N	629	7
4	Profit	7,63	6,68	28	364	N/V	497	6
5	Liberty	7,98	5,6	46	302	N	392	7
6	Desire	7,69	7,35	79		N/V	368	6
7	Kiss	8,26	7,32	17	564	N/V	633	4
8	Joy	8,6	7,22	40	300	N/V	533	3
9	Comedy	8,37	5,85	39	365	N	489	6
10	Dollar	7,47	6,07	46	575	N	611	6
11	Toy	7	5,11	4	567	N/V	569	3
12	Bouquet	7,02	5,46	4	566	N	599	7
		7,71	6,26	35	448		515,17	5,5
	List 2							
1	Gift	7,77	6,14	33	533	N	553	4
2	Glory	7,55	6,02	21	304	N/V	389	5
3	Passion	8,03	7,26	28	300	N	467	7
4	Dinner	7,16	5,43	91	542	N	570	6
5	Thrill	8,05	8,02	5	320	N/V	483	6
6	Snow	7,08	5,75	59	618	N/V	597	4
7	Success	8,29	6,11	93	295	N	443	7
8	Puppy	7,56	5,85	2	623	N	635	5
9	Diamond	7,92	5,53	8	610	N	623	7
10	Blossom	7,26	5,03	7	559	N/V	618	7
11	Lust	7,12	6,88	5	324	N/V	444	4
12	King	7,26	5,51	88	559	N	585	4
		7,59	6,13	36,67	465,58		533,92	5,5

Table A4: Mean ANEW Valence (VAL) and Arousal (AR) Ratings, Frequency (FR), Concreteness (CON), Part of Speech (PS), Imagability (IMG), And Number of Letters (NL), for Positive Targets in the stimulus list 1 & 2

	Positive Targets	VAL	AR	FR	CON	PS	IMG	NL
	List 1							
1	Scholar	7,26	5,12	15	450	N	451	7
2	Miracle	8,6	7,65	16	282	N	367	7
3	Delight	8,26	5,44	29	282	N/V	459	7
4	Fun	8,37	7,22	44	295	N	515	3
5	Triumph	7,8	5,78	22	332	N/V	470	7
6	Talent	7,56	6,27	40	290	N/V	399	6
7	Baby	8,22	5,53	62	589	N	608	4
8	Song	7,1	6,07	70	514	N	578	4
9	Star	7,27	5,83	25	574	N/V	623	4
10	Travel	7,1	6,21	61	402	N/V	506	6
11	Gold	7,54	5,76	52	576	N	594	4
12	Joke	8,1	6,74	22	388	N/V	483	4
		7,76	6,14	38,17	414,5		504,42	5,25
	List 2							
1	Win	8,38	7,72	55	364	N/V	454	3
2	Fantasy	7,41	5,14	14	295	N	455	7
3	Dancer	7,14	6	31	558	N	551	6
4	Palace	7,19	5,1	38	579	N	612	6
5	Rescue	7,7	6,53	15	373	N/V	456	6
6	Cake	7,26	5	9	624	N/V	624	4
7	Victory	8,32	6,63	61	376	N	461	7
8	Cash	8,37	7,37	36	547	N/V	588	4
9	Heaven	7,3	5,61	43	305	N	448	6
10	Pride	7	5,83	42	270	N	424	5
11	Circus	7,3	5,97	7	535	N	586	6
12	Dog	7,57	5,76	75	610	N/V	636	3
		7,58	6,06	35,5	453		524,58	5,25

Table A5: Stimulus pairs in the first and third lists including Negative-Negative pairs, Positive-Positive pairs, Negative-Positive pairs, and Positive-Negative pairs

	Negative	Negative		Negative	Positive
1	HORROR	RIOT	1	PRISON	DOG
2	BURN	TRAITOR	2	ANGER	CAKE
3	FRAUD	BOMB	3	ULCER	DANCER
4	VICTIM	CRISIS	4	ACHE	PALACE
5	INSULT	JAIL	5	DECEIT	RESCUE
6	DEBT	LICE	6	TRAGEDY	FANTASY
7	SIN	HATRED	7	TORNADO	CASH
8	POISON	MENACE	8	HATE	VICTORY
9	ROBBER	SLAVE	9	COFFIN	HEAVEN
10	CANCER	MISERY	10	MALICE	PRIDE
11	QUARREL	DEVIL	11	FILTH	CIRCUS
12	INJURY	VENOM	12	HURT	WIN

	Positive	Positive		Positive	Negative
1	TREAT	SCHOLAR	1	GIFT	SLIME
2	LEADER	MIRACLE	2	GLORY	TORTURE
3	HOLIDAY	BABY	3	PASSION	ASSAULT
4	PROFIT	FUN	4	DINNER	THIEF
5	LIBERTY	TALENT	5	THRILL	AGONY
6	DESIRE	SONG	6	SNOW	HELL
7	KISS	TRAVEL	7	SUCCESS	CRIME
8	JOY	STAR	8	PUPPY	SCORN
9	COMEDY	DELIGHT	9	DIAMOND	MEASLES
10	DOLLAR	TRIUMPH	10	BLOSSOM	BURIAL
11	TOY	GOLD	11	LUST	DEMON
12	BOUQUET	JOKE	12	KING	LIE

Within each list, half of the pairs were presented to the RVF and half to the LVF. The two lists were different in terms of the field of presentation.

Table A6: Stimulus pairs in the second and fourth lists including Negative-Negative pairs, Positive-Positive pairs, Negative-Positive pairs, and Positive-Negative pairs

	Negative	Negative		Negative	Positive
1	PRISON	SLIME	1	HORROR	SCHOLAR
2	ANGER	TORTURE	2	BURN	MIRACLE
3	ULCER	ASSAULT	3	FRAUD	BABY
4	ACHE	THIEF	4	VICTIM	FUN
5	DECEIT	AGONY	5	INSULT	TALENT
6	TRAGEDY	HELL	6	DEBT	SONG
7	TORNADO	CRIME	7	SIN	TRAVEL
8	HATE	SCORN	8	POISON	STAR
9	COFFIN	MEASLES	9	ROBBER	DELIGHT
10	MALICE	BURIAL	10	CANCER	TRIUMPH
11	FILTH	DEMON	11	QUARREL	GOLD
12	HURT	LIE	12	INJURY	JOKE

	Positive	Positive		Positive	Negative
1	GIFT	DOG	1	TREAT	RIOT
2	GLORY	CAKE	2	LEADER	TRAITOR
3	PASSION	DANCER	3	HOLIDAY	BOMB
4	DINNER	PALACE	4	PROFIT	CRISIS
5	THRILL	RESCUE	5	LIBERTY	JAIL
6	SNOW	FANTASY	6	DESIRE	LICE
7	SUCCESS	CASH	7	KISS	HATRED
8	PUPPY	VICTORY	8	JOY	MENACE
9	DIAMOND	HEAVEN	9	COMEDY	SLAVE
10	BLOSSOM	PRIDE	10	DOLLAR	MISERY
11	LUST	CIRCUS	11	TOY	DEVIL
12	KING	WIN	12	BOUQUET	VENOM

Within each list, half of the pairs were presented to the RVF and half to the LVF. The two lists were different in terms of the field of presentation.

Appendix B. Form (Participant Information)

PARTICIPANT INFORMATION
(All personal information will be kept confidential)

Name	Code
Gender	
Years of Formal Education	
Date of Birth	
Mother Tongue	
Other Languages Spoken	
Phone Number	
E-mail	
The last menstruation date (for women)	

Appendix C. Word Association Task

WORD ASSOCIATION TASK

Date: **Code:**

Age: **Years of education:**

Native language: **Other languages you speak:**

Age you started to acquire English:

Please read the instructions carefully before you begin.

Instructions:

In the next two pages you will see a list of words. Each word will typically make you think of some other associated words. Following each word, there are three blank lines. Upon reading each word, please write down (on the three lines) the first three words that come to your mind.

Two examples will help you to understand what we mean:

For instance, when you read a word such as "dog", you may automatically associate this word with another word such as "cat" and then possibly other associated words, such as "leash" or "bark".

As another example, upon hearing or seeing a word like "fork", you may be reminded of words such as "knife", "spoon", and then maybe "plate".

You can start now. Please remember to write down the first three words that come to mind. Do not think about the words for very long. If you only think of 2 words immediately, write them down and move onto the next item.
Thank you for your participation.

1- King ______ ______ ______
2- Sin ______ ______ ______
3- Ache ______ ______ ______
4- Victim ______ ______ ______
5- Success ______ ______ ______
6- Insult ______ ______ ______
7- Holiday ______ ______ ______
8- Desire ______ ______ ______
9- Diamond ______ ______ ______
10- Hate ______ ______ ______
11- Gift ______ ______ ______
12- Glory ______ ______ ______
13- Debt ______ ______ ______
14- Quarrel ______ ______ ______
15- Horror ______ ______ ______
16- Leader ______ ______ ______
17- Blossom ______ ______ ______
18- Profit ______ ______ ______
19- Treat ______ ______ ______
20- Prison ______ ______ ______
21- Comedy ______ ______ ______
22- Kiss ______ ______ ______
23- Snow ______ ______ ______
24- Tornado ______ ______ ______
25- Anger ______ ______ ______

26- Fraud	______	______	______
27- Deceit	______	______	______
28- Robber	______	______	______
29- Lust	______	______	______
30- Filth	______	______	______
31- Joy	______	______	______
32- Cancer	______	______	______
33- Injury	______	______	______
34- Dollar	______	______	______
35- Ulcer	______	______	______
36- Coffin	______	______	______
37- Poison	______	______	______
38- Dinner	______	______	______
39- Malice	______	______	______
40- Thrill	______	______	______
41- Passion	______	______	______
42- Puppy	______	______	______
43- Burn	______	______	______
44- Tragedy	______	______	______
45- Toy	______	______	______
46- Bouquet	______	______	______
47- Hurt	______	______	______
48- Liberty	______	______	______

Appendix D. Informed Consent Forms

INFORMED CONSENT FORM
Word association task

Title of the project
Study of word interaction visually presented to the left and right

Investigators
Dr. Yves Joanette

Collaborator
Ensie Abbassi

Funding Organization
Canadian Institute of Health Research (CIHR) MOP-15006

Preamble
We request your participation in a research task. However, before accepting to participate in this research project, please take the time to read, understand, and consider carefully the following information.
This informed consent form may contain words that you will not understand. We invite you to ask any questions to the researcher or members involved in the project, to explain or clarify any words or information.

Objective
The purpose of this task is to investigate aspects of word association. In particular, we are interested in determining those words that are closely related to a set of words that will be presented to you in this task. The knowledge gained will help us to understand how these words are represented and processed in the brain.

Procedures
A total of 20 individuals will participate in this task. You will be given a list of 48 words and will be asked to write down the first three words that you immediately associate with each word. A few examples will help you to understand the task. You will complete the task at your convenience; it should take approximately 10-15 minutes and it will occur in Dr. Yves Joanette's Communication Lab at the ground floor of André Roch Lecours Pavilion. You may ask any questions before you begin.

Inconveniences of the task

There are no medical procedures involved in the task and no known risks to participants.

Advantages of the task

While there is no direct benefit to you as a participant in this task, it is hoped that the results will contribute to our knowledge of the processes involved in language processing.

Financial compensation

You will receive compensation for your participation at a rate of $5 to cover your expenses.

Voluntary participation

Participation in this task is completely voluntary and you are free to withdraw at any time without prejudice.

Confidentiality

During your participation in this task, the researchers and their personnel will collect and record all information that concerns you in a research file. Only information needed for the correct performance of the study will be collected. This information may include your lifestyle, habits, and other information such as your name, gender, date of birth, ethnic origin and, for ladies, the last menstruation date.

All of the information collected in the course of the study will remain strictly confidential, within the limitations specified by law. In order to preserve your identity and the confidentiality of this information, you will only be identified by a code number. The key of the code linking your name to your research file will be kept by the study researcher.

The study researcher will use the study data for research purposes in order to meet the scientific objectives of the study as described in the consent form. Your personal information will be destroyed 5 years after the end of this project.

The study data will be kept for 25 years and may be published in medical journals or shared with other persons during scientific discussions. No publication or scientific communication will disclose any information that would allow you to be identified.

For monitoring and control purposes, your research file as well as your medical files may be consulted by a person designated by the Comité d’éthique de la recherche of Institut universitaire de gériatrie de Montréal, by a person designated by the minister of Health and Social Services, by authorized governmental health authorities, and by representatives of the sponsor. All of these persons and organizations observe a policy of confidentiality.

For protection purpose and in order to contact you quickly, your name, address, phone number as well as the beginning date and the ending date of your participation in the project will be conserved by the principal investigator in a repertory for one year after completion of the research project.

You have the right to consult your research file to verify the correctness of the collected Information, to have out-of-date or unjustified information corrected or deleted, and to make copies, for as long as the study researcher, establishment, or research institute possesses this information. However, in order to preserve the scientific integrity of the research, you will not have access to some of this information until the research is completed.

Source of funding for the project

All the pertaining cost and expenses of this research project will be covered by Canadian Institute of Health Research (CIHR).

Access to the researchers

As a participant, you have the right to ask questions at any time by contacting or leaving a specific message to Ensie Abbassi at (514) 340-3540, extension 4700 or by contacting Dr Yves Joanette at (514) 340-3540, extension 4767.

In case of complaint

For all problems concerning the conditions in which the task you participated in took place, you are able, after discussing with the person responsible for the project, make your concerns known to the person responsible for complaints at the institute universitaire de gériatrie de Montreal at the following address: The local service quality and complaints commissioner, institute universitaire de gériatrie de Montreal, 4565, chemin Queen-Mary, Montreal (Quebec) H3W 1W5. Tel: (514) 340-3517.

Information on ethics

The comite d'éthique de la recherche IUGM has approved this research project and ensures the rules of ethics will be respected during the entire research project. For more information, you may contact the secretary of the research ethics committee at (514) 340-2800 local 3250.

Future projects

Do you accept to be contacted again by a member of the research team in order to participate in subsequent projects?

Yes_________________ No_________________

These projects will be similar to this one. Your personal information will not be kept for more than five years and the period of recall will not therefore exceed this period. Of course, during this call, you will be free to accept or refuse at any time to participate in the research projects proposed.

Participant's consent

The task in the attached description has been explained to me and my questions have been answered to my satisfaction. I agree to participate in the task. It has been made clear to me that I am free to withdraw from the task at any time and that confidentiality will be ensured.

______________________ ______________________________

Name of participant Signature

Research declaration

I, undersigned, ---, certify:

To have explained to the participant the terms of the informed consent form and responded to the questions which have been asked and clearly indicated the terms of participation in the task described here. I will provide a signed copy of the informed form to the participant.

Name of researcher or his representative Signature

Date

INFORMED CONSENT FORM
Main study

Title of the project
Study of word interaction visually presented to the left and right

Investigator
Dr. Yves Joanette

Collaborator
Ensie Abbassi

Funding Organization
Canadian Institute of Health Research (CIHR) MOP-15006

Preamble
We request your participation in a research project. However, before accepting to participate in this research project, please take the time to read, understand, and consider carefully the following information.
This informed consent form may contain words that you will not understand. We invite you to ask any questions to the researcher or members involved in the project, to explain or clarify any words or information.

Objective
The purpose of this research is to investigate aspects of language processing in the brain. In particular, we are interested in examining how pleasant and unpleasant words are processed in the left and right hemispheres of the brain. The knowledge gained will help us to understand how pleasant and unpleasant words are represented and processed in the brain.

Procedures
A total of 80-100 individuals will participate in this research. You will be asked to judge whether words presented to you on a computer screen represent a pleasant word or unpleasant word of English. To participate in the task, you must have normal or corrected-to-normal vision. The exact procedure that will be explained to you by the researcher will be as follows. You will be seated in front of a computer with a chinrest stabilizing your head. English word pairs will be presented for a short period of time in varying positions on the screen while you focus on a central fixation point (marked by a +). Your task is simply to decide whether the second word of each pair is a pleasant word

(such as "prize") or unpleasant word (such as "pain") of English. There is a total of four blocks in the experiment, each containing 48 word pairs. Between each block, there will be a 3 minute break. Before experimental blocks, you will be presented two blocks of 30 word pairs in order to practice the procedure.

You may ask any questions before proceeding. Testing will occur over one session, lasting approximately one hour, and in Dr. Yves Joanette's Communication Lab at the ground floor of André Roch Lecours Pavilion.

Inconveniences of the research

There are no medical procedures involved in these tasks and no known risks to participants. You may find the tasks somewhat boring; you may also experience a very mild discomfort from the chinrest. For those reasons, you will be given several breaks during the testing session.

Advantages of the research

While there is no direct benefit to you as a participant in this research, it is hoped that the results will contribute to our knowledge of the processes involved in human communication. Such knowledge should, in turn, improve our management of communication problems experienced by individuals with left and right hemisphere brain damage.

Compensation in case of injury

In the event of complication resulting from your participation in this research project, you will receive all the necessary medical care, at no cost.

By taking part of this project, you do not resign any of your legal rights nor do you free the researchers, the sponsor or the establishment of any civil and professional responsibilities.

Financial compensation

You will receive compensation for your participation at a rate of $10 to cover your expenses.

Voluntary participation

Participation in this research is completely voluntary and you are free to withdraw at any time without prejudice. In that case, you will receive compensation for that portion of the session you attended.

Termination of project by the researcher

The researcher of the project may terminate your participation, without your consent, if new information or discoveries indicate that you do not follow the guidelines of the research project or if there are administrative reasons to abandon the project.

Confidentiality

During your participation in this study, the researchers and their personnel will collect and record all information that concerns you in a research file. Only information needed for the correct performance of the study will be collected. This information may include your lifestyle, habits, and other information such as your name, gender, date of birth, ethnic origin and, for ladies, the last menstruation date.

All of the information collected in the course of the study will remain strictly confidential, within the limitations specified by law. In order to preserve your identity and the confidentiality of this information, you will only be identified by a code number. The key of the code linking your name to your research file will be kept by the study researcher.

The study researcher will use the study data for research purposes in order to meet the scientific objectives of the study as described in the consent form. Your personal information will be destroyed 5 years after the end of this project.

The study data will be kept for 25 years and may be published in medical journals or shared with other persons during scientific discussions. No publication or scientific communication will disclose any information that would allow you to be identified.

For monitoring and control purposes, your research file as well as your medical files may be consulted by a person designated by the Comité d'éthique de la recherche of Institut universitaire de gériatrie de Montréal, by a person designated by the minister of Health and Social Services, by authorized governmental health authorities, and by representatives of the sponsor. All of these persons and organizations observe a policy of confidentiality.

For protection purpose and in order to contact you quickly, your name, address, phone number as well as the beginning date and the ending date of your participation in the project will be conserved by the principal investigator in a repertory for one year after completion of the research project.

You have the right to consult your research file to verify the correctness of the collected Information, to have out-of-date or unjustified information corrected or deleted, and to make copies, for as long as the study researcher, establishment, or research institute possesses this information. However, in order to preserve the scientific integrity of the research, you will not have access to some of this information until the research is completed.

Source of funding for the project

All the pertaining cost and expenses of this research project will be covered by Canadian Institute of Health Research (CIHR).

Access to the researchers

As a participant, you have the right to ask questions at any time by contacting or leaving a specific message to Ensie Abbassi at (514) 340-3540, extension 4700 or by contacting Dr Yves Joanette at (514) 340-3540, extension 4767.

In case of complaint
For all problems concerning the conditions in which the research project you participated in took place, you are able, after discussing with the person responsible for the project, make your concerns known to the person responsible for complaints at the institute universitaire de gériatrie de Montreal at the following address: The local service quality and complaints commissioner, institute universitaire de gériatrie de Montreal, 4565, chemin Queen-Mary, Montreal (Quebec) H3W 1W5. Tel: (514) 340-3517.

Information on ethics
The comite d'éthique de la recherche IUGM has approved this research project and ensures the rules of ethics will be respected during the entire research project. For more information, you may contact the secretary of the research ethics committee at (514) 340-2800 local 3250.

Future projects

Do you accept to be contacted again by a member of the research team in order to participate in subsequent projects?

Yes_________________ No_________________

These projects will be similar to this one. Your personal information will not be kept for more than five years and the period of recall will not therefore exceed this period. Of course, during this call, you will be free to accept or refuse at any time to participate in the research projects proposed.

Participant's consent
The research project in the attached description has been explained to me and my questions have been answered to my satisfaction. I agree to participate in the study. It has been made clear to me that I am free to withdraw from the study at any time and that confidentiality will be ensured.

____________________ ____________________________

Name of participant Signature

Research declaration
I, undersigned, ---, certify:
To have explained to the participant the terms of the informed consent form and responded to the questions which have been asked and clearly indicated the terms of participation in this project described here. I will provide a signed copy of the informed form to the participant.

________________________________ ____________________________

Name of researcher or his representative Signature

____

Date

Appendix E. Texts Used to Advertise the Research

The text that was used for internet advertisement

Yves Joanette's Communication Lab at the CRIUGM (l'Institut universitaire de gériatrie de Montréal) is looking for female and male volunteers to participate in a word interaction computer-based experiment. Time: approx. 1 hour. Participant characteristics: healthy right handed persons with normal or corrected to normal vision, between the ages of 20-35 or 60-75, with English as their first language. Participants should not be taking anti-depressant or anti-anxiety medication. Participants will receive a small compensation. If interested, please email us for further information. word.interaction@gmail.com

Participants Wanted

Study on Word Interaction

Are you a right-handed healthy person?

Is English your first language?

Are you between the ages of 20–35 or 60-75?

Do you have normal or corrected-to-normal vision?

If interested, please Email:

word.interaction@gmail.com

or call at: (514) 340-3540

for more information

Participants will receive a small compensation for their participation

word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com	word.interaction@gmail.com