General Discussion

CHAPTER 7

Using verbal material, this dissertation examined the implicit and explicit recognition of stimuli containing affective information. In the first three experiments, the lexical decision paradigm was chosen to overcome previous heterogeneous findings regarding the effects of emotional valence where subjects need not to pay attention to the affective nature of the to-be-tested items. As explained in the introduction the lexical decision task, where subjects have to judge whether a letter string is actual a word or not, may have a higher probability of eliciting effects of emotional valence than other tasks such as word stem completion. Furthermore, there exist numerous studies and models that could explain subjects' performance in the lexical decision task, and the variables that affect the processing of this task are well documented (Graf et al., 2005). Thus, by controlling the stimulus material for the variables known to affect lexical decision times, it was expected to find evidence for an enhancement of the processing of affective material (independent of its specific valence, namely positive or negative words). Enhancement effects of emotionally valenced words were hypothesized because converging empirical findings and corresponding theoretical explanations point to a central mechanism that facilitates the processing of affective stimuli in the brain.

In addition to this purely behavioural focus, this dissertation project follows a multi-methodological strategy. To reveal differences in the task demands associated with the processing of emotionally valenced words pupil data were measured as a psychophysiological indicator. Furthermore, functional imaging was used to find possible relations between the valence-specific processing of positive, neutral and negative words and cortical networks subserving the processing of emotional information in the lexical decision task. Since the explicit recognition task was carried out with the same sample of subjects and stimulus material it was also possible to directly compare the neuroimaging data in two different tasks, an implicit lexical decision task and an explicit recognition task. Whether and how the observed similarities and differences can be related to the hypothesized underlying processes will be discussed in this chapter.

Let us first consider the behavioural results in the lexical decision task. The data in chapters 2-4 found common enhancement effects of emotionally valenced words in a task that is assumed to support implicit processing. By showing valence-independent as well as valence-specific effects across different stimulus lists and different samples of subjects it can be concluded that the rated emotional valence of words modulates the processing of words

in the lexical decision task. Put another way, the dimensional construct of emotional valence has shown its appropriateness. In the first two experiments (the pilot study and the neuroimaging study in chapter 2) response times and error rates were lower when the presented stimuli were positive words. Somewhat surprisingly, this effect was not observed with the negative items. In their 2005 article, Kuchinke et al. asked whether there exist other underlying factors that might explain this valence-specific pattern of results. As a consequence, two follow-up studies were conducted which were reported in chapter 4 and chapter 5. In chapter 4, word frequency was introduced as a second factor. This factorial variation confirmed the observations of the first study and adds further discussion to the literature concerning emotional effects in the lexical decision task. Here, high-frequency words revealed similar results when they were categorized by their emotional valence. Only positive high-frequency words showed the processing advantage, whereas subjects' response times to high frequency negative words were comparable to that of high-frequency neutral words. This differential effect was not observed for the low-frequency words, where both valence conditions showed an enhanced processing (albeit negative words caused more errors than positive words). When high and low-frequency words were examined together, the overall effect showed facilitated responses for positive and negative words compared with neutral words.

Might the heterogeneous findings in previous literature at least partly be attributed to orthographic characteristics of the stimuli lists used in other studies? Following the assumptions of the present results, it seems likely that either not controlling for word frequency or looking only at high-frequency words will provide data that does not comprise differences between negative and neutral words[9]. In contrast, the effect of positive material is much clearer: positive words reliably enhance lexical decision times (see chapter 2 for a discussion).

To further investigate the processing of high-frequency negative words in the lexical decision task, emotional arousal was introduced as a further variable that is hypothesized to be orthogonal to emotional valence in affective space (Bradley et al., 1992; Lang et al, 1990). Emotional arousal has previously been shown to affect the processing and remembering of

[9] Unfortunately, most of the lexical decision studies that observed no differences between emotional words and neutral words (Bradley et al., 1994; Matthews and Southall, 1991; Parrot et al. 2005; Siegle et al., 2001; 2002) or slower responses for negative compared with positive words (Strauß, 1983) did not report the word frequency of their stimulus material. Ruiz-Caballero and Moreno (1992) who found slower responses to negative words compared with positive words used a sample of 24 rather high-frequency words which is in accordance with the data presented in chapter 3. Moreover, the word material used by Parrot et al (2005) was not controlled for word length, and according to the stimuli reported in the appendix of the article, happy words and their associated neutral words differed in their mean word length with longer word length for the positive word list. The direction of this effect will work against the advantage of positive words in the lexical decision task, because longer words are associated with longer response times in the lexical decision task.

pictures (Ochsner, 2000) and words (at least on the neural level, Kensinger and Corkin, 2004), but whether emotional arousal has an influence on implicit tasks like the lexical decision task has not been examined extensively. Again, the results of the factorial variation in the present dissertation project were clear-cut: in contrast to low arousing negative words, the expected processing advantage was only found for high arousing negative words in implicit word recognition using high-frequency words (chapter 5; see Thomas and LaBar, 2005, for comparable results in repetition priming).

Taking these three major findings together, the following assumption can be drawn: in contrast to earlier attempts in the literature, emotionally valenced words have consistently shown to speed up subject's response times when the word material is controlled for factors known to affect processing in the lexical decision task, such as word length and word frequency. Moreover, it should be more likely to observe effects of emotional content when high arousing words are processed (at least in regard to items with negative valence). Still, it seems probable that emotional arousal interacts with the processing advantage observed for negative words in a non-linear way. Both low arousing negative words and high arousing (negative) taboo words do not show the proposed processing advantage in the lexical decision task (chapter 5; MacKay et al., 2004).

Two considerations might help clarify the influence of emotional arousal: First, rated emotional arousal has been associated with physiological reactions to emotional stimuli (Bradley et al., 1992). Thus, during the rating of pictures and words on the arousal dimension subjects might recognize past physiological states and will scale their ratings in accordance with these past episodes. In an experimental setting, pictures and words are intended to cause comparable physiological states, which can be taken to facilitate the remembering of the appearance of a certain stimulus in a prior study session. It is expected that similar processes might operate for high arousing negative words during the processing of the lexical decision task. Since recognition of emotional information is incidental to the lexical decision paradigm, physiological reactions may be too slow to affect the early processing stages that have been proposed as the locus of effect of emotional valence. Accordingly, high arousing negative words are not thought to enhance the level of physiological arousal (see chapter 5). Thus, it is possible that high arousal values operate on the same dimension as high emotional valence by influencing the perceptual fluency or familiarity of the to-be-tested stimulus[10]. This point is especially important if one considers the high correlation between valence and arousal for negative verbal material (see Appendix C). The discussion of a collapsed valence/arousal dimension could clarify this contradiction. High arousing

[10] It has been hypothesized that recognizing physiological states would rely on elaborative processes, which are intended to affect explicit word recognition, but not the incidental processing of verbal emotional stimuli (see chapter 1).

negative words usually represent high levels of negative valence. Thus, splitting high and low arousing negative words might end up in an artificial situation which does not account for the nature of the incidental effects. Interestingly, Nakic et al. (2006) observed enhancement effects in the response times in their lexical decision study only for highly negative items in contrast to mildly negative and neutral words. Since they did not report arousal values for their material, it is expected that highly negative words comprise a higher level of arousal.

The second consideration concerns the non-linear effects of emotional arousal. Already in 1908 Yerkes and Dodson suggested that only moderate levels of emotion enhance memory performance, while extreme levels impair performance. Applying this Yerkes-Dodson law to the lexical decision task might explain why high arousing taboo words were not observed to enhance lexical decision times (MacKay et al. 2004). MacKay et al. identified attentional binding mechanisms possibly responsible for this effect. Other authors have hypothesized on a more general level that high levels of arousal reduce hippocampus functioning (Nadel and Jacobs, 1998). The question of whether these arousal-mediated processes operate similarly during the processing of the lexical decision task should be addressed in future research. Nonetheless, it will be difficult to find well-controlled and well-matched stimulus lists for high arousing taboo words and neutral or negative words.

With the assumption that facilitation effects can be observed that reflect the emotional intensity of the stimuli (defined here as either high values of positive valence or of the collapsed valence/arousal dimension for negative words) a computational model that simulates lexical decision performance was introduced in chapter 5. By extending the MROM (Grainger and Jacobs, 1996) with an affective evaluation mechanism that is proposed to enhance any activation in the mental lexicon associated with emotional information, the model, MROMe, was able to predict results concerning a sample of five letter words that are similar to the data obtained in chapters 2-4. It seems likely that a similar mechanism can explain lexical decision performance in subjects. As explained in chapter 5, the new evaluation module might account for faster response times and increased response biases. In addition, the implementation of the affective evaluation module suggests that enhanced perceptual processing and a higher response bias can be two sides of the same medal, rather than being contradicting aspects (as hypothesized by Zeelenberg, Wagenmakers, and Rotteveel, 2006).

Still, the question as to what extend the predictions of the simulation study can be generalized is open. Further simulations examine, for example, whether the MROMe might also predict the observed interaction between emotional valence and word frequency reported in chapter 3 (using a greater lexicon). Although the above discussion on valence and arousal may explain parts of this interaction effect, it opens the stage for some interesting insights into the temporal resolution of an early emotional evaluation mechanism.

Emotional processing was found to modulate the word frequency effect in chapter 3. We know from the word frequency literature that the earliest differences between high- and low-frequency stimuli can be observed in a time window 120-140 ms post stimulus onset according to ERP data (Assadolahi and Pulvermüller, 2001). Assuming that the processing of word frequency and emotional valence do not operate completely independent of each other, it is likely that differences between emotionally valenced and neutral words will also be observed in this early time window (see Bernat et al., 2001; Ortigue et al., 2004). It is unlikely to assume that only post-perceptual or (in this sense) late processes are responsible for the observed interaction effect.

Nonetheless, early and late influences of emotional content on the processing of the lexical decision task should be considered. Like the effects of word frequency on later processing stages, e.g., the N400 component of the ERPs (Dambacher et al., 2006; van Petten and Kutas, 1990), the effects of emotional valence might also be evident at early and late processing stages. For example, despite early effects of emotional valence Bernat et al. (2001) reported differences in the P300 and later ERP components that have been discussed as indexes of post-lexical processing of the subliminally presented word stimuli. It is possible that the observed differences between the performance on positive and negative words results from post-perceptual processing. Because enhancement effects of low-arousal positive words are visible in the low- and high-frequency condition, it can be suggested that positive words benefit more from early affective evaluation than do negative words. This is suggested from the results in chapter 3 where the processing of high frequency words is faster and less demanding (and accordingly will more rely on early processes) than the processing of low-frequency words. In other words: the advantage observed for high-frequency positive words may be attributed to facilitated processing in earlier stages than is the enhanced processing of both positive and negative words in the low-frequency condition. However, this assumption is contradicted by evidence found by Dijksterhuis and Aarts (2003). The authors observed a benefit for the subliminally processing of negative words compared with positive words in a lexical decision task and related this finding to a preferential processing of negative words.[11]

A further explanation for the observed differences between positive and negative words may arise from inter-individual differences. Much of the literature on emotional valence effects in the lexical decision task examines differences in the processing of emotionally valenced words by different patient groups: depressed subjects (Canli et al., 2004; Matthews and Southall, 1991; Ruiz-Caballero and Moreno, 1992; Siegle et al., 2001, 2002), anxious subjects (MacLeod and Metthews, 1991; MacLeod et al., 1987; Matthews et al., 1989;

[11] Note, that these results have been critisized in general due to methodological flaws (see Labiouse; 2004)

Nugent and Mineka, 1995; Parrot et al., 2005), or psychopaths (Williamson et al., 1989). A common goal of these studies was to test the assumptions of the mood congruency model (Bower, 1981). For example, they emphasize that depressed subjects ruminate on negative threat-related information, which therefore leads to increased response times in the lexical decision task (see Canli et al., 2004; Siegle et al., 2001). Although non-clinical students participated in the present lexical decision experiments[12], it seems possible that depression- or anxiety-related personality factors may have influenced the processing of the task. Moreover, it is probable that effects of personality traits do mainly affect the processing of high-frequency negative words as proposed by attention binding hypotheses (MacLeod and Matthews, 1991), because such trait-related attentional processes would inhibit the expected perceptual enhancement of negative information especially at early processing stages (which might be more evident in the faster processing of high-frequency words). Alternatively, it is plausible that a comparable number of subjects exhibiting happy or pleasant moods at the day of the experiment could cancel this. Interestingly, most of the reported studies did not observe significant disadvantages in the processing of negative or threat-related information for the clinical subject samples in implicit word recognition as was proposed by the mood congruency theory (Bower, 1981). Thus, it is questionable to which extent personality traits influence implicit processing of emotionally valenced words in the lexical decision task.

To sum up, the present dissertation found evidence for an enhanced implicit processing of both positively and negatively valenced words in the lexical decision task. It was shown that the effect of emotional valence interacts with word frequency. The multi-methodological approach of the presented studies was only partly able to validate the affective nature of the results (e.g. in the functional imaging studies). Neither measuring pupillary responses nor recording skin conductance responses revealed effects of emotionally valenced words in the lexical decision task. Although it is difficult to draw conclusions from null effects, the present results still might improve our understanding of the underlying effects. Assuming that these null effects are replicable and can not be attributed to methodological flaws in the experiments, the psychophysiological data question the nature of the emotional valence effects in the lexical decision task. The present data, in contrast to explicit tasks, suggest that the incidental processing of the emotional valence of words does not elicit peripheral physiological reactions. Thus, the proposed perceptual enhancement might be associated with enhanced retrieval processing from semantic memory (chapter 2), but does not produce different peripheral physiological reactions compared with neutral words. Hence, it is possible that the nature of perceptual enhancement effects in implicit visual word recognition are

[12] Although subjects have not been tested on anxiety or depression questionnaires one might assume that most of the subjects that participated the experiments will not elicit clinical symptoms of either disease. Nonetheless, clinical scales will be part of the follow up studies to completely rule out the possibility of biased data by pathological subjects

limited to visual and/or semantic processing whereas explicit recognition has been shown to elicit peripheral physiological reactions, which help to guide subjects' responses as additional external cues.

As outlined in this discussion, further research should address the questions of how individual differences affect the processing of emotional valence in visual word recognition and further examine the temporal aspects of the emotion-cognition interaction. It is expected that the recording of ERPs during the processing of the lexical decision task will be an adequate candidate for the investigation of the temporal dynamics of the emotional valence effects. Of further interest is, how the processing of emotionally valenced words in a data-limited variant of the lexical decision task is related to the present results, since it has been proposed that under data-limited conditions (short stimulus presentation durations) subject's responses primarily rely on a familiarity assessment mechanism (Jacobs et al., 2003). Moreover, the early enhancement of emotional valence processing should benefit from data-limited processing since post-perceptual processes are less pronounced in this task. How emotional valence influences the effortful and elaborative processing will be part of the discussion in the next section as well as the similarities and differences between the neural correlates of processing emotionally valenced words in the lexical decision task and in the yes/no recognition task.

Implicit and explicit recognition of emotionally valenced words

The first comparison between the implicit and explicit word recognition tasks examined in this dissertation project regards the before mentioned post-perceptual influences. As proposed in the introductory chapter, processing of an explicit yes/no recognition task is intended to rely on integrative and elaborative processes. If one examines the behavioral effects of emotionally valenced words in the recognition task (chapter 6; Appendix E) it seems clear that the processing speed of the target words (words that have been studied in the study phase of the recognition task) and the distractor words (newly presented words in the test phase) are not affected by the words' emotional valence. This is important to note, because the target words in the recognition task are identical to the word stimuli used in the lexical decision task in chapter 2 (Kuchinke et al., 2005) and also the subjects that solved both fMRI experiments were the same.

Is it possible that elaborative processes at time of retrieval overshadow the initial automatic processing facilitation for emotionally valenced words? Because subjects have not been instructed to respond as fast as possible in the recognition task this cannot be

answered here directly. Still, it remains possible that explicit processing does affect the processing speed to a lesser degree than does implicit recognition. Subjects were instructed to answer within the interstimulus interval of 2.8 seconds, which might be interpreted as forcing a speeded choice during the recognition test phase. In the light of such an interpretation it is rather unlikely that post-perceptual processes were responsible for the processing enhancement in the lexical decision task as hypothesized in the recognition task (e.g., recollection, Yonelinas, 2002).

A second result comes from the modulation of the hit and false alarm rates by emotionally valenced words. Here, in contrast to the response times, an effect of affective information was observable: during the recognition task, subjects found it easier to remember the appearance of positive and negative words in the preceding study phase (as revealed by higher hit rates compared with neutral words). Additionally, both categories of emotionally valenced words increased the false alarm rates. If one derives additional accuracy and bias measures from the present hit and false alarm rates (Windmann and Kutas, 2001; see Appendix E), it can be shown that the pattern in the hit and false alarm rates in the present study cannot be explained by higher discrimination accuracy for emotionally valenced words[13]. In contrast, the bias to respond 'old' was highest for positive and negative words. Thus, the behavioral data replicated earlier findings that indicate a higher emotion-induced bias to response 'old' to negatively valenced words (Windmann and Kutas, 2001) and extended them by demonstrating that this bias is also evident for positively valenced words.

It is difficult to compare the error data of the lexical decision task with that of the recognition task, since subjects made relatively few errors during the processing of the lexical decision task. On a descriptive level, the highest error rates for neutral items in the implicit task are still evident in the recognition task, where the highest rate of misses (the number of undetected 'old' words) can be observed for neutral words. It is also possible that this higher accuracy of emotionally valenced words reflects familiarity-based processing in the recognition task in a manner discussed similar to that in the implicit lexical decision task. As is evident in the recognition task such familiarity-based processing affects previously studied target items as well as unstudied distractor words, which leads to the higher overall response bias for emotionally valenced items (see Kensinger and Corkin, 2003). Interestingly, a similar response bias for negative words has been observed in a lexical decision task with subliminal stimulus presentation to both words and nonwords (Windmann

[13] An additional computed repeated measures ANOVA revealed that neutral words had higher accuracy measures compared with positive and negative words [$F(2,38)=4{,}149$, $P=0.023$], whereas positive and negative words did not differ. The reverse pattern occurred for the bias measures, where positive and negative words showed the highest bias [$F(2,38)=14{,}593$, $P<0.001$]. Again, no valence specific differences were observable between the positive and negative words (Appendix E).

et al., 2002). It will be interesting to see whether this response bias is also evident for the processing of positive information in the data-limited lexical decision task.

Still, it should be mentioned that the effects obtained in the yes/no recognition task seem to be less affected by valence-specific processing in the present study. In contrast to the lexical decision task results, positive and negative words affected recognition task measures to a comparable extend. Extending the arousal discussion above it seems likely that emotional arousal of word items does affect recognition performance to a lesser degree. It is difficult to examine this proposition for the present data, because the stimulus material in the recognition task has not been controlled for the arousal dimension. Null effects of arousal have been observed when the word material was controlled for emotional arousal in explicit recognition tasks (Kensinger and Corkin, 2003; Matthews and Barch, 2004). Possibly, arousal has only a small and early influence in word recognition, and is therefore more evident in the implicit lexical decision task and overshadowed by the emotion-induced response bias in an explicit recognition task. This effect should further be investigated as it contradicts predictions of arousal effects from the processing of pictures in explicit recognition (Ochsner, 2000). Here emotional arousal had a clear effect independent of the valence of the picture items. A possible solution to this dilemma would be the examination of the processing of both stimulus modalities (words and pictures) controlled for emotional arousal in a recognition test within the same subjects.

The neuroimaging results can provide further insights into these observations. Processing of emotionally valenced words in the lexical decision task and in the recognition task revealed a similar pattern of results in the prefrontal cortex. Although the processing of negative words was associated with small activations in both tasks, they were commonly located in right lateral regions, namely along the right inferior frontal gyrus. Similarly, regions associated with the processing of positive information have been identified in bilateral anterior frontal regions in both tasks. In addition, the explanations above might suggest that the processing of neutral words in the explicit recognition is associated with higher discrimination accuracy.

A region in the right frontal operculum has been identified which might be associated with better discrimination performance for neutral compared with emotionally valenced words as revealed by the according old/new contrast (Kuchinke, Jacobs, Võ, Conrad, Grubich, and Herrmann, 2006; see chapter 6). Interestingly, right dorsolateral regions have previously been associated with higher retrieval monitoring (see Henson et al., 2000 for a discussion) or post retrieval monitoring (Henson et al., 2003), although retrieval related activation has also been observed in left dorsolateral regions. Still, the possibility remains that the observed activation can be related to effortful (post-)retrieval processes. A similar conclusion can be drawn regarding the right dorsolateral activation in the present recognition study related to

the processing of negative words if one takes into account that the explicit recognition of negative words has been shown to increase recollection processes (Kensinger and Corkin, 2003). It is also evident, that the implicit recognition of negative words elicited right dorsolateral activations. According to the low temporal resolution of the fMRI, it can not be ruled out that post-perceptual retrieval processes are responsible for this activation pattern.

Bilateral anterior prefrontal cortex regions, like they have been observed for implicit and explicit processing of positive words in the present studies have been suggested to support retrieval processing. Activations in these regions may be elicited by retrieval success. As a result, valence-specific activations to the processing of positive or negative words, which have been found to elicit similar regions in prefrontal cortex across the implicit and the explicit task, may be associated with retrieval related processing. At this point, it is not clear how the prefrontal activations can be related to familiarity-based processing. One might assume that effortful retrieval processes might also elicit familiarity-based processes and vice a versa, so that it would be difficult to dissociate them on the basis of the present experiments. Moreover, it has been suggested that a familiarity-related signal is present in the medial temporal lobe (Henson et al., 2003; Rugg and Yonelinas, 2003), which has not been the focus of the present examination in the recognition task. Specifically, higher familiarity is proposed to result in lower activations in the bilateral medial temporal lobe, like they have been identified for negative words compared with neutral words in the left parahippocampus during the processing of the lexical decision task in chapter 2.

One way to further examine the differential influences of recollection and familiarity on recognition memory and its modulation by emotionally valenced information is provided by the dual process model (see Yonelinas, 2002). According to this model, the ratio of familiarity and recollection can be computed on a post-hoc basis using confidence ratings during the recognition test or by forcing subjects to determine whether they ‘remember’ or they have a ‘feeling of knowing’ that a certain item is old (so called remember/know recognition paradigm). Both paradigms have recently been investigated using event-related fMRI (Henson et al., 1999; 2000) and have shown its appropriateness for the examination of emotional valence effects on recognition memory (e.g., Kensinger and Corkin, 2004; Ochsner, 2000), but a combination of these paradigms has not yet been applied for the examination of emotionally valenced words in fMRI (possible due to methodological problems concerning the statistical power when well-controlled word lists have smaller sample sizes).

The activated regions revealed in the two imaging studies presented in this dissertation have shown that regions known to support the processing of emotional information in pictures are also evident in the processing of emotionally valenced words (see chapter2 and 6). Therefore, similar networks might operate in implicit and explicit word recognition that

support the retrieval or monitoring of positive or negative information in general. Thus, the results add further evidence to the literature on emotional valence processing comprising an anterior prefrontal cortex network that contributes to the processing of positive information (see Ashby et al., 1999) and right dorsolateral prefrontal cortex network that contributes to the processing of negative information. As outlined above, the present data does not allow for conclusions as to which processes are responsible for this pattern of results, but the evidence found in the literature points to retrieval based processing.

Conclusion

The results in this dissertation provide evidence for an emotion-induced recognition bias in both implicit and explicit word recognition. In implicit word recognition, the presentation of positive and negative words affected lexical decision times when subject had to judge the lexicality of a stimulus. Special attention was given to the selection of the stimulus material. Consequently, the influence of orthographic word characteristics was minimized. As a result one can conclude that the enhancing effect of emotional valence on the response times in the lexical decision task, which has been related to familiarity-based perceptual processes, is modulated by at least two factors: the frequency of the presented words and the emotional arousal of negatively valenced word stimuli. In demonstrating this it was possible to overcome previous heterogeneous findings in the literature. Additionally, a computational model was introduced which predicts the pattern of the empirical findings in the lexical decision tasks. Still, different questions have not been answered yet, e.g., how is emotional arousal related to the processing of positively valenced words? To further examine these effects, psychophysiological measures and functional imaging were applied. The words' emotional valence had no significant influence on either pupillary data or the skin conductance responses during the processing of the implicit task. Both measures have previously been shown to vary depending on the emotional content of presented stimuli in different paradigms. Therefore the incidental processing of the words may be responsible for these null effects, although this issue needs further investigations.

In contrast, functional imaging revealed different neural networks associated with the processing of positively valenced and negatively valenced words that are dissociable from the neural networks that support lexical decision performance in general. For example, right dorsolateral prefrontal cortex was found to be active during the processing of negatively valenced words, whereas orbitofrontal cortex was identified to support the processing of positively valenced words.

A further functional imaging study examined explicit processing of emotionally valenced words in a yes/no recognition task in the prefrontal cortex. Consistent with the literature, emotionally valenced words affected the recognition task performance by enhancing the hit rates and the false alarm rates compared with that of neutral words. This pattern of behavioral results could be related to an emotion-induced response bias for emotional words was indicated by a tendency to respond ‘old’ to emotionally valenced items independent of whether they are actually old or not. In contrast, the discrimination performance was reduced for emotionally valenced words compared to neutral words. Again, the functional imaging results point to an involvement of similar neural networks supporting the processing of positive and negative information. The discussion of these results considered the hypothesized processes supporting the recognition performance and revealed a number of open issues that should be addressed to future studies.