

It is remarkable to see how a beautiful smile can influence one's own feelings about a situation. From recent research in neurocognitive psychology we know that different brain regions, like the prefrontal cortex and the amygdala, are involved in the evaluation of happy and sad faces (Pessoa, McKenna, Gutierrez, and Ungerleider, 2002; Somerville, Kim, Johnstine, Alexander, and Whalen, 2004; Whalen, Rauch, Etcoff, McInerney, Lee, and Jenike, 1998). It was suggested that a first evaluation of the emotional nature of a face is fast and automatic. In other words, looking at a smiling face can affect our experiences and thus our behaviour even when we do not explicitly process its emotional connotation. Not only does the processing of emotional objects affect our own emotional state, but the emotional connotation can also enhance the recognition of an object or event which bears this information. An outstanding example of such a memory enhancement is September 11<sup>th</sup> 2001. Most of us will probably know when and where we first heard the message of the collapsing towers of the World Trade Center in New York. The highly significant circumstances of this event together with its stake of basal fears led to the building of vivid memories, so called 'flash-bulb' memories (Brown and Kulik, 1977).

But also less intense experiences of emotion have been shown to interact with the encoding and retrieval of long term memory representations. Influences of emotional information on memory performance have been observed in the processing of faces (e.g., Bradley, Mogg and Millar, 2000; Mather and Carstensen, 2003), pictures (e.g., Bradley, Greenwald, Petry, and Lang, 1992; Dolcos, LaBar and Cabeza, 2004, 2005; Ochsner, 2000), films (e.g., Cahill, Haier, Fallon, Alkire, Tang et al., 1996), stories presented by slides of pictures (e.g., Heuer and Reisberg, 1990), novels and stories (Christianson, 1992), and sentences (Maratos and Rugg, 2001). However, it appears that relatively little is known about the interplay between the reading of a word and the effect a words' emotional connotation takes.

In this thesis, I will investigate the implicit and explicit recognition of emotionally valenced words. The term "implicit recognition of emotionally valenced words" refers to situations where the evaluation of the emotional valence of a word is implicit or incidental to a subject during the processing of a task. In contrast, 'explicit recognition' is used in situations where subjects consciously shift their attention to the relevant features of the to-be-recognized object to support free recall, cued recall or recognition tests.

## Implicit and explicit memory processes

The distinction between implicit and explicit recognition processes has first been introduced following the examination of the recognition test performance of amnesic patients. Amnesic patients are severely impaired in standard (or explicit) memory tests such as free recall and recognition. But when the performance of amnesic patients in word identification tests was examined it could be shown that the amnesic patients' behavioural responses can be biased by prior exposure to test words in a way similar to that of control subjects (Graf and Schacter, 1985; Graf, Squire, and Mandler, 1984).

Analogous to the distinction between declarative and procedural knowledge, these results have been taken to suggest the existence of two memory systems. "One system [that] is impaired in amnesia and depends on the integrity of the damaged brain regions, and the other is intact in amnesia and is independent of these regions" (Squire, Shimamura, and Graf, 1985). A host of other variables have been identified to affect performance on implicit and explicit tests (Graf and Mandler, 1984; for a review see Schacter, 1987). For example, semantic processing (e.g., the levels of processing) improves performance on explicit but not implicit word fragmentation and word stem completion tests.

These dissociations have been explained in a variety of ways. Mandler and colleagues suggested that different processes operate at recognition: An automatic *integration* process that involves the temporary strengthening of a representations' internal organization and an effortful *elaboration* process (Mandler, 1980; Graf and Mandler, 1984). When an event is studied, it leads to an increase in activation of the perceptual aspects of that event in memory. It is this intra-item integration or strengthening of pre-existing memory representations which is associated with a higher familiarity of the studied event. Higher familiarity of a to-be-remembered item leads to better recognition performance or, in other words, recognition memory depends in part on the ability to detect the familiarity of the test items. By this view, subjects can note their own facility or fluency in perceiving familiar test items, and are then able to correctly attribute this observed familiarity to prior study phases in explicit memory tests.

In contrast, elaboration is proposed to represent a memory search process that supports recall and recognition. Here, inter-item information (like contextual cues) is used to form new representations, and words become more retrievable because there are more paths or retrieval cues which can be used to recall or recognize an event. More importantly it is stated that the elaboration process relies on intentional control by the subjects and is therefore supposed to be a non-automatic resource consuming process.

A related distinction has been developed by Jacoby and colleagues. Using their process dissociation procedure (Jacoby, 1991; Jacoby, Toth, and Yonelinas, 1993) automatic and controlled processes in recognition memory can be separated post-hoc by analyzing the erroneous answers, so that one will receive information about the ratio of automatic and controlled processing during the recognition test performance. Automatic processes are thought to be based on processing fluency, while controlled processes are associated with conscious strategic retrieval of studied items. Unlike the view of Mandler (1980; Graf and Mandler, 1984), an automatic (unconscious) process is not seen as an inherent aspect of a representations' internal organization, but as a processing characteristic. Subjects may process some items more fluently than others in a recognition memory test, and if this processing fluency is attributed to prior experiences with this item, the item appears to be more familiar. In implicit memory tests processing fluency is proposed to enhance the probability with which an item is identified, and as such, processing fluency and perceptual implicit memory should be related.

When they first introduced the implicit/explicit distinction, Graf and Schacter (1985) attempted to capture the important differences between the ways in which memory for previous experiences can be expressed: as conscious recollections or as automatic, nonconscious effects of past experiences on subsequent behavior and performance. From the current perspective, it seems obvious that neither implicit nor explicit memory processes comprise a homogenous category (Schacter and Buckner, 1998; Willingham and Preuss, 1995, Yonelinas, 2002). The highest agreement will be found regarding explicit memory processes at recognition, where most of the researchers accept the notion of two independent processes being involved, namely a fast and automatic familiarity-based process and the slower intentional process of recollection (Rugg and Yonelinas, 2003; Yonelinas, 2002). Recollection is described as an all or none process, where elements or particular details of a presented item are recognized. Recollection can be characterized as a high-threshold process, where only items falling above a certain threshold are remembered. However, there is disagreement about how familiarity should be related to implicit memory processes. Graf and Mandler (1984) described the implicit/explicit distinction with explicit recognition memory performance relying on both, integration (familiarity) and elaboration (recollection), while implicit recognition memory performance is only supported by the incidental integration process (see also Jacoby, 1991). In contrast, Tulving and Schacter (1990) argue that implicit memory relies on memory systems which can be separated from those that support recognition memory.

It has been criticized that there exists no coherent system or taxonomy of implicit memory processes (Willingham and Preuss, 1995). The only common attribute of implicit memory phenomena seems to be the absence conscious awareness, but it is unclear how much

implicit memory tests are contaminated by 'explicit' memory processes (e.g., intentional retrieval strategies, Jacoby, 1991) and how this fact is related to the different empirical findings. For example, in contrast to Mandler and Jacoby, implicit memory in priming studies has been shown to be independent of recognition memory (Squire, Shimamura, and Graf, 1985) and the implicit word fragment completion tasks does not seem to be influenced by the familiarity of the test items (Tulving, Schacter, and Stark, 1982).

In more general terms, there is an extensive body of research which provides evidence that familiarity and implicit memory are not identical but may reflect similar sub-processes (for a review see Yonelinas, 2002). Yonelinas (2002) proposes that different retrieval cues across implicit and explicit memory tasks are responsible for these observed dissociations between familiarity and implicit memory. In an implicit recognition task such as the lexical decision task, where similar retrieval cues (whole words) are presented like in standard recognition memory tests, implicit memory processes and familiarity should show a higher overlap (Yonelinas, 2002). In accordance, Jacobs, Graf and Kinder (2003) have related lexical decision performance to a familiarity-based process as predicted by computational modeling using the Multiple Read-Out Model (MROM, Grainger and Jacobs, 1996, see chapter 5).

## **Theoretical considerations on emotion**

'Do we run from the bear because we are afraid, or are we afraid because we run?'

William James

The above quotation by William James opens the view on a number of problems concerning psychological theories of emotion. Albeit scientists have been trying to solve the nature of human emotional experiences for more than one hundred years, there is still no consensus about what emotion is and what place emotions should have in theories of mind and behavior. Typical controversies concern the definition of emotion or the number of basic emotions (e.g., Ekman, 1992), and theories of emotional experiences can be grouped into several broad categories: feedback, central, arousal, and cognitive theories (LeDoux, 1996). Although these theories differ in certain degrees on how they view emotions and at which level they explain emotional experiences, each of these theories debates the nature of cognition-emotion interactions by proposing that emotional experiences are the result of prior emotional processes (Fellous, Armony, and Ledoux, 2000). For example, feedback theories (e.g., James, 1890) suggest that peripheral feedback completely determines the nature of emotional experience, thus the cortex is detecting emotionally significant stimuli by evaluating the responses appropriate to a stimulus. Central theories (e.g., Cannon, 1929;

Papez, 1937) see emotional experiences as the result of neural activity in the brain, where they are elaborated into perceptions and thoughts. Cognitive appraisal theories (Schacter and Singer, 1962; Scherer, 1987) emphasize that emotional experience is based on prior evaluations of situations. Schacter and Singer (1962) further developed James' theory of emotion by proposing that emotional experiences are the result of processes that become aware of the fact that the body is in a state of physiological arousal, and subsequently relate this unspecific, emotional ambiguous state to prior situational or physical experiences. Common to all these theories is that they require some kind of emotional encoding, the constitution of evaluative processes before a certain situation is categorized as potentially harmful or beneficial to the subject. Thus, these theories on emotional experiences agree in the fact that emotional processing precedes conscious emotional experience (LeDoux, 1992). Since the processes preceding conscious emotional experience are per definition non-conscious or preconscious, this means that they take place outside of conscious awareness (see Dehaene, Changeux, Naccache, Sackur, and Sergeant, 2006, for a taxonomy of conscious, preconscious and non-conscious processes).

## **Emotion and implicit memory**

The interaction between emotion and implicit memory can be examined in two different directions: (a) *Emotion as Implicit Memory*, where implicit memory may be expressed through emotional responses, or, in other words, emotional responses may reflect prior experiences as shown in amnesic patients. Damasio, Tranel and Damasio (1989), for example, reported in their case study that an amnesic patient, who showed an inability to recognize people preferred 'good' over 'bad' staff members (as indexed by experimentally varied prior encounters). As a second possibility (b) *Emotional Effects on Implicit Memory* can be examined, which will be discussed in the following sections in more detail.

From one point of view, it might be expected that emotional states or emotional content would have relatively little effect on implicit memory (Tobias, Kihlstrom, and Schacter, 1992). This discussion arose from the observation that implicit memory is mainly affected by perceptual features, e.g., changes in the surface features of events (Roediger, Weldon, and Challis, 1989). Since emotional content is thought to affect the connotative meaning of events on a conceptual level and not their perceptual features, it seems possible that emotional content does not show an effect on implicit memory tests (see Danion, Kauffmann-Muller, and Grange, 1995; Roediger and McDermott, 1992; Siegle, Ingram, and Matt, 2002). This issue has been examined using the word stem completion task. No differences in the emotional state between depressed and non-depressed control subjects were observed, nor did the emotional connotation of the words affect subjects' performance in this implicit

memory test (Danion et al., 1995). Although stem completion is a paradigm of choice for many studies of implicit memory, it has been criticized especially for its use in the investigation of emotion-dependent effects. Tobias et al. (1992) suggested that its data-driven nature may overshadow emotion dependent effects. If emotional effects are primarily conceptual, one might expect that they show less dependency on perceptual implicit memory tasks like word stem completion. Accordingly, Tobias et al. (1992) developed a set of conceptually driven implicit memory tasks and observed that, when emotional mood was incidentally varied during the encoding and retrieval phase depending on the listening of happy and sad music, mood congruency effects are evident even in implicit memory tasks.

Thus, the opposite view might also be correct: If emotional state and emotional content are viewed as contextual cues that are critical during encoding and retrieval of memory representations one would expect emotional effects to a greater extent in implicit than in explicit memory. It has been suggested that in implicit memory tasks the processing of perceptual features can be altered directly by environmental contexts. In analogy to mood dependent effects one might say that the world does look darker to sad people and brighter to those who are happy (Tobias et al., 1992). Again, the overshadowing of stronger contextual cues (such as the presented letters in a stem completion task) has been indexed as responsible for the observed inconsistency of state dependent memory. These potentially stronger cues may include experimenter-presented or subject-generated cues. Following such arguments, it should be easier to observe emotional state dependent effects when other 'superseding' cues are eliminated, as is the case, per definition, in implicit memory tasks.

Incidental effects of emotional content on memory processes where subjects were unaware of the emotional valence of the stimuli have been reported under different paradigms such as word stem completion tasks (e.g., Matthews, Mogg, May, and Eysenck, 1989), primed lexical decisions studies (e.g., Bradley, Mogg, and Williams, 1994), unprimed lexical decision studies (e.g., Challis and Krane, 1988, Strauss, 1983; Windmann, Daum, and Güntürkin, 2002), and fear conditioning (e.g., LaBar, LeDoux, Spencer, and Phelps, 1995; Bechara, Tranel, Damasio, and Adolphs, 1995). For example, mood congruency effects have been observed in a primed word completion task, where anxious subjects produced more threat related words than neutral words compared to control subjects (Matthews et al., 1989). In accordance with the '*Emotional State as Contextual Cue*' hypothesis the anxious subjects did not show this advantage in the subsequent explicit cued recall task. In a primed lexical decision task on non-clinical subjects a high negative affect group showed enhanced subliminal priming of depressive words relative to neutral words as opposed to a low negative affect group. Since subliminal primed lexical decisions are thought to depend to a lesser degree on explicit strategies and response bias than word stem completions, the

selective priming effect can be discussed in relation to an automatic integration process which has not been observed in the supraliminal priming condition or in the explicit free recall test (Bradley et al., 1994).

According to Bower's (1981) model, mood congruent effects are explained by emotional nodes in a relational network. Emotional nodes are linked with other memory representations such as happy or sad memories and are activated automatically when activation spreads through the network. Activation of emotional nodes is associated with increased accessibility of mood-congruent information. Because the model does not make differential predictions concerning implicit and explicit memory processes, it is useful in the explanation of anxious or depression-congruent effects in implicit memory. Strategic effects of subjects during explicit memory tests have been discussed to be responsible for the failure to consistently find the proposed mood-dependent effects in explicit tasks.

What becomes evident from this more general overview, is that effects of emotional experiences on implicit memory processes can be observed under certain circumstances. This also holds true for processing in the unprimed lexical decision task, where incidental effects of emotional valence are observed in some studies while others fail to find them. These aspects as well as methodological concerns that might also contribute to the inhomogeneous literature findings will be the focus of the chapters 2 - 4.

## **Emotion and explicit memory**

The cognitive domain where the influence of emotional experiences is best understood is explicit memory. From an evolutionary perspective, enhanced memory for emotionally significant events has an adaptive value because it predicts 'biologically important occurrences when similar events are re-encountered in the future' (Dolan, 2002). Accordingly, different studies found that individuals typically remember emotionally significant material better than neutral material (for reviews see Christianson, 1992; Hamann, 2001; Ochsner, 2000). An extreme example of an enhancement effect stems from naturalistic approaches examining the above mentioned 'flashbulb memory'. Exceptional, highly vivid memories are created when sudden, surprising events that have high emotional significance are encountered. In their classic study, Brown and Kulik (1977) found that the higher the degree of novelty and consequentiality associated with an event is rated (e.g., the assassinations of Martin Luther King or John F. Kennedy), the higher is the likelihood of remembering in great detail the circumstances in which the news were acquired. Support for the flashbulb hypothesis has been observed for happy and sad events of political and social life, autobiographical events, and eyewitness memory (Christianson, 1992; Conway, 1995; Reisberg, Heuer, McLean, and O'Shaughnessy, 1988; Walker, Vogl, and Thompson, 1997;

Winograd and Neisser, 1992). However, despite their high vividness and their highly rated imagery it has been suggested that flashbulb memories may sometimes not be as accurate as they seem to be. Neisser and Harsh (1992) asked subjects one day after the Challenger explosion in 1986 and again 3 years later about the situation when they first heard the news. Although the subjects reported highly vivid memories, they were often simply wrong.

The possibility exists, that this loss in accuracy over time reflects the flexibility and reconstructive power of the mental system instead of questioning the original vividness of flashbulb memories. According to the 'Easterbrook hypothesis', emotion has been hypothesized to produce a narrowing of attention (Easterbrook, 1959). Attentional resources are allocated to central features of an emotional event, and encoding of the surrounding peripheral details is less sensitive. As a result, central details of emotional events are better retained than peripheral details or the corresponding central details in neutral events (Heuer and Reisberg, 1990; 1992; Christianson and Loftus, 1987). Heuer and Reisberg (1990) reported that subjects who saw an emotional version of a slide story remembered more central and more detailed information than did subjects who were presented a neutral slide story in a surprise recognition test two weeks later. It should be noted, though, that different studies failed to replicate the predictions of the 'Easterbrook hypothesis' when they observed enhanced memory for both, central and peripheral information (for a review see Heuer and Reisberg, 1992).

However, the evidence from the literature supports the idea that memory for emotional content is enhanced even when the emotional intensity of the material is low, as is the case in typical laboratory studies. In such controlled laboratory experiments of explicit recognition memory, subjects are presented either a set of emotional stimuli or a set of neutral control stimuli designed to be as similar as possible to the emotional stimuli, but lacking their emotional connotation. As a result, it has been consistently found that the probability to remember a positively or negatively valenced word, picture or slide sequence is increased compared with neutral material in free recall tasks (Bradley et al., 1992; Cahill and McGaugh, 1995; Christianson, 1992; Danion et al., 1995; Doercksen and Shimamura, 2001; Hamann, Ely, and Grafton, 1999; LaBar and Phelps, 1998; Phelps, LaBar and Spencer, 1997; Talmi and Moscovitch, 2004).

When looking at recognition tests, where subjects have to indicate whether they have previously studied an item, the results appear to be less clear. Using a recognition task, Maratos and colleagues observed that more 'old' responses are given in relation to emotional items, independent of whether the item is actually old or new (Maratos, Allen, and Rugg, 2000; Maratos and Rugg, 2001). This tendency has been explained in terms of an '*emotion induced recognition bias*', which may reflect an adaptive elementary cognitive mechanism



that ensures that an event with potentially high survival value is not missed (Windmann and Kutas, 2001).

In contrast, Maratos et al. (2000) related this pattern of data to effects of semantic cohesiveness: Negative items are thought to represent a semantic category with strong inter-item associations, leading to higher false alarm rates for negative material in a recognition task. However, McNeely, Dywan, and Segalowitz (2004) showed that it is not semantic cohesiveness per se that explains the recognition bias for negative material. According to their results, emotionally salient words seem to be more fluently processed, even when compared with highly cohesive categorized neutral material. Through arousal-mediated processes at encoding and retrieval, emotional content might serve as an organizing and binding factor for memory processes (Talmi and Moscovitch, 2004).

In addition to an enhanced response bias, it has been suggested that emotional items are not recognized better than neutral ones in verbal recognition tasks (Danion et al., 1995; Maratos et al., 2000; Windmann and Kutas, 2001), whereas enhanced performance has been observed in recognition tasks focussing on emotional context effects in sentence processing (Maratos, Dolan, Morris, Henson, and Rugg, 2001) or pictorial backgrounds (Erk, Martin, and Walter, 2005; Smith, Henson, Dolan, and Rugg, 2004).

An explanation of these discrepancies emphasizes differences in the processes underlying recognition and recall performance. Recognition tasks have been suggested to differ more generally in terms of retrieval cues and the kind of response that they require (Yonelinas, 2002). Since no retrieval cues are given, recall has been thought to be based on more elaborative, strategic processing, whereas recognition performance may be based more on automatic and context-dependent familiarity-based processes. As a result recognition test performance is more susceptible to response biases as observed using emotional material, e.g., the emotion-induced response bias or overshadowing of emotional valence effects due to the given contextual cues similar to the overshadowing effects in implicit memory tasks.

Accordingly, enhanced recognition of emotionally valenced words was evident in source memory tasks which have been related to recollective processes (Doerksen and Shimamura, 2001; Kensinger and Corkin, 2003), and in a remember/know recognition paradigm using picture stimuli that are thought to provide more contextual cues than do words (Ochsner, 2000). In the remember/know paradigm subjects are forced to indicate whether they '*remember*' (recollection-based response) or '*know*' (familiarity-based response) if a presented item has been studied before. Furthermore, Ochsner (2000) observed that '*remember*' responses were enhanced for negatively valenced pictures, whereas positively valenced pictures elicited more '*know*' answers. In addition to these

valence-specific effects on recognition, an effect of emotional arousal was observed, when high arousing pictures were better recollected compared with low arousing pictures.

Emotional valence and emotional arousal are thought to represent orthogonal axes in a two dimensional space (Bradley et al., 1992; Lang, Bradley, and Cuthbert, 1990; Osgood, Suci, and Tannenbaum, 1957, Reisenzein, 1994; Wundt, 1896). Going back to Wundt's 'Theory of Emotion' which states that basic emotions can be grouped along two basic emotional states, namely pleasure-displeasure and arousal (see Reisenzein, 1994), emotional stimuli are proposed to vary from positive (pleasant) to negative (unpleasant) on the valence dimension and from calm to exciting on the arousal dimension. It is suggested that positive and negative words are more arousing than neutral words, as long as the stimulus material is not controlled for the arousal dimension. According to this dimensional approach, it can be questioned whether positive and negative valence affect recognition or whether it is the degree of increased arousal that determines the recognition of emotional material (Christianson, 1992; Bradley et al., 1992). Only recently, research has begun to directly contrast the effects of valence and arousal (Dolcos, et al., 2004; Kensinger and Corkin, 2003, 2004; Ochsner, 2000).

It has been argued that positive and negative information might be processed differently by the cognitive system. Negative information is suggested to attract more processing resources than positive information (Dijksterhuis and Aarts, 2003; MacKay, Shafto, Tayler, Marian, Abrams, and Dyer, 2004; Pratto and John, 1991). This has been explained by the emotion-based processing prioritization for negative information (Öhmann, 1979, Cacioppo and Gardner, 1999; also see Kensinger and Corkin, 2003; Ochsner, 2000), where the processing of negative stimuli is more critical for survival of the organism. Accordingly, Kensinger and Corkin (2003) have emphasized that negative information might be remembered with more accuracy, as revealed by higher recollection scores. In contrast, positive material was suggested to be better interconnected in memory than negative material (Ashby, Isen, and Turky, 1999; Isen, 1985) which goes in line with the observed pattern of enhanced familiarity responses in recognition tasks for positive material (Ochsner, 2000).

### **Neuroanatomy of memory for emotional material**

One of the major research questions regarding memory and emotion is whether special processes are needed to explain the enhanced memory for emotional material (Hamann, 2001). As outlined above, it seems likely that effects of emotional material on memory processes can be explained by ordinary cognitive mechanisms, like the attracting of attentional resources, enhanced integration and elaboration of memory representations, and

a response bias at time of retrieval. However, a wealth of data from patient studies and recent neuroimaging findings suggests that the processing of emotionally valenced material is associated with specific neural mechanisms that have not been identified in the processing of neutral material. Across studies, the amygdala has been consistently identified as significantly enhancing memory performance by processing the emotional significance of incoming events and making this information available for other brain regions (for reviews see Ashby et al., 1999; Damasio, 1996; Dolan, 2000; Hamann, 2001; Kensinger and Corkin, 2004; LeDoux, 1995; Ochsner and Barrett, 2000). Through its interconnections with other brain regions (e.g., anterior and posterior cingulate gyrus, hippocampus, prefrontal cortex), the amygdala is thought to manipulate or enhance the activity of other brain regions involved in memory processes in reaction to positive and negative stimuli, but it should also be noted that responding to emotional stimuli has been found to be preserved in patients with amygdala damage (Anderson and Phelps, 2001).

Kensinger and Corkin (2004) identified two different neural routes for processing emotional information, which supports the idea of different neural pathways for valence and arousal: an arousal-dependent amygdalar-hippocampal and a valence-dependent prefrontal cortex-hippocampal network. In addition, several neuroimaging studies have revealed different neural networks activated during the processing of positive and negative information (Canli, Desmond, and Zhao, 1998; Davidson, 1995; Maratos et al., 2001; Wager, Phan, Liberzon, and Taylor, 2003). For example, in prefrontal cortex, the recognition of negative words is associated with activity in right dorsolateral regions, whereas left dorsolateral prefrontal cortex and orbitofrontal cortex are more activated during the recognition of positive words (Maratos et al., 2001; for encoding related activity see Dolcos, et al., 2004). Since similar valence-specific differences have been observed in implicit memory tests (Kuchinke, Jacobs, Grubich, Vö, Conrad, and Herrman, 2005, see chapter 2) it seems unlikely that the differential processing of positive and negative items in the prefrontal cortex reflects differences along the familiarity - recollection distinction. Moreover, this pattern of data has been related to emotion-specific processing in general, similarly to an anterior prefrontal cortex involvement in the processing of reward, and enhanced monitoring following retrieval of negative information in right dorsolateral prefrontal cortex (see chapter 2 and 6).

### **Implicit and explicit recognition of emotionally valenced words**

When I started working on this dissertation project, the data on effects of emotional valence on implicit and explicit word recognition seemed rather heterogeneous. Both kinds of recognition tests appeared to be affected by the emotional valence of the test items in some studies and failed to do so in others. Thus, one first aim of this thesis is to test the construct

'emotional valence'. Does the rated emotional valence of words account for facilitation effects in implicit and explicit word recognition? Or need the current results to be ascribed to methodological flaws? To solve this question, special effort was taken on the selection of the stimulus material to control it for possible modulating variables. It was expected that, by matching the emotional word categories for different factors known to affect implicit and explicit word recognition (e.g., orthographic features of the stimulus material), enhancement effects of emotional valence should be observed.

Furthermore, the impact of emotional valence on implicit memory performance will be tested in this thesis using the lexical decision paradigm, an implicit memory task that is proposed to be less dependent on contextual cues like the wordstem completion task used by Danion et al. (1995). It is well known that responses in the lexical decision task depend on a familiarity assessment mechanism (Grainger and Jacobs, 1996), and as outlined before, the processing of emotional valence is thought to affect the familiarity of the items, too. Hence, when controlling the stimulus material for other factors known to affect lexical decision performance an enhanced performance for emotional words compared to neutral words was expected. In contrast to the proposal made by Danion et al. (1995), this would point to modulatory effects of emotional valence on implicit word recognition, as can be expected from the assumptions of the 'affective primacy hypothesis' (Murphy and Zajonc, 1993), according to which an unattentional memory system categorizes every stimulus as positive or negative (Murphy and Zajonc, 1993). According to these authors, affective connotation might even be processed before cognition takes place as part of the normal perception and it is suggested that such an evaluation mechanism may occur preconsciously at an early stage of perception (Anderson and Phelps, 2001; Windmann et al., 2002). Hence effects of emotional valence should also be visible in implicit word recognition.

This dissertation project follows a multi-methodological approach for investigating the effects of emotion on implicit and explicit word recognition. Besides the experimental gathering of behavioral data (e.g. response time and error rates), examining psychophysiological responses and neuroimaging data was intended to validate the behavioral effects of emotionally valenced words. Thus, event-related functional magnetic resonance imaging (fMRI) was applied to identify the neural networks responsible for the processing of positive, neutral and negative words. Pupillary responses and skin conductance responses were measured to reveal differences in the task demands and the physiological arousal in relation to the processing of affective stimuli. In a further step of the multi-methodological approach computational modelling was used to build a falsifiable model of emotional valence effects in the lexical decision task. The developed computational model provides a heuristic description of enhancement effects of emotionally valenced stimuli in the lexical decision task, which no other model of visual word recognition accomplishes so far

(see chapter 5 for a discussion of other computational models). By simulating lexical decision performance the model goes beyond a verbal description or mathematical modelling, since its predictions can be compared directly with subjects' performance. Thus, it represents a further method in the present multi-methodological approach.(Jacobs, Rey, Ziegler, and Grainger, 1998). It is important to note, that the newly developed model was not designed to make direct predictions on reading research, but that the outlines of this model in terms of predicted enhancements for affective material can be seen as a first implementation of basal semantics in the processing of the lexical decision task.

The study outlined in chapter 2 was designed to identify cortical regions involved in the processing of the lexical decision task with positive, neutral and negative words using event-related fMRI. The use of an event-related design in functional imaging was intended to reveal different brain regions being involved in the processing of emotional words even when the emotional nature of the task was incidental to the subjects. To refine the behavioural results observed in this study, two further lexical decision tasks with highly controlled stimulus material were designed.

In chapter 3 word frequency was introduced as a second factor and the behavioral performance of the subjects was additionally monitored by means of a psychophysiological measure, i.e. task-evoked pupillary response, which has previously been shown to reflect emotional processing. Furthermore, the influence of emotional arousal and emotional valence was contrasted directly in chapter 4, where lexical decisions to high and low arousing negative words and low arousing neutral words were recorded. In preparation of this study, normative arousal ratings for 600 German words had to be obtained. Again, a psychophysiological measure was recorded as a further dependent variable, namely skin conductance responses, that have been related to experiences of physiological arousal.

In line with the results of the lexical decision studies, in chapter 5 a computational model of the processing of emotionally valenced words in the lexical decision task will be introduced that predicts enhancement effects in the lexical decision task by using a minimal set of assumptions. Finally in chapter 6, explicit recognition of positive, neutral and negative words is examined in a yes/no recognition memory test using functional imaging data as an additional method for examining the modulatory effects of emotional valence.<sup>1</sup>

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<sup>1</sup> The following chapters (2, 3, 4, 6) are published in, or have been submitted to international journals. Each of these chapters is written to be read independently from the rest of this thesis. As a consequence, some redundancy between the chapters is unavoidable.