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Is it Memory or Illusion?
Electrophysiological Characteristics of True and False Recognition

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To my parents and my brother

Vorwort

Viele Personen haben an der Entstehung dieser Arbeit Anteil. Ihnen allen möchte ich an dieser Stelle aufs Herzlichste danken und um Nachsicht dafür bitten, dass ich im folgenden nicht jeden persönlich erwähnen kann.

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Unvorstellbarer Dank gebührt meinen Eltern und meinem Bruder,
sowie meiner gesamten Familie.

Contents

”I know it can’t’ve been like that,

but that’s what I remember.”

Pat Barker, *Regeneration*
cited in Schacter (1996)

Introduction

All what we know and what we do has a relation to our prior experiences. People are not always aware of this, but if we think about processes in everyday life where we need access to prior knowledge or experiences it is difficult to find a process that works without a contribution of our memory. Moreover, we will not find such a process for an adult and healthy person. All what happens, all what we do, and all what we feel, we do link it with prior experience, knowledge, and opinions. We are our memories.

To give an example, think about what we have to remember if we want to meet a friend to go with him/ her to the movies. Not all relevant information can be captured here. However, to give some examples, we have to remember the phone number or email-address of the friend (or we have to remember where we have written down this information), we have to remember a special cinema, and a special movie. Maybe, we have heard something interesting about one movie or we know that the friend we will meet does not like a special kind of movies. We have to know how we will get tickets and we have to be certain that we will not schedule the meeting for a time when we already have something planned. Another example for the permanent importance of memory is the situation when we come across a known person on the street. We remember different things about this person and behave in an appropriate way (is it our boss or our friend?). We also use our memory if we meet an unknown person. Some characteristics could remind us of another person and then we are in favour to think that both persons behave quite similarly. Such a prejudice, either positive or negative, can influence our behavior. Given the context (on the street or in an interview) we also know how we have to behave.

The importance of the memory for our own self-conception and for everyday life is especially apparent in persons showing memory distortions. Schacter (1996) described different patients suffering from memory impairments, like organic amnesia (for an overview of the amnesic syndrome cf. Parkin & Leng, 1993). Amnesic patients have severe difficulties in remembering recent events and new information, despite preserved intelligence, perception, and language. For instance, one patient described by Schacter (1996), Frederick, was not able to learn new episodic information and was not able to form new memory traces. The patient suffered from a memory impairment called anterograde amnesia. From earlier conversations Schacter had learned that Frederick liked to play golf and so they went together to a golf course. Frederick's golf vocabulary was perfect (semantic memory) and he was able to hold his own (procedural memory). He was, however, not able to remember for instance the location of the ball (episodic memory). As long as he could keep the location of the ball after the tee shot in his memory, he generally remembered the location. He had problems in remembering the balls location if the search for the ball was somewhat delayed. After the game, Frederick had no memory of any shot. Furthermore, when Schacter met him for their second golf match all memory of the first match was gone.

For a healthy person, memory is generally well adapted to the everyday demands of life. That is not surprising, because our well-being and even our survival may depend on access to reliable informations about the past. But memories are not always accurate and especially recently memory's reputation has been tarnished, for instance through reports about false traumatic memories in therapy patients (Lindsay & Read, 1994, for a detailed discussion of the recovered memory debate cf. Conway, 1997). Today we also know that it is easy to induce feelings in persons who appear to remember events clearly that have never happened (e.g., Ceci, 1995; Loftus & Pickrell, 1995). We can also look in our own environment. Sometimes when we talk with friends about past experiences it may happen that the same event is reported in very different ways by two persons. And both persons are certain that the version he or she told is the correct one.

The present work is concerned with the examination of such false memories that normally appear in our life. More specifically, it is focused on the question whether electrophysiological correlates of brain activity are useful to differentiate between true and false memories using recognition memory tests.

General memory concepts are presented in Chapter 1. The focus will be on neuropsychological models of long-term memory and on a framework of the constructive characteristics of memory processes. Chapter 2 is concerned with the present knowledge of false memories, reviewing results from behavioral studies, from neuropsychological studies of brain patients, and from brain imaging studies of healthy participants. Chapter 3 captures the method of Event-Related brain Potentials (ERPs) and its use in memory research. Chapter 3 is finished with a summary of the main questions and aims for the present work, before a first study examining electrophysiological correlates of true and false recognition is addressed in Chapter 4. Two follow up studies are described in an article published in Cognitive Brain Research. Chapter 5 contains this article (Nessler, D., Mecklinger, M. & Penney, T.B., 2001. Event-related brain potentials and illusory memories: The effects of differential encoding. Cognitive Brain Research, 10, 283-301.), while Chapter 6 contains a second article (Nessler, D. & Mecklinger, M., under revision)[1]. Finally, behavioral results from an additional study performed with patients suffering from frontal brain lesion are described in Chapter 7 (Nessler, D., Mecklinger, A., von Cramon, D.Y. & Matthes-von Cramon, G., poster presented at the 8th Annual Meeting of the Cognitive Neuroscience Society in March 2001; see also Mecklinger, A., Nessler, D. & von Cramon, D.Y., in prep.). Chapter 8 integrates the results from the different studies and finishes with conclusions and an outlook on future questions of interest.

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[1] For stylistic reasons the format of the articles was adapted.

Chapter 1

Memory Systems and Processes

Memory processes involve at least three stages: encoding, storage, and retrieval (e.g., Tulving, 1994). Encoding refers to the acquisition of information. It means all the processes that mediate between an experience and the formation of a memory trace for this experience. Storage refers to the maintaining of information over different time periods and retrieval captures the access to the stored information.

The differentiation between a *short-term memory* and a *long-term memory* is one of the oldest and most widely accepted (e.g., James, 1890; cited in Squire, Knowlton & Musen, 1993, see also Atkinson & Shiffrin, 1968). Some of the best evidence for distinguishing between these kinds of memory has come from the study of patients suffering from anterograde amnesia. Such patients show an inability to store new episodic information after the onset of the disorder. Often the patients perform normally on immediate recall tasks of short lists. However, they show dramatic impairments if they are distracted between study and test phase, if studied items are not in the focus of attention for the whole delay period. The patients can retain information for a short time, they have a functioning short-term memory, but they cannot transfer information to a long-term memory system (cf. Milner, 1958; Cave & Squire, 1992).

The term short-term memory is the more traditional one and refers to one of the most central findings in early cognitive psychology that people are limited in the amount of information they can rehearse at any one time. Today most researchers use the term *working memory* that was suggested by Baddeley and his colleagues as an alternative to the term short-term memory (for an overview of working memory cf. Baddeley, 1994, 1995, 2000; Miyake & Shah, 1999). It is proposed that working memory consists of a set of mechanisms that work together to perform strategic processing. Thus, it is more focused on attention and cognitive processes. Such a view better handles the diversity of the short-term memory phenomena (for an overview of short-term memory and working memory cf. Barsalou, 1992, S.92-115).

In the present study processes of long-term memory are examined, so in the following I will focus on systems and processes involved in this kind of memory.

1.1 Long-Term Memory

At first long-term memory was seen as an unique system, and for instance Lashley (1950) proposed that it would not be possible to localize different aspects of the memory in the brain. Some years later this was raised into question by reports from the patient H.M.. He showed after bilateral medial temporal-lobe resection amnesia for all events that occurred after the operation (Scoville & Milner, 1957). It was mentioned already that a differentiation between a short-term memory and a long-term memory can be concluded from results obtained in patients suffering from amnesia. Furthermore, H.M. showed an intact memory for experiences acquired before the operation as well as the intact ability to learn implicitly knowledge or skills. These results indicated that the medial temporal lobe structure is especially important to form explicit memory for new experiences. Damage to the medial temporal lobe structure leads to the amnesic syndrome. Other studies showed that organic amnesia can also result from the lesion of diencephalic structures such as the mammillary bodies. Patients suffering from organic amnesia are not able to store new experience (anterograde amnesia) for later explicit retrieval, but depending on the extend of the damage they can also show difficulties in the recall or the recognizing of information related to the pre-morbid period (retrograde amnesia). The neuropsychological case of H.M. initiated many research on the differentiation of various types of memory structures and pointed towards the importance of clinical-neuropsychological case studies for the creation of psychological theories. Subsequently, long-term memory has come to be viewed as a complex and diverse collection of separate but interacting systems and processes that serve different functions. As it is suggested by the data obtained for patient H.M. as well as for other patients suffering from bilateral hippocampal lesions (cf. Scoville & Milner, 1957; Cave & Squire, 1992) most authors differentiate between *implicit* (non-declarative) and *explicit* (declarative) memory. Implicit memory is obtained when the experience of an event affects later behavior in the absence of conscious retrieval, while explicit memory refers to the conscious recollection of that experience.

The differentiation of implicit and explicit memory systems was also used in the model described by Squire and colleagues (Squire & Knowlton, 1994; Squire & Zola, 1996, cf. also Squire & Knowlton, 2000). They proposed a taxonomy of long-term memory and related the different systems to neuroanatomical structures. As pictured in Figure 1.1, *implicit memory* describes a collection of different abilities: memory of skills and habits, simple forms of conditioning, and priming (for an overview of implicit memory cf. also Schacter, 1994). Implicit memory is assessed by so called ’indirect’ tasks in which memory for study items is incidental to task performance and expressed by speeded reactions or identification accuracy. The critical feature of these tasks is that performance can be influenced by, but is not dependent upon, explicit memory for studied items. Commonly used tasks examining effects of priming are word stem or word fragment completions. Participants are required to study different words (e.g., *table*). Subsequently, they are presented with word stems (e.g., *tab*-), some of which belong to the studied words. Each stem has to be completed with the first word that comes to mind. Participants are typically biased to complete stems with studied words, even if unaware of the relationship between study and test items. Responses to stems that are completed with study words are also faster than to stems that have no relationship to the studied words. Amnesic patients can perform normally in such tasks, while they show impairments for ’direct’ memory tasks such as free recall, cued recall, or recognition (for an overview see Squire et al., 1993; Gabrieli, 1998).

These tasks measure *explicit memory* processes, which can be divided into *episodic* and *semantic* stores (Tulving, 1984, cf. also Figure 1.1). Episodic memory consists of context-specific personal memories (e.g., what one has done yesterday), while semantic memory refers to a fact-based store for general information, which is not associated with contextual information (e.g., that Germany is an European country). In explicit or direct tasks participants are exposed to a series of items in a study phase, and than, after some delay, the retrieval test follows. In retrieval tests of free recall participants are required to generate the studied items (OLD items) without a cue, while in retrieval tests of cued recall a fragment of the item is given. In recognition tests participants are tested with lists that include the OLD items randomly intermixed with non-studied items (NEW items). Participants have to decide, for instance, by button press whether each item was studied before (old response) or was not studied before (new response). There is another kind of recognition task which does not consist of separated study and test phases. Instead, items are repeated in one continuous series and participants indicate to each item whether it had already appeared earlier in the list or not (continuous recognition paradigm).

There is a great amount of studies examining explicit memory processes. For instance, one important issue concerns the relationship between how an item is processed at study and its retrievability. As it is assumed in the *Levels of Processing Framework* (cf. Craik & Lockhart, 1972), depth of encoding increases the memorability and the strength of memory traces. Items processed to the level of their physical features (shallow encoding) are less likely to be remembered than those processed semantically (deep encoding). However, the level of processing manipulation has no influence on implicit memory (Schacter & Graf, 1986). The strength of memory traces is also enhanced by motor actions. In this field of episodic memory research, participants are required to (symbolically) perform different tasks during the study phase, as for example *’beat an egg’*. Memory, as revealed by recall or recognition tasks, is strongly enhanced by such subject-performed tasks (SPT) as compared to verbal tasks (VT) (for an overview see Cohen, 1989, Engelkamp & Zimmer, 1994; Engelkamp, 1998). It is assumed that this enactment effect reflects the good item specific information that is provided by the performance of the action. In sum, learning instructions that are generally assumed to be ’memory efficient’ (i.e., imagery, the generation of stories, or motor actions) result in a better performance in episodic tests (cf. Engelkamp & Zimmer, 1994).

As mentioned earlier, it is argued that indirect tasks measure implicit memory, while direct tasks measure explicit memory. However, it is difficult to ensure that these two kinds of tasks do fully separate the two kinds of memory. Instead, test performance can also result from a mixing of both processes (e.g., Gabrieli, 1998; Rugg, 1995b; Schacter, 1997). This discussion became especially important for the *dual process account of recognition memory*. Because of its special relevance for the present study this model is introduced in the next paragraph.

1.1.1 Recognition Memory

Recognition memory is seen as a dual process (e.g., Gardiner & Java, 1993; Mandler, 1980) claiming that a *familiarity* and a *recollection* component reflect two qualitatively different ways in which information about a past experience can be assessed (cf. also Friedman & Johnson, 2000; Mecklinger, 2000). The familiarity component refers to recognition judgments that are based on a feeling that an item was recently encoded in the absence of any specific context information of the actual event. Such a process happens for instance, if we see a familiar face but we cannot say the name of the person or in which context we have met the person. In the case of recollection contextual information about the learning episode is retrieved, and there is the phenomenological experience of having brought something back to mind.

Results from different studies support the distinction of familiarity and recollection. For instance, Hintzmann and Curran (1994) showed different temporal characteristics for both components. Participants were required to learn words and to give old/new recognition judgements in a later test. This test included NEW words, studied words (OLD), and words that were identical to studied words but were changed with respect to the feature number between the study and the test phase (similar words). The authors applied the response-signal technique (Dosher, 1984) where participants are asked to give an immediate recognition response when a signal is presented. This signal follows the test item after a variable delay. The authors reported a higher proportion of false old responses for similar words at short delays than at long delays. This was interpreted as a reflection that familiarity arises earlier during retrieval than recollection. Similar but number-changed words may elicit familiarity quickly after presentation. Recalled information may become available later and is reflected in the larger amount of correct rejections in long than in short delays.

Whereas there are no doubts that recollection refers to explicit memory processes, some authors argue that familiarity is an implicit memory process (e.g., Jacoby & Dallas, 1981; Jacoby, 1991). According to this view, recognition judgements based on familiarity are made when an item is processed relatively ’fluently’, and such processes are held to be related to those processes which underly implicit memory. Consequently, only recollection, but not familiarity, should depend on the medial temporal lobe that is seen as the key structure in the explicit memory system (Squire et al., 1992). Other models assume that both, familiarity and recollection, are components of an explicit memory system. In support for this account, Knowlton and Squire (1995) required amnesic patients to indicate whether a recognition judgement is based on consciously recollected aspects of prior experience of the item or not. Patients should indicate whether they have a vivid memory of the actual presentation of the item (Remember) or whether they merely belief that a test item had occurred in study without any recollection of the specific study episode (Know). Such a *Remember/Know procedure* (Tulving, 1985) is seen as a possibility to disentangle familiarity and recollection processes. While a Remember response is associated with recollection, an association between a Know response and familiarity is proposed. Amnesic patients were similarly impaired in Remember and Know recognition judgements indicating that damage of the medial temporal lobe impaired familiarity as well as recollection processes. In line with the increasing evidence that familiarity and recollection components of recognition memory are functions of the explicit memory system and depend on brain systems damaged in amnesia (cf. Haist, Shimamura & Squire, 1992; Mecklinger, von Cramon & Matthes-von Cramon, 1998; Smith & Halgren, 1989), the term familiarity is used in the following to refer to an explicit mechanism only.

1.2 Neuropsychological Models of Long-Term Memory

Neuropsychological studies of patients with brain damage have given first information how different memory processes are associated with different brain structures. Recently, due to the great technical advances, brain imaging studies of healthy persons have also been conducted more and more and support the development of neuropsychological models. Regarding such empirical evidence, Squire and colleagues refer their taxonomy of long-term memory (cf. section 1.1) to neuroanatomical structures, which might be involved in the different processes (Squire & Knowlton, 1994; Squire & Zola, 1996; Squire & Knowlton, 2000).

Different brain regions are seen to be involved in implicit memory processes (cf. Figure 1.1). For instance, the striatium might be critical for procedural mem-

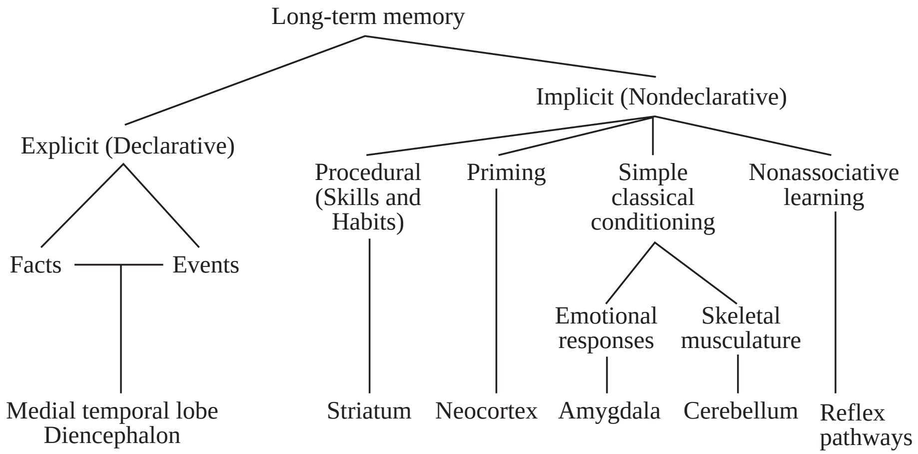

Figure 1.1: *Taxonomy of long-term memory systems with specific brain structures associated with each system (adapted from Squire & Zola, 1996, p.13516).*

ory (skills and habits) while the amygdala is involved in emotional learning. Priming is claimed to be driven by non-frontal neocortical structures. As already discussed, an important role for explicit memory processes is attributed to the medial temporal lobe. Reviewing evidence from studies with humans as well as monkeys, Squire and Zola-Morgan (1991) differentiate further between the brain structures within the medial temporal lobe. As indicated in Figure 1.2, the medial temporal lobe memory system consists of the hippocampus, the entorhinal cortex, the parahippocampal cortex, and the perirhinal cortex. The cortical input to the hippocampal region originates from the entorhinal cortex. The major sources of projections to the entorhinal cortex (nearly two third) are the adjacent perirhinal and parahippocampal cortices, which in turn get projections from unimodal and polymodal areas in the frontal, temporal, and parietal lobes. The entorhinal cortex also receives other direct input from orbital frontal cortex, cingulate cortex, insular cortex, and superior temporal gyrus. All projections are reciprocal.

It is claimed that the medial temporal lobe system is necessary for the direct consolidation of information in the neocortex by gradually binding together the different cortical regions that store memory for the whole event. Thus, the medial

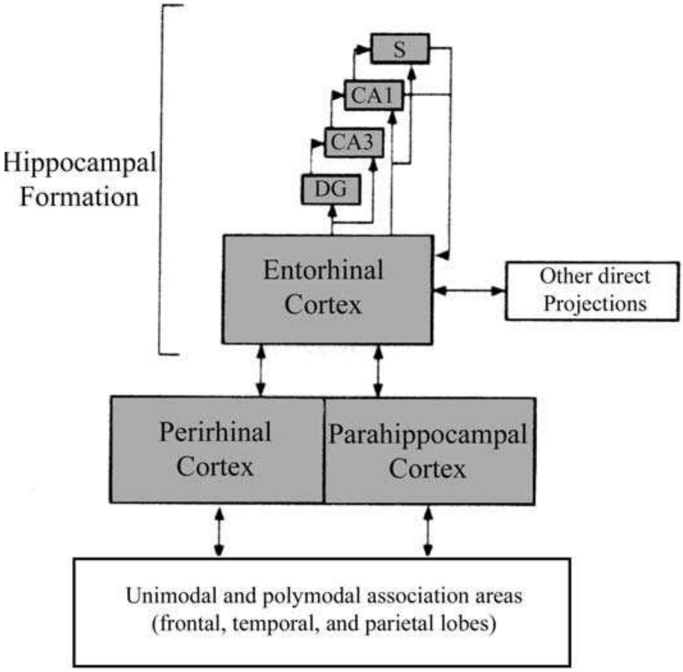

Figure 1.2: *Schematic view of the medial temporal lobe memory system (adapted from Squire & Knowlton, 2000, p.767). The hippocampal region includes: dentate gyrus (DG), cell fields of the hippocampus proper (CA3, CA1), subicular complex (S).*

temporal lobe might be engaged at the time of learning to form a so called memory trace. Moreover, to recollect a recent event consciously the memory trace also must be reactivated via the hippocampal component. This process, called ecphory by Seamon (1921, cited in Moscovitch, 1992), can occur if a cue automatically triggers the hippocampal index and interacts with a memory trace. Such ecphoric processes occur persistently, that means we remember countless daily events without intending to remember them. However, not all memory retrieval seems to be dependent on the medial temporal lobes. As already mentioned, patients suffering from lesions in this area are often not impaired in the retrieval of events which occurred some years before the damage. So, it is proposed that the medial temporal lobe is only needed at the time of learning and for some time afterwards. When the consolidation process is finished, retrieval becomes independent of the medial temporal lobe and access to representations of the long-term memory can be gained via an extra-hippocampal route. For such retrieval processes and for more strategic memory search, the frontal lobes are seen as being especially important.

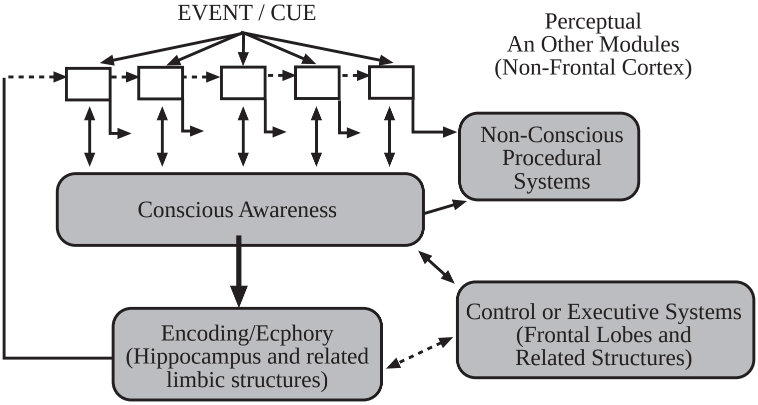

Figure 1.3: *Neuropsychological Model of Memory (adapted from Moscovitch, 1994, p.1346). Four essential components are proposed: A* ***non-frontal neocortical component*** *consists of perceptual and interpretative semantic modules and is assumed to be involved in the performance on implicit tests of memory. Different cortical modules register the information as a structural, pre-semantic representation. There are different modules, for instance for reading, for object perception, or for face perception as it is suggested by results of neuropsychological studies of brain-damaged patients (e.g., Gabrieli, 1998). The output of the modules is passed on central system structures for early semantic interpretation. Degenerations of this central system are observable in demented patients who are able to read and identify objects on a perceptual level but at the same time do not know what it means (Chertkow & Bub, 1990, cited in Moscovitch, 1992). This first component presumed to be located in the posterior and mid-lateral neocortex leaves a perceptual and semantic record that is regarded to be the basis for perceptual and conceptual repetition priming effects. Also tapping implicit memory processes, a* ***basal ganglia component*** *is supposed to be involved in performance on sensorimotor procedural tests of memory. When the information from the first component is apprehended consciously then it will be picked up by the* ***medial temporal/hippocampal component****. This structure covers encoding, storage, as well as retrieval on explicit episodic tests of memory that are associatively dependent. A* ***central system, frontal-lobe component*** *is seen as involved in more strategic memory processes (work with memory) and in procedural tests that are rule-bounded.*

This is pointed out in the neuropsychological model proposed by Moscovitch (cf. Figure 1.3, Moscovitch, 1992, 1994). A frontal system is seen as critical for strategic memory processes or so called ’working with memory’. Such claims are supported by results from studies of patients with frontal lesions as well as with healthy participants (for an overview of memory and frontal lobe function, cf. Shimamura, 1994). Strategic processes are for instance engaged if the retrieval cue does not elicit the target memory automatically but provides only a starting point for a following memory search. The frontal lobes are involved in the selection and implementation of strategies that evaluate the shallow output from the hippocampal component. Other functions are the determination of the correct temporal sequence and the spatial context of the retrieved experience. Resulting information can be used to guide further mnemonic searches, to direct thoughts, or to plan future actions. The frontal lobes are also involved in encoding, they organize the input to the hippocampal component. In sum, the frontal lobes are seen as especially involved in processes which convert automatic triggered retrieval to an intelligent, goal-directed, and voluntary controlled activity (cf. Moscovitch, 1992).

1.3 Constructive Memory Framework

As indicated in the previous section, strategic aspects are involved in the retrieval of past experiences. This points to the fact that the brain does not simply remember stored traces. Instead, the system ’works’ with the features that are remembered. This is in line with approaches claiming that most memory processes are constructive rather than reproductive (cf. Reyna & Lloyd, 1997). Reproductive memory refers to the accurate rote production of material from memory, for example the retrieval of a learned poem. However, most memory processes are more reconstructive, which accentuates the active process of filling in missing elements while remembering. Consequently, errors in such constructive processes, which might be more natural in normal life, are not surprising and belong to the act of retrieval.

Schacter and colleagues (1998a) provide a *Constructive Memory Framework* (CMF) that outlines the types of problems that the human memory system must solve to produce mainly accurate representations of the past. This model, emphasizing encoding and retrieval processes, is sketched in Figure 1.4 and is described subsequently.

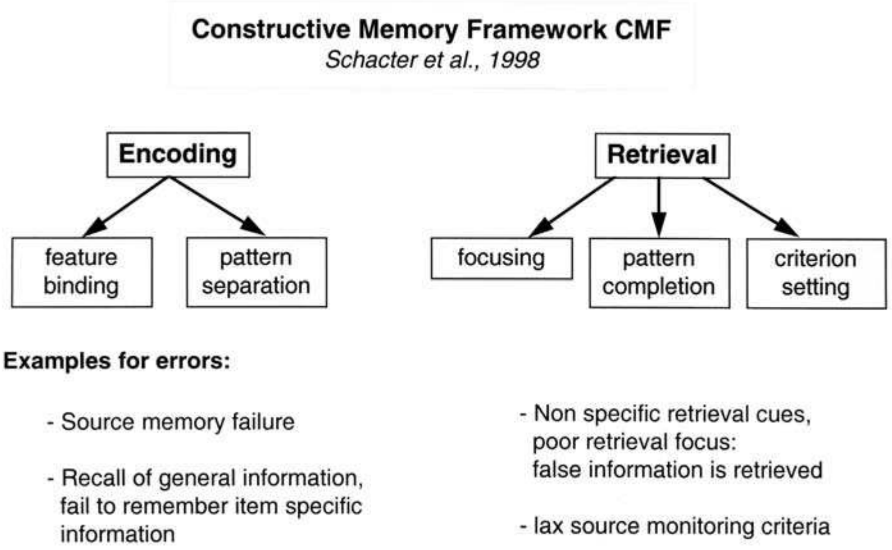

Figure 1.4: *The Constructive Memory Framework (CMF) and some examples for errors (cf. Schacter et al., 1998a).*

A representation of a new experience is stored as a pattern of features, with different features representing different facets of the experience. These features, which are the output from perceptual and semantic modules (cf. the *non-frontal neocortical component* in the model proposed by Moscovitch), are distributed widely across different parts of the brain. *Feature binding* means that these features have to be linked together at encoding to form a bound representation, mediated by the hippocampal formation (cf. Moscovitch, 1992; Squire & Knowlton, 1994). Inadequate feature binding in encoding can result in a *source memory failure* in later retrieval (Johnson, Hashtroudi & Lindsay, 1993). In recognition memory tests such a source memory failure is seen as the inability to assess whether an association triggered by an item at the test phase is a memory from the study phase, comes from another episode, or is being generated for the first time at the test phase. Such a failure describes the inability to assess in which context a retrieved feature was experienced. For instance, a person has seen two different movies on two different days and later the person cannot remember at which day he or she had seen which movie. Another possibility for source memory failures is that there is not enough information stored to separate different but in some features overlapping episodes. *Pattern separation* (cf. McClelland, McNaughton & O'Reilly, 1995) means the processes that are necessary to bind episodes in such a way that a later differentiation is possible. When pattern separation fails and episodes overlap extensively only general similarities (Hintzman & Curran, 1994) or so called gist information (Reyna & Brainerd, 1995) might be recalled perfectly[1]. In such a situation individuals may fail to remember distinctive, *item specific information* that would allow to differentiate one episode from another.

Similar kinds of problems arise when information is retrieved from memory. *Focusing* as a part of retrieval means that first the rememberer has to form a refined description of the characteristics of the episode to be retrieved. Quality and correctness of focusing depend on the retrieval cue. For instance, a retrieval cue that matches more than the soughtafter episode can activate false information. After retrieving different features and *completing the pattern* of an episode a decision has to be made about whether the information constitutes an episodic memory or is a generic image. The rememberer has to perform a *criterion setting* process in which the diagnostic value of the different information for the determining of the origin of the retrieved pattern has to be considered. The use of lax source monitoring criteria increases the probability of accepting images or fantasies.

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[1] In the following the term *general information* is used to refer to similarities between different episodes.

In sum, the act of memory retrieval is seen as the outcome of multiple, fundamentally reconstructive component processes suggesting that errors can occur at every point of the process. Such errors cause the creation of false memories which are considered in the next Chapter.

Chapter 2

False Memories

”Error production is, after, a part of normal human behavior.”
(cited in Elton, Band & Falkenstein, 2000, p.85)

The following Chapter is concerned with errors in the memory process that are observable through the creation of false memories. The term *false memory* is defined in section 2.1, while I will focus in this Chapter on a special kind of false memory: *false recognition*. A historical overview about research to the topic is given (section 2.2). The basic paradigm used for the investigation of false recognition is introduced in section 2.3. In section 2.4 results from behavioral studies are reviewed. The investigation of patients suffering from brain damage can also provide useful information about the processes involved in false recognition as indicated in section 2.5. The Chapter is completed by the review of results from brain imaging studies with healthy participants (section 2.6).

2.1 What are False Memories?

Illusions of memory are a perennial source of fascination. Also with regard to the constructive model of memory (CMF, cf. section 1.3), it seems surprisingly how often and with what confidence people remember things and events that never happened. As indicated by the description of the CMF, errors can occur at every point of the memory process. Such errors can result in the retrieval of false information, i.e., can result in so called false memories. To phrase it more specifically, false memories are seen as the illusion of remembering events that never happened (for reviews see Schacter et al., 1998a; Schacter, Coyle, Fischbach, Mesulam & Sullivan, 1995; Roediger, 1996; Reyna & Lloyd, 1997; Lampinen, Neuschatz & Payne, 1998).

There are two major types of memory distortions that illustrate constructive processes: That are first *intrusions* and *confabulations* where people recall on their own non-presented information (intrusion) together with previously studied information or provide narrative descriptions of events that never happened (confabulation). The other type of memory distorsions is called *false recognition*. In this case people claim that a presented novel item or event was studied before. Such false recognition can for instance arise from phonologic (e.g., Reinitz, Verfaellie & Milberg, 1996; Rubin, Van Petten, Glisky & Newberg, 1999) or episodic (e.g., Miller & Gazzaniga, 1998) relations between studied items and non-studied test items. I will review some points of all mentioned kinds of memory distortions. However, in this Chapter I will focus on false recognition arising from a semantic overlap between study and test items which is most relevant for the issues under investigation and was also of interest in a majority of studies.

2.2 Historical Overview

Experimental interests in false memories started with the famous *War of the Ghosts* study from Bartlett in 1932. Participants read an Indian folktale and were required to recall it repeatedly. Bartlett reported intrusions in the memory of the participants over repeated attempts to recall the story. Although his results could not be replicated by other authors (cf. Roediger & McDermott, 1995), many studies followed the lead of Bartlett in examining errors by using materials that tell a story. For instance, Bransford and Franks (1971) required participants to study different sentences about different features of a story. Some sentences consisted of only one information, other sentences consisted of more than one information, but no sentence contained all information about the story. However, in the later recognition test participants were often convinced that they had heard the sentence containing all information.

Especially during the past few years interests in memory distortions increased rapidly, largely released by debates about the accuracy of traumatic memories recovered in psychotherapy (e.g., Loftus, 1993; Lindsay & Read, 1994). It is argued that certain therapeutic practices can cause the creation of false memories. For instance, Roediger, Wheeler and Rajaram (1993, cited in Schacter et al., 1995, p.17) required participants to make guesses about what items had appeared in a learned study list. Later they often believed that many of their incorrect guesses were real memories. Such results elicited questions whether we can trust our memories and whether there are special characteristics of a memory. Such characteristics could tell us whether a remembered event is a real memory or an illusion. Work on eyewitness testimony is another area where knowledge about occurrence of false memories is important. The most famous studies in this area are those by Loftus and her colleagues concerning the effects of misleading post-event suggestions (e.g., Loftus & Pickrell, 1995; Loftus, Feldman & Dashiell, 1995). In a typical design, participants first see slides or videotapes of an event. Then questions about the event follow where some of them contain suggestions of incidents that never occurred. In the last phase of the design, participants are asked to indicate what occurred in the original event. In one study by Loftus, Miller and Burns (1978), participants watched a slide presentation of a car accident. Then misleading information that a stop sign was a yield sign was presented to one group of participants via questionnaire. Later, in the test phase, participants were asked whether a stop sign or a yield sign was presented in the original slide presentation. While the rate of correct responses was 75 % for not-misleaded participants, the rate for the misleaded group was only 41 %. Reports like this indicate that participants can be disturbed by misleading post-event suggestions. Some authors explained the effect as the overwriting of the seen episode, while others claimed that the effect was due to source monitoring confusion (Johnson et al., 1993). That means that participants might not be able to differentiate whether the information they retrieved was presented in the scenes or only occurred in the questions.

Studies of misleading suggestions are a prominent example of false recognition and are also in the focus of recent interests, especially for research to eyewitnesses testimony. However, it was the review and the modification of a paradigm first introduced by Deese (1959) that leveraged research to semantic false memories. This was done by Roediger and McDermott (1995), who demonstrated high levels of false recall and false recognition using word lists of semantic associates. The basic paradigm which was used subsequently by a large number of examinations is introduced in the next section 2.3 before empirical evidence for false recognition arising from semantic relations in behavioral studies is reviewed in section 2.4.

2.3 The Basic Paradigm

The basic paradigm used by most authors examining semantic false recognition was introduced first by Deese in 1965. Deese tested memory for word lists using a single-trial free-recall paradigm. He was especially interested in the prediction of the occurrence of intrusions. Deese developed 36 word lists each consisting of 12 words that are primary associates of a critical non-presented word (the so called *LURE word*). After the study phase, some of the lists reliably induced participants to recall the LURE word as an intrusion in the later test. Roediger and McDermott (1995) revived and modified the materials from Deese and developed a paradigm for the examination of false memories. Subsequently, the so called *Deese paradigm* was used in many studies examining characteristics and processes underlying false recall and recognition of semantically related material.

The procedure in the Deese paradigm is as follows: First, participants learn different lists of semantic associatives to a critical non-presented word, i.e., the

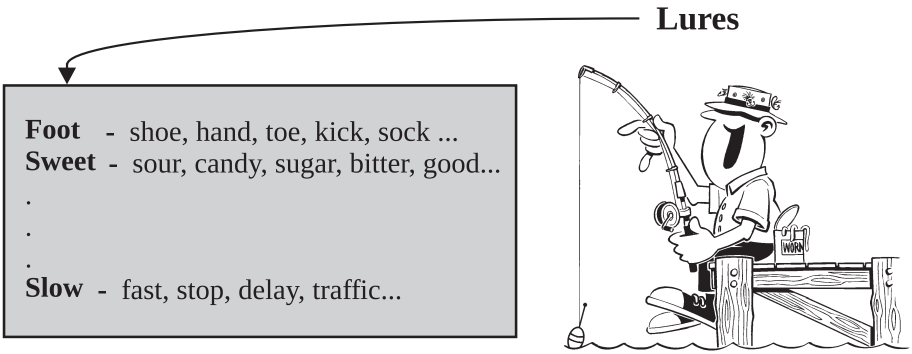

Figure 2.1: *Illustration of the Deese Paradigm (Deese 1965; cf. Roediger & McDermott, 1995). A detailed description is given in the text.*

LURE word. As shown in Figure 2.1 participants learn for instance: *shoe, hand, toe, kick, sandals, soccer, yard, walk, ankle, arm, boot, inch, sock, smell, mouth*, words that are all high associates to the LURE word *foot*, which is not presented in the study phase. After a delay, recall or recognition memory tests are performed in which participants often claim that they have also studied the LURE word *foot*. False alarm rates for such LURE words (false recall or recognition) exceeded 70 % in some conditions and were often nearly as high as the true recall or recognition rate. Participants are often also very confident that they have done a correct judgement. Different behavioral results, starting with the well known study of Roediger and McDermott (1995), are reviewed in the next section.

2.4 Behavioral Evidence for False Memories

Roediger and McDermott (1995) used in a first experiment six of Deese’s (1959) 12-item study lists to replicate the high delusion rate for critical LURE words. Participants were required to learn the lists for a later recall test. In this test participants often recalled the non-presented LURE words, similar to the results reported by Deese. The authors found a mean false recall probability of the critical LURE words of 40 % compared to a true recall rate of 65 %. In a following recognition memory test the false recognition rate for LURE words of 84 % approached even the true recognition rate of 86 %, while the rate of false old responses to non-related non-studied words (NEW words) was rather small (2 %). In a next step the authors expanded the original materials to twenty-four 15-item lists and revealed with these materials 62 % true recall compared to a rate of 55 % false recall in a second experiment. Participants who performed a recognition memory test showed 72 % false recognition that was slightly larger than the rate of true recognition with 65 %. Both recognition rates were enhanced for participants that performed the recognition memory test after the recall test (true recognition: 79 %, false recognition 81 %). Results suggest that true and false recognition behave very similar, an assumption that was further supported by the rates of Remember responses (Remember/Know procedure, cf. section 1.1.1). Participants provided similar rates of Remember responses to true and false recognition suggesting that LURE words were retrieved like OLD words. In sum, authors showed a powerful false memory effect in both recall and recognition within the same paradigm using semantic associates. Due to the high rates of Remember responses to false recognition, it was suggested that LURE items did not just evoke a feeling of familiarity but instead were consciously recollected as having occurred in the study phase.

Also in line with this interpretation are results reported by Payne, Elie, Blackwell and Neuschatz (1996). The authors used the word lists from the Deese paradigm and showed that the critical non-presented LURE words were recalled and recognized nearly as often as studied OLD items. Participants also indicated that they experienced the false recognized or recalled LURE words as being similar to the recognized or recalled OLD words. Participants also reported without hesitation whether a particular item had been presented in a male or in a female voice even when in fact these words had not been presented.

Results of the indistinguishability between true and false recognition support the idea that participants generate non-presented LURE words at the time of study in response to an associated word via spreading activation through the mental lexicon. The *Implicit Associative Response (IAR)* idea was first proposed by Underwood (1965) who stated that when participants see a word such as *butter* they might think of the associate *bread*. Later, if *bread* is presented in a recognition test, participants might claim that they recognize its occurrence in the studied list because of the earlier implicit associative response.

Given these results, it seems plausible to assume that the more associative words are studied the higher is the possibility of the activation of the LURE word. Robinson and Roediger (1997) required participants to study word lists containing 3-, 6-, 9-, 12-, or 15-associates taken from the Deese lists. Independent from the length of the word lists, which was held constant in a second experiment by using non-related filler words, the authors reported decreasing veridical recall and increasing false recall with increasing numbers of associates. After the recall test, participants also performed a recognition memory test. Although the recognition rates might be influenced by the preceding recall test, false recognition also increased with increasing rates of studied associates. The relation between the number of studied associates and false recognition was also supported by other studies (Hall & Kozloff, 1973; Shiffrin, Huber & Marinelli, 1995) and was also found for words from different semantic categories: In one experiment, Hintzmann (1988) required participants to learn different words, varying the number of words from one semantic category between 0 to 5 items. In the later recognition test, the rate of accurate recognition of studied category members as well as the rate of false recognition of non-studied members from studied categories increased as a function of category size in the encoding list.

It was shown that the activation of LURE words via IAR might also occur even when there is no memory for studied items. Seamon, Luo and Gallo (1998) presented word lists from the Deese paradigm at rates of 2 sec, 250 ms, or 20 ms per word. In the later recognition test, the authors reported reliable false recognition even when participants were unable to discriminate studied words (OLD words) from unrelated non-studied words (NEW words). This result indicates that LURE words are activated non-consciously. However, the predominance of Remember responses for false recognition in the studies mentioned above (Roediger & McDermott, 1995; Payne et al., 1996) suggests that the associative response also had to occur consciously to the participants during encoding. It is argued that memory traces were also formed for non-presented but semantically related LURE words and that later recognition was based on a failure of reality monitoring in retrieval (Johnson & Raye, 1981) or of source memory failure (Johnson et al., 1993, cf. also section 1.3).

So far, evidence for the high similarity between true and false recognition was reviewed. There are, however, also other studies reporting differences in the characteristics of true and false recognition. For instance, Read (1996) required participants to read 12 associates of the critical non-presented LURE word *sleep* and to recall these words after a short delay. In the test, participants often claimed that the study list also contained the LURE word. Interestingly, Confidence and Remember ratings for false recall resembled ratings for true recall only if the LURE word *sleep* was assigned to an early position in the list.

Similar results were also found in a second experiment, where Read (1996) manipulated the encoding conditions. One group of participants was focused on the list order in encoding (serial-learning), a second group should concentrate on the meaning of the studied words (elaborative-rehearsal), while a third group was required to keep in mind the last word presented (maintenance-rehearsal). Elaborative rehearsal and maintenance rehearsal produced similar rates of false recall (73 % vs. 76 %, respectively), while the serial-learning condition led to fewer recalls of *sleep* (50 %). Although participants reported high rates of Confidence and Remember responses for false recall in all three encoding conditions, the rate was lower than the rate reported for actual studied items. However, like in the first experiment, differences between these rates were smallest when the LURE word *sleep* was assigned to an early list position.

That false recall is not always subjectively equivalent to memories of real events was also supported in a study performed by Mather, Henkel and Johnson (1997). Participants learned auditorily presented word lists of the Deese paradigm. In the subsequent recognition test, half of the participants completed a memory characteristics questionnaire (MCQ) for each word called old, while the other group of participants gave Remember/Know judgements. The MCQ ratings showed that false recognition was accompanied by less auditory details and less remembered feelings and reactions than true recognition. Participants also were less likely to assign Remember responses to falsely recognized LURE words than to true recognition. In sum, both the MCQ and the Remember ratings indicated that there were differences between true and false memories (for similar results cf. Norman & Schacter, 1997). In addition, Mather et al. (1997) reported lower rates of false recognition for a thematically intermixed word order during study than for a thematically blocked word order (for similar results cf. McDermott, 1996). The authors claimed that the blocked study-acquisition favors the use of information that items have in common (i.e., general information) to encode or recognize items. It is suggested that this information can override perceptual differences (i.e., item specific information) that might help individuals to distinguish true from false memories.

Consequently, these results showing differences in the characteristics of true and false recognitions are more in line with an explanation of false recognition using the *Fuzzy trace model* (e.g., Brainerd, Reyna & Brandse, 1995a; Reyna & Brainerd, 1995). The Fuzzy trace theory maintains that persons may develop two separate representations during encoding: a *verbatim memory trace* and a *gist representation* of the semantic context. It is proposed that while true recognition can be caused by the access of the verbatim representation or of the gist representation, false recognition might be only based on the gist representation. For instance, results from a study performed by Gallo, Roberts and Seamon (1997) can be interpreted in line with this model. Authors reported that participants could reduced their false recognition rate if they were forewarned about the effect. It might be that forewarned participants tried to use more verbatim than gist representation that in turn reduced false alarms to LURE words.

One potential problem for the Fuzzy trace model is that false recall and recognition were experienced as tapping quite specific knowledge by participants in many studies, even if some studies challenge the similarity between true and false recognition. For instance, participants claim to remember the actual occurrence of the items in the lists and are willing to attribute serial positions to these items. Furthermore, if OLD words were prior studied in different voices, participants attributed one voice to falsely recognized non-studied items (cf. Payne et al., 1996). However, due to the higher rates of such item specific informations revealed in studies like the one of Mather et al. (1997) it might be that verbatim and gist representation exist for true and false memories but that verbatim is larger for actually studied words. Within the domain of autobiographical memory, Conway and Rubin (1993) also referred to different forms of memory, differentiating between *general event knowledge* and *event specific knowledge*. While general events are associated with high-level episodes such as *going on holiday in Germany*, event specific knowledge means special episodes within the general event, like *visiting the Völkerschlachtdenkmal*. When this model is accommodated to the Deese paradigm, then the general event represents the information that matches between words from a list (i.e., all words have a semantic relation to a non-studied word) and the specific event would refer to the remembering of the specific item. Note that also results of the relation between numbers of studied associates and rates of false recognition can be interpreted in terms of a differentiation between general and item specific information. The study of more associates could lead to a larger amount of general information, i.e., is more likely to match with the LURE word. However, strong item specific memory traces can also suppress the effect of general information. McDermott (1996) required participants to study and recall the same lists of semantic associates across five study-test trials. Free recall of studied words increased systematically across trials whereas false recall of semantically related words decreased systematically across trials.

Another study performed by Israel and Schacter (1997) also pointed towards the usefulness of strong item specific information to suppress false recognitions. Authors found clear decrease in false recognition after studying pictures rather than words only. The additional studying of pictures enhanced discrimination between OLD and non-studied items. Furthermore, rates of Remember responses for OLD items increased while rates of Remember responses for false recognition decreased.

In sum, different studies were reviewed showing high false recall and recognition rates for semantic related materials using the Deese paradigm. Results can be interpreted in terms of mainly encoding-related processes, that point to the activation of LURE words in encoding via associative mechanism and the later retrieval of such intern generated memory traces like true memories. However, behavioral results from the Deese paradigm also support more retrieval-related assumptions for the creation of false recognition. In such models, false responses to LURE words occur because such words have a high overlap with the general information of the studied words.

2.5 Neuropsychological Studies of Brain-damaged Patients

Neuropsychological studies of patients with brain lesions have long been concerned with memory processes. With the already mentioned constraints such studies provide an useful source for decomposing and understanding the dynamic interplay of psychological and biological processes that contribute to memory processes (cf. Chapter 1). However, beside observations concerning confabulations about past experiences in patients with lesions to the ventromedial frontal lobes and nearby regions in the basal forebrain (for an overview about confabulations cf. Moscovitch, 1995), the false recognition phenomena was only recently part of systematic investigations in patients suffering from medial temporal lobe lesion or frontal lesion. At first a short overview is given about studies performed with patients suffering from lesions of the medial/temporal and/or the diencephalic brain regions, lesions that lead to amnesia. A second section is concerned with empirical evidence from patients with frontal lobe lesions. As it was indicated in section 1.2 these brain structures are especially important for memory processes.

2.5.1 Medial Temporal/ Diencephalic Lesion

There were several studies performed by Schacter and colleagues examining false recognition after medial temporal or diencephalic lesions using word lists from the Deese paradigm. Schacter, Verfaellie and Pradere (1996d) reported fewer rates of true recognition and higher rates of false alarm to NEW unrelated words for amnesic patients than for their matched controls. This result is not surprising because amnesic patients are highly impaired in the encoding of new information and it was shown that such patients are highly affected in recognition memory or recall tests (for an overview, see Parkin & Leng, 1993). More interestingly, amnesic patients revealed a smaller rate of false recognition than did controls. This result was replicated (Schacter, Verfaellie & Anes, 1997b) and further extended to perceptual false recognition, where LURE words are physically, rather than conceptually, related to previously studied words. Data indicated that medial temporal/ diencephalic structures play a role in storage and/or retrieval of the semantic (or perceptual) information that drives false recognition in healthy controls. However, an earlier study performed by Cermak, Butters and Gerrein (1973) in which related non-studied words were preceded by a single homophone, associate, or synonym, revealed higher overall levels of false recognition for amnesic patients than for controls.

It was argued that these varying results are caused by the different experimental designs. It is likely that controls build a semantic gist and use this general information for judgements in the test phase after studying word lists from the Deese paradigm. This should not happen for amnesic patients, who hence show reduced levels of false recognition. However, in the single word paradigm controls might not build such a semantic gist. Instead, item specific information may be more important for the recognition judgements. This provides an explanation for the smaller level of false recognition for controls than for amnesic patients in such a paradigm. Another difference between the studies was that Cermak et al. (1973) examined only patients suffering from the Kor- sakoff Syndrome, a special kind of organic amnesia that most commonly arises from chronic alcoholism. Schacter et al. (1997b) examined mixed groups of non-Korsakoff and Korsakoff patients. While non-Korsakoff patients show the already mentioned damage to the medial-temporal or/and diencephalic brain structures, Korsakoff patients exhibit also widespread reductions in grey matter volumes in the orbito-frontal cortex.

To clarify the described differences and to compare different groups of patients suffering from organic amnesia, an additional experiment was performed by Schacter and colleagues (Schacter, Verfaellie, Anes & Racine, 1998b). The same study lists of semantic associates were repeatedly presented to and tested on Korsakoff patients, non-Korsakoff patients, and matched controls. Participants studied six lists of words and performed a recognition test after a delay. This procedure was then repeated another four times. Reduced true and false recognition rates for amnesic patients in the first study-test trial compared to their controls replicated results from prior studies of Schacter and colleagues. Across study-test trials true recognition increased in all groups. However, while controls decreased their rate of false recognition across trials (for similar results cf. McDermott, 1996, see section 2.4) Korsakoff patients showed an increasing level of false recognition. For non-Korsakoff amnesics no systematic pattern was found, they showed fluctuating levels of false recognition across trials.

It was suggested that the repeated presentation of word lists lead to an increasing representation of the semantic gist in all participants. Controls might be able to use their also increasing item specific information to reject non-studied related words. This was supported by a signal detection analyses which revealed increasing conservative response criterias across trials for controls (for same assumptions, cf. Israel & Schacter, 1997). Amnesic patients in general cannot use such item specific information due to their impairment of explicit memory. However, data revealed an increase in the sensitivity to general information for Korsakoff patients but not for non-Korsakoff amnesics. Non-Korsakoff amnesics might be at least partially able to suppress the strengthening influence of semantic gist. The additional frontal lobe lesion in Korsakoff patients might impair post-retrieval and verification processes that are necessary to suppress false recognition. An alternative possibility is that deficits in source memory (Schacter, Harbluk & McLachlan, 1984; Janowsky, Shimamura & Squire, 1989b) are implicated in the observed effects.

It is indicated by the results obtained for Korsakoff patients that the frontal lobe structures play an important role in memory processes. In the next section the involvement of this structures is reviewed in more detail by the description of results found by patients with intact medial temporal and intact diencephalic structures but frontal brain lesion.

2.5.2 Frontal Lobe Lesion

Studies of patients with frontal lobe lesion implicate that this structure plays an important role in memory for temporal order, source memory, as well as many other aspects of encoding and retrieval conditions (cf. Janowsky et al., 1989; Shimamura & Squire, 1987; Schacter, 1987; Shimamura, 1994). A number of investigators have argued that confabulation is associated with frontal-lobe lesion (e.g., Kapur & Coughlan, 1980; Moscovitch, 1995) and it was also shown that frontal lobe damage is associated with high rates of false recognition. Case studies of patients with ruptured anterior communicating artery aneurysms and associated frontal-lobe damage report an unusually high number of false alarm responses on recognition tests which were accompanied by high confidence (Delbecq-Derouesne, Beauvois & Shallice, 1990; Parkin, Blindschaedler, Harsent & Metzler, 1996).

The most famous case of frontal lobe lesion was reported by Schacter, Curran and their colleagues (Schacter, Curran, Galluccio, Milberg & Bates, 1996b; Curran, Schacter, Norman & Galluccio, 1997, cf. also Schacter, 1996). They described a patient B.G. suffering from a right fronto-lateral brain lesion in front of the precentral gyrus. The patient showed pathologically high rates of false alarms to non-studied words which were semantically related to the studied items, i.e., to LURE words. Furthermore, most of B.G.s false alarms were accompanied by Remember responses. Schacter et al. (1996b) suggested that B.G.s false recognition deficit reflects the use of inappropriate decision criteria at test. B.G. said ’Remember’ if an item matched general characteristics of the study episode, whereas control participants said ’Remember’ only if they retrieved specific information about that item’s presentation in study. However, Curran et al. (1997) increased B.G.s ability to recollect specific details about presented words by providing a semantic encoding task. In this design all false alarm responses were Know responses, indicating that B.G. was able to discriminate between studied and non-studied words when he had access to good recollective informations. In an additional experiment Curran et al. (1997) showed that Remember responses to non-studied items were based on specific information from an inappropriate context. This result is in line with other studies showing that frontal lobe damage leads to a deficient source monitoring (e.g., Janowsky, Shimamura & Squire, 1989b). In sum, it was suggested that B.G. suffered from the overreliance of general similarity between test items and general characteristics of the study episode.

2.6 Electrophysiological and Haemodynamical Studies

Compared to the great amount of studies on true recognition performed with healthy participants (cf. Mecklinger, 2000; Rugg & Allan, 2000, see also section 3.2.2) there are only some studies examining electrophysiological and haemodynamical correlates of brain activity to false recognition. The former method, i.e, the measurement of Event-Related brain Potentials (ERPs), provides a high temporal resolution of the ongoing changes in electrophysiological brain activity. This great advantage comes along with a relatively poor spatial resolution (cf. Fabiani, Gratton & Coles, 2000a; Hillyard & Kutas, 1983). In contrast, haemodynamical correlates of brain activity that are provided by functional Magnetic Resonance Imaging (fMRI) are characterized by a high spatial resolution but a poor temporal resolution. Another method providing high temporal resolution by the examination of blood flow changes is the Positron Emission Tomography (PET) (for an overview about the different methods e.g., Posner & Raichle, 1996). In the following section studies using ERP, fMRI, and PET measurements will be described focusing again on false recognition elicited by semantically related materials.

As it is the case for behavioral studies of false recall and recognition, most of the studies investigating correlates of brain activity for false recognition, used variants of the Deese paradigm. Schacter et al. (1996c) used PET to examine blood flow changes within the brain correlated with false recognition. Participants studied auditory presented words from the Deese lists for a later recognition memory test in which blood flow was measured. Rates of true recognition (68 %) were only slightly different from the rates obtained for false recognition (58 %) and also brain activities for both conditions were quite similar. However, blocks of OLD items produced more blood flow than blocks of related LURE words in the left temporo-parietal region, an area that is seen as related to phonological processing. Consequently, results are in line with behavioral studies in which more auditory details for OLD words than for LURE words were obtained (e.g., Mather et al., 1997). This interpretation has to be made with some caution because of the proximity of the temporo-parietal region to those implicated in semantic processing and the possibility of differential semantic context effects in the Deese paradigm. LURE words share, by definition, semantic features with many studied words and are highly associated to all words in the special word lists. Such relations are smaller for OLD words, a difference that could be also reflected by differential blood flow in the left temporo-parietal region (Rubin et al., 1999). Schacter et al. (1996c) also reported a statistical trend for greater blood flow during blocks of LURE words in the prefrontal cortex, indicating that this structure might be involved in the effortful processes necessary to distinguish true from false memories. Other regions such as the medial temporal lobe showed similar increases in blood flow for OLD and LURE words.

One problem of the PET study might be that it required a blocked presentation of the different item types, which is not the case for behavioral studies. To examine directly whether brain activity found in the PET study can account for the processes occurring in behavioral studies of false memory, Johnson et al. (1997) studied electrophysiological correlates of true and false recognition in a random and a blocked test presentation. Behavioral results did not differ between the both test presentations of OLD, LURE, and NEW words; Rates of false recognition (67 % blocked, 70 % random) and rates of true recognition (66 % blocked, 61 % random) were rather similar and larger than old responses to NEW words (25 % blocked, 30 % random). Interestingly, differences arose in the measured ERPs. In the random condition ERPs for true and false recognition were similar, while ERPs for true recognition were more positive then those measured for false recognition in the blocked condition. The authors argued that the different pattern of results for the random and blocked test presentation reflects different response criteria. It was suggested that participants judged mainly on the basis of an overall feeling of semantic familiarity in the random condition, while they more likely attempted to assess perceptual and contextual qualities of their memories in the blocked condition. Thus, it was concluded that brain activation found in the PET study (Schacter et al., 1996c) does not necessarily reflect brain activation patterns occurring in behavioral studies because test conditions were largely different.

Another ERP study was reported by Düzel and colleagues (1997) who used a randomized paradigm similar to that used by Johnson et al. (1997). Rates of false recognition (50 %) were somewhat smaller than the rates of true recognition

(63%) but both rates were higher than false responses to NEW items (21 %). ERPs to true and false recognition were similar although a larger N400 was obtained for OLD words. This result might also be related to differential semantic context effects for OLD items and related LURE words in the specific implementation of the Deese paradigm like it was discussed for the results from the PET study performed by Schacter et al. (1996c). As already mentioned, LURE words are related to a larger number of studied items then are studied items themselves. OLD words were selected for their semantic relationship to the critical LURE word but not for their relationship to each other. Consequently, OLD words (e.g., *strong*) provide semantic context for LURE words (e.g., *man*). However, it might be that OLD words provide no or even smaller amounts of semantic context for other OLD words (e.g., *beard*) from the respective Deese list in the recognition test. Because the N400 amplitude is exquisitely sensitive to the semantic context (for review Kutas & Van Petten, 1994), this may account for the N400 difference between true and false recognition observed by Düzel et al. (1997; cf. Rubin et al., 1999). Note that the smaller N400 found for false recognition could also result in an overestimation of the somewhat later occurring positive old/new ERP effect for false recognition.

Schacter and colleagues (1997a) used fMRI measures to compare haemodynamic responses to OLD words and related LURE words with random and blocked presentations as it was done by Johnson et al. (1997). Blood oxygenation levels in the left temporo-parietal cortex did not discriminate the two item types in either format. Also other regions showed no difference for true and false recognition.

In sum, studies using the Deese paradigm showed similar brain activations for true and false recognition particularly when random test presentations were used. Small differences between true and false recognition found in some studies might reflect the differential semantic relations of OLD and LURE words to other OLD words in the respective list. Consequently, it seems that false recognition is based on the same processes like true recognition, supporting the view that LURE words were already activated at encoding (IAR, cf. section 2.4) and later retrieved like studied words. However, it might be that it is the difference in semantic relations for OLD and LURE words that enhances artificially the activation of LURE words via associative mechanisms. This could result in equivalent activation for LURE and OLD words in the encoding phase and, in turn, in equivalent brain activities for true and false recognition in the test phase. Miller and Wolford (1999) pointed to an additional problem of the word lists from the Deese paradigm. It was argued that the asymmetrical relationship between OLD and LURE words could also lead to different response criterions in the test phase.

The present work examines brain activation patterns for true and false recognition with materials overcoming the limitations mentioned for the lists from the Deese paradigm. Before questions and aims are introduced at the end of the next Chapter, an overview about the method of Event-Related brain Potentials (ERPs) is given. ERPs were used in the present experiments to examine true and false recognition because this method is well suited for the examination of cognitive processes involved in memory retrieval.

Chapter 3

Electrophysiology of Memory

The measurement of electric activity of the brain (Electroencephalogram, EEG) provides a non-invasive method to directly examine brain functions and to make inferences about regional brain activity. Moreover, Event-Related brain Potentials (ERPs), small voltage oscillations embedded in the background EEG, reflect activity time-locked to the ongoing information processing of a particular event (Hillyard & Kutas, 1983). ERPs allow a high temporal resolution and can be used as a link between neuroscience and cognitive psychology. They are a method to investigate functionally relevant brain activity. The present Chapter introduces the electrophysiology of the brain in general and of memory processes in particular. In the first section, a short overview of the EEG and the ERP approach is given (3.1.1), and the physiological basis for the electric activity is introduced (3.1.2). Then different approaches for the identification of ERP components are described (3.1.3) and inferences that can be made from ERP data are discussed (3.1.4). Finally, ERP correlates of memory functions are reviewed in section 3.2 focusing on ERP effects obtained in recognition memory tasks (section 3.2.2) especially relevant for the present study.

For a comprehensive overview of EEG and ERPs and their use in cognitive psychology, the reader is referred among others to Andreassi (1980), Hillyard and

Kutas (1983), Cooper, Osselton and Shaw (1984), Coles and Rugg (1995), Luck and Girelli (1998), Fabiani et al. (2000a). An overview of ERP correlates of memory functions is for instance given by Rugg (1995b), Johnson (1995), Rugg and Allan (2000), or Friedman and Johnson (2000).

3.1 Human EEG and ERPs

3.1.1 Overview and Advantages

There has been an increasing interest in the relation between electric activity of the brain and psychological processes ever since Berger (1929) reported his first recording of electric activity from the human brain. To obtain an EEG electrodes have to be attached on the surface of the scalp. The exact location of different electrodes on the scalp is mainly referenced to the 10-20 system (cf. Figure 3.1, Jasper, 1958). This system specifies electrodes in terms of their proximity to particular regions of the brain (frontal, central, temporal, parietal, occipital) and in terms of the location of the lateral plane (odd number for left, z for midline, even numbers for right). To get more spatial information the 10-20 system is usually enhanced by the use of a higher density of electrodes.

First examinations and analyses of electric activity of the brain were concerned with spontaneous rhythmic oscillations, i.e, the electroencephalogram (EEG). The most common characteristics of the EEG are the frequency and the amplitude parameters, which depend on developmental conditions as well as on activation states. In general, the measured brain activity is described with regards to one of four frequency ranges. Activity at a rate of 8 to 13 Hz with a magnitude of about 20 to 60 microvolts is called the *Alpha* frequency range. Such activity preponderances the EEG if a person is relaxed, has closed the eyes, or is tired. Waves in the *Beta* frequency range (14 to 30 Hz) are common when a person is involved in mental or physical activity. Such brain activity is marked by low amplitudes of around 2 to 20 microvolts. Furthermore, the *Theta* frequency range (frequency

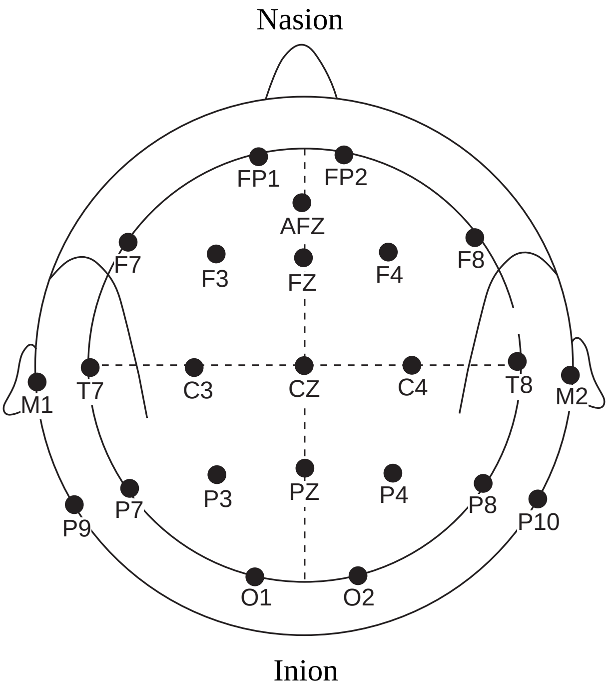

Figure 3.1: *The 10-20 system for electrode placement (adapted from Coles & Rugg, 1995, p.4). The principal locations are defined in terms of the relative distances (in 10 or 20 percentile values) along two major axes: the anterior-posterior axis (from nasion to inion) and the coronal axis (from left to right postauricular points). Other locations are defined in relation to these principal locations.*

around 4 to 7 Hz, amplitude of around 20 to 100 microvolt) is obtained during drowsiness. The *Delta* range appears only during deep sleep in healthy individuals. Waves in this frequency range are marked by large amplitudes (20 to 200 microvolt) and low frequencies (0.5 to 3.5 Hz) (for an overview of descriptive characteristics of the EEG and routine frequency analysis see Davidson, Jackson & Larson, 2000).

More recent research focuses on electric activities that are time-locked to internal or external events. ERPs are small voltage oscillations (a few microvolts) embedded in the EEG (about 50 microvolts). They occur in preparation for, during, or in response to sensory, cognitive, and motor events and they provide precise information about the time course of information processing. The most common method to extract the ERPs from the background EEG is the averaging of samples of the EEG that are time-locked to the repeated occurrence of a particular event. All aspects of the EEG not time-locked to the event are assumed to vary randomly, and should therefore be eliminated by averaging (for a detailed discussion of the ERP methodology and averaging techniques cf. Cooper et al., 1984; Coles & Rugg, 1995; Fabiani et al., 2000a). The excellent intrinsic temporal resolution in the milliseconds range is the most important advantage of the ERP method, establishing a link between brain activity and ongoing behavior. Furthermore, ERPs can be recorded noninvasively from healthy human individuals as well as from patients. The use of this technique is relatively inexpensive compared to other brain imaging methods (e.g., fMRI, or Magnetoencephalography, MEG).

These great advantages come along with a relatively poor spatial resolution. Even with the use of high-density electrode arrays an exact localization of the generating brain structures is not possible. This is caused by the highly resistive properties of the skull, which acts as a spatial low-pass filter and smears the electric activity over broad areas on the scalp. In addition, the measured activity on the scalp can result from the activation of one structure, from independent activations of many different structures, or from the combined activity of different structures in a network. Consequently, there is no unique solution for the question which structures cause measured ERPs.

Despite these, temporal and spatial changes in scalp recorded activity can provide useful information on brain-behavior relations, especially on the time course of neural events underlying changing behavior.

3.1.2 Physiological Basis of Electric Brain Activity

What makes it possible to observe electric activity on the scalp?

The exact physiological background is still an unsolved question (for a discussion of the physiological determinants of the EEG cf. Nunez, 1981; Allison, Wood & McCarthy, 1986) but biophysical and neurophysiological considerations suggest that EEG-waveforms are not generated by single axonal action potentials. Instead, it is assumed that the waveforms do result from a modulation of dendritic inhibitory or excitatory post-synaptic potentials (IPSP and EPSP, respectively). EEG-waveforms are generated when neurotransmitters bind with receptors on post-synaptic neurons (cf. Birbaumer, Elbert, Canavan & Rockstroh, 1990; Cooper, Osselton & Shaw, 1984). Further, such post-synaptic potentials also have a longer duration than action potentials and are more likely to be synchronous. Synchronization is necessary because the electric activity associated with a particular neuron is very small, so that the neural activity to be recorded on the scalp requires the integrated activity of a large number of neurons. Neurons also have to be arranged in a parallel orientation, to summate their individual electric fields. Such orientations are known as ’open fields’ and are obtained in the cortex, the cerebellum, or parts of the thalamus where neurons are organized in layers. Such a field can be represented as a single, equivalent current dipole that causes a passive volume conduction through the conductive medium of the brain. Because neural tissue and overlying skull act as low-pass filters the field will diminish with distance from the source and will be visible over broad areas of the scalp (cf. Davidson, Jackson & Larson, 2000; Luck & Girelli, 1998). In contrast to neurons in an open field configuration there are also neurons that are concentrically or randomly organized as it is the case in some mid-brain nuclei. Such neurons generate electric fields that are oriented in very different, sometimes opposite directions and therefore will cancel each other. Consequently, no activity from such structures can be measured on the scalp. Thus, one should be aware of the fact that only a subset of the entire electric brain activity can be recorded from scalp electrodes (cf. Fabiani et al., 2000a).

3.1.3 ERP Components

The voltage by time function resulting from averaging contains a number of positive and negative peaks (cf. Figure 3.2).

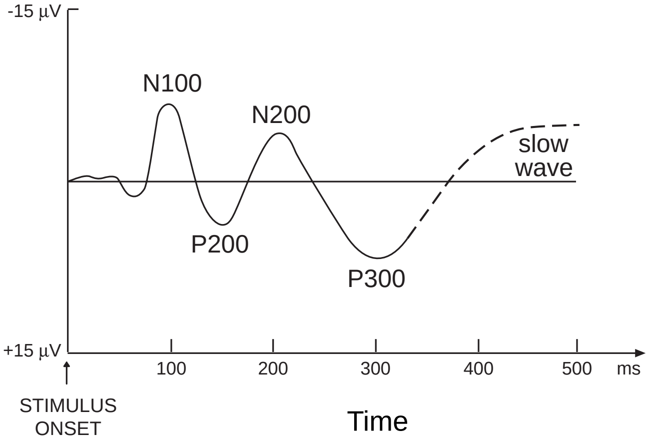

Figure 3.2: *An idealized waveform of the computer-averaged auditory Event-Related Potential (ERP) to a brief sound (Figure adapted from Hillyard & Kutas, 1983, p.35).*

Traditionally these peaks are described as components in terms of their topographical scalp distribution, their polarity, their latency characteristics, as well as their amplitude relative to the baseline (i.e., a positive peak obtained around 300 ms after the stimulus is called P300). The baseline is usually defined as the mean voltage level for a period of time probably not influenced by the event (often preceding the stimulus). The first 300 ms after the occurrence of the stimulus are mainly caused by physical properties of the external eliciting event. Such early deflections are called exogenous types of ERPs. For the analysis of cognitive processes endogenous types of ERPs are important. This term labels later deflections that are determined more by the nature of the interaction between the person and the eliciting stimuli (cf. Donchin, Ritter & McCallum, 1978).

However, the use of such descriptive terms do not allow an unequivocal interpretation of the functional significance of the ERP deflections. This is because volume conduction does not allow us to detect the exact source of the ERPs. One further consequence of volume conduction is the absence of a correspondence between the timing of the distinctive features of an ERP waveform and the temporal characteristics of the neural systems whose activity is reflected. Caused by these difficulties the proposal was made that the term ’component’ should be reserved for features of the waveform that can be attributed to the activity of specific neuronal populations. Consequently, the *physiological approach* labels only those parts of ERPs as a component which can be unequivocally related to one neuronal generator (cf. Näätänen & Picton, 1987). To isolate such possible intracranial sources of electric activity measured on the scalp different techniques are used. For instance, intracranial recordings in humans (c.f., Rugg, 1995a) and lesion studies (e.g., Mecklinger, von Cramon & Matthes-von Cramon, 1998) were performed, although such studies do not allow unambiguous inferences on the function in the non-lesioned brain (cf. Gabrieli, 1998; Mecklinger, 2000). Other authors directly examined the correspondence between electrode site and underlying cerebral structure by using the EEG technique as well as radiographic or magnetic resonance imaging techniques (e.g., Homan, Herman & Purdy, 1987; Lagerlund et al., 1993). Results reported by Homan et al. (1987) are displayed in Table 3.1.

A common method to infer ERP sources directly from the measurements recorded on the scalp is the dipole localization technique (e.g., BESA2000, MEGIS Software GmbH, Munich, Germany; CURRY4, NeuroScanLabs; for an overview of dipole localization see Scherg & von Cramon, 1985; Scherg & Picton, 1991). The localization of dipoles starts from the assumption that the ERP waveforms represent the summation of the activity of a number of different sources of fixed locations within the brain and that these sources can be appropriately modeled as equivalent dipoles. A dipole solution consists of the specification of the sources for an ERP waveform (number, location, orientation, time course, and relative strength of the activity). The similarity between the empirically observed scalp fields and the scalp fields which can be computed by the proposed source solution can be measured and this is called the ’goodness of fit’. However, the source analysis does not lead to an unequivocal solution. Different patterns of source activations can be represented in an equal ERP pattern.

Table 3.1: *Localization of the scalp electrodes of the 10-20 system according to Homan et al., 1987, p.379.*

Electrode position	**Brodman area**	**Cortical structures**
FP1, FP2	10	Rostral limit of superior frontal gyrus.
F3, F4	46	Middle frontal gyrus, near superior frontal sulcus; rostro-caudal location - even with temporal pole.
F7 F8	45 46	Inferior frontal gyrus rostral portion of pars triangularis.
C3, C4	4	Precentral gyrus, shoulder to wrist area, caudal to middle frontal gyrus.
P3, P4	7	Superior parietal lobule near intra-parietal sulcus, superior to posterior portion of supra-marginal gyrus.
TP3, TP4	40	Inferior parietal lobule, anterior portion of supra-marginal gyrus.
T1, T2	38	Temporal pole overlapping superior temporal sulcus, more in middle than superior temporal gyrus.
T3 T4	21 22	Overlapping middle and superior temporal gyri, rostro-caudal location - posterior to rolandic fissure.
T5	37	Left-middle temporal gyrus caudal to termination of sylvian fissure.
T6	19,37,39	Overlapping superior temporal sulcus, with rostro-caudal location with termination of sylvian fissure.
O1, O2	17	Occipital lobe, lateral and superior to occipital pole, overlapping calcarine fissure.

Consequently, it is useful to constrain the locations or parameters of putative sources in the light of anatomical knowledge. Opitz, Mecklinger, von Cramon and Kruggel (1999) described the combination of electrophysiological and haemodynamic measures from one experimental design. Haemodynamic data allowed the localization of brain structures underlying specific cognitive functions with a high spatial resolution. Further, this data were used as constraints for the localization of dipoles for ERP measures, which provide a temporal resolution with milliseconds accuracy. (cf. also, Opitz, Mecklinger, Friederici & von Cramon, 1999b).

Another approach to define a component is the use of the relation between a part or feature of ERPs and a specific psychological process, i.e, the use of the correlation to a cognitive function (e.g., Donchin, 1981; Donchin, Spencer & Dien, 1997). The *psychological approach* allows the identification of a component when multiple generators, which form a functionally homogeneous system, contribute to an ERP pattern. Different processing operations are likely to occur parallel and therefore any feature of an ERP waveform can reflect more than one process. Consequently, a subtraction of waveforms obtained in different experimental conditions should be useful to extract and to isolate unique components, whose presence differentiate between the conditions. Beside the subtraction method the Principal Components Analysis (PCA) tries to exploit patterns of covariation in the ERP data sets. An overview of the subtraction method and the PCA as well as a discussion of some critical points dealing with the varying latencies in ERP waveforms are given in Coles and Rugg (1995).

Physiological and psychological approaches were described as if they are exclusive, but for most researchers both approaches are important: Note that both polarity and topographical distribution implying a consistency in physiological sources as well as latency and sensitivity to experimental manipulations implying a consistency in psychological functions are usually used to define a component (cf. Coles & Rugg, 1995). In the following, two examples of ERP-components are given that are of special interest for the present work: the P300 and the N400 respectively.

P300

The P300, first described by Sutton, Braren, Zubin and John (1965), is a positive ERP deflection after stimulus presentation maximal at centro-parietal locations in the time window between 300 and 900 ms. The P300 is most easily recorded in the *Oddball paradigm* in which participants are presented with two stimuli or classes of stimuli. The probability of one stimulus is generally less than for the other, and the task may be to count the rarer of the two stimuli. The basic conclusion of these kinds of tasks is that the amplitude of the P300 is inversely proportional to the subjective probability of task-relevant events (Squires, Wickens, Squires & Donchin, 1976). The amplitude is also influenced by the task relevance at any level of probability. The more relevant the event is for the task the larger the P300 is. Also the participant's resources, invested in the tasks, are reflected in the amplitude. Latency of P300 may be independent of the time it takes to generate specific motor or verbal responses to the events (Donchin et al., 1997). Different modifications of the Oddball paradigm were used and it was shown that the P300 is no uniform phenomena. Instead, the component is seen as the summation of activity from multiple, functionally independent generators (e.g., Johnson, 1993). Furthermore, different P300 components could be differentiated (for an overview cf. Opitz, 1999). The classical centro-parietal P300 to rare, task relevant stimuli (Sutton et al., 1965), described above, is called *P3b*. If the stimulus is rare but not relevant for the task, then the P300 component is more distributed at fronto-central recording sites and has a shorter latency. This so called *P3a* was first described by Squires, Squires and Hillyard (1975). Courchesne, Hillyard and Galambos (1975) reported an additional P300 component. Participants were shown rare and frequent numbers, but they were also presented with patterns of colors which were not task relevant. These novel stimuli elicited also a P300 with a shorter latency than the P3b. The so called *novel P3* is maximal at fronto-central locations. Although the P3a and the novel P3 seems to be rather similar, functional differences are assumed. Both components are elicited by stimuli not relevant for the task.

However, while the P3a is elicited by rare stimuli, the novel P3 is elicited by novel stimuli.

N400

The N400 is a negative ERP deflection in the time window between 250 and 600 ms, peaking around 400 ms, which is associated with processes of semantical classifications. The component was first observed by Kutas and Hillyard (1980), who recorded ERPs in a sentence-reading task. Participants were required to silently read serially presented words in order to answer questions at the end of the experiment. Some sentences ended with a semantically incongruous (but syntactically correct) word and elicited a N400 component that was larger than that elicited by words that were congruent with the meaning. There appeared to be a correspondence between the amplitude of the N400 and the degree of incongruity. Moderately incongruous words elicited a smaller N400 than strongly incongruous words. These results have been replicated and extended repeatedly (cf. Kutas & Van Petten, 1994). It is assumed that the N400 is an obligate reaction of a word, which can be reduced if the meaning of a word is predicted by the former context. N400-like components were also found with non-verbal materials as pictures (e.g., Barrett & Rugg, 1990) and faces (e.g., Bentin & McCarthy, 1994). In general, research on the N400 shows that this component is sensitive to the violations of semantic expectancies and is independent of the kind of the stimuli.

3.1.4 Inferences from ERP Data

The goal of cognitive psychology is to identify cognitive processes that mediate between the environment and overt behavior. Cognitive processes are implemented by the brain and it is assumed that the measurement of brain activity can provide insights into their nature. It is assumed that the high temporal resolution of ERPs makes it possible to distinguish between subprocesses underlying different cognitive functions, which cannot be differentiated with behavioral measures alone. Consequently, differences in timing and scalp topographies of particular ERP components are used to make inferences about the timing and the spatial configuration of the brain activity involved in cognitive processes (cf. Rugg & Coles, 1995; Fabiani et al., 2000a). Different steps are necessary to infer the functional significance of an ERP component. At the first the component has to be ’discovered’. Then antecedent conditions have to be proposed. Such conditions refer to those experimental manipulations that will produce consistent variations (amplitude, latency, scalp distributions) in an ERP component. This step is followed by inferences about the psychological and/or neurophysiological functions of the interesting ERP component (cf. Fabiani et al., 2000a).

For instance, to examine whether two conditions differ temporally, appropriate separations along the time dimension have to be chosen (time windows). Furthermore, the comparison of topographical scalp distributions of the observed components under different experimental conditions can provide useful information about the reflected cognitive processes. ERP effects show topographical differences, if their neural generators differ with respect to their localization. Are the topographical distributions similar but ERP effects differ with respect to their magnitude, then it can be inferred that respective experimental conditions engaged the same population of generators with different strength of their activity (Johnson, 1993).

In sum, in the section 3.1 it was shown that despite some limitations, the measurement of ERPs provide an useful method to investigate physiological as well as psychological processes. ERPs ”...can serve as ...’windows’ on cognition - and can serve as ... ’windows’ on the brain”(cited in Coles, 1989, p.251).

3.2 ERP Correlates of Memory Processes

The study of human memory is hampered by the covert nature of the processes which allow us to remember past experiences: encoding, storage, and retrieval (Johnson, 1995). Behavioral measures alone cannot specify all brain processes involved in the given cognitive processes, because they occur after all sensory, cognitive, and motor processes are completed. Over the last 20 years, numerous studies have shown that ERPs are sensitive to mnemonic processes. Consequently, there is a great interest to define exactly what aspects of memory are reflected in the ERPs[1]. ERPs allow an exact description of the neuronal activity in relation to an event. The high temporal resolution of the ERP method makes this technique ideal for studying brain mechanism involved in memory. The following section provides a summary for knowledge about electrophysiological correlates of encoding as well as of retrieval processes. Because recognition processes are most relevant for the present study, this will be considered in more detail in section 3.2.2.

3.2.1 Electrophysiological Correlates of Encoding

Memory encoding refers to the processes that lead to the formation of a memory trace for an experience. But not everything what is experienced is later remembered. Consequently, it is of interest whether the measurement of ERPs reveal differences during encoding that might shed light on why some items are remembered and other items are forgotten. The ERP technique allows to sort items on the basis of whether the items are remembered in a subsequent memory test or not. Using this possibility, Sanquist, Rohrbaugh, Syndulko and Lindsley (1980) were the first who reported that during encoding subsequently successfully recognized items elicited more positive going ERPs (around 500 ms post-stimulus and later) than subsequently not recognized items. The so called *Subsequent Memory Effect*

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[1] Note that we can only detect processes that are time-locked to an event. This is for instance not always possible for rehearsal or free recall.

(SME)[2] was replicated in many studies (for reviews see Johnson, 1995; Rugg, 1995b), thereby at least two temporally and topographically different components could be differentiated. These are a parietal SME in the time range of the P300 and a late frontally distributed SME, which are assumed to be associated with differential processes involved in encoding.

A dissociation in two different encoding-related ERP components was for instance described by Karis, Fabiani and Donchin (1984). They used the *Von Restorff* paradigm in which some study trials (isolates) deviate in at least one feature (e.g., different size) from the other study items. This should result in better memory for the isolates. Isolates and non-isolates showed more positive going ERPs (between 500 and 900 ms) for subsequently recalled as opposed to unrecalled words, although the P300 amplitudes were smaller for the non-isolated words. Interestingly, participants showing large *Von Restorff* indices (recall advantage of isolated over non-isolated words) reported rote mnemonic strategies, while other participants reported the use of more elaborative strategies. A posthoc comparison of the SME for isolates between this two groups of participants revealed a parietal maximal positivity (in the range of the P300) for the group reporting rote memory strategies. However, a positive SME was only found in a late time window (starting around 800 ms) at frontal locations in the group with more elaborative strategies.

The differential topographical distribution of the SME could be further substantiated in a study manipulating encoding strategy directly. Fabiani, Karis and Donchin (1990) required participants either to rehearse study items by rote (repeating the words silently) or by elaboration (connecting or organizing the words, by making sentences, or forming images or pictures). SME was found for isolates as well as for non-isolates. However, this effect was confined at posterior locations between 350 and 800 ms in the rote condition, while SME was evident at frontal locations between 800 and 1180 ms in the elaborative condition. In sum, it

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[2] The positive ERP effect for subsequently recognized items is sometimes also labeled 'Dm' (difference due to memory) effect.

was claimed that non-elaborative mnemonic strategies lead to a subsequent memory effect arising from the modulation of the P300 component, while elaborative mnemonic strategies are associated with frontal-maximum positive ERP differences. The frontal effect was seen as an index of extended processing that overwrites the encoding process reflected by the P300. The P300 subsequent memory effect may reflect variations in item distinctiveness which causes subsequent memory in the absence of elaborative strategies (Donchin & Fabiani, 1991, for a critical discussion cf. Rugg, 1995b).

Mecklinger and Müller (1996) found no evidence for the overwriting effect of the frontal SME. The authors reported a SME comprised of a P300 and a frontally located slow wave following the P300 for objects. In a spatial task, thought to invoke less mnemonic strategies, no SME was revealed.

Many other studies focused on that part of the SME which temporally overlap the P300. It was shown that the parietal positivity, identified as SME, cannot be accounted in terms of the modulation solely of the P300 (e.g., Friedman, 1990b; Paller, Kutas & Mayes, 1987a). The parietal part of SME is larger for tasks requiring semantic processing than for task which do not (Paller et al., 1987a). Furthermore, the parietal part of SME is suggested to be correlated with the strength of encoding (Paller, McCarthy & Wood, 1988) and is suggested to reflect elaboration (Cycowicz & Friedman, 1999; Friedman, Ritter & Snodgrass, 1996; Friedman & Trott, 2000). There are also claims suggesting that the effect indexes memory encoding processes for explicit memories but not for implicit memories (Paller, 1990, but cf. Paller, Kutas, Shimamura & Squire, 1987).

In sum, many studies report more positive going waveforms for items subsequently retrieved than for items not subsequently retrieved. Although this SME is seen as reliable, the positivity is not consistently found and conditions which modulate the effect are unclear. Maybe, the connection of EEG and fMRI-studies is a way to clarify unsolved questions in future research.

3.2.2 Electrophysiological Correlates of Retrieval

General Overview

Beside the attempts to assess electrophysiological correlates of encoding there are many ERP studies which concentrate on ERP effects during memory retrieval. Numerous experiments have been conducted using incidental or intentional retrieval tasks.

Incidental retrieval is assessed with indirect tasks *(*cf. section 1.1) in which stimulus repetition is irrelevant for the response. Participants are not required to indicate or even be aware that the item has been presented earlier (e.g., Bentin & Peled, 1990; Penney, Mecklinger & Nessler, 2001; Van Petten & Senkfor, 1996). For instance, participants have to respond to occasional target items (e.g., nonwords) embedded in non-targets (e.g., words), which are repeated over intervals of less than a minute. ERPs elicited by repeated items are usually more positive-going than ERPs to the first presentation of the items (cf. Figure 3.3).

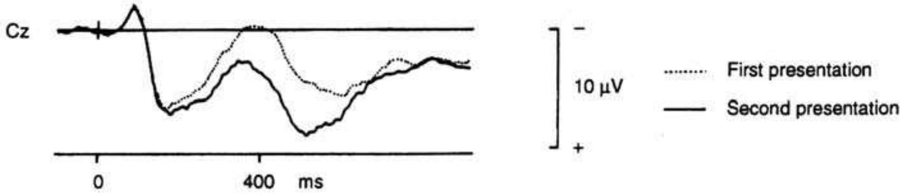

Figure 3.3: *The ERP repetition effect (adapted from Rugg, 1995b, p.146) Grand-average ERPs from a mid-central electrode Cz elicited by the first and by the second presentation of a non-target word (inter-item lag of six). Participants were asked to press a button to infrequently occurring targets.*

The question arises whether these so called ERP repetition effects reflect the same processes that are responsible for repetition priming effects on task performance (cf. section 1.1). Although behavioral priming and ERP repetition effects are observed in very similar tasks, it cannot be certainly assumed that these effects reflect the same processes. Behavioral priming effects are observable even hours or even days later (e.g., Jacoby, 1983), but ERP repetition effects are rather short-living, they disappear in less than 15 min (e.g., Rugg, 1990). Thus, there is no clear association between incidental ERP effects and implicit memory processes. One cannot be certain whether the ERP effect is really related to implicit processes or whether the participants are aware of the prior presentation of the item and explicit processes are reflected in the positivity.

The latter suggestion seems possible, because also ERPs elicited by repeated stimuli in *intentional* memory tests (cf. direct tasks, section 1.1) are usually more positive than the ERPs elicited by the initial presentation. This positive effect starts around 300 ms and is called *ERP old/new effect* (for an overview see Johnson, 1995; Rugg, 1995b; Rugg & Doyle, 1994; Rugg & Allan, 2000). In intentional memory tasks (cued recall or recognition) stimulus repetition is relevant for the task. Participants are required to indicate whether an item has been presented previously in the experiment. Thus, ERP old/new effects are seen as reflecting explicit memory processes.

Most *cued recall* tasks use word stems which have to be completed by participants with studied words. If participants do not remember a studied word they are required to provide the first word that comes in mind. For instance, Allan and Rugg (1997) reported more positive going waveforms for completed stems corresponding to a studied item than for stems completed with non-studied words. The positive ERP effect started around 300 ms and continued until the end of the recording epoch at 1950 ms. This effect was shown to be absent for ERPs elicited by stems completed with unstudied items falsely recognized as belonging to the study list as well as for ERPs elicited by correct completions not recognized as such (implicit memory) (for an overview of ERP studies using cued recall, see Allan, Wilding & Rugg, 1998; Rugg & Allan, 2000).

Tasks of *recognition* usually use study-test paradigms in which the study and the test phase are separated by a delay or continuous paradigms in which items were repeated in one continuous serie. Beside the advantage that the ERPs can be directly related to the participant performance, one critical point in old/new recognition tasks is that participants make differential responses (old vs. new) to the items of greatest experimental interest. However, studies reporting an absence of positive ERP effects for old judgements to NEW items and for new judgements to OLD items (e.g., Allan et al., 1998 Neville, Kutas, Chesney & Schmidt, 1986; Smith, 1993; Van Petten & Senkfor, 1996; Walla, Endl, Lindinger, Deecke & Lang, 2000) support the view that ERP old/new effects are related to retrieval processes and are not related to the execution of the different responses (old vs. new) or simple to the item repetition.

Also results from Curran (1999) reaffirmed this claim. In this study, participants were required to learn words and pseudo-words. ERPs were recorded in the later test phase, where participants performed either a recognition memory task (intentional task) or a lexical decision task (incidental task). Task condition was manipulated within participants by the use of six different study-test blocks. Previously studied words elicited more positive going ERPs than NEW words. That was true for both task conditions. The ERP pattern was identical whether an intentional or an incidental task was used. Thus, results support the claim that ERP old/new effects are related to retrieval processes and are not simply related to different responses. Results do also assume that ERP repetion effects in incidental tasks are related to explicit memory processes as it is the case for effects of intentional tasks (cf. above). Since an influence of retrieval intention was present in other studies (e.g., Paller & Gross, 1998), it has been suggested that the similar ERP effects for both tasks might be specific for the used conditions (for a detailed discussion cf. Curran, 1999).

So, a recent study by Rugg et al. (1998a) provide some evidence for the claim that ERP effects related to implicit or explicit processes can be differentiated. They compared electrophysiological correlates of implicit and explicit memory in a task with similar conditions and a procedure that ensured that neural correlates of implicit memory were not influenced by explicit memory. Participants were required to learn words for a later recognition memory test. In the test phase, ERPs from frontal electrode sites were more positive for recognized OLD words than they were either for NEW words or for unrecognized OLD words reflecting explicit memory. However, in the same time range ERPs from parietal locations were more positive-going for correctly detected OLD words as well as for missed OLD words than ERPs for NEW words. This early parietal effect, equivalent for recognized and unrecognized OLD items, is seen as a neural correlate of memory in the absence of conscious recognition, i.e., of implicit memory.

After this overview of electrophysiological correlates of retrieval, recognition-related activity is described in more detail in the next section.

Electrophysiological Correlates of Recognition Memory

It was already mentioned that true recognition elicits more positive ERP waveforms than correctly rejected NEW words in explicit old/new recognition tests. These effects are assumed to comprised of different spatio-temporally ERP old/new effects that are associated with distinct cognitive processes underlying true recognition. Smith and Halgren (1989) were the first who proposed that the recognition-related positivity is formed by a frontally focused N400-like component that is reduced with repetition and a late positive component at parietal locations that is enhanced by repetition (e.g., Friedman & Johnson, 2000; Mecklinger, 2000). Although the close time relation between both ERP old/new effects makes it sometimes difficult to distinguish between them, they show different sensitivities to test-manipulations suggesting that both effects are associated with different subprocesses of recognition memory.

The attenuation of the frontally focused N400-like component, the so called *early frontal old/new effect*, may occur because access to conceptual and perceptual information related to the test word is facilitated for OLD words due to prior studying and results in a feeling of *familiarity*. This early frontal effect starts around 300 ms, lasts approximately 200 ms, and cannot be explained by perceptual priming. This was indicated by studies showing that the change of the modality for the materials from study to test does not affect this old/new

ERP difference (e.g., Domalski, Smith & Halgren, 1991; Richardson-Klavehn & Bjork, 1988; Wilding, Doyle & Rugg, 1995). The second parietal deflection, called *parietal ERP old/new effect*, starts around 400 ms and lasts for several hundred milliseconds. This effect, which is usually left lateralized or bilateral, is associated with consciously controlled *recollection* (for reviews see Johnson, 1995; Rugg, 1995b). Thus, the early frontal and the somewhat later arising parietal ERP old/new effect are seen as associated with both processes, familiarity and recollection, as proposed in dual-process accounts of recognition memory (cf. 1.1.1).

Evidence for such a differentiation was provided by many studies. For instance, Smith (1993) required participants to study words for a later old/new recognition memory test. ERPs were recorded in the test phase in which participants additionally gave a Remember/Know response (cf. section 1.1.1) in the case they have recognized an item. Smith (1993) found that ERP old/new effects for recognized items associated with Remember responses and for items associated with Know responses did not differentiate before 550 ms. While early old/new effects were similar for both item types, ERPs for Remember items were more positive going than ERPs for Know items between 550 and 700 ms. This supports the view of an electrophysiological dissociation between early familiarity and somewhat later arising recollection processes (for similar results see Düzel et al., 1997). The earlier electrophysiological sign of familiarity is also in line with the earlier start of familiarity processes found for reaction time data (cf. section 1.1.1, Hintzman & Curran, 1994).

Johnson, Kreiter, Russo and Zhu (1998) used four repetitions of a study-test recognition paradigm to examine electrophysiological correlates of recognition memory. Participants learned words and gave old/new recognition judgments after a short break. To study the effects of learning on the memory-related ERP activity the study and test phase were each repeated four times using new lists of NEW words for each test. Johnson et al. (1998) reported more positive-going ERPs to correct responses to OLD words than to correct rejections of NEW words at frontal locations between 400 and 490 ms. Neither the amplitude nor the latency of this activity varied as a function of true recognition rate, which increased with the number of test repetitions. Given this, Johnson et al. (1998) associated the early frontal effect with familiarity assessment. A second old/new effect was found at parietal locations maximal between 500 and 700 ms. This parietal effect was positively correlated with the true recognition rate as well as with decision confidence (cf. also Johnson, Pfefferbaum & Kopell, 1985) indicating that this effect may reflect recollection processes.

Strong evidence for a differentiation between the early frontal and the middle parietal effect was also reported by the study of Rugg et al. (1998a), described above. Words in the study phase were learned either during a shallow or a deep encoding task. Thus, beside the differentiation between implicit and explicit memory processes (see above), it was also possible to differentiate subprocesses involved in explicit memory. Rugg et al. (1998a) found more positive going ERPs for recognized OLD words than for correctly rejected NEW words starting around 300 ms. ERP differences were insensitive to the depth of processing manipulation at frontal recording sites between 300 and 500 ms. However, deeply studied recognized items showed larger parietal positivities than shallowly studied recognized items from around 500 ms onwards (for similar results e.g., Paller, Kutas & McIsaac, 1995). These results support the association between the frontal ERP old/new effect and familiarity assessment and between the parietal ERP old/new effect and conscious recollection.

ERP results of the study of Curran (1999, see above) also support the differentiation of at least two processes involved in recognition memory. Curran found a frontal maximal N400-like ERP old/new effect (FN400) between 300 and 500 ms post-stimulus that was similar for words and pseudo-words. The parietal old/new effect between 400 and 700 ms, however, was larger for words. Given the evidence that words are more likely to be recognized on the basis of remembering whereas pseudo-words recognition is more driven by knowing (e.g., Gardiner &

Java, 1990), the parietal effect was associated with recollection and the FN400 was seen as reflecting familiarity assessment.

Results obtained in a study by Ullsperger et al. (2000), in which a directed forgetting paradigm was used, are in line with the differentiation between an early frontal and a middle parietal effect. Study items were followed by an instruction either *to forget* or *to remember* the item. In the later recognition memory test, which consisted of *to remember* as well as of *to forget* items, both item types were expected to evoke feelings of familiarity. However, recollection should only occur for *to remember* items which were prior intentional encoded. As it was suggested both item types elicited topographically comparable frontal old/new effects between 350 and 550 ms, but a parietal effect between 550 to 850 ms was only obtained for *to remember* but not for *to forget* words.

In sum, empirical evidence support the differentiation between an early frontal ERP old/new effect reflecting familiarity assessment and a middle parietal ERP old/new effect associated with conscious recollection. Since the effects disappear after damage of the medial temporal lobe (e.g., Mecklinger et al., 1998) this structure is seen as crucial for the occurrence of both effects. However, it is very unlikely that the generators of both old/new effects are localized within the medial temporal lobe as scalp electrodes appear to be largely insensitive to ERP activity generated in the hippocampus and adjacent structures. Scalp recorded ERP old/new effects rather reflect the activity of cortical regions responsive to input from the medial temporal memory system (cf. Rugg, 1995a).

Wilding, Rugg and colleagues (Wilding et al., 1995; Wilding & Rugg, 1996, 1997) reported an additional *right frontal ERP effect* arising somewhat later and sustaining longer in time than the parietal ERP old/new effect. For instance, Wilding and Rugg (1996) required participants to learn words which were spoken either by a female or by a male voice. Later participants performed a recognition test including visually presented studied (OLD) and non studied (NEW) items. Furthermore, for each recognized item participants were required to judge in which voice the word was studied. Wilding and Rugg (1996) found more positive going ERPs for recognized than for NEW items. Moreover, the ERP old/new effect between 500 and 800 ms was larger for items which were in addition attributed to the correct source (male/female voice). That supports the association of the effect with recollection of item specific information from the study phase. More interesting, the authors also reported a later positive effect maximal at right frontal locations extended up to the end of recording epoch (1400 ms). This later effect was larger for recognized words which were also accompanied by a correct voice judgement than for words with incorrect voice judgement. It was suggested that this effect indexes operations on the products of the retrieval process and is necessary for the recovery of contextual information. Furthermore, the larger effect for correct source judgements suggested a relation to retrieval success. Wilding and Rugg (1996) assumed that the frontal positivity might be mediated by structures of the frontal lobe with a greater contribution coming from the right than the left hemisphere. This is in agreement with findings that prefrontal lesions are associated with poor source memory (e.g., Janowsky et al., 1989b). Furthermore, this suggestion also matches with functional neuroimaging studies showing activation in the right dorsolateral prefrontal cortex during tasks of episodic memory retrieval (e.g., Rugg, Fletcher, Frith, Frackowisk & Dolan, 1996; Henson, Rugg, Shallice, Josephs & Dolan, 1999; Schacter, Alpert, Savage, Rauch & Albert, 1996a, for an overview see Ranganath & Paller, 1999; Wagner, Desmond, Glover & Gabrieli, 1998).

However, the experimental procedure used by Wilding and Rugg (1996) required two responses to be made to each item judged old. Thus, it is arguable that the right frontal old/new effect is a consequence of the double-response procedure. This issue was addressed in a follow up study where participants also studied words spoken by female or male voice (Wilding & Rugg, 1997). In the recognition memory test an ’exclusion’ task was used (cf. Jacoby, 1991) in which only a single response was required for each test word. In this exclusion task participants were asked to respond with one button to visually presented, recognized target words (either all words studied in the male voice or all words studied in the female voice, randomized for participants). The other button had to be pressed by the participants if the items were NEW or OLD words which were studied in the other, non-target voice. Although both classes of OLD words elicited parietal old/new effects which were somewhat larger for the target OLD words, only target OLD words elicited a late right frontal effect. Thus, results further support the association between the parietal ERP old/new effect and processes necessary for recollection as well as the association between the right frontal effect and successful retrieval. However, the latter effect is not an obligatory correlate of successful source discrimination. Participants appear to be able to classify accurately nontargets without the benefit of the processes reflected in the right frontal old/new effect. Some later studies replicated the findings of Wilding and Rugg supporting the view that retrieval success is reflected in the late right frontal positivity (e.g., Rugg, Schloerscheidt & Mark, 1998b; Mecklinger & Meinshausen, 1998). But there are also other studies which did not find frontal ERP effects that distinguish between accurate and inaccurate source judgements (cf. Senkfor & Van Petten, 1998; Penney, Mecklinger, Hilton & Cooper, 1999). Moreover, Ullsperger et al. (2000) reported larger late right frontal effects for words associated with a forget instruction indicating a relation to retrieval effort. Ranganath and Paller (1999) also found a late frontal ERP effect for NEW words.

These findings argue against a unitary functional account of the late right frontal ERP old/new effect. Although there is no doubt on the relation to recognition related processes, it is suggested that the late right frontal positivity may also reflect general task related processes which are elicited by the instructions to the participants as to what they should do (see also Düzel et al., 1999). Even though there is no consensus so far on its precise functional significance the effect seems to reflect cognitive operations that depend on more global aspects of the context in which retrieval takes place (cf. Friedman & Johnson, 2000; Mecklinger, 2000, Wagner et al., 1998).

In sum, based on temporal and topographical distributions several subcomponents of the old/new ERP differences have been distinguished. Recently, Mecklinger (2000) summarized the great amount of evidence for different electrophysiological effects related to recognition memory in a neurocognitive model of recognition memory (cf. Table 3.2). As indicated by empirical results three different spatio-temporally ERP old/new effects, which are associated with distinct cognitive processes underlying true recognition, are distinguished (cf. also, Friedman & Johnson, 2000). These effects are an early *fronto-medial ERP old/new effect* that is associated with familiarity assessment and a somewhat later *parietal ERP old/new effect* that is seen as correlate of conscious recollection. Finally, a *late right frontal ERP old/new effect* may reflect post-retrieval processes.

Table 3.2: *A Neurocognitive Model of Recognition Memory according to Mecklinger (2000).*

Processes	**Familiarity assessment**	**Recollection**	**Post-retrieval evaluation**
ERP correlate	frontal old/new effect	parietal old/new effect	late right frontal old/new effect
Timing	300-500 ms	400-700 ms	800-.. ms
Brain Systems	MTL	MTL	Right PFC

Note. ms = milliseconds; MTL = Medial temporal lobe; PFC = Prefrontal cortex.

In the present study this model is used to compare electrophysiological processes underlying true and false recognition. Aims and questions for the present work are summarized in the next section.

3.3 Questions and Aims

In Chapter 2 different studies were reviewed showing high rates of false recognition for semantically related words using word lists from the Deese paradigm. Two different approaches that could account for the high rates of false recognitions were discussed. The first model holds that LURE words are activated in encoding via associative mechanism, and later, hence memory traces were formed, retrieved like really studied words (IAR, Underwood, 1965, cf. Schacter et al., 1998a, see also, section 2.4, 2.5). The other account claims that LURE words were falsely judged as old because they match general information with studied words (Fuzzy Trace Model, Reyna & Brainerd, 1995; general event and event-specific knowledge, Conway & Rubin, 1993, cf. Schacter et al., 1998a, see also, section 2.4, 2.5). The different approaches make different assumptions for brain activity that should be elicited in a recognition test. While the first model would expect similar brain activation patterns for true and false recognition, the second assumes that item specific information, which is only (or more) present for true recognition, should account for differences in the correlates of brain activity.

First brain imaging studies (cf. section 2.5) report no differences between correlates of brain activity for true and false recognition. These results implicate that familiarity and recollection processes, which are involved in true recognition (cf. section 1.1.1), might also occur for false recognition supporting an activation of the LURE words at encoding. However, the asymmetrical relationship between OLD and LURE words in the Deese paradigm caused some difficulties in the interpretation of the results. The differential semantic relationship to the studied theme of OLD and LURE words can result in differential brain activity. For instance, LURE words are more semantically primed by other words in the retrieval phase than OLD words. This may result in smaller N400 effects for LURE words (Kutas & Van Petten, 1994) and in turn to an overestimation of the somewhat later occurring positive old/new ERP effect for false recognition (cf. Rubin et al., 1999, see also section 2.6). Furthermore, there could also be different response criterions for LURE and OLD words (Miller & Wolford, 1999). Consequently, the aims of he present work were as follows:

- Examination of true and false recognition using materials that overcome the limitation of the Deese lists.
- Comparison of electrophysiological correlates of true and false recognition to make inferences about memory processes involved.

More precisely, the goal of Experiment 1 was to examine whether words from different semantic categories were useful as materials for the investigation of the false memory phenomena (Chapter 4). Furthermore, the three different spatio-temporal ERP patterns of the neurocognitive model of recognition memory proposed by Mecklinger (2000, see also section 3.2.2) were used to examine cognitive subprocesses underlying true and false recognition. Note, that a similar account was also used by Curran (2000). In this study participants were required to discriminate between previously studied words (OLD words), similar words that changed number between study and test (similar words), and NEW words. An early frontal ERP old/new effect (so called FN400) between 300 and 500 ms post-stimulus was similar for recognized OLD words and for false recognition of similar words. However, true and false recognition could be distinguished in the parietal component (400-800 ms). While true recognition elicited a positive ERP effect at parietal locations compared to correct rejections of NEW words, ERPs to false recognition of similar words were not different from ERPs to NEW words. Curran claimed that familiarity is similar for OLD and LURE words and drives especially false recognition, while the parietal component is associated with the recollection of the number.

In the present work, false recognition of words is examined by using completely different words within same categories. False recognition should elicit an early frontal ERP old/new effect but no parietal effect, if false recognition of non-studied semantically related words only arises from an overlap of general information, i.e., from familiarity assessment. However, if LURE words are activated in prior encoding, then parietal old/new effects should also occur for false recognition.

Results of the Experiment 1 are discussed in this light (Chapter 4) but some changes of the design were necessary. Experiment 2 (Chapter 5) used well balanced amounts of OLD, LURE, and NEW words to directly compare ERP waveforms elicited by true and false recognition. Experiment 3 investigated the influences of encoding manipulations (Chapter 5), while the delay between study and test phase was manipulated in Experiment 4 (Chapter 6). Experiment 5 discusses behavioral results from patients suffering from frontal lobe lesion (Chapter 7). This study was conducted to examine whether the high false recognition rate observed by the patient B.G. (cf. section 2.5.2) is a general characteristic of frontal lobe pathology. Specific questions and hypotheses for the different experiments are outlined in the respective Chapters.

Chapter 4

Experiment 1

4.1 Introduction

In this first study the focus is on the question whether words from different semantic categories would be able to elicit reliable false recognition. Prior studies often used word lists from the Deese paradigm (Deese, 1959) and found high rates of false recognition which were nearly similar to the rates of true recognition (e.g., Roediger & McDermott, 1995; McDermott, 1996, see also Chapter 2). It is proposed that these high rates of false recognition are related to the used word material. OLD words in the Deese paradigm were chosen due to their associative relation to the LURE words, which are the theme words in each list. This high semantic relation causes the false old responses to LURE words in the recognition test. However, while OLD words (e.g., *coal*) have per definition high semantic relations to the respective LURE word (e.g., *black*), semantic relations between OLD words from one list are smaller (e.g., *coal* and *white*).

Given such differential semantic relations of OLD and LURE words it is difficult to interpret any obtained differences in brain activation between true and false recognition. Are differences in brain activation associated with semantic relations or are they a possibility to differentiate between true and false recognition (cf. section 2.6)?

The important benefit of using words from different categories instead of words from the Deese lists is that OLD and LURE words share similar characteristics. This is because in categorical lists OLD and LURE words were chosen due to their semantic relation to the category name, which is the theme in these lists. That should warrant that OLD and LURE words have similar semantic relation to other words from the respective list. Because LURE words are not the theme in these lists they should be also signed by smaller typicality than the LURE words from the Deese lists. Furthermore, all words in the categorical materials are nouns what is not the case for words from the Deese paradigm.

In sum, the use of categorical lists for the investigation of false recognition would overcome the unsymmetrical characteristics of OLD and LURE words from the Deese paradigm and is assumed to be better suited to compare electrophysiological correlates of true and false recognition. Different semantic relations for both item types could not be any longer an argument to explain differential brain activity (cf. Rubin et al., 1999, see section 2.6) and such a categorical procedure could also eliminate the possibility of different response criterions for LURE and OLD words (Miller & Wolford, 1999).

Although most studies of the false memory phenomena used lists from the Deese paradigm, some studies also reported false recognition for categorical materials (cf. Hintzman, 1988; Brainerd et al., 1995b). For instance, Seamon, Luo, Schlegel, Greene and Goldenberg (2000) used 12 word lists each composed of 14 exemplars from the semantic category norms described by Battig and Montague (1969). Words for the highest and lowest category exemplars were used as critical LURE words, while the other words were presented in the study phase for 20 ms or 2 sec each (between-subject variable). A later recognition memory test revealed similar rates of true and false recognition for participants who saw each study word only 20 ms (56 % and 50 %, respectively). Participants who were more aware of the studied words due to the longer encoding-presentation time of

2 sec showed smaller rates of false recognition (25 %) than of true recognition (89 %). Rates of false recognition in both groups were larger than the rates of false alarm for non-related NEW words (26 % for 20 ms presentation time and 4 % for 2 sec presentation time) indicating that words from different semantic categories are sufficient enough to elicit reliable false memories. However, rates of false recognition for words from different categories are smaller than for word lists from the Deese paradigm. As it was mentioned before, words are not chosen due to their relationship with the critical LURE word in categorical lists. Instead, words are chosen because of their membership to a special category. Consequently, semantic associations for LURE words in categorical lists are smaller than for LURE words from the Deese lists. This might explain the smaller rates of false recognition in categorical lists (for the relation between the strength of semantic relationship and false recognition rate cf. Robinson & Roediger, 1997; Hintzman, 1988, see also section 2.4).

ERPs are recorded to get additional information about the cognitive processes involved in true and false recognition. To compare electrophysiological correlates for both kinds of recognition, the neurocognitive model of recognition memory is used (Mecklinger, 2000, cf. also section 3.2.2). This model summarizes results from prior studies to true recognition, which associated an early fronto-medial ERP old/new effect with familiarity assessment. A somewhat later arising parietal ERP old/new effect is seen as a correlate of conscious recollection, while a late right frontal ERP old/new effect may reflect post-retrieval processes.

This neurocognitive model is applied to the two different models which can account for the high rates of false responses to semantically related words (cf. Chapter 2). False recognition should elicit an early frontal ERP old/new effect but no parietal effect, if false recognition of non-studied semantically related words only arises from an overlap of general information, i.e, from familiarity assessment (cf. more encoding-related model, Chapter 2, see also Schacter et al., 1998a). The other model holds that LURE words are activated in prior encoding via associative mechanism and hence memory traces are also formed for

LURE words (cf. more retrieval-related model, Chapter 2, see also Schacter et al., 1998a). Consequently, parietal ERP old/new effects should also occur for false recognition. However, given that this model is the correct one, it is assumed that parietal ERP old/new effects should be larger for true than for false recognition. Due to prior studying there should be larger amounts of item specific information for true recognition than for false recognition.

4.2 Methods

4.2.1 Participants

Twenty-two volunteers (13 female) between 18 and 31 years of age (mean 26 years) participated in the present study. They were students at the University of Leipzig, were right-handed, and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h for their participation. None of the participants had prior experience with the task.

4.2.2 Experimental Material

Stimuli consisted of 300 German nouns taken from a categorical word pool. This pool was created in a categorical noun generation experiment performed with 139 undergraduate students at the University of Leipzig (107 female), between 18 and 34 years old (mean = 22). The present experiment used 30 categories. The exemplars for each category were selected in such a way that the mean word typicality of the 10 category examples was similar across the categories. The words were used to construct 6 randomized study-test-lists, which were balanced across participants. Each study list comprised 150 words and contained 6 members from each of 25 categories. Each test list consisted of these 150 studied words (OLD), 100 non-studied words from studied categories (LURE), and 50 NEW words drawn from the 5 non-studied categories. To increase the likelihood of false alarms to LURE items, these words were always drawn from the five most typical words of each category.

4.2.3 Procedure

The participants were seated comfortably in an acoustically and electrically shielded dimly lit chamber in front of a 17” computer monitor. They sat at a distance of about 100 cm from the screen and during the test phase they held a small response box on their lap. Each participant performed one session consisting of a study and a test phase that were separated by a visuo-motor tracking task of 10 minutes duration (cf. Figure 4.1). Participants were told that they would hear a tape recorded word-list and that they would be asked to recognize the words later. In the study phase, participants heard 150 words in a female voice (six nouns from each of 25 categories). The name of a word category appeared on the screen for 2400 ms and was followed by a delay of 1600 ms. Next, the six nouns from the category were played at a rate of one every two seconds. Prior to the test phase, participants performed the tracking task. In the recognition test, the items were presented visually in a quasi random order with the constraint that no more than 3 words of the same type (OLD, NEW, LURE) were presented consecutively. Each test trial started with a fixation cross in the middle of the screen. After 100 ms the screen went blank for 500 ms and then the word was presented visually for 200 ms. The next trial started after a delay of 2800 ms (blank screen) during which participants were required to indicate as quickly and as accurately as possible whether the presented word was heard in the study phase (old response) or not (new response).

They responded by pressing the left or the right button of the response box with the thumb of the corresponding hand. The response button used for old responses was counterbalanced across participants. After 150 items the participants were given a short break. Including electrode application and removal each session lasted about 1.5h.

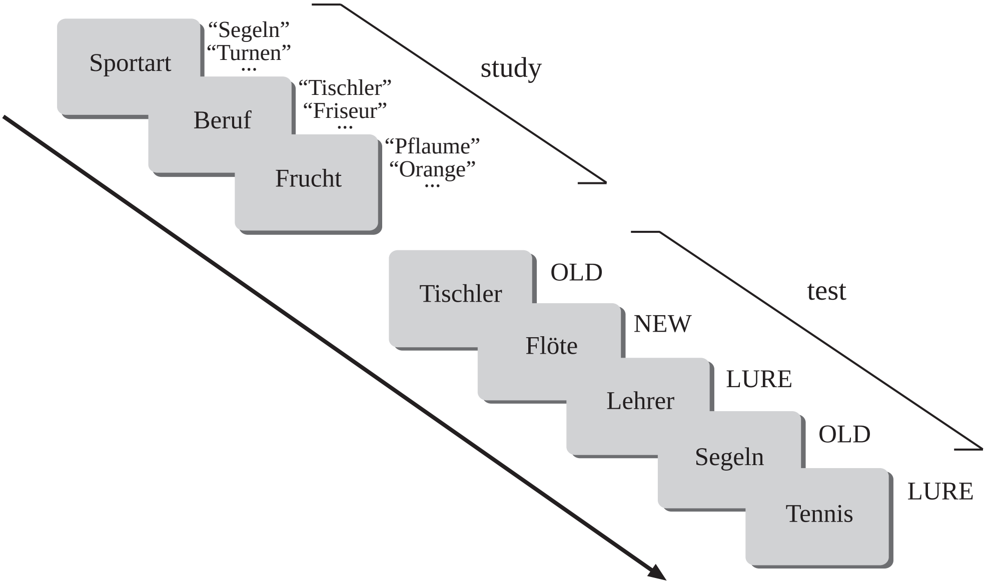

Figure 4.1: *Schematic view of the study and the test phase in Experiment 1. A detailed description is given in the text.*

4.2.4 ERP Recording

The EEG activity was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electro-cap International) from 61 scalp sites of the extended ten-twenty system. Electrode labelling was based on the standard nomenclature (Sharbrough, Chatrian, Lesser, Lüders, Nuwer & Picton, 1990). The ground electrode was positioned 2cm to the right of Cz. The vertical Electro-oculogram (EOG) was recorded from electrodes located above and below the right eye. The horizontal EOG was recorded from electrodes positioned at the outer canthus of each eye. Electrode impedance was kept below 5 kOhms. The right mastoid was recorded as an additional channel. All scalp electrodes were referenced to the left mastoid and were off-line re-referenced to both mastoids. EEG and EOG were recorded continuously with a band pass from DC to 30 Hz and were A-D converted with 16 bit resolution at a sampling rate of 250 Hz.

4.2.5 Data Analysis

Behavioral Data

Reaction time was defined as the interval between the appearance of the test item and the participant's key-press. Data were averaged separately for each response condition.

ERP Data

In the test phase, ERPs were computed for each participant at all recording sites with epochs extending from 200 ms before onset of word presentation until 2000 ms thereafter. ERPs were selectively averaged for the following combinations of item types and responses: old responses of OLD words (true recognition), old responses of LURE words (false recognition), new responses of LURE words, and new responses of NEW words. Since there were too few old responses to NEW items and too few new responses to OLD items to form reliable ERPs, these conditions were excluded from further analyses.

The average voltages in the 200 ms preceding stimulus presentation served as a baseline. Prior to averaging, each epoch was scanned for EOG and other artifacts and averages were lowpass filtered below 10 Hz. For statistical analysis mean amplitude measures from six topographical regions, so called *regions of interests* (ROI) were used. The following regions were defined: left frontal (F9, AF7, F7, F5, FT9, FT7, FC5); medial frontal (AFz, AF3, AF4, Fz, F3, F4, FCz); right frontal (F10, AF8, F8, F6, FT10, FT8, FC6); left parietal (TP9, TP7,CP5,P9, P7, P5, PO7); medial parietal (CPz, Pz, P3, P4, PO3, POz, PO4); and right parietal (TP10, TP8, CP6, P10, P8, P6, PO8). [1]

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[1] For a more detailed description of EEG analysis see the Experiment 2 (Chapter 5).

Prior studies revealed at least three spatio-temporal ERP effects in explicit recognition memory tasks (e.g., Johnson et al., 1998; Ullsperger et al., 2000, cf. also Mecklinger, 2000). Consequently, three different time windows were used for the quantification of the ERP effects. The early frontal old/new effect was examined in a time window between 400 and 550 ms, the parietal old/new effect was analyzed between 550 and 700 ms, whereas the late right frontal old/new effect was examined between 1000 and 1400 ms. For each time window it was tested whether true recognition elicited old/new effects. ERP measures were subjected to a two-way repeated-measures ANOVA with the factors condition (2 levels: true recognition, new responses of NEW words) and ROI (6 levels: left frontal, medial frontal, right frontal, left parietal, medial parietal, right parietal). The same ANOVA design was used to test whether false recognition also elicited old/new ERP effects. In an additional analysis procedure, brain activity elicited by new and old responses of LURE words was directly contrasted using a two-way repeated-measures ANOVA with the factor condition type (2 levels: false recognition, new responses of LURE words) and the factor ROI (6 levels) for the early time window (400-550 ms).

In order to avoid reporting large amounts of statistical results not relevant for the issues under investigation, only main effects or interactions including the condition factor are reported. In the case of significant interactions involving this factor, one-way ANOVAs with the factor condition were performed to examine the effects of this factor in each of the topographical regions. Measures of treatment magnitude (ω^2, cf. Keppel, 1991) for the single effects are reported in combination with main effects of condition. All effects with more than one degree of freedom in the numerator were adjusted for violations of sphericity according to the Greenhouse and Geisser formula (Greenhouse & Geisser, 1959). Scalp potential topographic maps were generated using a two-dimensional spherical spline interpolation (Perrin, Pernier, Bertrand & Echallier, 1989) and a radial projection from Cz, which respects the length of the median arcs.

4.3 Results

4.3.1 Behavioral Data

Mean reaction times and proportion of old responses to OLD, LURE and NEW words are presented in Table 4.1. Participants showed more false alarms to LURE words (false recognition) than to NEW words. Further, correct responses were faster for OLD and NEW words than for LURE words.

Table 4.1: *Mean reaction times (in ms) of the old and new responses, and mean proportion (in %) of the old responses to the different item-types in Experiment 1. The standard error of the mean is presented in parentheses.*

Item	**Response**	**Reaction time**	**Proportion old-response**
OLD	old	892 (44)	72.6 (2.4)
	new	1066 (53)	
LURE	old	1037 (54)	30.1 (2.8)
	new	1015 (50)	
NEW	old	1122 (88)	11.5 (2.2)
	new	940 (49)	

This pattern of results was confirmed by statistical analyses. A repeated-measures ANOVA for the proportions of old responses (3 levels) revealed reliable differences between the three item types $(F(2,42) = 189.28, p < .001)$. Separate tests showed that LURE words elicited more false alarms than NEW words $(F(1,21) = 99.34, p < .001)$. The rate of old responses to OLD words (true recognition) was higher than the rate of old responses to LURE words (false recognition) $(F(1,21) = 116.29, p < .001)$. Reaction times for the four response categories relevant for the ERP analyses (true recognition, false recognition, new responses to LURE words, new responses to NEW words) were significantly different as revealed by a one-way repeated measures ANOVA ($F(3,63) = 17.61, p < 0.001$). Separate tests showed that old responses to OLD words were faster than new responses to NEW words ($F(1,21) = 5.76, p < .05$). There was no difference in reaction time between old and new responses to LURE words ($F(1,21) = 0.94$), but participants responded faster to OLD and NEW words than to old responses to LURE words ($F(1,21) = 31.79, p < 0.001; F(1,21) = 11.22, p < 0.01$, respectively) as well as to new responses to LURE words ($F(1,21) = 32.52, p < 0.001; F(1,21) = 35.07, p < 0.01$, respectively).

4.3.2 ERPs

ERP old/new Effects to OLD and LURE Words

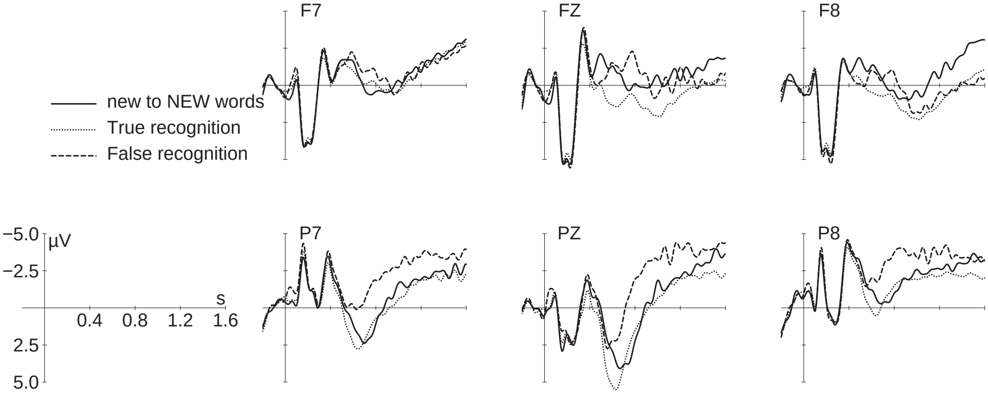

Figure 4.2: *ERPs elicited by true recognition, false recognition, and correct rejections to NEW words at left frontal (F7), middle frontal (Fz), right frontal (F6), left parietal (P7), middle parietal (Pz), and right parietal (P8) electrode sites. In this and the following figures, negative voltages are plotted upwards.*

Figure 4.2 displays the ERP waveforms at two midline electrodes and at lateral frontal and parietal recording sites elicited by true recognition, false recognition, and new responses to NEW words.

Starting at around 400 ms the waveform elicited by *true recognition* was more positive than that for NEW words. This ERP old/new effect first appeared at frontal and parietal locations. From around 800 ms until the end of the recording epoch the old/new effect was maximal at right frontal locations. Positive ERP differences relative to NEW words were also obtained for *false recognition* at frontal locations in an early time window (400-550 ms). There appeared a large negativity maximal at parietal locations for false recognition relative to new responses to NEW words between 550 and 1600 ms. Additionally, there was a late right frontal positive ERP effect relative to new responses to NEW words. It started at around 1200 ms and extended until the end of the recording epoch over right frontal locations.

The results of the two-way ANOVAs with the factors condition and ROI for (a) true recognition and new responses of NEW words and (b) false recognition and new responses of NEW words are displayed in Table 4.2.

Table 4.2: *ANOVA results (F-values) for the old/new effects to true and false recognition in the three time windows in Experiment 1.*

		True recognition		
	df	300-500 ms	500-700 ms	1200-1600 ms
Cond	1.21	10.26**	10.31**	10.96**
Cond x ROI	5.105	4.24*	4.04*	3.97*
		False recognition		
Cond	1.21	1.61	1.32	0.02
Cond x ROI	5.105	2.31(*)	2.12	6.87***

Note: Cond = Condition. df = degrees of freedom. ROI = regions of interest. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; (*) $p < 0.1$.

In the early time window (400-550 ms) for true recognition there was a significant main effect of condition as well as a significant interaction condition x ROI. Based on this interaction separate test performed for the different ROIs revealed significant effects at medial frontal ($\omega^2 = .38$), right frontal ($\omega^2 = .22$), medial parietal ($\omega^2 = .34$), and right parietal locations ($\omega^2 = .37$). Analyses for false recognition showed no main effect of condition but a marginally significant interaction condition x ROI. Separate tests revealed positive effects at right frontal locations ($\omega^2 = .19$) and a trend at medial frontal locations ($\omega^2 = .09$).

In the middle time window (550-700 ms), analyses of true recognition revealed a significant main effect of condition as well as a significant condition x ROI interaction. ERPs for true recognition were more positive than ERPs to new responses to NEW words at medial frontal ($\omega^2 = .33$), right frontal ($\omega^2 = .32$), medial parietal ($\omega^2 = .34$), and right parietal ($\omega^2 = .31$) locations. There was no significant effect found for false recognition.

As it is evident from Table 4.2, ANOVAs in the late time window (1000-1400 ms) revealed a significant main effect of condition as well as a significant condition x ROI interaction for true recognition. There was no condition effect but a condition x ROI interaction for false recognition. For true recognition, separate tests for the different ROIs showed more positive ERPs at the medial frontal ($\omega^2 = .36$), the right frontal ($\omega^2 = .47$), and the right parietal ROI ($\omega^2 = .14$). For false recognition, ERPs were more positive at right frontal ($\omega^2 = .20$) but more negative at left parietal ($\omega^2 = .17$) and medial parietal ROIs ($\omega^2 = .15$).

ERPs for Correctly Classified LURE Words

As an alternative measure of familiarity ERPs to old and new responses to LURE words were contrasted in the early time window (400-550 ms). LURE words that attract an old response should be more familiar than those that are rejected. Figure 4.3 displays the topographical distribution of the effect in the early time window and the ERP waveforms for a medial frontal electrode site (Fz).

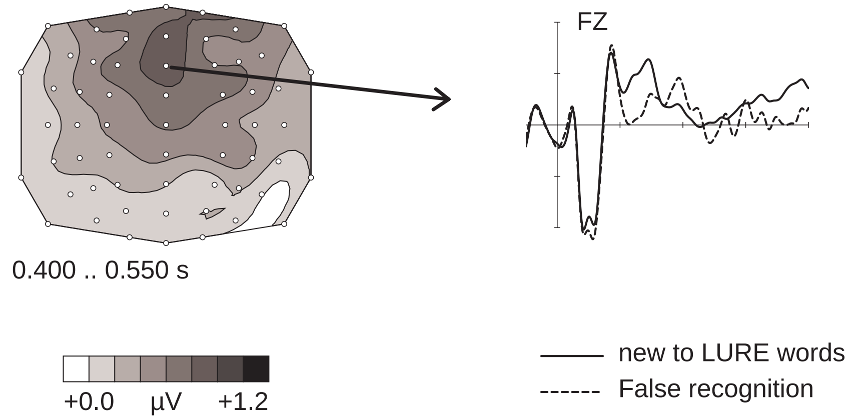

Figure 4.3: *Topographic distribution of the difference wave for ERPs to false recognitions and and new responses to LURE words in the early (400-550 ms) time interval (left). The corresponding ERPs are plotted for a middle frontal (Fz) electrode site (right).*

There was a marginally significant main effect of condition $(F(1,21) = 4.02, p < 0.1)$ and a significant condition x ROI interaction $(F(5,105) = 2.96, p < 0.05)$. ERPs to false recognition were more positive than ERPs to new responses to LURE words at the medial frontal ROI $(\omega^2 = .22)$ and at the right frontal ROI $(\omega^2 = .15)$. Analysis performed for the left frontal ROI showed a marginally significant effect $(\omega^2 = .09)$, while no difference at parietal locations was obtained.

In sum, differential recognition related brain activity for true and false recognition was found. While true recognition elicited an early frontal, an early parietal, as well as a late right frontal ERP old/new effect, for false recognition the analyses only revealed an early frontal ERP old/new effect and a late right frontal ERP old/new effect. Moreover, false recognition gave rise to a medial parietal negative slow wave in the late time window.

4.4 Discussion

The present study was performed to investigate whether words from different semantic categories are useful to study the false recognition phenomena. Electrophysiological correlates of true and false recognition were compared to study whether processes involved in both kinds of recognition are similar or different.

As suggested, false alarm rates were higher to semantically related words (LURE) than to words from non-studied categories (NEW) indicating that the materials are useful to examine semantic false recognition. In contrast to prior studies performed with the Deese lists, which often report nearly identical rates of true and false recognition (e.g., McDermott, 1996; Johnson et al., 1997), rates of false recognition were smaller than rates of true recognition. This result replicates prior studies performed with categorical materials (e.g., Seamon et al., 2000). It is suggested that smaller rates of false recognition in categorical lists compared to the Deese lists reflect the different semantic relations between the words in both paradigms (for the influence of strength of semantic relation, e.g., Robinson & Roediger, 1997). In the Deese paradigm, OLD words of each list were chosen due to their associative relation to the LURE words, which are the theme words in each list. In categorical lists, OLD and LURE words were chosen due to their semantic relation to the category name, which is the theme in these lists. Consequently, LURE words in categorical lists should be signed by smaller typicality for the theme than the LURE words from the Deese lists and this should be reflected by smaller rates of false recognition. However, the important benefit of using words from different categories is that OLD and LURE words share similar characteristics. This means that OLD and LURE words have similar relations to other words from the respective list. This is not given in the lists of the Deese paradigm where OLD words were choosen due to their relation to the critical LURE word but not due to their relation among each other.

In sum, different semantic categories are shown to be suitable to study electrophysiological correlates of true and false recognition. Although rates of false recognition are smaller for the categorical materials than for the Deese lists, reliable false recognitions are elicited. Finally, the rate of false recognition is high enough to obtain reliable ERPs.

All prior ERP studies examining semantical false recognition used the word lists from the Deese paradigm and reported similar ERPs for true and false recognition. The present study shows that the use of words from different semantic categories results into different ERPs. While for true recognition an early frontal, an early partietal, as well as a late right frontal ERP old/new effect were obtained, only a small early frontal ERP effect as well as a late right frontal ERP effect were found for false recognition. The early frontal ERP effect to false recognition may indicate that false old responses to LURE words occurred as a result of an illusory feeling of familiarity. This was supported by an additional analysis revealing more positive going waveforms for false recognition than for new responses to LURE words. LURE words were judged as old if they elicited a feeling of familiarity. However, if LURE words elicited no feeling of familiarity, then they were judged as new. The absence of a parietal ERP old/new effect for false recognition indicates that recollection did not occur for LURE words. This is in line with the fact that LURE words were not studied before. However, some authors has been suggested that LURE words could be activated via spreading activation, may it be conscious or unconscious (cf. Underwood, 1965; Schacter et al., 1998a, see also Chapter 2). It is assumed that such an activation in encoding could lead to memory traces for LURE words. This could explain similar ERP waveforms found for true and false recognition in prior studies with the Deese paradigm (Düzel et al., 1997; Johnson et al., 1997). However, as indicated by the absence of a parietal ERP old/new effect for false recognition, there was no evidence for recollection processes in the present study. That may be associated with the differential semantic relation between OLD and LURE words in both paradigms. LURE words in the Deese paradigm are more typical for the studied theme than LURE words in different categories. It may be that activation in encoding does only occur for words with high semantic relations, i.e., only for

LURE words from the Deese paradigm. Another possibility for the failure to find parietal old/new effects for false recognition might be related to the numbers of the different item types. As shown in Figure 4.2 there appeared a large positive peak for NEW words at parietal locations. In the present experiment only small numbers of non-studied words from non studied categories (NEW words) were used; 10 words from each of 5 categories. In the context of 10 words from each of 25 semantic categories, which were used as OLD and LURE words, it might be that NEW words behave like deviants in an Oddball paradigm and elicited a related P300 effect that overlayed a parietal recollection effect for LURE words (for an overview about cognitive processes which are assumed to be related with the P300 see Donchin et al., 1997; Opitz, 1999).

Furthermore, a late right frontal ERP old/new effect was found for true as well as for false recognition. Although the occurrence of the late frontal positivity is assumed to reflect retrieval-related processes, there is no consensus about the exact functional interpretation up to now (cf. section 3.2.2). It has been claimed that the effect is related to retrieval success (e.g., Wilding & Rugg, 1997) or to retrieval effort (e.g., Ullsperger et al., 2000). However, in the present study the effect occurred for true and false recognition. OLD and LURE words share semantic features they are both words from a studied category. Consequently, a possible interpretation of the effect might be that it reflects one kind of processing of the studied theme.

In sum, it was shown that categorical materials can be used to examine semantic released false recognition. The categorical paradigm is assumed to be more useful than the Deese paradigm to examine processes involved in memory distorsions because it overcomes some critical points stated for the Deese lists. Furthermore, differences for electrophysiological correlates of true and false recognition were found. While both kinds of recognition elicited early frontal ERP old/new effects, which reflect familiarity assessment, a parietal ERP old/new effect was only found for true recognition. This seems to indicate that recollection processes, which are associated with the parietal ERP old/new effect, occurred for true recognition only. However, it cannot be ruled out that this result is influenced by a large P300 Oddball effect for NEW words due to the small probability for this word type.

To overcome this possible P300 Oddball effect for NEW words word type frequencies were changed in Experiment 2 described in the next Chapter. The results of this follow-up experiment led in turn to hypotheses about the influence of encoding processes on the electrophysiological brain activation patterns for false recognition. These hypotheses were tested in Experiment 3 also described in Chapter 5. An article about Experiment 2 and 3 is published in Cognitive Brain Research (Nessler, D., Mecklinger, M. & Penney, T.B. (2001). Event-related brain potentials and illusory memories: The effects of differential encoding. Cognitive Brain Research, 10, 283-301.). The Chapter 5 contains this article. For stylistic reasons the format, the tables, and the figures were adapted.

Chapter 5

Effects of Differential Encoding

5.1 Abstract

This study[1] investigates event-related potentials (ERP) elicited by true and false recognition using words from different semantic categories. In Experiment 2, ERPs for true and false recognition were more positive than for correctly rejected NEW words starting around 300 ms after test word presentation (old/new ERP effects). ERP waveforms for true and false recognition revealed equal early (300-500 ms) fronto-medial old/new ERP effects, reflecting similar familiarity processes, but smaller parietal old/new ERP effects (500-700 ms) for false relative to true recognition, suggesting less active recollection. Interestingly, a subsequent performance based group comparison showed equivalent old/new ERP effects for true and false recognition for participants with high rates of false recognition. In contrast, false recognition failed to elicit an old/new ERP effect in a group with low false recognition rates. To examine whether this between group difference

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[1] The Chapter contains the following article: Nessler, D., Mecklinger, M. & Penney, T.B. (2001). Event-related brain potentials and illusory memories: The effects of differential encoding. Cognitive Brain Research, 10, 283-301; For stylistic reasons the format was adapted. Note, that the first Experiment presented in the article is labeled here ’Experiment 2’ and the second experiment presented in the article is labeled here ’Experiment 3’ to be consistent in terms of the present work.

was driven by the differential use of information that studied words and semantically related non-studied test words (LURE) have in common (conceptual similarity), we manipulated encoding strategy in Experiment 3. When encoding focused on conceptual similarity, comparable ERP effects for true and false recognition were obtained, suggesting that both forms of recognition were equally based on familiarity and recollection processes. Conversely, when encoding was focused on item specific features, differences in brain activity for true and false recognition were obtained. The ERP data indicate that, in addition to the false recognition rate, strategic processes during encoding, such as processing conceptual features, are an important factor in determining electrophysiological differences between true and false recognition.

5.2 Introduction

The act of remembering is the outcome of multiple, fundamentally reconstructive, component processes (for an overview see Reyna & Lloyd, 1997; Schacter et al., 1998a). These processes include inferences drawn on the basis of feelings of familiarity elicited by a stimulus as well as the active recollection of a memory trace (e.g., Mandler, 1980; Strack & Bless, 1994). Although the majority of memory studies have focused on whether or not studied items are accurately recalled or recognized, more recently the investigation of memory illusions, so called false memories, has received increased attention. In the typical laboratory study of false memory, participants learn lists of associate words of a non-presented word, the so called LURE word. The critical finding, replicated many times (e.g., McDermott, 1996; Payne et al., 1996; Read, 1996), is that in a subsequent recall or recognition test, participants falsely recall or recognize the LURE words at a much higher rate than words unrelated to the study lists.

One explanation of false recognition holds that it is due to a feeling of familiarity and is not due to the active recollection of a memory trace. According to this explanation, LURE words feel familiar and are judged old because they are broadly consistent with the conceptual features that were studied; they largely match the overall themes of words encountered in the study phase (Schacter et al., 1998a; Schacter, Isreal & Racine, 1999)[2]. Support for this view comes from studies showing that more sensory and distinctive details (item specific memory traces) are retrieved for true than for false recognition (McDermott, 1997; Norman & Schacter, 1997, Mather et al., 1997; see also Schacter et al., 1999).

An alternative explanation suggests that the false memory phenomen is based on both inferences drawn on the basis of feelings of familiarity and the active recollection of a memory trace. According to this model, the non-studied LURE words are activated, and hence memory traces formed, during study of the associated words via spreading activation through the mental lexicon (e.g., Collins & Loftus, 1975; Underwood, 1965). For example, studying words like *butter* or *sandwich* could lead to the activation of the word *bread*. In the test phase, participants may correctly recognize *butter* as a studied word but may also falsely recognize a LURE word like *bread* because it was also activated during study. Consequently, in this model, false recognition results from feelings of familiarity that arise due to conceptual similarities between OLD and LURE words and from prior activation in the study phase with a failure to attribute that activation to its correct source (Gallo et al., 1997; Johnson & Raye, 1981; Johnson et al., 1993). Support for this view is provided by Roediger and McDermott (1995). They required participants to indicate whether an old response was based on consciously recollected aspects of prior experience, i.e. a memory trace ('Remember' response), or merely on the belief that a test word had occurred in study without any recollection of the specific study episode, i.e. familiarity ('Know' response). Importantly, 'Remember' response rates following true and false recognition were equal, indicating that participants used similar information for true and false recognition (for similar results see also Payne et al., 1996).

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[2] The label ”conceptual similarity”is used to indicate overlapping conceptual information, i.e. information which is common for some items.

Event-related potentials (ERPs) can provide an additional source of information about whether the cognitive processes involved in true and false recognition are the same or different. This is because the timing and scalp topography of particular ERP components allows inferences about the timing and nature of cognitive processes underlying recognition memory judgments to be made (e.g., Donchin et al., 1997; Johnson, 1993; Rugg & Coles, 1995). In the case of studies of false recognition the reasoning is that if the same cognitive processes underlie true and false recognition, then the ERP patterns elicited should be the same. Indeed, Johnson et al. (1997) and Düzel et al. (1997) found equivalent ERPs for true and false recognition when a random word order test presentation was used, suggesting that true and false recognition engage the same neural and cognitive processes. Assuming that both familiarity and active recollection processes underlie true recognition in their experiments, then these results are consistent with the view that both processes also underlie false recognition.

However, both of these ERP studies used word lists from the false memory paradigm introduced by Deese (1965) . In this paradigm, the LURE words are theme words (e.g., *sweet*) that are more highly associated with the studied words (e.g., *candy, sour*) than the studied words are to each other (for a critical discussion of the Deese paradigm see Miller & Wolford, 1999; Rubin et al., 1999). Consequently, a difficulty with this paradigm is that it may enhance activation of LURE words via associative mechanisms in the encoding phase, leading to equivalent activation for LURE and studied words. This, in turn, could result in equivalent ERP waveforms for true and false recognition. Given this possibility, the goal of the present study was to determine whether OLD and LURE words elicited equivalent ERPs when the LURE words were equivalently related to a studied theme as were the OLD words. As the ERP data were analysed within a theoretical framework based on ERP studies of true recognition a brief description of the evidence for this framework follows.

True recognition elicites more positive ERP waveforms than correctly rejected NEW words in explicit old/new recognition tests (for reviews see Johnson, 1995;

Rugg, 1995b). These ERP old/new effects have a broad temporal and spatial distribution and can be decomposed into at least three spatio-temporally specific effects (cf. Friedman & Johnson, 2000; Mecklinger, 2000) that are associated with distinct cognitive processes underlying true recognition. These effects are an early fronto-medial old/new ERP effect, a somewhat later parietal old/new ERP effect and a late right frontal old/new ERP effect.

The fronto-medial focused positivity starts around 300 ms and lasts approximately 200 ms. This early old/new effect is assumed to arise from the attenuation of a frontally focused N400-like component that occurs because access to conceptual and perceptual information related to the test word is facilitated (Curran, 1999, 2000; Johnson et al., 1998; Mecklinger, 1998; Mecklinger & Meinshausen, 1998, Penney, Mecklinger, Hilton & Cooper, 2000) and results in a feeling of familiarity (Mecklinger, 2000). That the effect is not driven by active recollection of item specific information is supported by its insensitivity to depth of processing manipulations (Rugg et al., 1998a).

The second positive deflection, maximal at parietal locations, starts around 400 ms and lasts for several hundred milliseconds. This parietal old/new ERP effect, which is usually left lateralised or bilateral shows larger amplitudes for deeply than for shallowly encoded items (e.g., Paller, Kutas & McIsaac, 1995; Ullsperger, Mecklinger & Müller, 2000). Consequently, a relation to consciously controlled recollection of item specific information from the study phase is assumed (Düzel et al., 1997; Paller & Kutas, 1992; Smith, 1993; Wilding & Rugg, 1996, see Johnson, 1995; Rugg, 1995b for reviews).

Third, a late right frontal old/new effect, which onsets around 800 ms, but is sustained longer in time than the ERP effects described above, has also been reported (Allan et al., 1998; Mecklinger & Meinshausen, 1998; Wilding & Rugg, 1996). At present there is no consensus on its precise functional significance (cf. Friedman & Johnson, 2000; Mecklinger, 2000). Although a relation to recognition related processes is assumed, sometimes the effect is present for NEW words (e.g., Ranganath & Paller, 1999), suggesting that the late right frontal positivity also reflects general task related processes (see also Düzel et al., 1999).

In the present study, if false recognition is based on both familiarity and active recollection, then the ERP waveforms for true and false recognition are expected to be equivalent. More specifically, relative to new responses of NEW items true and false recognition are expected to elicit early fronto-medial old/new ERP effects and parietal old/new ERP effects. If, however, false recognition is based only on familiarity, then it will fail to elicit a parietal old/new effect.

5.3 Experiment 2

5.3.1 Methods

Participants

Twenty-two volunteers (13 female) between 19 and 28 years of age (mean 23 years) participated. They were students at the University of Leipzig, were right-handed, and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h for their participation. None of the participants had prior experience with the task.

Experimental Material

Stimuli consisted of 300 German nouns taken from a categorical word pool. This pool was created in a categorical noun generation experiment performed with 139 undergraduate students at the University of Leipzig (107 female), between 18 and 34 years old (mean = 22) (for details see Ullsperger et al., 2000). The present experiment used 30 categories, and the exemplars for each category were selected so that the mean word typicality of the 10 category examples was similar across the categories. The words were used to construct 3 randomised study-test-lists, which were balanced across participants. Each study list comprised 90 words and contained 5 members from each of 18 categories. Each test list consisted of these

90 studied words (OLD), the remaining 90 non-studied words from studied categories (LURE) and 120 NEW words drawn from the 12 non-studied categories. To increase the likelihood of false alarms to LURE items, these words were always drawn from the seven most typical words of each category.

Procedure

The participants were seated comfortably in an acoustically and electrically shielded dimly lit chamber in front of a 17” computer monitor. They sat at a distance of about 100 cm from the screen and during the test phase they held a small response box on their lap. Each participant performed one session consisting of a study and a test phase that were separated by a visuo-motor tracking task of 10 minutes duration. Participants were told that they would hear a tape recorded wordlist and that later they would be asked to recognise the words. In the study phase, participants heard 90 words in a female voice (five nouns from each of 18 categories). The name of a word category appeared on the screen for 2400 ms and was followed by a delay of 1600 ms. Next, the five nouns from the category were played at a rate of one every two seconds. Prior to the test phase, participants performed the tracking task. In the recognition test, the items were presented visually in a quasi random order with the constraint that no more than 3 words of the same type (OLD, NEW, LURE) were presented consecutively. Each test trial started with a fixation cross in the middle of the screen. After 100 ms the screen went blank for 500 ms and then the word was presented visually for 200 ms. The next trial started after a delay of 2800 ms (blank screen) during which participants were required to indicate as quickly and as accurately as possible whether the presented word was heard in the study phase (old response) or not (new response). They responded by pressing the left or the right button of the response box with the thumb of the corresponding hand. The response button used for old responses was counterbalanced across participants. After 150 items the participants were given a short break. Including electrode application and removal each session lasted about 1.5h.

ERP Recording

The EEG activity was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electrocap International) from 61 scalp sites of the extended ten-twenty system. Electrode labelling was based on the standard nomenclature (Sharbrough et al., 1990). The ground electrode was positioned 2cm to the right of Cz. The vertical Electro-oculogram (EOG) was recorded from electrodes located above and below the right eye. The horizontal EOG was recorded from electrodes positioned at the outer canthus of each eye. Electrode impedance was kept below 5 kOhms. The right mastoid was recorded as an additional channel. All scalp electrodes were referenced to the left mastoid and were offline re-referenced to both mastoids. EEG and EOG were recorded continuously with a band pass from DC to 30 Hz and were A-D converted with 16 bit resolution at a sampling rate of 250 Hz.

Data Analysis

Behavioral Data Reaction time was defined as the interval between the appearance of the test item and the participant’s keypress. Data were averaged separately for each response condition.

ERP Data In the test phase, ERPs were computed for each participant at all recording sites with epochs extending from 200 ms before onset of word presentation until 2000 ms thereafter. ERPs were selectively averaged for the following combinations of item types and responses: old responses of OLD words (true recognition), old responses of LURE words (false recognition), new responses of LURE words, and new responses of NEW words. Because there were too few old responses to NEW items and too few new responses to OLD items to form reliable ERPs, these conditions were excluded from further analyses.

The average voltages in the 200 ms preceding stimulus presentation served as a baseline. Prior to averaging, each epoch was scanned for EOG and other artefacts. Whenever the standard deviation in a 200 ms time interval exceeded 30 μV in an EOG channel or 40 μV in the Pz channel the epoch was rejected. In a second step, the EEG epochs were visually scanned for further artefacts. The averages were lowpass filtered below 10 Hz in order to increase the signal-to-noise ratio by eliminating those frequencies that were irrelevant to the measurements of interest (Picton et al., 2000). Because some of the ERP components were not clearly visible as peaks at all electrode sites, mean amplitude measures were considered more reliable for component scoring than peak measures (Hoormann, Falkenstein, Schwarzenau & Hohnsbein, 1998). In order to avoid a loss of statistical power that is implicated when repeated-measures ANOVAs are used to quantify multi-channel and multi-time window data (Gevins, Cutillo & Smith, 1995 Gevins et al., 1996; Oken & Chiappa, 1986), electrode sites were pooled to six topographical regions, so called *regions of interests* (ROI). The following regions were defined: left frontal (F9, AF7, F7, F5, FT9, FT7, FC5); medial frontal (AFz, AF3, AF4, Fz, F3, F4, FCz); right frontal (F10, AF8, F8, F6, FT10, FT8, FC6); left parietal (TP9, TP7,CP5,P9, P7, P5, PO7); medial parietal (CPz, Pz, P3, P4, PO3, POz, PO4); and right parietal (TP10, TP8, CP6, P10, P8, P6, PO8). According to Homan, Herman and Purdy (1987), who established a correspondence between electrode site and underlying cerebral structures using radiographic techniques, the medial frontal region is approximately over the middle frontal gyri (Brodmann area BA 46). The left and right frontal regions are approximately over the inferior frontal gyri (BA 45 on the left and BA 46 on the right). The left and right parietal regions cover approximately the posterior part of the middle temporal gyri and the anterior occipital sulcus (BA 19, 37), whereas the medial parietal region is approximately over the occipital gyri and the superior parietal lobe.

For statistical analysis, a hypothesis-driven approach was chosen. Based on prior studies examining ERPs in explicit recognition memory tasks (e.g., Curran, 1999; Rugg et al., 1998a, cf. also Mecklinger, 2000), three different time windows were used for the quantification of the ERP effects. The early frontal old/new effect was examined in a time window between 300 and 500 ms, the parietal old/new effect was expected to be maximal between 500 and 700 ms, whereas the late right frontal old/new effect was examined between 1200 and 1600 ms. For each time window we first tested whether true recognition elicited old/new effects. ERP measures were subjected to a two-way repeated-measures ANOVA with the factors Condition (2 levels: true recognition, new responses of NEW words) and ROI (6 levels: left frontal, medial frontal, right frontal, left parietal, medial parietal, right parietal). Using the same ANOVA design, we next tested whether false recognition elicited similar old/new effects. Second, ERP differences between the old/new effects for true and false recognition were examined in an additional two-way repeated-measures ANOVA (factors: Condition (2 levels: true recognition minus new responses of NEW words, false recognition minus new responses of NEW words); ROI (6 levels)), separately for the time windows. In order to test whether the old/new effects differed topographically, the same repeated measure two-way ANOVA was conducted on the difference waves after they had been rescaled such that amplitude differences between the two contrasted conditions were removed (McCarthy & Wood, 1985).

In an additional analysis procedure, we directly contrasted brain activity elicited by new and old responses of LURE words using a two-way repeated-measures ANOVA (factors: Condition type (2 levels: false recognition, new responses of LURE words); ROI (6 levels)) for the early time window (300-500 ms).

In order to avoid reporting large amounts of statistical results not relevant for the issues under investigation, only main effects or interactions including the Condition factor are reported. In the case of significant interactions involving this factor, one-way ANOVAs with the factor Condition were performed to examine the effects of this factor in each of the topographical regions. Measures of treatment magnitude (ω^2, cf. Keppel, 1991) for the single effects are reported in combination with main effects of Condition. All effects with more than one degree of freedom in the numerator were adjusted for violations of sphericity according to the Greenhouse and Geisser formula (Greenhouse & Geisser, 1959). Scalp potential topographic maps were generated using a two-dimensional spherical spline interpolation (Perrin et al., 1989) and a radial projection from Cz, which respects the length of the median arcs.

5.3.2 Results

Behavioral Data

Mean reaction times and proportion of old responses to OLD, LURE, and NEW words are presented in Table 5.1. Participants showed more false alarms to LURE words (false recognition) than to NEW words. Further, correct responses were faster for OLD and NEW words than for LURE words.

Table 5.1: *Mean reaction times (in ms) of the old and new responses, and mean proportion (in %) of the old responses for the different item-types in Experiment 2. The standard error of the mean is presented in parentheses.*

Item	**Response**	**Reaction time**	**Proportion old-response**
OLD	old	914 (35)	77.8 (2.8)
	new	1129 (71)	
LURE	old	1132 (53)	26.4 (2.9)
	new	1064 (54)	
NEW	old	1163 (68)	5.3 (1.4)
	new	930 (43)	

This pattern of results was confirmed by statistical analyses. A repeated-measures ANOVA for the proportions of old responses (3 levels) revealed reliable differences between the three item types $(F(2,42) = 249.05, p < .001)$. Separate tests showed that LURE words elicited more false alarms than NEW words $(F(1,21) = 90.17, p < .001)$, and that the rate of old responses of OLD words (true recognition) was higher than the rate of old responses of LURE words (false recognition) $(F(1,21) = 165.88, p < .001)$. Reaction times for the four response categories relevant for the ERP analyses (true recognition, false recognition, new responses of LURE words, new responses of NEW words) were significantly different as revealed by a one-way repeated measures ANOVA $(F(3,63) = 27.71, p < 0.001)$. Separate tests showed that participants responded faster to OLD and NEW words than to LURE words.

ERP Data

ERP old/new Effects to OLD and LURE Words Figure 5.1 displays the ERP waveforms at two midline electrodes and at lateral frontal and parietal recording sites elicited by true recognition, false recognition, and new responses of NEW words.

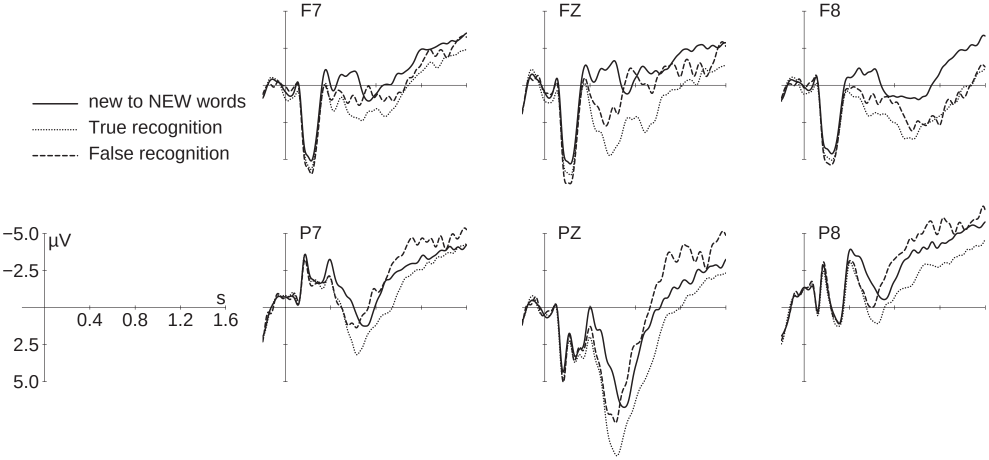

Figure 5.1: *ERPs elicited by true recognition, false recognition, and correct rejections to NEW words at left frontal (F7), middle frontal (Fz), right frontal (F6), left parietal (P7), middle parietal (Pz), and right parietal (P8) electrode sites.*

Starting at around 300 ms the waveform elicited by *true recognition* was more positive than that for NEW words. This old/new ERP effect appeared first at frontal locations and extended to parietal locations somewhat later. From around

800 ms until the end of the recording epoch the old/new effect was maximal at right frontal locations. Similar positive ERP differences relative to NEW words were also obtained for *false recognition*, but the old/new effect between 400 and 800 ms was less pronounced than for true recognition. Notably, for false recognitions only, there was a negative component over bilateral parietal locations. It started around 900 ms and extended until the end of the recording epoch over parietal locations.

The results of the two-way ANOVAs with factor condition and ROI for (a) true recognition and new responses of NEW words and (b) false recognition and new responses of NEW words are displayed in Table 5.2.

Table 5.2: *ANOVA results (F-values) for the old/new ERP effects to true and false recognition in the three time windows in Experiment 2.*

		True recognition		
	df	300-500 ms	500-700 ms	1200-1600 ms
Cond	1.21	40.56***	62.54***	11.49**
Cond x ROI	5.105	3.81*	6.73**	3.85*
		False recognition		
Cond	1.21	5.61*	8.20**	0.50
Cond x ROI	5.105	0.58	2.31(*)	7.68***

Note: Cond = Condition. df = degrees of freedom. ROI = regions of interest. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; (*) $p < 0.1$.

In the early time window (300-500 ms), for both true and false recognition, there were significant main effects of Condition. Based on the significant Condition x ROI interaction for true recognition, seperate tests were performed for the different ROIs. For true recognition, there were significant old/new effects for all six ROIs, but the medial frontal ROI showed the highest treatment magnitude $(\omega^2 = .65)$. In the middle time window (500-700 ms), analyses of true and false recognition revealed significant main effects of Condition as well as a significant Condition x ROI interaction for true recognition and a marginally significant interaction for false recognition. For true recognition, all ROIs showed significant old/new effects, but the treatment magnitude, even though quite large at the medial frontal ROI $(\omega^2 = .71)$, was largest at the medial parietal ROI $(\omega^2 = .72)$. However, for false recognition separate tests for single ROIs revealed a larger old/new effect at the medial frontal $(\omega^2 = .32)$ than at the medial parietal ROI $(\omega^2 = .24)$. As is evident from Table 2, ANOVAs in the late time window (1200-1600 ms) revealed a significant main effect of Condition as well as a significant Condition x ROI interaction for true recognition. There was only a Condition x ROI interaction for false recognition. For true recognition, separate tests for the different ROIs showed more positive ERPs at the medial frontal $(\omega^2 = .38)$, the right frontal $(\omega^2 = .38)$ and the right parietal ROI $(\omega^2 = .28)$. For false recognition, ERPs were more positive at the medial frontal $(\omega^2 = .13)$ and the right frontal $(\omega^2 = .29)$, but more negative at the medial parietal ROI $(\omega^2 = .14)$.

Topographic Analyses of old/new Effects For the present study it was of major relevance to directly compare the amplitude differences and topographical distributions of the old/new effects elicited by true and false recognition. For this reason, ANOVAs were performed on the difference measures (true recognition minus new responses of NEW words; false recognition minus new responses of NEW words) for raw data and amplitude normalised data (McCarthy & Wood, 1985). The scalp topographies of the old/new effects elicited by OLD and LURE words are depicted in Figure 5.2.

There was no difference between the old/new effects elicited by the two forms of recognition in the early time window (300-500 ms) as the ANOVA showed no significant main effect $(F(1,21) = 1.39)$ or interaction $(F(5,105) = 0.34)$. In the

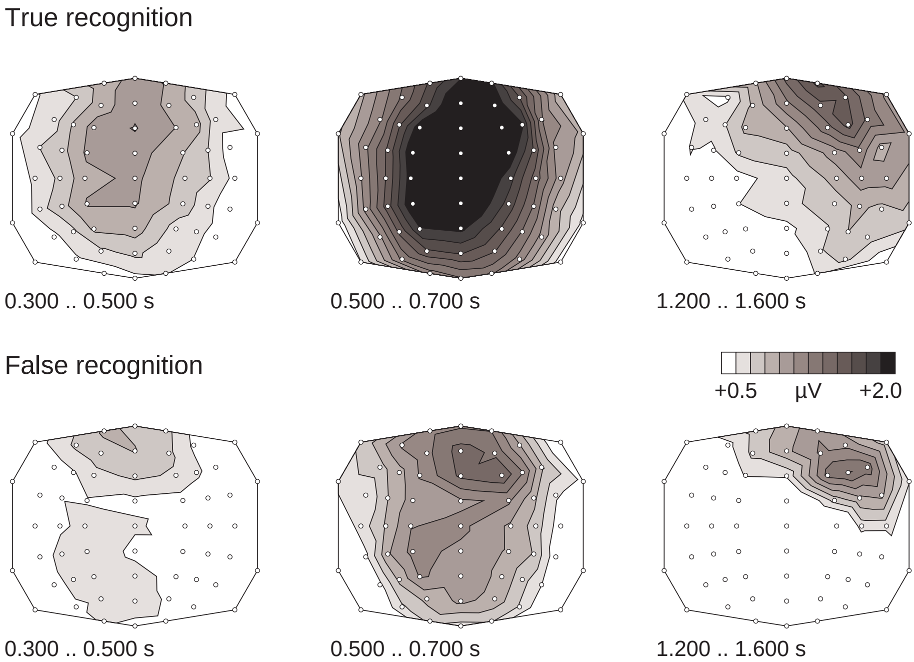

Figure 5.2: *Topographic distributions of the difference waves for ERPs to true recognition and new responses to NEW words, and to false recognition and new responses to NEW words in the early (300-500 ms), middle (500-700 ms), and late (1200-1600 ms) time interval in Experiment 2.*

middle interval there was a main effect of Condition $(F(1,21) = 5.47, p < 0.05)$, indicating larger effects for OLD words. The ANOVA performed on amplitude normalised data revealed no significant Condition x ROI interaction $(F(5,105) = 2.25, p > 0.05)$, suggesting that the topographical distributions were the same for true and false recognition. To compare the magnitude of the late frontal effect in both recognition conditions, we restricted the analyses to frontal locations. There was no difference between the old/new effects elicited by both recognition forms, as the ANOVA performed for difference waves showed no significant main effect $(F(1,21) = 0.87)$ or interaction $(F(2,42) = 0.06)$.

ERPs for Correctly Classified LURE Words As an alternative measure of familiarity, we further contrasted old and new reponses to LURE words in the early time window (300-500 ms). LURE words that attract an old response should be more familiar than those that are rejected. Figure 5.3 displays the topographical distribution of the effect in the early time window. There was a significant main effect of Condition $(F(1,21) = 6.79, p < 0.05)$ indicating more positive ERPs for false recognition.

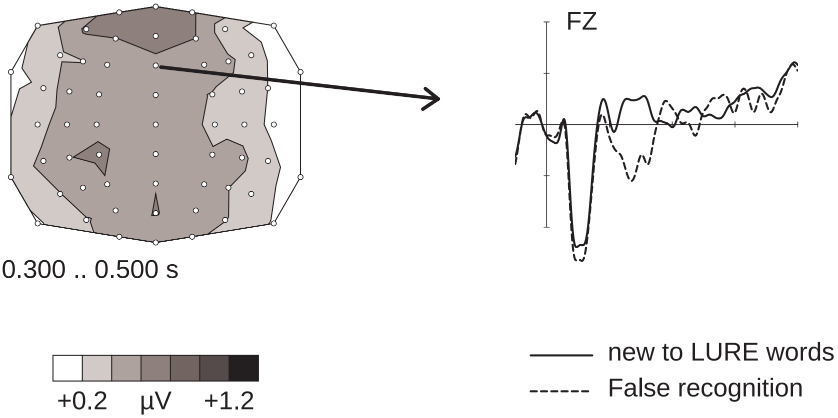

Figure 5.3: *Topographic distribution of the difference wave for ERPs to false recognitions and and new responses to LURE words in the early (300-500 ms) time interval (left). The corresponding ERPs are plotted for a middle frontal (Fz) electrode site (right).*

In sum, differential recognition related brain activity for true and false recognition was not obtained before 500 ms. While both forms of recognition elicited similar early old/new ERP effects, a positivity starting around 500 ms was significantly smaller for false recognition than for true recognition. Moreover, in a late time interval both recognition forms elicited a right frontal effect, while only false recognition gave rise to a medial parietal negative slow wave.

Effects of Different Rates of False Alarm to LURE Words The present study found dissociable brain activity for true and false recognition using OLD and LURE words from the same semantic categories in a random word order test

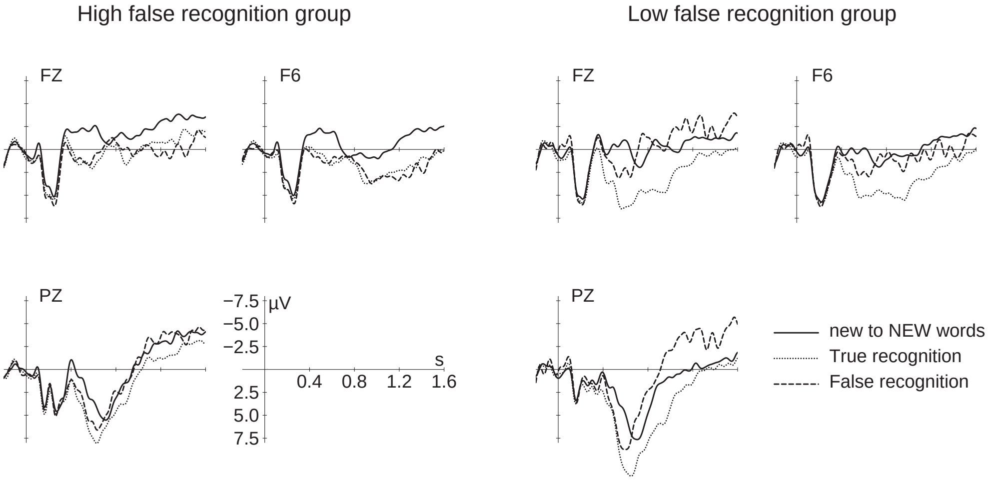

Figure 5.4: *ERPs elicited by true recognition, false recognition and new responses to NEW words for the group with high false recognition rates (left) and the group with low false recognition rates (right) in Experiment 2. To illustrate the three ERP old/new effects (cf. Mecklinger, 2000), middle frontal (Fz), middle parietal (Pz), and right frontal (F6) electrode sites were chosen.*

presentation, whereas prior ERP studies failed to find recognition related dissociations between true and false recognitions (Johnson et al., 1997; Düzel et al., 1997). These studies also reported higher rates of false recognition, 50% and 70% in the studies of Düzel et al. and Johnson et al., respectively, against only 26% false recognition in the present study. It is conceivable that the lower false recognition rate was responsible for the ERP differences obtained here.

To examine whether the lower error rates to LURE words in the present study caused the differential ERP patterns elicited by true and false recognition, we compared two groups of 10 participants each. Participants were assigned to the groups based on their false alarm rates to LURE words, i.e. a group of participants with high false recognition rates (mean rate of false recognition 38.5%) and participants with low false recognition rates (mean rate of false recognition 15.3%). If the similarity between brain activity elicited by true and false recognition memory is determined by false recognition rate, then ERPs elicited by true and false recognition should be more similar in the group with high false recognition rates than in the group with low false recognition rates.

Table 5.3: *ANOVA results (F-values) for the ERP old/new effects to true and false recognition in the three time windows, separately for the group with high false recognition rates (a) and the group with low false recognition rates (b) in Experiment 2.*

(a) Group with high false recognition rates

True recognition		df	300-500 ms	500-700 ms	1200-1600 ms
	Cond	1.9	8.70*	11.91**	2.64
	Cond x ROI	5.45	1.68	2.27	2.30
False recognition					
	Cond	1.9	3.61(*)	11.65**	3.64(*)
	Cond x ROI	5.45	1.97	3.48(*)	4.28*

(b) Group with low false recognition rates

True recognition		df	300-500 ms	500-700 ms	1200-1600 ms
	Cond	1.9	34.56***	99.37***	7.12*
	Cond x ROI	5.45	2.03	4.00(*)	1.62
False recognition					
	Cond	1.9	1.39	2.14	0.88
	Cond x ROI	5.45	0.17	0.54	3.33*

Note: Cond = Condition. df = degrees of freedom. ROI = regions of interest. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; (*) $p < 0.1$.

From Figure 5.4 it appears that for participants with high false recognition rates the ERPs for true and false recognition were highly similar, whereas for the group with low false recognition rates the ERPs for false recognition resemble those elicited by new responses of NEW words. This was confirmed by statistical analysis, as shown in Table 5.3. Old/new effects were elicited by true recognition for both groups, although the analysis did not reveal a late right frontal effect in the group with high false recognition rates. Further, there were old/new effects in all three time ranges for false recognition in the group with high false recognition rates, whereas no positive old/new effect appeared for false recognition in the group with low false recognition rates. Interestingly, there was a late negative deflection for false recognition at medial parietal locations in the group with low rates but not in the group with high false recognition rates.

5.3.3 Discussion

As expected, we found higher false alarm rates to non-studied, but semantically related, LURE words (false recognition) than to non-studied NEW words that were not members of studied categories. The proportions of false recognition found in Experiment 2 were lower than in studies performed with the Deese paradigm (e.g., Gallo et al., 1997; McDermott, 1996; Roediger & McDermott, 1995), but resemble those found in a behavioral study that also used categorical lists (Seamon et al., 2000). This outcome indicates that the strength of semantic relations between the studied (OLD) and LURE words influences the false recognition rate. The important issue here, however, is whether both familiarity and active recollection processes contributed to false recognition given the weaker semantic relations between studied and LURE words.

In contrast to prior studies (Düzel et al., 1997; Johnson et al., 1997), the initial analyses showed ERP differences between true and false recognition. While both forms of recognition elicited similar early fronto-medial old/new ERP effects, there was a smaller parietal old/new ERP effect for false than for true recognition between 500 and 700 ms.

As described in the Introduction, prior studies of true recognition suggest that the early frontal effect reflects facilitated access to conceptual information associated with a feeling of familiarity (Curran, 2000; Mecklinger, 2000). This old/new ERP effect was similar for true and false recognition, indicating that both forms of recognition were based on feelings of familiarity due to conceptual similarity. Further, more positive ERP waveforms for old than for new reponses to LURE words in this early time window indicate that semantically related words that attract an old response are more familiar than such words that elicit a new response.

While both explanations of false recognition presented in the Introduction make similar predictions about the involvement of familiarity inducing processes, they differ in their predictions about the involvement of recollection based processes. Whereas the first approach specifies only familiarity based false recognition, the second also includes recollection based processes. Given that the parietal ERP effect indicates active recollection of a memory trace (e.g., Mecklinger, 2000; Rugg, 1995b), there seems to be recollection based false recognition in the present study also. Analyses revealed significant old/new ERP effects at parietal locations for true and for false recognition in the middle time window (500-700 ms). Although this effect was smaller for false than for true recognition, the old/new ERP effects showed similar topographical distributions reflecting that the underlying neural activity had the same source and suggesting that the same cognitive processes were involved. However, the differenting strengths of the ERP effects suggests that less conscious recollection occured for false recognition. Therefore, true and false recognition are differentiated under testing conditions that involve similar semantic relations for OLD and LURE words.

Note, that this effect in the middle time interval was also pronounced at frontal locations, such that a contribution from the early frontal effect cannot be excluded. However, in contrast to true recognition the treatment magnitude measures for false recognition indicate larger old/new ERP effects at the medial frontal ROI than at the medial parietal ROI. This pattern further emphasizes that less conscious recollection occured for false than for true recognition.

Finally, both true and false recognition judgments showed more positive going waveforms than new responses of NEW words at right frontal locations in a late time window. Interestingly, there was a late bilateral parietal negative slow wave to false recognitions. The possible functional implications of both late effects are addressed in the General Discussion.

Overall then, it appears that false recognition arises from familiarity as well as active recollection processes. However, in contrast to prior ERP studies which reported no differences in brain activity for true and false recognition (Düzel et al., 1997; Johnson et al., 1997), differential ERP patterns were observed in this study. Smaller parietal ERP old/new effects for false than for true recognition indicate that false recognition is based to a lesser extent on recollection processes than is true recognition in a paradigm where LURE and OLD words have symmetric semantic relations. Consequently, the degree of recollection seems to be overestimated for false recognition in prior ERP studies with the Deese paradigm (Düzel et al., 1997; Johnson et al., 1997), due to the higher associative relation between LURE words and studied words than between the studied words (cf. Miller & Wolford, 1999; Rubin et al., 1999).

However, an alternative explanation is that the ERP differences between true and false recognition in the present study were due to the low rate of false recognition relative to earlier studies (e.g., Gallo et al., 1997; Payne et al., 1996). Indeed, this interpretation is supported by the finding that a subgroup of participants with high false recognition rates showed equal old/new ERP effects for true and false recognition, whereas the low false recognition group failed to show old/new effects for false recognition.

Because the ERP results for the group with high false recognition rates resemble the ERP results reported for the Deese paradigm, the semantic relations of LURE words are not sufficient to explain the similarity in brain activity. The group with high false recognition rates showed similar fronto-medial as well as similar parietal ERP effects for true and false recognition indicating that both forms of recognition are based on familiarity and recollection processes to the same extent, and could not be differentiated. This was not true for participants with low false recognition rates, where ERPs for false recognition showed no old/new ERP effect at all. A possible explanation is that individual differences in encoding strategy are responsible for the obtained ERP results. In the Deese paradigm, all OLD words in one list are related to a LURE word and, consequently, support activation of this LURE word via spreading activation during encoding. When OLD and LURE words are equivalently related OLD words should provide less semantic activation of LURE words and activation via associative mechanisms during encoding should be smaller. However, activation could be forced if participants focused attention on categorical features, i.e. the information that OLD words have in common (conceptual similiarity). Perhaps such an encoding strategy was used by participants in the high false recognition group, whereas participants in the low false recognition group did not focus on conceptual similiarity but memorized item specific features.

A second experiment was performed in order to examine this issue. We directly manipulated encoding strategy by requiring participants to focus either on conceptual similiarity, i.e. categorical information, or item specific features. In the Category Group participants were required to assign words to a specific category (e.g., *teacher* to *profession*), whereas participants in the Item Group judged whether study words were animate or inanimate. The rationale behind this manipulation was that the Category Group would use conceptual similarity to a higher degree than the Item Group, whereas recognition judgments would be based more on item specific memory traces in the Item Group than in the Category Group. Focusing on categorical information (Category Group) was expected to heighten activation via associative mechanisms in study and consequently recollection based false recognition in the test phase. Further, focusing on categorical information was expected to support also familiarity based false recognition. Consequently similar old/new ERP effects for true and false recognition were expected in this group. The animacy judgement to each study word in the Item Group was expected to lead participants to think more about the concepts themselves and consequently activate item specific information to a higher extent than participants from the Category Group. An attentional focus on item specific features was not expected to support familiarity or recollection based false recognition. Consequently, neither an early fronto-medial nor a parietal ERP old/new effect for false recognition was predicted for this group.

5.4 Experiment 3

5.4.1 Methods

Participants

Thirty-six volunteers (25 female) participated in the experiment. They were students at the University of Leipzig, were between 20 and 32 years of age (mean: 23 years), were right handed and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h. None of the participants had any prior experience with the task.

Stimuli and Procedure

A schematic view of the study and the test phase in Experiment 3 is given in Figure 5.5. We used the same word list as in Experiment 2. In the study phase, Category Group participants assigned words to a specific category, while participants in the Item Group judged whether words represented animate or inanimate objects. The nouns were presented in random order at a rate of one word every 5000 ms. At the beginning of each study trial, a fixation cross appeared in the middle of the screen and 500 ms later there was an auditory word presentation. After another 2000 ms two names of categories were presented on the screen (left and right sides) for the Category Group. In the Item Group the words *belebt* (Engl. living) and *unbelebt* (Engl. non-living) appeared on the screen (also left and right sides and changing locations for each study trial). After the participant responded with a left or right button press, the screen went blank. Participants had 2500 ms to make this decision before the next trial started. The recognition test was the same for both groups and was the same as Experiment 2 with one exception. Participants additionally indicated their confidence for each old/new response. After the response delay (2800 ms) *sicher* (Engl. certain) and *unsicher* (Engl. uncertain) appeared on the screen (left and right side but in the same location for all test trials and counterbalanced across participants) and participants pressed the appropriate button. After the response, the screen went blank and 2200 ms after the confidence decision prompt the next test trial started. Each trial lasted 5800 ms.

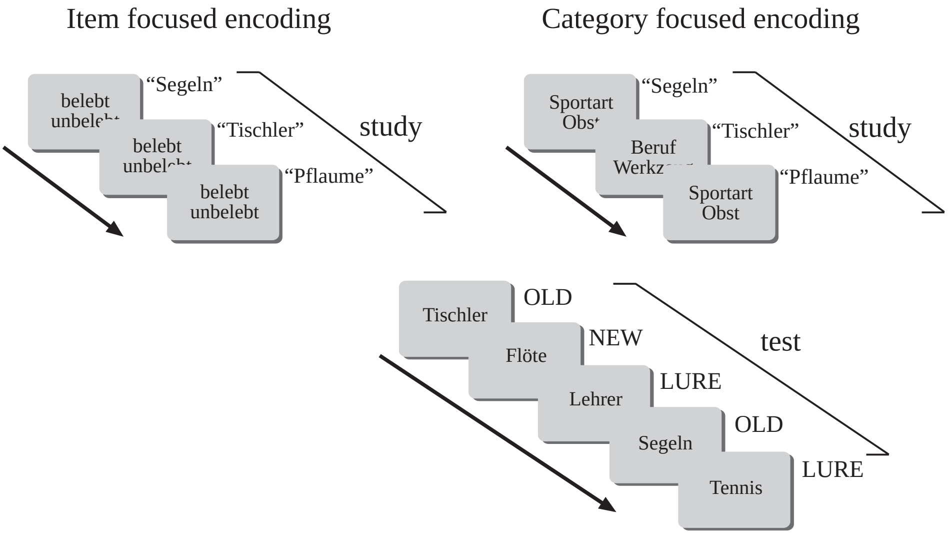

Figure 5.5: *Schematic view of the study and the test phase in Experiment 3. A detailed description is given in the text.*

ERP Recording and Data Analysis

The procedure for EEG recording and data analysis was the same as in Experiment 2. Additionally, behavioral data were also examined for effects of confidence. This was not possible for the ERPs as, depending on condition, there were too few high or low confidence judgments to form reliable ERPs.

5.4.2 Results

Behavioral Data

The proportion of old responses, mean reaction times, and the proportion of high confidence ratings for the Category Group (a) and the Item Group (b) are displayed in Table 5.4.

Table 5.4: *Mean reaction times (in ms) of the old and new responses, mean proportion (in %) of the old responses, mean proportion (in %) of the high confidence responses for: (a) the Category Group; and (b) the Item Group in Experiment 3. The standard error of the mean is presented in parentheses.*

Item	**Response**	**Reaction time**	**Proportion old response**	**Proportion high confidence**
(a) Category Group				
OLD	old	1051 (45)	70.4 (3.9)	72.2
	new	1171 (70)		36.9
LURE	old	1177 (60)	34.6 (3.6)	34.0
	new	1108 (64)		57.3
NEW	old	1245 (84)	8.0 (2.5)	24.8
	new	983 (57)		82.9
(b) Item Group				
OLD	old	1128 (63)	75.4 (2.7)	80.8
	new	1300 (70)		40.8
LURE	old	1278 (81)	33.8 (2.3)	42.0
	new	1236 (73)		61.0
NEW	old	1312 (84)	16.9 (2.2)	26.2
	new	1179 (70)		67.0

An ANOVA treating Group as a between subjects factor and Condition (3 levels: OLD words, LURE words, NEW words) as a within subjects factor was conducted on the proportions of old-responses. There was a significant main effect of Condition $(F(2,68) = 340.80, p < 0.001)$. Post hoc tests revealed that there were more old responses to OLD (true recognition) than to LURE words (false recognition) $(F(1,35) = 283.87, p < 0.001)$ and more old responses to LURE (false recognition) than to NEW words $(F(1,35) = 107.06, p < 0.001)$ in both groups. Although there was no interaction of Condition with Group, a separate analysis revealed fewer false alarms to NEW words in the Category than in the Item Group $(F(1,34) = 7.29, p < 0.05)$. The reaction time analysis revealed a significant main effect of Condition $(F(3,102) = 16.95, p < 0.001)$. Correct responses to OLD and NEW words were faster than responses to LURE words and correct reactions to LURE words were faster than incorrect reactions to LURE words. The analysis of confidence ratings revealed more high confidence judgments to correctly rejected NEW words in the Category than in the Item Group $(F(1,35) = 7.08, p < 0.05)$, but there was no group difference in confidence for true or false recognition. Analyses comparing rates of high confidence judgments for true and false recognition in both Groups revealed a significant main effect of Condition $(F(1,34) = 237.07, p < 0.001)$, reflecting higher confidence for true recognition in both groups.

ERP Data

ERP old/new Effects to OLD and LURE Words Figure 5.6 displays the ERP waveforms elicited by true recognition, false recognition, and new reponses to NEW words for (a) the Category Group, and (b) the Item Group at a middle frontal, a middle parietal and a right frontal recording site. Starting around 300 ms, ERPs for *true recognition* were more positive than those to new responses of NEW words in both groups. There were old/new ERP effects early in time as well as a late right frontal old/new effect. *False recognition* also showed more positive ERPs than did ERPs for new responses of NEW words starting around 300 ms. The ERPs indicated smaller early frontal and parietal old/new ERP effects (300-700 ms) to false than true recognition in the Item Group, whereas the early old/new effects elicited by true and false recognition were highly similar in the Category Group. In both groups, starting around 800 ms and maximal at right frontal locations, there were more positive ERPs for false recognition than for new responses of NEW words. Further, in the Item Group there were more negative ERPs for false recognition than for new responses of NEW words at parietal sites between 700 and 1200 ms.

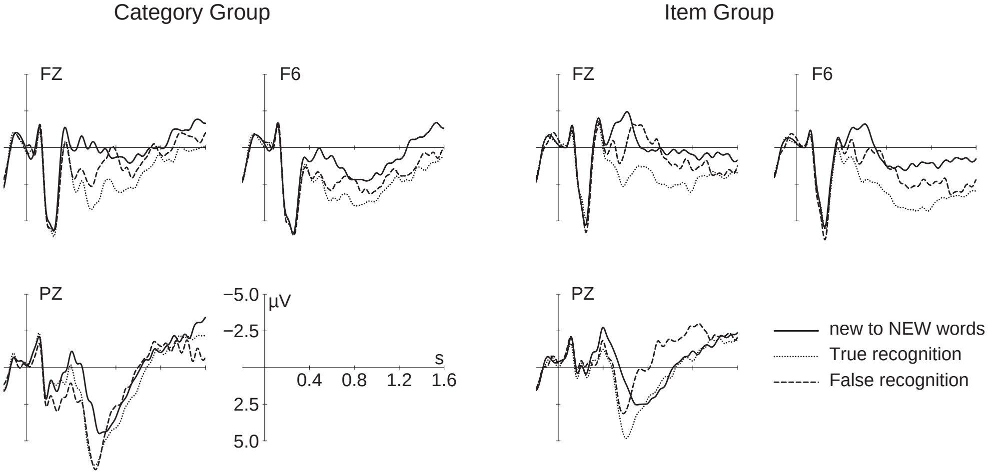

Figure 5.6: *ERPs elicited by true recognition, false recognition, and new responses to NEW words for the Category Group (left) and the Item Group (right) in Experiment 3 at middle frontal (Fz), middle parietal (Pz), and right frontal (F6) electrode sites.*

Statistical analyses were performed for the same time windows as in Experiment 2. The results of the two-way ANOVAs for true recognition and new responses of NEW words as well as for false recognition and new responses of NEW words for the Category Group and the Item Group are shown in Table 5.5. The *Category Group* analyses revealed a main effect of Condition for true and false recognition in the early time window (300-500 ms). Separate tests for the different ROIs based on a significant Condition x ROI interaction for true recognition revealed significant old/new ERP effects at all locations, with the highest treatment magnitude at the medial frontal ROI ($\omega^2 = .38$). In the middle time window (500-700 ms), a significant main effect of Condition and a significant Condition x ROI interaction were obtained for true recognition.

Table 5.5: *ANOVA results (F-values) for the ERP old/new effects to true and false recognition for the Category Group (a) and the Item Group (b) in Experiment 3.*

(a) Category Group	**True recognition**			
	df	300-500 ms	500-700 ms	1200-1600 ms
Cond	1.17	7.67*	16.57***	2.71
Cond x ROI	5.85	3.39*	4.79**	5.07**
	False recognition			
Cond	1.17	22.36***	21.05***	4.28(*)
Cond x ROI	5.85	2.18	1.95	0.47

(b) Item Group	**True recognition**			
	df	300-500 ms	500-700 ms	1200-1600 ms
Cond	1.17	18.41***	53.14***	5.66*
Cond x ROI	5.85	1.02	4.46*	1.51
	False recognition			
Cond	1.17	2.69	4.83*	2.00
Cond x ROI	5.85	1.25	0.43	2.42(*)

Note: Cond = Condition. df = degrees of freedom. ROI = regions of interest. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; (*) $p < 0.1$.

Separate analyses revealed significant old/new effects at all 6 ROIs, but treatment magnitudes were highest at the medial frontal ($\omega^2 = .52$) and the medial parietal ROIs ($\omega^2 = .43$). For false recognition there was only a main effect of

Condition. ANOVAs for the late time window (1200-1600 ms) revealed a significant Condition x ROI interaction for true recognition, but only a marginally significant main effect of Condition for false recognition. Separate tests for the different ROIs indicated more positive waveforms to true recognition at the medial frontal ($\omega^2 = .24$) and the right frontal ROI ($\omega^2 = .28$) in this time interval.

The *Item Group* analyses revealed a significant main effect of Condition for true but not for false recognition in the early time window (300-500 ms). As can be seen in Table 5.5, in the middle time window (500-700 ms) there was a significant main effect of Condition for true and false recognition, but only true recognition gave rise to a significant Condition x ROI interaction. Separate tests for different ROIs revealed significant old/new effects at all locations for true recognition, but treatment magnitude was highest at the medial frontal ROI ($\omega^2 = .70$). In the late time window (1200-1600 ms), there was a significant main effect of Condition for true recognition with the highest treatment magnitudes at the medial frontal ($\omega^2 = .24$) and the right frontal ROI ($\omega^2 = .21$), and a marginally significant Condition x ROI interaction for false recognition. Separate tests performed for false recognition revealed marginally significant effects at the medial frontal ($\omega^2 = .13$) and at the right frontal ROI ($\omega^2 = .14$).

Topographic Analyses of Old/new Effects ANOVAs were performed on the difference measures (true recognition minus new responses of NEW words; false recognition minus new responses of NEW words) to compare the amplitude differences and topographical distributions. Because for the Item Group no old/new effects for false recognition were found in the early time interval, the analyses were restricted to the middle and late time window in this group. The scalp topographies of the old/new effects elicited by true and false recognition for both groups are presented in Figure 5.7 and Figure 5.8.

Neither analysis performed for the different time windows in the Category Group revealed a significant main effect or interaction. In the Item Group, there was a significant main effect of Condition ($F(1,17) = 4.88, p < 0.05$) in the mid-

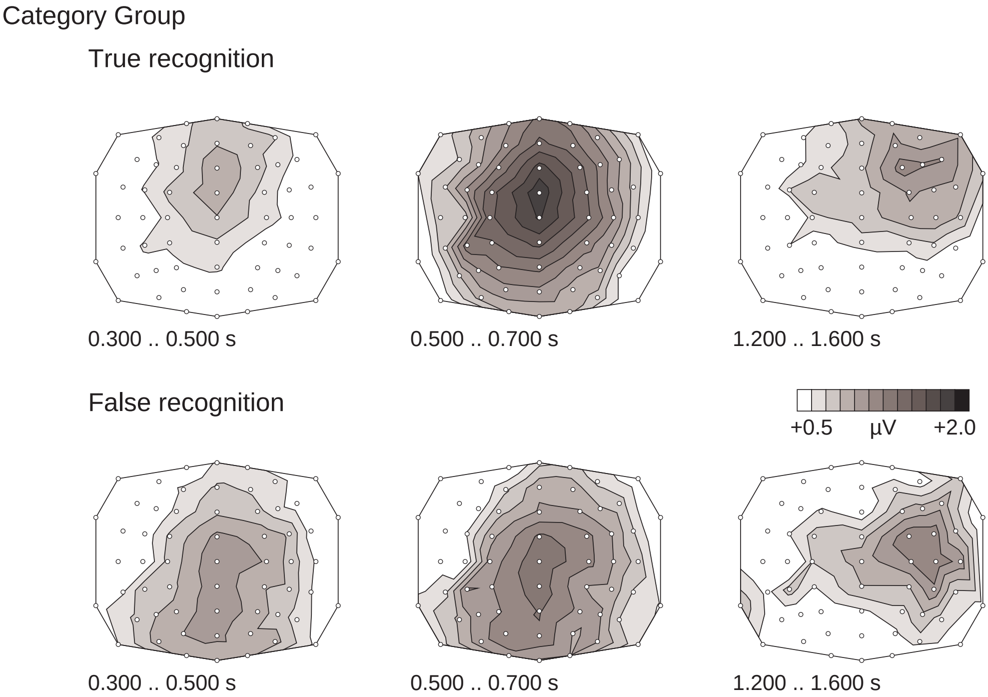

Figure 5.7: *Topographic distributions of the difference waves for ERPs to true recognition and new responses to NEW words, and to false recognition and new responses to NEW words in the early (300-500 ms), middle (500-700 ms), and late (1200-1600 ms) time interval for the Category Group in Experiment 3.*

dle time window only, indicating larger old/new effects to true than to false recognition. The ANOVA performed for the amplitude normalised old/new differences revealed a significant Condition x ROI interaction $(F(5,85) = 3.58, p < 0.05)$, suggesting that there was a different topographical distribution of the old/new effects for true and false recognition.

In sum, while both groups showed old/new effects to true recognition there was an early frontal effect for false recognition in the Category but not in the Item Group. Further, the old/new ERP effect for false recognition in the middle time

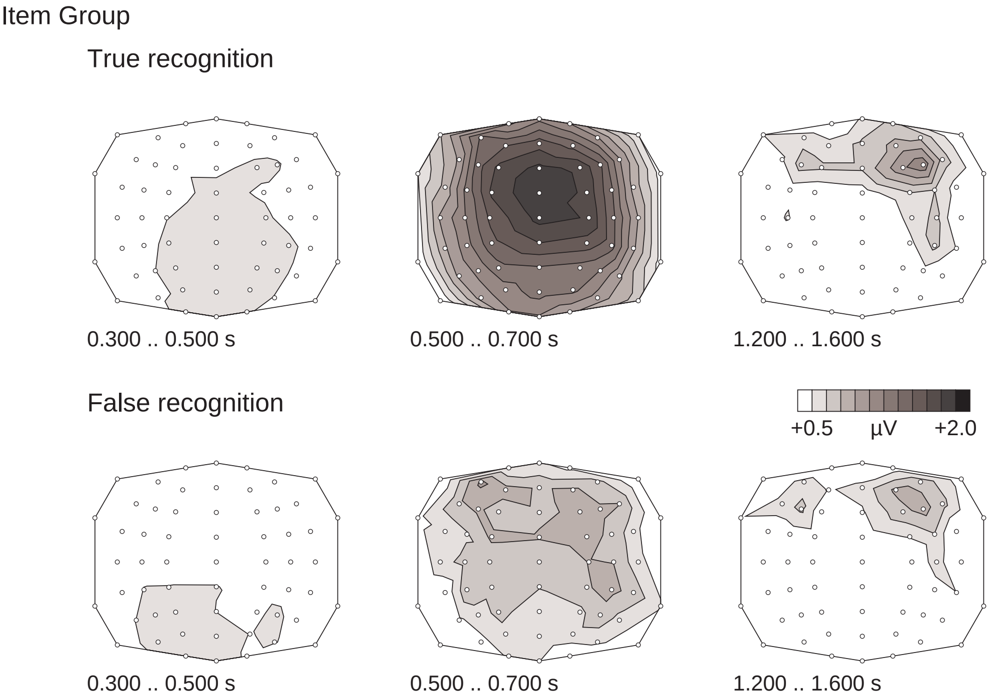

Figure 5.8: *Topographic distributions of the difference waves for ERPs to true recognition and new responses to NEW words and to false recognition and new responses to NEW words in the early (300-500 ms), middle (500-700 ms), and late (1200-1600 ms) time interval for the Item Group in Experiment 3.*

window was smaller than for true recognition in the Item Group, whereas similar parietal effects were obtained in the Category Group.

ERPs for Correctly Rejected LURE Words Figure 5.9 displays the topographical distribution of the ERP differences between old responses of LURE words (false recognition) and new responses of LURE words in the early time window (300-500 ms) for each group separately.

A two-way ANOVA with the factors Condition (2 levels: false recognition, new responses of LURE words) and ROI (6 levels) was performed for both groups.

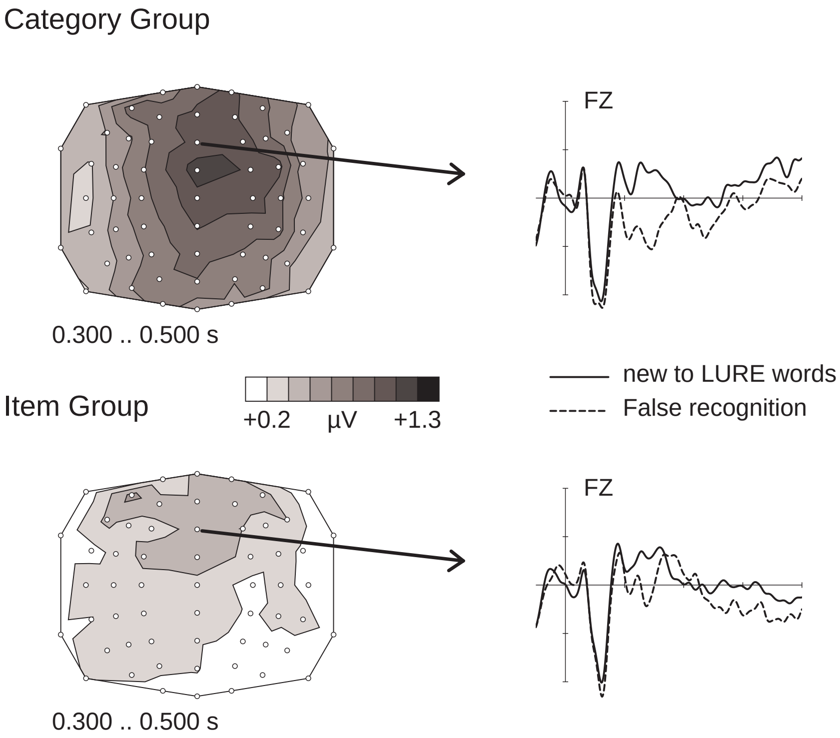

Figure 5.9: *Topographic distributions of the difference waves for ERPs to false recognition and new responses to LURE words for the Category Group and for the Item Group in the early (300-500 ms) time interval (left). The corresponding ERPs are plotted for a middle frontal (Fz) electrode site (right).*

ERPs for false recognition were more positive than for new responses of LURE words in the Category Group (main effect of Condition: $(F(1,17) = 29.54, p < 0.001)$), but not in the Item Group $(F(1,17) = 1.83, p > 0.1)$.

Late Parietal Negativity In Experiment 2, the analyses revealed a parietal negativity for false recognition in the late time window. In Experiment 3, we failed to find significant negative deflection in the late time window (1200-1600 ms), but there was a bilateral parietal negativity for false recognition between 700 and 1200 ms in the Item Group (Figure 5.6). Separate two-way ANOVAs, with the factors Condition (2 levels: true recognition or false recognition, new responses of NEW words) and ROI (6 levels) were conducted for each group in this time interval. The analyses revealed a parietal negativity to false recognition in the Item Group only. Separate tests for different ROIs, based on a significant Condition x ROI interaction $(F(5,85) = 7.38, p < 0.001)$, indicated more negative going waveforms at right, left and medial parietal ROIs.

5.4.3 Discussion

Experiment 3 was performed to determine if differences in encoding focus lead to differential ERP patterns for true and false recognition.

Participants in the Category Group made fewer false alarms to NEW words and higher confidence ratings to correct rejections of NEW words than participants in the Item Group, indicating that categorical information, i.e., conceptual similarity, was used to a larger extent by participants in the first group. This pattern of results suggests our encoding manipulation was successful. Even though false recognition rates were similar for the Category Group and the Item Group, there were differences in the ERP patterns elicited in the two groups. In support of our hypotheses, true and false recognition elicited similar old/new ERP effects in the Category Group, and different old/new ERP effects in the Item Group. When participants focused attention mainly on the categorical relations of the studied items (Category Group), brain activity and, consequently, the underlying cognitive processes, were equivalent for true and false recognition. Both forms of recognition were based on familiarity, as indicated by similar early fronto-medial ERP effects, as well as on recollection of item specific memory traces, as indicated by similar parietal ERP effects. However, when participants focused attention on item specific information, i.e. distinctive features of concepts activated by the animacy judgments (Item Group), true and false recognition could be separated on the basis of their brain activity. In the Item Group, there was an early fronto-medial ERP effect for true but not for false recognition. LURE words might not appear to be familiar, because participants were not focused on categorical relations in encoding. Accordingly, the similar early ERP waveforms for new and old responses of LURE words indicated that it was not familiarity that drove false recognition in this condition. There was a parietal old/new ERP effect for true, and, interestingly, also a smaller one for false recognition. The small parietal positivity in the absence of a frontal effect obtained for false recognition in the Item Group may indicate that automatic spreading activation, i.e., activation elicited by the exposure of a related word without the need to focus on categorical relations, can lead to recollection based false recognition. It seems that this form of recollection can occur without an accompanying familiarity process. There is some evidence for the occurence of conscious recollection in the absence of familiarity (Jacoby & Dallas, 1981; Mandler, 1980, cf. Aggleton & Brown, 1999).

Compared to new responses of NEW words, both forms of recognition showed at least trends for more positive going waveforms at right frontal locations in a late time window (1200-1600 ms), but did not differ from each other in either group. Finally, the Item Group showed a late parietal negativity (700-1200 ms) for ERPs for false recognition compared to ERPs for new responses of NEW words. Possible functional implications of both the late frontal and late parietal ERP effects are addressed in the General Discussion.

In sum, the results of Experiment 3 suggest that differences in ERP patterns for true and false recognition depended on strategic aspects during encoding. If participants focused attention on categorical relations of the studied items (Category Group), then true and false recognition were based on both familiarity and recollection processes. However, brain activity for false recognition in a group focusing more on item specific information (Item Group) indicated recollection but not familiarity based false recognition.

5.5 General Discussion

Taken together, the results from the group analysis of Experiment 2 and the results from Experiment 3 support the view that participants differentially encoded categorical relations of the studied words. When participants had high false recognition rates (Experiment 2), suggesting the use of categorical relations, or when participants directly focused on categorical relations (Experiment 3; Category Group) ERP effects for true and false recognition were similar (see results summary in Table 5.6).

Table 5.6: *Across experiment comparison: Patterns of mean differences of the old/new ERP effects elicited by true and false recognition for all participants in Experiment 2, for the group with high false recognition rates in Experiment 2, for the group with low false recognition rates in Experiment, and the Category Group and the Item Group in Experiment 3.*

Experiment 2	**All participants** (N=22)			**High false recognition** (N=10)		**Low false recognition** (N=10)	
Recognition	True		False	True	False	True	False
Early frontal	+		+	+	(+)	+	-
Middle parietal	+	>	+	+	+	+	-
Late right frontal	+		+	-	+	+	-
Late parietal	-		+	-	-	-	+

Experiment 3	**Category Group** (N=18)		**Item Group** (N=18)		
Recognition	True	False	True		False
Early frontal	+	+	+		-
Middle parietal	+	+	+	>	+
Late right frontal	+	(+)	+		(+)
Late parietal	-	-	-		+

Note : $+ = p < 0.05; (+) = 0.05 < p < 0.1; -p > 0.1$.

This outcome resembles ERP results obtained in prior studies with the Deese paradigm (Düzel et al., 1997; Johnson et al., 1997). Therefore, true and false recognition seem to be based on both familiarity and recollection processes in experiments in which participants might focus their attention on information that items have in common, i.e. their categorical relationship.

When participants used more item specific information, as is probably the case for the low false recognition group in Experiment 2 and the Item Group in Experiment 3, differential ERP patterns arose for true and false recognition. The absence of an early fronto-medial ERP effect for false recognition in both groups indicates that these words did not elicit feelings of familiarity. The absence of a parietal ERP effect in the low false recognition group in Experiment 2 suggests recollection based false recognition also failed to occur. However, the small effect for the Item Group suggests that recollection based false recognition in the absence of familiarity (Mandler, 1980, cf. Aggleton & Brown, 1999) did occur in this case. The view that there might be some differences between the two groups is also reflected by the higher false recognition rate in the Item Group than in the low false recognition group in Experiment 2. Although it was shown that encoding strategy influences neuronal activity for false recognition, the different assignment to the groups in both Experiments might be responsible for mentioned differences between the low false recognition group and the Item Group.

In sum, the results indicate that strategic differences in the encoding of categorical information can influence brain activity for false recognition. This view confirms and extends a proposal, made by Johnson et al. (1997) , that was based on a manipulation of testing conditions rather than encoding strategy. They compared brain activity for true and false recognition in a blocked test presentation (LURE words and OLD words appeared in different test blocks) with brain activity in a random word order test presentation using word lists from the Deese paradigm. Although there were no ERP differences for true and false recognition in the random design, ERP waveforms were more positive for true than for false recognition between 50-775ms and 775-1500 ms in the blocked design. The authors suggested that judgments in the random design were based mainly on an overall feeling of familiarity that arose due to focusing attention on conceptual similarity. Our interpretation for the group with high false recognition rates (Experiment 2) and for the Category Group (Experiment 3) is consistent with this view.

In addition to the aforementioned medial-frontal and parietal old/new ERP effects there were pronounced positive differences at right frontal recordings sites in the late time window (1200-1600 ms). However, the pattern of right frontal effects for true and false recognition differed across Experiments and groups (cf. Table 6). In Experiment 2, participants with high false recognition rates showed a right frontal old/new ERP effect for false but not for true recognition, suggesting that searching for and accessing weaker representations in memory requires more retrieval effort. This result supports the retrieval effort account of the frontal slow wave (Henson, Rugg, Shallice, Josephs & Dolan, 1999; Schacter, Alpert, Savage, Rauch & Albert, 1996a; Schacter, Reiman, Curran, Yun, Bandy, McDermott & Roediger, 1996c). In contrast, the ERP waveforms for participants with low false recognition rates were more in line with the retrieval success account (e.g., Buckner, Koutstaal, Schacter, Wagner and Rosen, 1998b Rugg et al., 1996; Wilding & Rugg, 1996). In this group, there was a right frontal old/new effect for true but not for false recognition. In Experiment 3, both true and false recognition showed more positive ERP waveforms relative to NEW words in a late time window (1200-1600 ms) irrespective of encoding instruction, challenging both the retrieval effort and the retrieval success account. Although ERP measures do not allow a precise localization of the neural regions that contribute to scalp-recorded ERPs, the effect found at right frontal electrodes is assumed to reflect the involvement of the right prefrontal cortex in episodic retrieval tasks (e.g., Mecklinger, 2000; Rugg et al., 1996). A similar view has been proposed based on neuropsychological findings with patient B.G., who had an infarction in right frontal lobe (Curran et al., 1997; Schacter et al., 1996b). While B.G.'s true recognition was not impaired, he showed large false recognition rates to semantically related items. The authors assumed an over-reliance on familiarity resulting from deficits in monitoring memory contents. Therefore, the late right frontal ERP effect for true and false recognition found in the present study may reflect monitoring or evaluation processes required for old responses to studied and non-studied words that share semantic features. However, the differential pattern of effects found in both experiments indicate that the involvement of right frontal cortex may additionally depend upon cognitive operations set by a specific retrieval context (Mecklinger, 2000; Wagner et al., 1998).

Interestingly, there was a late parietal negativity elicited by false recognition only for participants with low false recognition rates in Experiment 2 and in the Item Group in Experiment 3. Wilding and Rugg (1997) reported a similar parietal negativity for false alarms in a memory exclusion task. Because reaction times were longer for false alarms relative to correctly recognized target words, the authors suggested that the negativity reflected response related processes rather than mnemonic processes. However, although reaction times for false recognition were longer than for true recognition or new responses to NEW words, the view of a response related process does not explain the absence of a negative slow wave for participants with high false recognition rates in Experiment 2 and in the Category Group in Experiment 3. Düzel et al. (1997) found a similar negativity between 600 and 1000 ms for true and false recognitions that attracted a ’Know’ response (cf. Tulving, 1985). Further, Rubin et al. (1999) , using conjunction LURE words, found that ERPs for false recognition were more negative than for true recognition between 600 and 900 ms. Unfortunately, neither study offered an clear explanation of the effect.

Interestingly, a prior fMRI study from our lab, contrasting BOLD responses for false recognition with new responses of NEW words, revealed significant activation in the anterior cingulate cortex (ACC) (Mecklinger, Nessler, Penney & von Cramon, 1999). To examine whether ACC activity accounts for the bilateral negative slow wave in the present experiments dipole analyses were performed. A single dipole was placed at the Talairach coordinates of the ACC activation for false recognition relative to new responses of NEW words reported by Mecklinger et al. (1999) [3]. Dipole orientation and strength were fitted in the ERP difference waveforms (false recognition minus new responses of NEW words) for the low false recognition rate group (Experiment 2) and the Item Group (Experiment 3). The single dipole model accounted for 87.5% of the variance in the difference wave between 900 and 1200 ms for the low false recognition group. The dipole analysis for the negative slow wave of the Item Group in the 700-1200 ms time range revealed 88.35% explained variance. The ACC is considered as a part of an attention network (Carter, Braver, Barch, Botvinick, Noll & Cohen, 1998, cf. Mecklinger, 2000) and is active under conditions of high task demands and remote memory requirements (Paus, Koski, Caramanos & Westbury, 1998). In the present experiments the ACC activation for the two mentioned groups, which were assumed to focus mainly on the recollection of item specific features from the study phase to evaluate their recognition responses, may reflect the attentional modulation of an enhanced response conflict. This conflict may have been caused by old responses to categorically familiar words (LURE) in the presence of little or no conscious recollection of item specific information.

5.5.1 Conclusion

The present studies were performed to examine the contribution of familiarity and conscious recollection to false recognition judgments. The results indicated that focusing on categorical relations of the study words lead to true and false recognitions that were driven by both familiarity and recollection. True and false recognition could not be differentiated on the basis of ERP waveforms, supporting prior ERP studies performed with the Deese paradigm (Düzel et al., 1997; John-

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[3] Dipole analyses were performed with the Programm CURRY 4 (NeuroScanLabs). A realistically shaped head model with three volumes was developed using the Boundary Element Method (Fuchs, Drenckhahn, Wischman & Wagner, 1998). The Talairach coordinates used for the dipole analyses were x: -9mm, y: 8mm, z: 40, and the dipole was allowed to vary in location within a sphere with 5mm radius.

son et al., 1997). Conversely, ERP effects for false recognition that were different from those elicited by true recognition were obtained when participants focused on item specific information activated by animacy judgments during encoding rather than on categorical relations. ERP waveforms in this condition revealed some recollection based false recognition, but there was no evidence for familiarity based false recognition. In sum, it is the strength of the use of conceptual similarity that drives the neuronal differences between true and false recognition.

Chapter 6

False Recognition and Illusory Familiarity

Results from Experiment 3 (cf. Chapter 5) assume that false recognition can arise from illusory recollection as revealed by a parietal ERP old/new effect. Interestingly, there was no early frontal old/new ERP effect, seen as a correlate of familiarity assessment, for false recognition in the item specific encoding group. This suggests that illusory familiarity is no stringent condition for the creation of false recognition, that was directly examined in Experiment 4. This Experiment is described in the following article: Nessler and Mecklinger (under revision), False Recognition is not always based on Illusory Familiarity: Evidence from Event-Related brain Potentials. The Chapter contains this article. Note, that for stylistic reasons the format was adapted.

6.1 Abstract

Event-related potentials (ERP) elicited by true and false recognition were investigated after short (40 sec) and long retention delays (80 sec). Models of false recognition would expect that increased false recognition, found for the long

delay, comes along with increased illusory familiarity. Instead, an early frontal old/new ERP effect, seen as a correlate of familiarity assessment, was only found for the short delay. Consequently, results indicate that there is no causal relationship between familiarity and false recognition. Response-related averages showed an Error-Related Negativity (ERN) for false and true recognition, indicating that the effect is not related to error trials per se, but rather may reflect a misrepresentation of the correct response. Larger and slightly topographically different ERNs for false recognition suggest an additional contribution of high task demands under conditions of response uncertainty to this effect.

6.2 Introduction

During the past few years studies of false memories have been considered more and more useful to learn about the nature of basic memory processes. Consequently, there has been an increasing amount of research to different kinds of memory distorsions, including behavioral as well as electrophysiological and neuroimaging techniques (for overviews see Lampinen et al., 1998; Reyna & Lloyd, 1997; Schacter et al., 1998a).

For instance, false recognition, one type of memory distortions, was examined arising from phonologic (Rubin et al., 1999) or episodic (Miller & Gazzaniga, 1998) relations between studied items and unstudied test items. However, a majority of studies are concerned with false recognition arising from a semantic overlap between study and test items. In the typical task, participants learn lists of semantically associated words of a non-presented word, the so called LURE word (Deese, 1959). In a subsequent memory test, participants falsely recognize the LURE words at a much higher rate than words unrelated to the study lists (e.g., McDermott, 1996; Payne et al., 1996; Read, 1996).

Such false recognition is often suggested to arise from a feeling of familiarity. According to this explanation, LURE words are judged old because they match conceptual features with the studied words (e.g., Schacter et al., 1999, 1998a)

Support for this view comes from behavioral studies showing that less sensory and distinctive details (item specific memory traces) are retrieved for false than for true recognition (Mather et al., 1997; McDermott, 1997; Norman & Schacter, 1997; Schacter et al., 1999)

Event-related potentials (ERPs) can provide an additional source of information about the cognitive processes involved in true and false recognition. This is because the timing and scalp topography of particular ERP-components allows inferences about the timing and nature of cognitive processes underlying true and false recognition memory judgments (e.g., Donchin et al., 1997; Johnson, 1993; Rugg & Coles, 1995).

Prior ERP studies reported more positive going waveforms to true recognition than to correctly rejected NEW words in explicit old/new recognition tests (for reviews see Johnson, 1995; Rugg, 1995b; Rugg & Allan, 2000). This so called old/new ERP effect can be decomposed in at least three different spatio-temporally specific subprocesses (cf. Friedman & Johnson, 2000; Mecklinger, 2000) that are associated with distinct cognitive processes underlying true recognition. These subprocesses are an early fronto-medial old/new ERP effect, a somewhat later arising parietal old/new ERP effect and a late right frontal old/new ERP effect.

The early frontal effect starts around 300 ms and may arise from the attenuation of a frontally focused N400-like component. Frontal positivity does not only arise for studied items but also for erroneously classified plurality reversed LURE words (Curran, 2000) and semantically related non-studied LURE words (Nessler, Mecklinger & Penney, 2001). This may suggest that the effect occurs because access to conceptual and perceptual information related to the test word is facilitated. Further, the frontal effect is insensitive to a depth of processing manipulation (Rugg et al., 1998a) indicating that the frontal positivity may not be driven by recollective experience. Instead, the effect is assumed to be associated with familiarity assessment during recognition judgements (e.g., Johnson et al., 1998; Mecklinger, 2000; Ullsperger et al., 2000). However, a depth of processing manipulation influenced the somewhat later arising parietal old/new ERP effect (Rugg et al., 1998a). The strength of this positivity, which reaches its maximum between 400 and 700 ms, does also depend on other manipulations that enhance recollective experience (e.g., Paller & Kutas, 1992; Smith, 1993; Wilding & Rugg, 1996; Ullsperger et al., 2000) Consequently, the effect is seen as a correlate of consciously controlled recollection of item specific information from the study phase or as a consequence thereof (for reviews see Johnson, 1995; Rugg, 1995b). A late right frontal effect starting around 800 ms and sustaining longer in time than the ERP-effects described above, is seen as related to postretrieval processes, although at present there is no consensus on its precise functional significance (cf. Friedman & Johnson, 2000; Mecklinger, 2000).

First studies comparing electrophysiological correlates of brain processes involved in true and false recognition failed to support the assumption that false recognition is mainly based on familiarity processes. Instead, the high similarity of ERP waveforms elicited by true and false recognition (Düzel et al., 1997; Johnson et al., 1997) seems to indicate that false recognition is based on both familiarity assessment and conscious recollection. Support for this view was provided by a recent study (Nessler et al., 2001): Similiar old/new ERP effects were found to true and false recognition for a group of participants with high rates of false recognition in a first experiment and for a group of participants focusing on categorical features of study words (Category Group) in a second experiment. Interestingly, there was no electrophysiological correlate of familiarity assessment for false recognition in a group making only few false alarms to LURE words (Experiment 1) as well as in a group of participants focusing on item specific features (Item Group, Experiment 2). Although the rates of false recognition in the Category Group and Item Group were similar in Experiment 2, no early frontal old/new effect for false recognition was found in the Item Group, challenging a direct connection between illusory familiarity and false recognition.

The major goal of the present study was to clarify the contribution of familiarity assessment to false recognition. This issue was approached by manipulating the retention delay between study and test items in a recognition memory test, because a variety of studies have shown that retention delay has an influence on the early frontal effect which is assumed to be related to familiarity assessment. For instance, Rugg and Nagy (1989) using a continuous recognition memory paradigm found no difference in the old/new ERP effect elicited after 6 (about 36 sec) and after 19 (about 114 sec) intervening items. When participants performed a second recognition test after about 45 minuts, in which they had to differentiate between words occuring in the first test and NEW words, waveforms revealed only a small parietal old/new effect but no early frontal ERP effect. This suggests differential time courses for the processes that give rise to conscious recollection and familiarity assessment.

Guillem, Rougier and Claverie (1999) used a similar continuous recognition memory test for the measurement of short (6 intervening items, about 35 sec) and long-delay (19 intervening items, about 95 sec) intracranial ERP repetition effects. Their results also showed that the N400 responded differentially as a function of the interitem lag, whereas P600 was insensitive to the lag manipulation. Interestingly, a study using an auditory recognition memory task with only short delays (2sec vs. 4-12sec) also reported a fronto-central distributed N400 to be modulated by the delay manipulation whereas the amplitude of a parietally focused effect (P3) was not (Chao, Nielson-Bohlman & Knight, 1995).

These results indicate that the early frontal old/new ERP effect, which is assumed to reflect familiarity assessment, shows a fast decay over time, i.e., can be influenced by a delay manipulation.

For this reason we examined ERPs elicited by true and false recognition at two different delay conditions in the present study. Given that familiarity activation shows a decay over time, the early frontal old/new ERP effect elicited by false recognition were expected to be modulated by retention delay. In accordance with models suggesting that false recognitions arise from illusory familiarity, the decrease in familiarity should come along with smaller false recognition rates. However, based on behavioral results of prior studies that showed a decrease in performance (Friedman, 1990b; Hintzman, 1969; Nielsen-Bohlman & Knight, 1995; Poon & Fozard, 1980), we would predict an increase in false recognition rate for the long delay.

6.3 Methods

6.3.1 Participants

Fifteen volunteers (6 female) between 20 and 30 years of age (mean 23 years) participated. They were students at the University of Leipzig, were right-handed and had normal or corrected-to-normal vision. They reported to be in good health and were paid 12 DM/h for their participation. None of the participants had prior experience with the task.

6.3.2 Experimental Material

The present experiment used 10 German nouns from 30 categories each (300 words). The mean word typicality of the 10 category examples was similar across the categories (cf. Nessler et al., 2001; Ullsperger et al., 2000). The words were used to construct 4 different task blocks comprised of 10 study-test trials. Each trial consisted of a study phase, a delay, and a recognition test phase. One study phase consisted of 12 words, i.e., 4 words from 3 different categories each. The delay lasted either 40 or 80 seconds. The respective test phase included 10 words from the 12 studied words (OLD words), 2 non-studied words from each of the 3 studied categories (6 LURE words), and 1 non-studied word from 8 non-studied categories each (8 NEW words). LURE words were always drawn from highly typical exemplars of each category. Each word appeared only once in each of the 4 different task blocks, given the repetition of studied words in the test phase of the respective trial. Study categories were randomly assigned to the 10 study-test trials of each task version. The duration of the delay in each trial was also randomized, with 5 short (40 sec) and 5 long (80 sec) delays in each task version.

6.3.3 Procedure

A schematic view of the study and the test phase in Experiment 4 is given in Figure 6.1. The participants were seated comfortably in an acoustically and electrically shielded dimly lit chamber in front of a 17” computer monitor. They sat at a distance of about 100 cm from the screen and during the test phase they held a small response box on their lap.

Participants performed two different sessions on 2 different days. Two task versions were performed on the first day, the remaining two on the second day. The two sessions were separated by at least 3 and maximal 8 intermediate days.

In each study phase participants heard nouns, spoken by a female voice, which were played at a rate of 3 seconds in a random order. Prior to the test phase of each study-test trial, participants counted loudly backwards starting from a digit presented on the screen. This delay lasted 40 or 80 seconds in a random order. In the recognition test the words were presented visually to control for sensory based priming effects. Words appeared in a quasi random order with the constraint that no more than 2 words of the same type (OLD, NEW, LURE) were presented consecutively. Each word presentation in the test phase started with a fixation cross in the middle of the screen. After 200 ms the screen went blank for 400 ms and then the word was presented visually for 500 ms. The participants were required to indicate as quickly and as accurately as possible whether the presented word was heard in the study phase (old response) or not (new response). They responded by pressing the left or the right button of the response box with the thumb of the corresponding hand. Response hand was counterbalanced across participants. After 2500 ms, in which the screen was blank, participants received feedback. A green (+) was presented for correct answers for 200 ms and a red (-) for an incorrect one. Blank screen followed for another 1000 ms before the next trial started.

Participants were given a short break between the two task versions which were performed on one day. The sequence of the different lists was counterbalanced across participants. Including electrode application and removal the sessions on every day lasted about 2.5h.

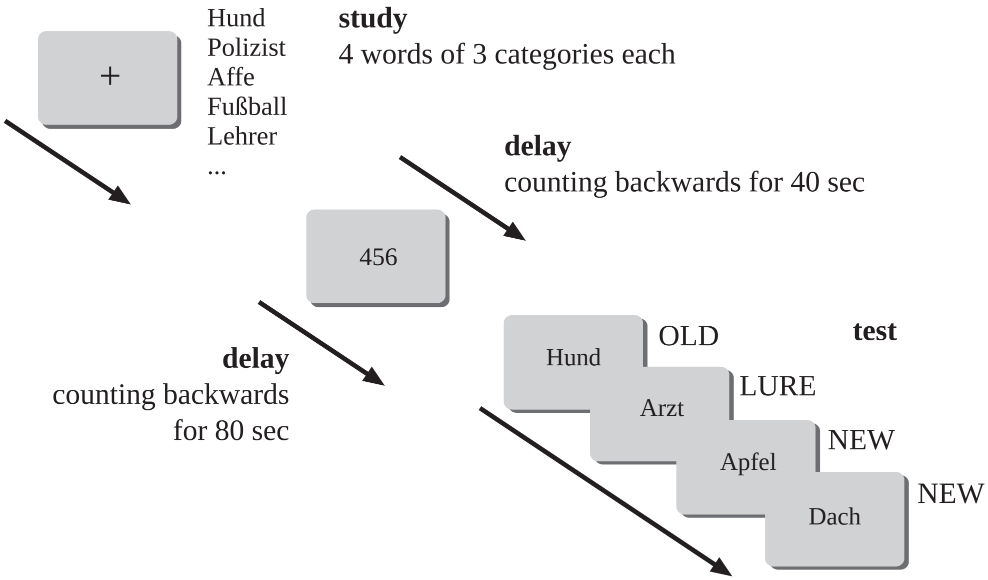

Figure 6.1: *Schematic view of the study and the test phase in Experiment 4. A detailed description is given in the text.*

6.3.4 ERP Recording

The EEG activity was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electrocap International) from 61 scalp sites of the extended ten-twenty system. Electrode labelling was based on the standard nomenclature of the 10-20 system (Sharbrough et al., 1990). The ground electrode was positioned 2 cm to the right of Cz. The vertical Electro-oculogram (EOG) was recorded from electrodes located above and below the right eye. The horizontal EOG was recorded from electrodes positioned at the outer canthus of each eye. Electrode impedance was kept below 5 kOhms. The right mastoid was recorded as an additional channel. All scalp electrodes were referenced to the left mastoid and were offline re-referenced to both mastoids. EEG and EOG were recorded continuously with a band pass from DC to 30 Hz and were A-D converted with 16 bit resolution at a sampling rate of 250 Hz.

6.3.5 Data Analysis

Behavioral Data

Reaction time was defined as the interval between the appearance of the test item and the participant's keypress. Data were averaged separately for each response condition.

ERP Data

In the test phase, ERPs were computed for each participant at all recording sites with epochs extending from 200 ms before onset of word presentation until 1600 ms thereafter. ERPs were selectively averaged for the following combinations of item types and responses: old responses to OLD words (true recognition), old responses to LURE words (false recognition), new responses to LURE words and new responses to NEW words. Because there were too few old responses to NEW items and too few new responses to OLD items to form reliable ERPs, these conditions were excluded from further analyses.

The average voltages in the 200 ms preceding stimulus presentation served as baseline. Prior to averaging, each epoch was scanned for EOG and other artefacts. Whenever the standard deviation in a 200 ms time interval exceeded 30 μV in an EOG channel or 40 μV in the Pz channel the epoch was rejected. In a second step, the EEG epochs were visually scanned for further artefacts. The averages were lowpass filtered at 10 Hz. Because some of the ERP components were not clearly visible as peaks at all electrode sites, mean amplitude measures were considered more reliable for component scoring than peak measures (Hoormann et al., 1998). In order to avoid a loss of statistical power that is implicated when repeated-measures ANOVAs are used to quantify multi-channel and multi-time window data (Gevins, Cutillo & Smith, 1995; Gevins, Smith, Le, Leong, Bennett, Martin, McEvoy, Du & Whitfield, 1996; Oken & Chiappa, 1986), electrode sites were pooled to six topographical regions, so called *regions of interests* (ROI). The following regions were defined: left frontal (F9, AF7, F7, F5, FT9, FT7, FC5); medial frontal (AFz, AF3, AF4, Fz, F3, F4, FCz); right frontal (F10, AF8, F8, F6, FT10, FT8, FC6); left parietal (TP9, TP7,CP5,P9, P7, P5, PO7); medial parietal (CPz, Pz, P3, P4, PO3, POz, PO4) and right parietal (TP10, TP8, CP6, P10, P8, P6, PO8). According to Homan, Herman and Purdy (1987) who established a correspondence between electrode site and underlying cerebral structures using radiographic techniques, the medial frontal region is approximately over the middle frontal gyri (Brodmann area BA 46). The left and right frontal regions are approximately over the inferior frontal gyri (BA 45 on the left and BA 46 on the right). The left and right parietal regions cover approximately the posterior part of the middle temporal gyri and the anterior occipital sulcus (BA 19, 37), whereas the medial parietal region is approximately over the occipital gyri and the superior parietal lobe.

For the statistical analysis of stimulus-related ERP-waveforms two different time windows were used. Based on prior studies examining ERPs in explicit recognition memory tasks (e.g., Curran, 1999; Rugg et al., 1998; cf. also Mecklinger, 2000) , the early frontal and the early parietal old/new ERP effect were examined between 300 and 600 ms, whereas the late right frontal old/new effect was examined between 1000 and 1600 ms. For each time window it was tested whether true and false recognition elicited old/new effects in both delay conditions. ERP measures were subjected to two-way repeated-measures ANOVAs with the factors condition (2 levels: true/ or false recognition, new responses to NEW words) and ROI (6 levels: left frontal, medial frontal, right frontal, left parietal, medial parietal, right parietal). Because in the present study early frontal old/new ERP effects were of particular importance additional analyses were performed as follows: ERP-differences of the early frontal old/new ERP effects for true recognition between the both delay conditions as well as for false recognition between the both delay conditions were examined in two-way repeated-measures ANOVAs. Following factors were used: Condition (2 levels: true/ or false recognition minus new responses to NEW words in the short delay; true/ or false recognition minus new responses to NEW words in the long delay) and ROI (3 levels; left frontal, medial frontal, right frontal). Furthermore, brain activity elicited by old and new responses to LURE words were directly contrasted at frontal locations using a two-way repeated-measures ANOVA with factors condition (false recognition, new responses to LURE words) and ROI (3 levels; left frontal, medial frontal, right frontal) for the early time window (300-600 ms).

In order to avoid reporting large amounts of statistical results not relevant for the issues under investigation, only main effects or interactions including the condition factors will be reported. In case of significant interactions involving these factors, one-way ANOVAs were performed to examine the effects in each of the topographical regions. Measures of treatment magnitude (ω^2, cf. Keppel, 1991) for these single effects are reported in combination with main effects of condition. All effects with more than one degree of freedom in the numerator were adjusted for violations of sphericity according to the Greenhouse and Geisser formula (Greenhouse & Geisser, 1959). Scalp potential topographic maps were generated using a two-dimensional spherical spline interpolation (Perrin et al., 1989) and a radial projection from Cz, which respects the length of the median arcs.

6.4 Results

6.4.1 Behavioral Data

Mean reaction times and proportions of old responses to OLD, LURE and NEW words are presented separately for the two different delays in Table 6.1. Participants showed more false alarms to LURE words (false recognition) than to NEW words in both delay conditions. Performance decreased in the long delay, reflected in smaller true recognition rates, increased false alarm rates to LURE and NEW words, as well as in longer reaction times for the long delay compared to the short delay. This pattern of results was confirmed by statistical analyses.

Table 6.1: *Mean reaction times (in ms) of the old and new responses, and mean proportion (in %) of the old responses for the different item-types in the short (a) and the long retention delay (b) in Experiment 4. The standard error of the mean is presented in parenthesis.*

Item	**Response**	**Reaction time**	**Proportion old-response**
(a) Short retention delay			
OLD	old	744 (44)	87.3
	new	1019 (78)	
LURE	old	959 (67)	17.7
	new	850 (56)	
NEW	old	824 (102)	1.6
	new	749 (46)	
(b) Long retention delay			
OLD	old	756 (46)	85.9
	new	1007 (82)	
LURE	old	980 (69)	21.3
	new	861 (57)	
NEW	old	945 (117)	2.0
	new	765 (47)	

To examine the expected decrease in performance for the long delay a two-way repeated-measure ANOVA with the factors delay (2 levels) and the factor item type (3 levels; OLD, LURE, NEW words) for the proportion of correct responses was conducted. There was a main effect of delay $(F(1,14) = 8.36, p <$

$.05)$ indicating more correct reponses in the short than in the long delay. Analysis also revealed reliable differences between the three item types $(F(2,28) = 47.60, p < .001)$ as well as a significant interaction delay x item type $(F(2,28) = 4.93, p < .05)$. Separate tests for the different item types revealed higher false recognition rates in the long than in the short delay $(F(1,14) = 11.69, p < .01)$. True recognition rate and rate of new responses to NEW words in both delays failed to reveal statistically significant differences ($F(1.14) = 2.41, p > .1; F(1.14) =$ 0.43, respectively), reflecting the fact that the delay manipulation mainly influenced response rates to LURE words. This was also supported by an analysis showing a higher relative false recognition rate (false recognition minus false alarms to NEW words) for the long than for the short delay $(F(1.14) = 5.61, p < .05)$.

Reaction times were only analyzed for the four response categories relevant for the ERP analyses (true recognition, false recognition, new responses to LURE words, new responses to NEW words). A two-way repeated-measure ANOVA with the factors delay and item type revealed reliable differences between the two delays $(F(1,14) = 7.39, p < .05)$, reflecting faster responses for the short than for the long delay. There was also a significant main effect of item type $(F(3,42) = 35.65, p < .001)$, but no significant interaction delay x item type $(F(3,42) = 0.17)$. Old responses to OLD words and new responses to NEW words, which revealed no reaction time differences in the short and in the long delay ($F(1,14) = .19; F(1,14) = .47$, respectively) were faster than responses to LURE words in both delays. Further, reaction times for new responses to LURE words were faster than false recognition, in the short as well as in the long delay ($F(1,14) = 19.88, p < .001, F(1,14) = 20.86, p < .001$, respectively).

6.4.2 ERP Data

ERP old/new Effects to OLD and LURE Words

Figure 6.2 displays the ERP waveforms at one right frontal and at two midline electrodes elicited by true recognition, false recognition, and new responses to NEW words.

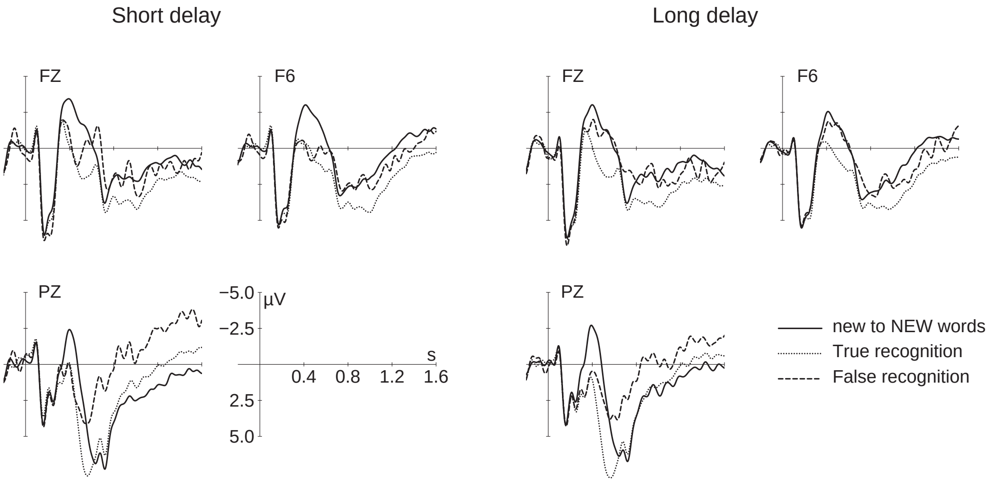

Figure 6.2: *ERPs elicited by true recognition, false recognition, and correct rejections to NEW words at middle frontal (Fz), right frontal (F6) and middle parietal (Pz) electrode site for the short retention delay (left) and the long retention delay (right).*

Starting at around 300 ms and extending until 650 ms the waveforms elicited by *true recognition* in both delays were more positive than for NEW words. This old/new ERP effect appeared at frontal and parietal locations. From around 750 ms until the end of the recording epoch ERPs for true recognition were more positive at frontal, but more negative at parietal locations than ERPs for NEW words in both delays.

Positive ERP-differences relative to NEW words were also obtained for *false recognition* in both delays between 300 ms and 600 ms. However, while the old/new ERP effect was broadly distributed over the scalp in the short delay, the positivity in the 300 to 600 ms time interval was mainly restricted to parietal recording sites in the long delay. Starting at around 800 ms the ERPs to false recognition were more negative going than to new responses to NEW words at parietal recording sites. The late parietal negativity to false recognition was larger than the negativity obtained for true recognition in both delays.

Statistical analyses were performed for an early (300-600 ms) and a late (1000-1600 ms) time window. The results of the two-way ANOVAs for true recognition and new responses of NEW words as well as for false recognition and new responses of NEW words for the short retention delay and the long retention delay are shown in Table 6.2.

Table 6.2: *ANOVA results (F-values) for the old/new effects to true and false recognition in the both time windows for the short and the long retention delay.*

		True recognition			
		Short delay		**Long delay**	
	df	300-600ms	1000-1600ms	300-600ms	1000-1600ms
Cond	1.14	77.72***	1.16	77.04***	0.64
Cond x ROI	5.70	8.01**	9.18***	23.98***	6.98***

		False recognition			
		Short delay		**Long delay**	
	df	300-600ms	1000-1600ms	300-600ms	1000-1600ms
Cond	1.14	7.99*	0.37	5.00*	0.13
Cond x ROI	5.70	0.64	7.58***	4.18**	5.57**

Note: Cond = Condition. df = degrees of freedom. ROI = regions of interest. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; (*) $p < 0.1$.

As can be seen from Table 6.2, the *short delay* analysis revealed a main effect of condition for true and false recognition in the early time window (300-600 ms). Based on a significant condition x ROI interaction for true recognition separate tests were performed. They revealed significant old/new ERP effects at all locations, with the highest treatment magnitude at the medial frontal ROI $(\omega^2 = .78)$.

ANOVAs for the late time window (1000-1600 ms) revealed a significant condition x ROI interaction for true as well as for false recognition. Separate tests for the different ROIs indicated more positive waveforms to true recognition at medial frontal $(\omega^2 = .25)$ and at right frontal ROIs $(\omega^2 = .52)$. A significant effect for the medial parietal $(\omega^2 = .27)$ and a marginally significant effect for the left parietal ROI $(\omega^2 = .19)$ indicated more negative going waveforms for OLD words than for NEW words. For false recognition separate tests for the different ROIs revealed more negative going waveforms at left parietal $(\omega^2 = .26)$ and medial parietal $(\omega^2 = .38)$ recording sites.

The *long delay* analyses revealed a main effect of condition as well as a significant condition x ROI interaction for true and false recognition in the early time window (300-600 ms). Separate tests for the different ROIs for true recognition revealed significant old/new ERP effects at all locations, with the highest treatment magnitude at the medial parietal ROI $(\omega^2 = .90)$. Separate tests for the different ROIs for false recognition showed no old/new effect at frontal ROIs (left frontal ROI: $F(1,14) = 0.64$, medial frontal ROI: $F(1,14) = 2.57, p > 0.1$, right frontal ROI: $F(1,14) = 0.31$) but ERPs to false recognition were more positive than ERPs to new responses to NEW words at parietal ROIs. Treatment magnitudes were highest at the medial parietal ROI $(\omega^2 = .46)$.

ANOVAs for the late time window (1000-1600 ms) revealed a significant condition x ROI interaction for true as well as for false recognition. Separate tests for the different ROIs indicated more positive waveforms to true recognition at the medial frontal ROI $(\omega^2 = .26)$ and the right frontal ROI $(\omega^2 = .27)$ in this time interval. At the left parietal ROI $(\omega^2 = .13)$ there was a marginally significant effect towards more negative going waveforms for ERPs to true recognition. Separate tests for the different ROIs to false recognition revealed more negative going waveforms at the left parietal ROI ($\omega^2 = .25$) and a marginally significant effect at the medial parietal ROI ($\omega^2 = .19$).

Comparision of the Early Old/new Effects

For the present study it was of major relevance to directly examine whether early frontal old/new ERP effects elicited by true and false recognition varied with the retention delay.

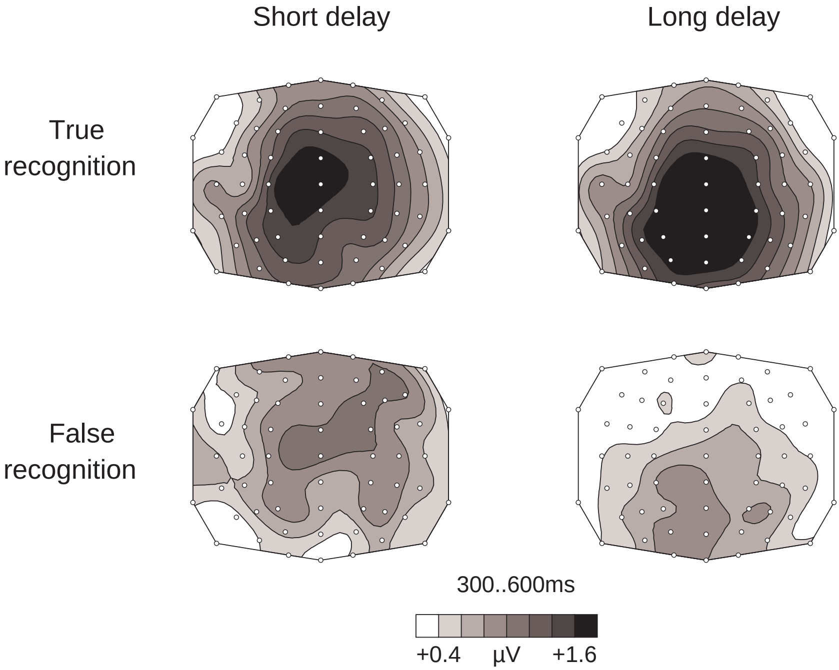

Figure 6.3: *Topographic distributions of the difference waves for ERPs to true recognition and new responses to NEW words and to false recognition and new responses to NEW words in the early (300-600 ms) time interval for the short retention delay (left) and the long retention delay (right).*

For this reason, amplitude differences to true recognition (true recognition minus new responses of NEW words) and to false recognition (false recognition minus new responses of NEW words) were compared between the two delays for the frontal locations in the early time window. The scalp topographies of the early old/new ERP effects elicited by OLD and LURE words in both delay conditions are depicted in Figure 6.3.

The ANOVA performed for the amplitude differences to true recognition in the early time window (300-600 ms) showed no main effect of delay $(F(1,14) = 2.17, p > 0.1)$ and no interaction delay x ROI $(F(2,28) = 0.30)$. For false recognition, analysis revealed a main effect of delay $(F(1,14) = 4.94, p < 0.05)$, reflecting larger early frontal old/new ERP effects in the short delay. The interaction delay x ROI showed no significant effect $(F(2,28) = 0.20)$.

ERPs for Correctly Classified LURE Words

As an additional measure of familiarity assessment, we further contrasted old and new responses to LURE words at the three frontal ROIs in the early time window (300-600 ms) for both delay conditions. If false recognition is based on illusory familiarity, LURE words that attract an old response should be more familiar than those that are rejected (e.g., Schacter et al., 1998a). Figure 6.4 displays the topographical distribution of the effect in the early time window for both delays.

There was a significant main effect of condition $(F(1,14) = 10.31, p < 0.01)$ indicating more positive ERPs to false recognition than for new responses to LURE words at frontal locations in the *short delay* condition. The interaction condition x ROI showed no statistical significance $(F(2,28) = 1.94, p > 0.1)$. ANOVA performed for ERPs measured at frontal ROIs in the *long retention delay* condition failed to show differences between false recognition and new responses to LURE words (main effect Condition: $F(1,14) = 1.36, p > 0.1$; interaction Condition x ROI: $F(2,28) = 0.28$).

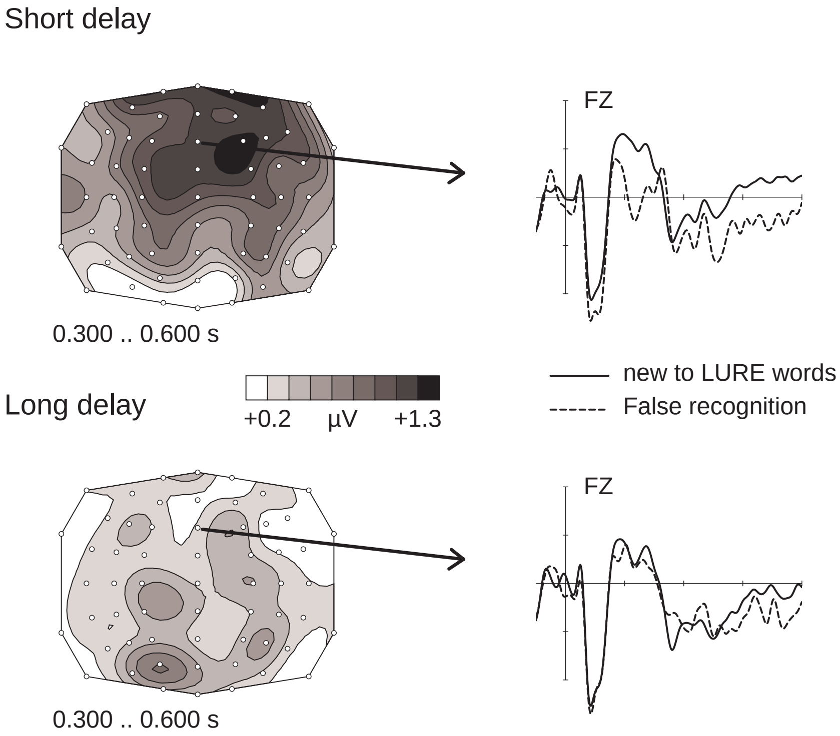

Figure 6.4: *Topographic distributions of the difference waves for ERPs to false recognition and new responses to LURE words in the early (300-600 ms) time interval (left) for the short retention delay (above) and the long retention delay (down). The corresponding ERPs are plotted for a middle frontal (Fz) electrode site (right).*

Response-Related Activity

The present study found parietal negative slow waves that started around 800 ms irrespective of delay condition. They were largest for false recognition for which longest reaction times were obtained, but also present for true recognition. Similar late parietal negativities were also found in previous ERP studies (e.g., Düzel et al., 1997; Wilding & Rugg, 1997), although so far there is no clear explanation of these effects. FMRI-constrained dipole analyses suggest that the Anterior Cingulate Cortex (ACC) contributes to this late parietal slow wave in the case of prolonged and erroneous responses to LURE words (Mecklinger et al., 1999; cf.

Mecklinger, 2000; Nessler et al., 2001). Because the ACC is considered to be involved in error detection (Dehaene, Posner & Tucker, 1994), and because late parietal negativities occured only for erroneous responses in these prior studies, it is conceivable that response-related processes such as the Error-Related Negativity (ERN, Gehring, Goss, Coles, Meyer & Donchin, 1993) contribute to this effect. To examine the contribution of response-related processes to the late parietal negativity, response-related averages were created, starting 200 ms before the response was given until 700 ms thereafter. The EEG analyses procedure was the same as for the stimulus-related averages, with the exception that the average voltages in the 200 ms preceding the response served as baseline.

Figure 6.5 displays the response-related ERP waveforms at three midline electrodes elicited by true recognition, false recognition, and new responses to NEW words. A pronounced negativity was revealed for false recognition peaking around 70 ms after the response at medial central scalp locations. True recognition elicits a negativity relative to new responses to NEW words as well, but this effect is smaller than the effect obtained for false recognition in both delays, especially at central and parietal locations.

Statistical analyses were performed for three medial ROIs: medial frontal (AFz, AF3, AF4, Fz, F3, F4); medial central (FCz, FC3, FC4, Cz, C3, C4) and medial parietal (CPz, Pz, P3, P4, CP3, CP4) between 20 and 120 ms after the response. The results of the two-way ANOVAs for true recognition and new responses to NEW words as well as for false recognition and new responses to NEW words for the short retention delay and the long retention delay are shown in Table 6.3.

As can be seen from Table 6.3, analyses for both delays revealed a main effect of condition for true and false recognition. Furthermore, there was a marginally significant interaction condition x ROI for false recognition in the short delay and a significant interaction in the long delay. Separate tests performed for the different ROIs revealed negativity for false recognition at all 3 ROIs in the short delay (medial frontal ROI: $\omega^2 = .53$, medial central ROI: $\omega^2 = .48$, medial parietal

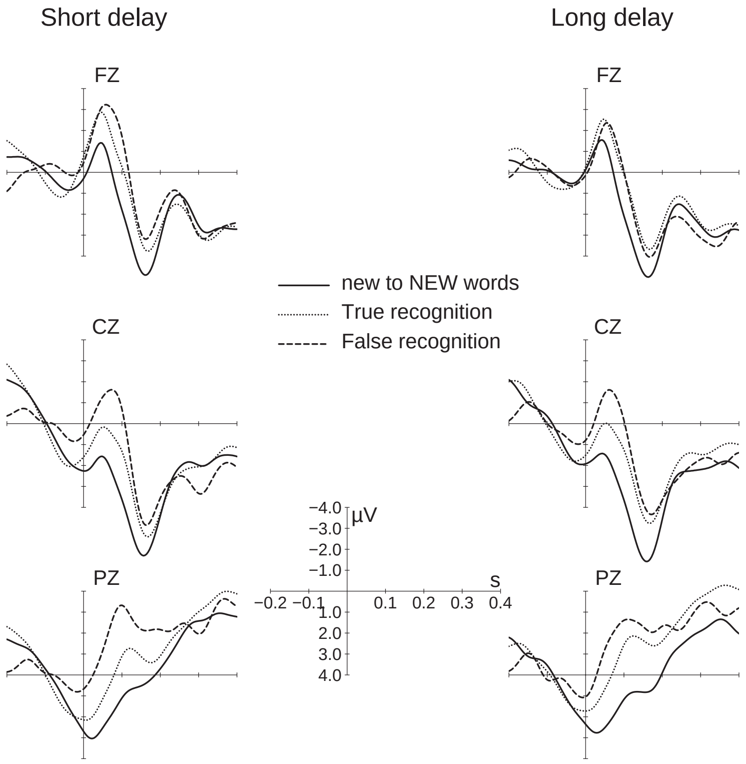

Figure 6.5: *Response-related averages elicited by true recognition, false recognition and correct rejections to NEW words at middle frontal (Fz), middle central (Cz) and middle parietal (Pz) electrode site for the short retention delay (left) and the long retention delay (right).*

ROI: $\omega^2 = .42$) as well as in the long delay (medial frontal ROI $\omega^2 = .20$, medial central ROI $\omega^2 = .43$, medial parietal ROI $\omega^2 = .48$).

Comparision of the Negative Effects for True and False Recognition

To directly examine whether the response-related negativity varied in scalp topography for true and false recognition, amplitude differences for true and false recognition (true recognition minus new responses of NEW words, false recognition minus new responses of NEW words, respectively) were compared in each

Table 6.3: *ANOVA results (F-values) for the response-related averages to true and false recognition relative to new responses to NEW words between 20 and 120 ms for the short and the long retention delay.*

True recognition

		Short delay	**Long delay**
	df	20-120 ms	20-120 ms
Cond	1.14	10.70**	12.66**
Cond x ROI	2.28	0.14	2.77

False recognition

		Short delay	**Long delay**
	df	20-120 ms	20-120 ms
Cond	1.14	15.84**	13.45**
Cond x ROI	2.28	3.25(*)	8.10*

Note: Cond = Condition. df = degrees of freedom. ROI = regions of interest. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; (*) $p < 0.1$.

delay. The scalp topographies of the response-related potentials elicited by true and false recognition in both delay conditions are depicted in Figure 6.6.

The ANOVA performed for the amplitude differences in the *short delay* showed a main effect of condition $(F(1,14) = 5.93, p < 0.05)$, and a marginally significant interaction condition x ROI $(F(2,28) = 3.83, p < 0.1)$. Separate tests for the different ROIs revealed significant effects at the medial central $(\omega^2 = .22)$ and the medial parietal location $(\omega^2 = .31)$, no difference was obtained at the medial frontal ROI.

The ANOVA for the amplitude differences in the *long delay* revealed a marginally significant main effect of condition $(F(1,14) = 3.17, p < 0.1)$, and an interaction condition x ROI $(F(2,28) = 8.47, p < 0.01)$. Separate tests for the different ROIs

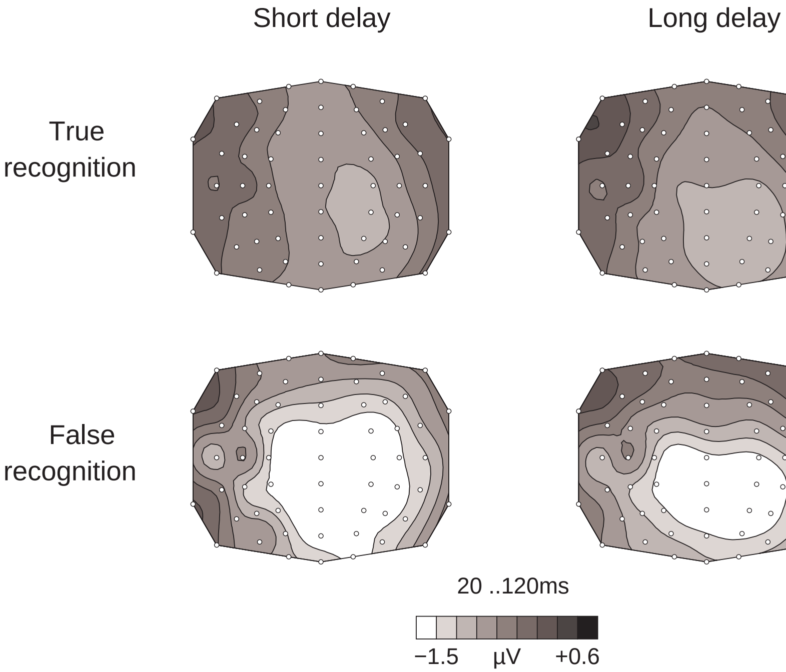

Figure 6.6: *Topographic distributions of the difference waves for the response-related ERPs (20-120 ms) to true recognition and new responses to NEW words (above), and false recognition and new responses to NEW words (down) for the short retention delay (left) and the long retention delay (right).*

revealed a marginally significant effect at the medial central ($\omega^2 = .15$) and a significant effect at the medial parietal location ($\omega^2 = .25$), no difference was obtained at the medial frontal ROI.

To examine whether the negativities for true and false responses were driven by similar brain structures, ANOVA's were performed for the amplitude normalized old/new differences (cf. McCarthy & Wood, 1985). There were marginally significant condition x ROI interactions in the short as well as in the long delay ($F(5,85) = 2.72, p = 0.10$, $F(2,28) = 3.85, p = 0.06$) respectively, suggesting that there tended to be differential topographical distributions.

In sum, the results indicate that ERPs to true recognition are not affected by retention delay. However, false recognition elicited an early frontal positivity relative to new responses to NEW words as well as to new reponses to LURE words only for the short retention delay. Late parietal negativities for true and false recognition relative to new responses reflect response-locked processes, i.e., an ERN to both kinds of old responses [1].

6.5 Discussion

In the present study true and false recognition were examined after two different retention delays. Consistent with other studies (cf. Chao et al., 1995; Friedman, 1990b; Nielsen-Bohlman & Knight, 1995) a main effect of delay for rates of correct responses as well as for reaction times indicate that memory performance declined from the short to the long delay. However, most pronounced was the increase for false old responses to LURE words in the long delay. This pattern of results suggests that memory traces degraded over time and participants based their judgements more on familiarity assessment, i.e., the judgement of the categorical similarity between test and study items. However, the conclusion that false recognition in the long delay resulted from a larger proportion of familiarity-based judgements is challenged by the ERP results.

Although in the short delay false recognition elicited an early frontal positivity relative to new responses to NEW words as well as to new responses to LURE words, seen as reflecting such familiarity assessment (cf. Mecklinger, 2000), there was no early frontal effect in the long delay condition. Consequently, the results rather suggest that the degraded memory traces in the long delay condition lead to lower feelings of familiarity for semantically related items. The decline of the early frontal old/new ERP-effect, i.e., the decrease in familiarity assessment accompanying false recognition supports the view that there is no causal rela-

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[1] Note, that beside negativities at frontal sites response-related ERPs also showed large effects at central-parietal locations in the present study. Event though prior studies, in which speeded, easy task conditions were used, reported fronto-central distributed ERNs we will refer to the component found in the present study as an ERN-like component.

tionship between the rate of false recognition and familiarity-related processes as reflected by the early frontal effect. The combined results rather suggest that memory traces were more degraded in the long delay condition and that this gave rise to decreased performance and fewer feelings of familiarity for semantically related LURE words.

The decline of the early frontal positivity after long delays resembles earlier findings (Chao et al., 1995; Guillem et al., 1999; Rugg & Nagy, 1989; see also Van Petten, Kutas, Kluender, Mitchiner & McIsaac, 1991). However, these studies report an attenuation of the ERP effect elicited by true recognition, while in the present study there was no hint for a decline of the frontal old/new effect to true recognition. Some other studies also failed to show an influence of the retention delay on ERPs elicited by true recognition of pictures (e.g., Friedman, 1990a) and of words (e.g., Friedman, 1990b). In order to address this discrepancy future research should focus on factors affecting old/new ERP effects to true recognition after different retention delays. However, the differential results obtained for true and false recognition indicate that electrophysiological correlates of false recognition are more susceptible to delay manipulations than correlates of true recognition.

In addition to the early frontal old/new ERP effects, prior recognition memory studies reported parietal and late right frontal old/new ERP-effects (e.g., Ullsperger et al., 2000; Wilding, 1999; for overviews see Mecklinger, 2000; Rugg & Allan, 2000). Although parietal positivities were obtained for true and false recognition between 300 and 600 ms, it should be noted that these effects were confounded by a parietal N400 effect to NEW words. In the present task each NEW word was drawn from another semantic category, not presented during the study phase resulting in larger centro-parietally focused N400 components to NEW words (cf. Kutas & Van Petten, 1994). That might lead to an overestimation of the parietal old/new effect in the 300 to 600 ms time interval.

Late right frontal old/new ERP effects were found for true recognition in both delay conditions in the present study, but no effect was obtained for false recognition. This finding supports retrieval success accounts of the late right frontal old/new ERP effect that claims that this effect is related to the successful recollection of memory traces (Rugg, Fletcher, Frith, Frackowisk & Dolan, 1996; Wilding & Rugg, 1996). However, other studies also reported late right frontal effects for false recognition (Nessler et al., 2001) or false source judgements (Senkfor & Van Petten, 1998), suggesting that multiple processes such as strategic monitoring and/or evaluation processes take place in this time interval (cf. Mecklinger, 2000).

In the present study it is also possible, that the late right frontal ERP-effect for false recognition is overlayed and attenuated by a large late parietal negativity. Wilding and Rugg (1997) associated such a late parietal negativity with prolonged responses, while Düzel et al. (1997) reported negativities between 600 and 1000 ms for true and false recognitions that attracted a ’Know’ response (cf. Tulving, 1985).

Because in all of these studies late negativities occured approximatelly at the time of the response, response-related averages were created in the present study. False and true recognition revealed a negative ERP relative to new responses to NEW words between 20 and 120 ms after the response. This component was identified as an Error-Related Negativity (ERN, Gehring et al., 1993). Prior investigations examined the ERN in very easy but speeded tasks, in which errors might be conscious at the moment of the response (so called ’slips’ cf. Elton et al., 2000; Reason, 1990). Given the rather low task demands in the present study (i.e., the range of correct old responses across participants was 71% to 94% and some of them made no false old responses to NEW items) it is conceivable that participants were well aware of making erroneous responses and that this is reflected in the ERN.

Some authors also argue that the ERN could reflect evaluative monitoring processes (cf. Luu, Collins & Tucker, 2000; Tucker, Hartry-Speiser, McDougal, Luu & deGrandpre, 1999; Tucker & Luu, 2000), that are assumed to be mediated by the rostral division of the Anterior Cingulate Cortex (ACC) (Bush, Luu & Posner, 2000). Source localization studies support the claim that this structure might be a possible generator of the ERN (cf. Dehaene et al., 1994; Luu et al., 2000; Holroyd, Dien & Coles, 1998). Furthermore, recent fMRI results (Mecklinger et al., 1999; cf. Mecklinger, 2000;) and source localization results of ERP data (Nessler et al., 2001) suggest that the ACC is also involved during erroneous responses to semantically associated words.

However, the interpretation that the ERN in the present study occured for the detection of an error is challanged by the fact that a similar deflection was also elicited by correct responses. A recent model accounts for ERN in correct trials by the assumption that an ERN is evoked whenever there is a mismatch between the actual response and the internal representation of what should be the correct response (e.g., Coles, Scheffers & Holroyd, 2000; Scheffers & Coles, 2000). Consequently, an ERN for correct trials might be attributable to an inaccurate representation of the appropriate response. According to this framework the ERN to correct old responses is also considered as a reflection of error processing and such a model can account for the negativities to true recognition found in the present study.

However, the larger and slightly topographically different ERN for the erroneous and prolonged responses to LURE words compared to correct old responses suggests that an additional process contributed to the effect. The most noticeable difference between OLD and LURE words is the prior studying. LURE words were not studied before, but categorically related, and caused by this it might be that the responses to LURE items were associated with response competition and high uncertainty about what is the correct response (cf. Mecklinger, 2000). Consequently, it is suggested that false responses to LURE words occurred under enhanced cognitive and monitoring demands, processes which are also assumed to reflect activity of the ACC (e.g., Bush et al., 2000; Carter, Braver, Barch, Botvinick, Noll & Cohen, 1998; Paus, Koski, Caramanos & Westbury, 1998).

In sum, ERN found for true and false recognition reflects error detection processes due to an internal representation of what is the correct response (Coles et al., 2000). However, for false recognition the effect may also capture response conflict or its attentional modulation caused by an enhanced response uncertainty.

6.5.1 Conclusion

The present study was performed to examine the relation between familiarity processes and false recognition. The combined analysis of performance and ERP measures indicates that higher rates of false recognition in the long as compared to the short retention delay do not result from higher reliance on familiarity processes. They rather suggest a general degradation of memory traces that led to poorer recognition performance and fewer familiarity-based recognition judgements for semantically related test items. The presence of an ERN to true and false recognition indicates that this effect may depend on both, an erroneous internal representation of the correct response and on error processing. Furthermore, larger and slightly topographically different ERNs to false recognition suggest that higher cognitive task demands under conditions of response uncertainty additionally contribute to the ERN.

Chapter 7

False Recognition in Patients with Frontal Lobe Lesions

7.1 Introduction

The frontal lobe (especially the right hemisphere) are considered to be involved in episodic memory retrieval (Buckner et al., 1996; Nyberg et al., 1996, cf. section 1.2). A great amount of evidence for this stems from brain imaging studies (for an overview cf. Ranganath & Paller, 1999; Wagner et al., 1998) as well as from the examination of patients with focal brain lesions located in frontal brain areas (cf. Shimamura, 1994). The memory impairment of frontal lobe patients is described as qualitatively dissimilar from that encountered in patients with amnesic syndrome (cf. Moscovitch, 1995; Schacter et al., 1998a). Usually, amnesic patients show anterograde amnesia after a lesion of the hippocampal formation (cf. Parkin & Leng, 1993). Instead, in frontal lobe patients neuropsychological research has typically suggested that encoding, consolidation, and retrieval aspects of memory are not or only slightly impaired (e.g., Milner, Corsi & Leonard, 1991; Janowsky, Shimamura, Kritchevsky & Squire, 1989a). Such patients have true memories on prior experiences, this means that they are able to encode new information after the time of the brain lesion. Further, frontal lobe lesion is often associated with confabulations and false recognition.

In order to examine the functional role of the frontal lobe in false recognition a study was conducted in which patients with frontal lobe lesion participated. Data from prior studies performed with frontal lobe patients suggest that frontal lobe structures might be especially involved in organizational and strategic aspects of memory (often referred to as ’working memory’ Baddeley, 1995). That could be for instance the generation of retrieval cues or the initiation and execution of strategic behavior (cf. Moscovitch, 1992; Schacter et al., 1998a; Stuss et al., 1994). Patients with frontal lobe lesions are impaired in the inhibition of irrelevant information (Shimamura, Jurica, Mangels, Gershberg & Knight, 1995), in task involving temporal order information (Milner, Corsi & Leonard, 1991; McAndrews & Milner, 1991), and in the remembering of the source of acquired knowledge (e.g., Janowsky et al., 1989b). Another very typical result reported in case examinations of patients suffering from frontal lobe injury is confabulation in tests of free recall (e.g., Moscovitch, 1995). Hanley, Davies, Downes and Mayes (1994), for instance, reported a marked impairment in recall with normal recognition memory for a frontal lobe patient. Their assumption that recall but not recognition is impaired after frontal lobe lesion was challenged in other studies. For instance, Delbecq-Derouesne et al. (1990) described experiments performed with the frontal lobe patient R.W., who was impaired in tests of free recall as well as in test of recognition. The patient suffered from a ruptured anterior communicating artery aneurysm and had bilateral areas of hypodensity in the medial aspects of the frontal lobe, in the right temporal pole, the fusiform, and the parahippocampal gyri. Although R.W. showed relatively preserved free recall of studied items he also made many intrusions. The patient was also impaired in tests of recognition memory. He made an abnormal large number of confident false recognition. Therefore, the authors suggested that a dissociation between performance in recognition and recall tests does not provide a good account for the description of the impariment in frontal lobe patients. It was assumed that R.W. could not distinguish studied items from other misleading information and that this caused the obtained memory impairment.

This interpretation is in line with results found for patient B.G., as already described in section 2.5.2. B.G. showed extraordinarily high false alarm rates on recognition memory tests (Schacter et al., 1996b; Curran et al., 1997). His pathological rate of false old responses could be sharply reduced by testing him with items that differed substantially from those he had studied. It was suggested that B.G.'s impairment is related to an overreliance of general similarity between test items and general characteristics of the study episode (Schacter et al., 1996b; Curran et al., 1997). This was supported by a signal detection analysis which revealed that B.G. had a deficit in sensitivity as well as a more liberal response bias than control participants.

Parkin et al. (1996) described another patient, J.B., who suffered from a ruptured anterior communicating artery aneurysm, leading to an atrophy in the left frontal cortex and the left caudate. J.B.'s intellect appears largely intact, and he also performed well at tests of the frontal lobe. However, he exhibits marked difficulties in tests of memory, especially for verbal memory in accordance to his left-sided lesion. To explore the nature of J.B.'s memory deficit in more detail the authors used different tests of recall and recognition. For instance, unrelated target words were studied in one recognition procedure. In the test phase J.B. made old/new judgements to the studied words and distractors, from which half were unrelated and half were either semantically or phonologically related to studied words. J.B.'s performance was below the performance of a control group. He made fewer correct old responses to studied words (true recognition) as well as more false old responses to distractors. Although J.B. made false old responses to related distractors (false recognition) he also made some false responses to unrelated words in this task. Another recognition test used abstract designs. J.B. made no false old responses to unrelated pictures, while the rate of false old responses to related distractors was again high and above that reported for controls. The authors reported also that J.B. was often sure that he gave the correct response, although he classified all responses as ’Know’. Given these results, it was assumed that J.B. recognition memory is non-recollective and familiarity based, this means that J.B. is overreliant on familiarity cues.

In sum, results from different studies of patients with frontal lobe lesion indicate that some frontal lobe structures are important for the correct rejection of non-studied but semantically related items. It has been suggested that patients are impaired in the dissociation of retrieved studied material and material that comes in mind due to the relation to the studied items (Schacter et al., 1998a). However, note that the reported studies are case examinations of patients suffering from different frontal lesions, using different designs, and reporting different results. The goal of the present experiment was to examine whether a selective abnormal increase in false recognition is a general characteristic of frontal lobe pathology or whether this depends on specific frontal lobe structures. Therefore, patients with different lesions of the frontal lobe were investigated in one study using one design. The paradigm as introduced in Chapter 6 was used. This paradigm was especially adapted for patient investigations as for instance the short blocks allowed breaks and as the feedback about performance allowed some positive influence on motivation. The use of this paradigm makes it also possible to analyze participants performance at two different retention delays. Recognition should become more difficult as lag increases (e.g., Friedman, 1990b; Hintzman, 1969). Given that encoding, consolidation, and retrieval processes depend mainly on the hippocampal formation, which is intact in frontal lobe patients, the decrement for true recognition should not be different for patients than for healthy controls. However, if the prevention of false recognition is mainly dependent on the functioning of the frontal lobe, then increasing lag should be especially heighten false recognition rates in patients.

7.2 Methods

7.2.1 Participants

A group of six frontal lobe patients and 12 age and education matched controls participated in the experiment. Descriptions of the lesioned brain structures for the patients are given in Table 7.1. Four patients had bifrontal lesions. The damage was restricted to the left side of the frontal lobe in patient 332, while patient 273 showed an extended right-hemispheric lesion including the posterior division of the middle and inferior frontal gyri. Other main clinical data are reported in Table 7.2. The mean age of the patients was 45 years (range 26-60). One female and five male right-handed patients participated. A selection of relevant neuropsychological data is also displayed in Table 7.2. Intelligence measures were provided by the vocabulary intelligence test (MWT-B, Lehrl, 1989; Lehrl, Merz, Burkard & Fischer, 1991) and by the Performance exerciser (LPS3, Horn, 1983). For the investigation of memory the revision of the Wechsler Memory Scale was used (Wechsler, 1987). The scores for digit and visual span are indicative of short-term storage capacity. As indicated in Table 7.2, there were some differences between the patients. In general, patients 150, 273, and 300 performed less well on the tests than patients 203 and 330 (patient 332 participated only in the LPS3). That was true for the intelligence tests as well as for the memory tests. There were 12 control participants, all of whom were right-handed, with a mean age of 43 years (range 24-58). Respectively 2 control participants were selected to match one patient with respect to sex, age, and education (years of schooling).

7.2.2 Stimuli and Procedure

The same word list and procedure as in Experiment 4 were used (see Chapter 6). The two sessions were separated by at least six and maximal fifteen intermediate days.

Table 7.1: *Lesion description for the six frontal lobe patients under investigation.*

(A) Patients with bifrontal lesions

Patient		**FP**	**FM**	**FO**	**FL**	**Brodmann areas**
150	L	+	+a	+a	-	10, 9m, 32, 12, 11
	R	+	+a	+a	-	
203	L	+	+a	+a	-	10, 9m, 32, 12, 11
	R	+	+a	+a	-	
300	L	+	+a	+	-	10, (9m), 12, 11, 46, (47)
	R	+	+a	+	-	
330	L	+	+	+	+	10, 9, 8, 6, 32, 24, 46, 45
	R	+	+a	+a	-	10, 12, 11, (46), (47)
(B) Patient with left frontal lesions						
332	L	+	+a	+l	+	10, 9, 32, 24, 46, (45)
(C) Patient with right frontal lesions						
273[1]	R	+	+	+	+	10, 9, 8, 6, 46, 45, 44, 47

Note. FP = fronto-polar; FM = fronto-medial; FO = fronto-orbital; FL = fronto-lateral; L = left hemisphere; R = right hemisphere; + = lesion; +a = lesion anterior; +l = lesion lateral; - = no lesion

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[1] The lesion area of patient 273 also includes other regions in the right hemisphere: temporo-polar and temporo-lateral (T1,T2,T3) brain areas

Table 7.2: *Individual patient information, clinical, and neuropsychological data, for the six frontal lobe patients under investigation.*

Patient	**150**	**203**	**273**	**300**	**330**	**332**
Sex	m	f	m	m	m	m
Age (years)	26	50	60	39	49	47
Schooling (years)	10	8	8	10	10	12
Time since lesion (months)	40	82	40	228	33	48
MWT-B	23	62	46	29	-	-
LPS3	27	60	20	73	84	95
WMS-R						
Attention	77	99	75	90	99	-
Verbal	75	121	89	63	103	-
Visual	109	107	86	89	100	-
Delay	87	123	82	64	-	-
General	84	119	87	69	101	-
Digit span (f)	29	13	48	35	53	-
Digit span (b)	29	34	2	30	34	-
Visual span (f)	2	90	27	47	25	-
Visual span (b)	12	79	10	13	79	-

Note. MWT-B = vocabulary intelligence test (Lehrl, 1989; Lehrl et al., 1991); LPS3 = Performance exerciser (Horn, 1983); WMS-R = Wechsler Memory Scale-Revised (Wechsler, 1987). Scores for the MWT-B, the LPS3, for Digit span (subtest WMS-R) and Visual span (subtest WMS-R) are provided in Percentile Equivalents, the five indices of the WMS-R yield a mean score of 100 in the normal population with a standard deviation of 15; f = forward; b = backward.

7.3 Results

Mean reaction times and proportion of old responses to OLD, LURE, and NEW words are presented in Table 7.3 for both groups.

Table 7.3: *Mean reaction times (in ms) of the old and new responses, and mean proportion (in %) of the old responses for the different item-types in the short and the long retention delay for the patient group and the control group. The standard error of the mean is presented in parentheses.*

Item	**Response**	**Reaction time**		**Proportion old-response**	
		Patients	**Controls**	**Patients**	**Controls**
		Short retention delay			
OLD	old	1053 (186)	773 (40)	79.8 (3.1)	88.6 (1.1)
	new	1366 (234)	1098 (95)		
LURE	old	1197 (243)	1030 (68)	28.5 (3.8)	20.3 (3.1)
	new	1204 (191)	885 (53)		
NEW	old	1222 (231)	962 (71)	9.2 (2.9)	1.7 (0.5)
	new	1127 (175)	785 (35)		
		Long retention delay			
OLD	old	1061 (197)	796 (41)	79.8 (3.4)	87.2 (1.5)
	new	1347 (238)	1118 (82)		
LURE	old	1241 (224)	1057 (77)	30.6 (3.7)	21.8 (2.8)
	new	1205 (190)	914 (53)		
NEW	old	1241 (230)	1008 (83)	10.6 (2.7)	2.6 (0.6)
	new	1131 (172)	805 (35)		

Table 7.3 shows that all participants made more false alarms to LURE words (false recognition) than to NEW words in both delay conditions. There was also a slight increase in false old responses to NEW and LURE words for the long delay condition in both groups. Control participants showed higher rates of true

recognition, smaller rates of false recognition, and smaller rates of false responses to NEW words than patients. However, patients performed well above chance indicating that they had memories on the prior studying.

Furthermore, in both groups and for both delay conditions reaction times were faster to true recognition and correct rejections to NEW words than to false recognition and new responses to LURE words. Overall, reaction times were faster in the short delay condition. This was particularly clear for the reaction times to false recognition in the group of patients. Control participants were generally faster than patients.

This pattern of results was confirmed by statistical analyses. At first, statistical analysis for the proportion of old responses is described. An ANOVA was conducted treating group as a between subjects factor and delay (2 levels: short, long) and item type (3 levels: OLD words, LURE words, NEW words) as within subjects factors. There was a significant main effect of group $(F(1,16) = 13.19, p < 0.01)$ reflecting more true responses for control participants. A marginal significant main effect for delay $(F(1,16) = 3.7, p = 0.07)$ pointed to the higher rates of true responses in the short delay than in the long delay. There was also a main effect of item $(F(2,32) = 46.17, p < 0.001)$. Although there was no interaction with the factor item type, separate analyses were performed. The ANOVA performed for true recognition revealed a significant main effect of group $(F(1,16) = 9.90, p < 0.01)$ but no main effect or interaction with the factor delay ($F(1,16) = 0.27; F(1,16) = 0.27$, respectively). The analysis of the rate of new responses to LURE items showed marginally significant main effects of group $(F(1,16) = 3.87, p = 0.07)$ and delay $(F(1,16) = 4.16, p = 0.06)$. More new responses to NEW items in the control group than in the patient group $(F(1,16) = 15.66, p < 0.01)$ and larger rates of new responses to NEW items in the short than in the long delay $(F(1,16) = 7.02, p < 0.05)$ were revealed. The nonparametric Wilcoxon-tests for dependent samples were used to examine whether the patients differ from their chance performance (50 %). This was the case for all item types

(OLD words, LURE words, NEW words) in the short retention delay as well as in the long retention delay (in all cases $p < 0.01$).

Concerning the reaction times, an ANOVA treating group as a between subjects factor and delay (2 levels: short, long) and item type (4 levels: true recognition, false recognition, new responses of LURE words, new responses of NEW words) as within subjects factors revealed a marginally significant main effect of group $(F(1,16) = 3.27, p = 0.09)$ and item type $(F(3,48) = 21.18, p < 0.001)$. The main effect of delay $(F(1,16) = 10.51, p < 0.01)$ reflected faster responses in the short delay condition than in the long delay condition. There was a marginally significant interaction of group and item type $(F(3,48) = 2.80, p = 0.09)$ indicating different effects for the item types in both groups. To examine this interaction separate T-tests were performed comparing the reaction times for the different item types between both groups. However, there was no significant effect for unique item types. This might be based on the large differences in variance.

In sum, patients performed well above chance. Consequently, it is suggested that encoding, consolidation, and retrieval processes are intact, in agreement with results from prior studies (e.g., Milner et al., 1991; Janowsky et al., 1989a). However, control participants showed better rates of performance as well as faster reaction times than frontal lobe patients. In the present study different study-test blocks were used. This may have required the differentiation between memory traces from different blocks in each test phase. Prior studies showed that frontal lobe patients were impaired in the inhibition of irrelevant information (Shimamura et al., 1995), and this could have caused the worse performance of the patients compared to the healthy controls. However, the present study does not support the assumption that frontal lobe patients are especially impaired in the correct rejection of LURE words. This means that there was no evidence for a special impairment of reactions to non-studied but semantically related words. The increasing retention delay also did not have a differential influence on the performance for the item types in both groups (as is reflected by the failure to find an interaction delay x item type).

In the prior analyses, data were averaged across all patients. In order to get an individual pattern of results individual data for patients and their respective control participants were analyzed in a second step. Mean proportion of old responses to OLD, LURE, and NEW words for each patient and the mean for the respective control participants are presented in Table 7.4.

Table 7.4: *Mean proportion of the old responses for the different item-types in the short and the long retention delay for each patient compared with the mean from the two controls.*

	Proportion old-response					
	Short retention delay			**Long retention delay**		
Patient	**OLD**	**LURE**	**NEW**	**OLD**	**LURE**	**NEW**
150	82.5	20.8	3.1	76.0	29.2	5.6
mC	92.5	17.5	1.9	92.5	14.6	1.3
203	73.0	25.8	5.0	83.5	30.8	8.1
mC	88.8	20.8	1.9	90.5	22.1	3.1
273	79.0	44.2	12.5	71.5	45.0	16.3
mC	84.8	14.2	2.2	85.5	15.9	1.9
300	72.0	34.2	21.9	79.0	29.2	20.0
mC	87.8	25.4	0.9	84.5	32.1	1.9
330	79.5	19.2	8.8	74.5	16.7	11.3
mC	87.0	22.9	3.8	87.8	21.3	5.9
332	93.0	26.7	3.8	94.5	32.5	2.5
mC	91.2	20.9	0.6	82.6	26.3	5.0

Note. mC = mean of the two control participants for each patient.

Furthermore, the rate of correct responses for the different item types was computed as percentage for each patient compared to the respective controls in Table 7.5. This provides a better rating of individual impairments for the patients, because the performance is related to performance of age and education matched controls.

Table 7.5: *Percentage of correct responses for the different item-types in short and long retention delay for each patient in relation to the mean of the two controls*

	Percentage of correct response					
	Short retention delay			**Long retention delay**		
Patient	**OLD**	**LURE**	**NEW**	**OLD**	**LURE**	**NEW**
150	89.2	96.0	97.8	82.2	82.9	95.5
203	82.2	93.7	96.8	92.3	88.8	94.2
273	93.2	65.0	88.2	83.6	61.4	83.9
300	82.0	88.7	79.4	93.5	104.3	81.5
330	91.4	103.8	94.1	84.9	97.3	92.3
332	102.0	94.2	96.6	114.4	91.5	100

As reflected by the rates of old responses in Table 7.4 and by the data given in Table 7.5 it seems that only patient 273 showed a special decrement for responses to LURE words compared to the respective control participants. All values in Table 7.5 are at least around 80 %, while patient 273 achieved only around 60 % of the performance of his respective control participants to LURE words. This indicates that only for this particular patient the differentiation of studied and non-studied semantically related material is impaired. This is also indicated by individual reaction time data presented in Table 7.6.

Table 7.6: *Mean reaction times (in ms) for the different item-types in the short and the long retention delay for each patient compared with the mean from the two controls.*

		Reaction time			
Patient	**Delay**	**True recognition**	**False recognition**	**new to LURE**	**new to NEW**
150	short	706	787	755	733
mC	short	628	726	667	627
150	long	704	831	755	745
mC	long	645	745	700	626
203	short	897	1067	1015	945
mC	short	698	955	851	791
203	long	900	1084	1070	979
mC	long	713	974	861	802
273	short	685	665	877	860
mC	short	819	1088	864	761
273	long	674	688	900	866
mC	long	856	1259	882	791
300	short	950	905	1077	1111
mC	short	789	1119	945	825
300	long	918	1129	1019	1062
mC	long	812	1153	987	876
330	short	1912	2256	2006	1934
mC	short	735	966	829	759
330	long	1965	2200	2012	1930
mC	long	755	896	861	774
332	short	1168	1503	1498	1180
mC	short	953	1339	1153	938
332	long	1207	1522	1474	1204
mC	long	983	1286	1187	959

Note. mC = mean of the two Control participants for each patient.

Generally, participants showed shorter reaction times for true than for false recognition (sole exception: patient 300, short delay). It can be assumed that a decision for LURE words was more complicated and involved more effortful processes than the decision for an OLD word. A decision to a non-studied but semantically related word may require more often an analysis of item specific features, in which participants were engaged to solve the question whether the word was studied before or was only internally generated. Patient 273 showed nearly identical reaction times for true and false recognition in both delays assuming that he was not engaged in the additional retrieval processes to reject LURE words. Rather, it seems that patient 273 decided on the basis of general information only, this means that he was more reliant to general information.

To examine the deficit of patient 273 in more detail, different measurements were performed contrasting his performance descriptively with the mean values and the range of the other frontal lobe patients, who did not show pathologically increased rates of false recognition. Table 7.7 shows the comparison of the mean proportions of old responses to OLD, LURE, and NEW words between patient 273 and the remaining patients. For false recognition patient 273 is outside the range of other frontal lobe patients in both retention delays. This might reflect his pathologically enhanced false recognition. However, true recognition rate is also outside the range of the other patients in the long delay condition.

One explanation for the enhanced false recognition rate could be that patient 273 used more liberal response criteria's. To examine this a nonparametric signal detection procedure was used, as described by Koutstaal and Schacter (1997, cf. also Schacter et al., 1998b; Curran et al., 1997). In this procedure A' is computed as an estimate of sensitivity and B"D is computed as an estimate of response bias (Donaldson, 1992). The following formulas were used:

$$A' = 0.5 + [(H - FA)(1 + H - FA)]/[4H(1 - FA)]$$

$$BD'' = [H(1 - H) - FA(1 - FA)]/[H(1 - H) + FA(1 - FA)]$$

Table 7.7: *Mean proportion (in %) of the old responses for the different item-types in the short and the long retention delay for patient 273 compared with the mean from the other patients.*

	Short retention delay				**Long retention delay**			
	273	**mPat**	**Max**	**Min**	**273**	**mPat**	**Max**	**Min**
OLD	79.0	80.0 (3.8)	93.0	72.0	71.5	81.5 (3.6)	94.5	74.5
LURE	44.2	25.3 (2.6)	34.2	19.2	45.0	27.7 (2.8)	32.5	16.7
NEW	12.5	8.5 (3.5)	21.9	3.1	16.3	9.5 (3.0)	20.0	2.5

Note. mPat = mean of the five patients.

Values of A’ range from 0 to 1, with change performance being 0.5. Higher values indicate greater sensitivity. Values of the corresponding bias measure B”D range from -1.00 (indicating extremely liberal responding) to +1.00 (indicating extremely conservative responding). Since these measures are not defined with Hit and False alarm rates of 0 or 1, the data were first transformed. P(x) was computed as $(x+0.5)/(n+1)$ rather than as x/n (cf. Snodgrass & Corwin, 1988). If participants showed below chance sensitivity ($A' < 0.5$), modified formulas were used (Aaronson & Watts, 1987). Following Koutstaal and Schacter (1997) three different types of signal detection analyses were performed. The first measure estimates sensitivity and response bias comparing true recognition with false alarms to unrelated (NEW) words. Values are seen as measures of item specific true recognition and are labeled *sensitivity unrelated* and *response bias unrelated*. In a second analyses an additional measure of item specific true recognition was provided. True recognition was compared to false recognition (*sensitivity related*, *response bias related*). In a last analyses false recognition is depicted as a form of memory for the general information. Thus, false recognition is compared to false alarms to NEW words (*sensitivity general*, *response bias general*). In accordance to Curran et al. (1997) the values for Patient 273 were descriptively compared to the mean values and the range (i.e., the maximum and the minimum values) of the remaining five patients.

Table 7.8: *Measures of Sensitivity and Response Bias for both retention delays. Values are shown for item specific memory: unrelated (true recognition compared to false alarms to NEW words), for item specific memory: related (true recognition compared to false recognition), and for general information (false recognition compared to false alarms to NEW words)*

	Short retention delay				**Long retention delay**			
	273	**mPat**	**Max**	**Min**	**273**	**mPat**	**Max**	**Min**
				Item specific memory, unrelated				
A’	0.90	0.91 (0.02)	0.97	0.83	0.86	0.92 (0.02)	0.98	0.87
BD”	0.30	0.47 (0.11)	0.74	0.16	0.34	0.38 (0.10)	0.67	0.03
				Item specific memory, related				
A’	0.77	0.85 (0.02)	0.90	0.77	0.71	0.85 (0.01)	0.89	0.82
BD”	-0.49	-0.17 (0.13)	0.04	-0.65	-0.34	-0.25 (0.17)	0.26	-0.78
				General memory				
A’	0.77	0.71 (0.03)	0.77	0.63	0.74	0.70 (0.04)	0.81	0.60
BD”	0.79	0.92 (0.04)	0.98	0.74	0.72	0.92 (0.03)	0.97	0.81

As it is shown in Table 7.8 patient 273 is outside the range of the values from the other patients for *sensitivity unrelated* and *sensitivity related* as well as for *response bias general* in the long retention delay. No descriptive difference was found for the short retention delay.

The small values for *sensitivity related* of patient 273 (note that *sensitivity related* for patient 273 was at the minimum range border of the values for the other patients in the short retention delay) may support his impaired ability to differentiate between studied and non-studied but semantically related words. However, values for *sensitivity unrelated* as well as values for *response bias general* do assume that also differentiation between studied and non-studied non-related material is impaired, and that patient 273 showed more liberal response criteria's for NEW items in the long retention delay. However, most important, enhanced false recognition seems to be not related to a more liberal response bias. Instead, sensitivity values let assume that the enhanced rate of false recognition reflect a differentiation deficit between studied and non-studied but semantically related material for patient 273. Such a differentiation deficit could be based on an overreliance to general information or on impaired processes in the analyzing of item specific information. The reaction time patterns could differentiate between these two possible interpretations. While an overreliance to general information let assume that reactions should be fast, impaired analyzes processes should be reflected by long reaction times. Reaction times for patient 273 were short in general, more interesting, there were no larger reaction times for false than for true recognition as it was found for the other patients and control participants (cf. Table 7.6). This indicates that patient 273 shows an overreliance to general information. To examine this in more detail speed-accurracy trade-off functions (Luce, 1991) are obtained by computing response accuracy as a function of response latency in four different latency bins. Trials for LURE words and for OLD words were classified into four quartiles on the basis of reaction time. For each condition accuracy values are shown in Figure 7.1. Rates of errors for OLD words increased with increasing reaction times for patient 273 as well as for the other patients in both delay conditions. It may be that patients needed more time for the decisions to OLD words if they were uncertain about prior studying. This uncertainty might also result in more errors. On the other hand, a strong memory trace may lead to quick and correct responses. Error rates for LURE words were nearly similar for the different latency bins for the group of the five patients in both delays. Most interesting, error rates for LURE words decreased rapidly with increasing reaction times for patient 273 indicating that he traded speed for accuracy. It is suggested that patient 273 is overreliant to general information and that he showed fast responses with the costs of high error rates. Further, the small error rate for very slow responses indicates that item specific analyses are not impaired. Instead, it is assumed that patient 273 made his decision before he was involved in the more effortful analyses.

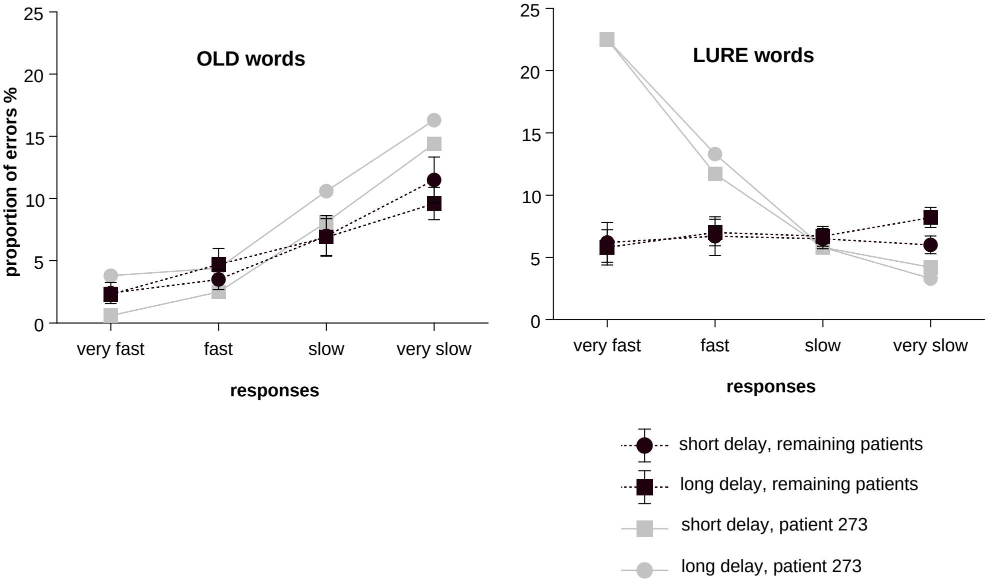

Figure 7.1: *Speed-accurracy trade-off functions for patient 273 and the remaining patients. Values were obtained by computing response accuracy as a function of response latency in four different latency bins for both retention delays. Mean proportion of the old responses for each reaction time condition are given. The standard error of the mean is also presented for the group of the five remaining patients.*

7.4 Discussion

True and false recognition were behaviorally examined after two different retention delays for six patients suffering from a frontal lobe lesion and 12 controls. Patients and controls showed higher rates of false recognition than false old responses to NEW words, and performance decreased from a short (40 sec) to a long (80 sec) retention delay in both groups. Control participants performed generally better than patients, they responded faster and made fewer errors. The general impairment in memory performance for patients as compared to controls could be related to the design of the present study. The different study-test trials might have caused on interference for the patients, as it is known that the frontal lobe is important for the inhibition of irrelevant information (e.g., Shimamura et al., 1995; Incisa della Rocchetta & Milner, 1993). However, the patients performed well above chance and this ability to learn new material is in agreement with results from other studies (Milner et al., 1991; Janowsky et al., 1989a).

Beside the involvement of the frontal lobe in reducing interference associations to other functions of episodic memory are assumed, such as effortful retrieval, focusing, criterion setting, or post retrieval verification processes (cf. Schacter et al., 1998a). Above mentioned processes are seen as especially important for the differentiation of studied and non-studied but semantically related material. This is supported by the results of prior studies with patients suffering from frontal lobe injury, which reported high rates of false recognition (e.g., Schacter et al., 1996b; Parkin et al., 1996).

In the present study patients with bifrontal and left frontal lesions showed no remarked enhancement of false alarms to LURE words. This latter effect was only obtained in one patient with an extended right-hemispheric lesion including the posterior division of the middle and inferior frontal gyri. This lesion area is comparable to the lesion of patient B.G.. Extending the findings as described on patient B.G., this result suggests that the right posterior fronto-lateral cortex is more relevant for the differentiation of semantically related material than fronto-orbital and fronto-polar regions. It is suggested that enhanced false recognition is no general characteristic of frontal lobe lesion. Instead, the right posterior fronto-lateral cortex may be especially involved in the differentiation of studied and non-studied but semantically related material. However, this interpretation is only based on descriptive analyses, and the lesion of patient 273 also includes other regions in the right hemisphere (cf. Table 7.1). Future studies are necessary to support the interpretation of the special role of this frontal lobe area including patients with more localized lesions.

In the following, some speculations about processes involved in the false recognition deficit are given. A very first possibility might be that there is an incorrect criterion setting that could result in liberal response criteria's. That was also found for patient B.G. (Curran et al., 1997). The authors performed a signal detection analysis and reported a deficit in sensitivity but also a more liberal response criteria for this patient compared to control participants. To examine whether an incorrect criterion setting was also present for patient 273, values for sensitivity and response bias were compared with the mean of the other patients in the present study. Values were examined with respect to item specific information as well as general information (cf. Koutstaal & Schacter, 1997). Although patient 273 was not different from the range of the other patients in the short retention delay, sensitivity for item specific information seems to be impaired at least in the long retention delay. Patient 273 showed no more liberal response bias to non-studied semantically related words than the other patients. However, patient 273 seems to be more liberal for an old-decision to non-studied and non-related words (NEW), at least in the long delay condition. However, it is assumed that enhanced false recognition for patient 273 is related to an impairment in the use of item specific information to reject non-studied related words rather than to more liberal response criteria's.

One interpretation for the deficit in sensitivity holds that it is based on impairments in the analyzing of item specific information and that the effortful processes necessary to distinguish accurate from illusory memories are impaired. Such processes could for instance include the examination of the amount of item specific information and refer to an involvement in source memory judgements (Johnson et al., 1993). Another possibility might be that patient 273 is overreliant to general information and that he is not involved in effortful processes although they are intact. The later is assumed by results given by the analyzing of errors as function of response times. Patient 273 showed a speed-accuracy trade-off for the decisions to LURE words. Error rates were especially high after fast reactions but decreased rapidly if he toke more time for the response. Consequently, it seems that the effortful analyses of item specific information were intact, but that the patient mainly used general information for the reactions. It can be assumed that the frontal lobe lesion of patient 273 results in an overestimation of the importance of general information. An other possibility might be that connections between parallel occurring processes are impaired. This means that there are for instance two processes: the process to respond with old or new and the analyzing process. In the healthy brain, there is a permanent connection between both processes, and if analyzing is more complicated then the response is delayed. The lesion of patient 273 could have destroyed or delayed connections so that the feedback about the more complicated analyzing process appears after the response is given. However, for slow reactions the information from the analyzing process can be used and results in fewer rates of errors.

So far, all mentioned interpretations are related to the time of retrieval, while other interpretations hold that lesions of the frontal lobe also impair the ability to encode distinctive item attributes at study. The results from Experiment 5 suggest that a false recognition deficit does only occur after lesion of a special part of the right hemisphere. In this context, the examination of two split brain patients by Phelps and Gazzaniga (1992) is of special interest. Patients were asked to perform a recognition memory test in order to examine the involvement of the left and the right hemisphere in memory retrieval. In the study phase patients saw a series of pictures representing a common scene. Later, their memory for these pictures were tested using a lateralized old/new recognition test. Distractor pictures were either consistent or inconsistent with the scene. The right hemisphere performed above chance on consistent distractor pictures, the level of accuracy was comparable for orginal pictures and consistent distractor pictures. However, the left hemisphere performed below chance on consistent distractor pictures. Consequently, the results suggest that the left hemisphere is more influenced by general informations of a scene, while the right hemisphere is more involved in the processes using item specific information to differentiate between studied and non-studied but semantically related material (for same results cf. Metcalfe, Funnell & Gazzaniga, 1995). This is consistent with results from the present study in which a selective impairment for responses to semantically related non-studied words was only found after a lesion of the right hemisphere. Moreover, Phelps and Gazzaniga (1992) assumed that recognition-related processes are more relevant for the false recognition deficit than encoding-related processes. This was concluded because encoding was identical in this study and independent from the fact whether the left or the right hemisphere was asked to give the later response. This might also give some hints for the interpretation of the false recognition deficit found for J.B.. Although this patient suffered from a left-sided lesion, he did also show high rates of false recognition. Given that the left hemisphere is more involved in encoding (cf. HERA model, Tulving, Kapur, Craik, Moscovitch & Houle, 1994) it might be that J.B.'s memory impairment is mainly driven by an encoding deficit. This is also in line with the fact that this patient only gave Know responses. It is suggested that J.B. was inable to encode item specific features, which could be sufficient to differentiate semantically related material in a later test. In the present study patients with left sided frontal lesion showed no differential impairment. Maybe, encoding was less demanding in the present study due to the use of short lists or that relevant left frontal regions were still intact.

Different retention delays in the present study made it possible to examine forgetting rates. The results showed no difference between the group of patients and the group of control participants. This is in line with results found for true recognition reported by prior studies (Kopelman & Stanhope, 1997; Swick & Knight, 1999). However, regarding individual results for patient 273, who seems to be impaired in the differentiation of studied and non-studied but semantically related words, the results suggest that his impairment is also influenced by the delay manipulation. Although rates of false recognition for this patient were pathologically enhanced in both retention delays, rates of true recognition were outside the range of the other patients only for the long delay condition. The same was true for sensitivity and response bias. Values for patient 273 were outside the range of the other patients only in the long delay condition. However, given the descriptive status of the reported results further studies are necessary to evaluate these suggestions.

In sum, the present results suggest that patients with frontal lobe lesions do not generally show enhanced false recognition. Rather, it is indicated that the right posterior fronto-lateral cortex is especially important for the differentiation of studied and non-studied but semantically related material in the retrieval phase.

Chapter 8

General Discussion

The present work examined behavioral and electrophysiological correlates of false recognition, one kind of false memories. False recognition was not only investigated in healthy participants but also in patients suffering from frontal lobe injury.

Errors in the retrieval process were observed as long as memory was part of cognitive research. However, a systematic investigation of the processes involved in false memories had not started until a few years ago. Many behavioral studies were performed (for overviews cf. Schacter et al., 1998a; Reyna & Lloyd, 1997; Lampinen et al., 1998) and showed that errors do often occur. High rates of false responses could be obtained if non-studied items shared features (either semantic or phonological) with studied material (e.g., Roediger & McDermott, 1995; Rubin et al., 1999). Such errors are called false memories or false recognition and are usually larger than false responses to non-studied, non-related items (basic false alarm). Behavioral results showed for instance that rates of false recognition increased the larger the semantic associations to studied items got (e.g., Robinson & Roediger, 1997).

Behavioral studies alone cannot provide information which brain structures or processes are involved in recognition memory. Is false recognition based on similar or on different processes as compared to true recognition? Are similar or different brain structures involved? The present studies used electrophysiological measures to investigate the cortical involvement in true and false recognition (Experiment 1-4). More specifically, it was asked whether true and false recognition can be associated with different brain activation patterns. Brain structures of the frontal lobe are seen as especially involved in the processes that prevent false recognition (e.g., Schacter et al., 1998a). Consequently, in Experiment 5 the investigation of patients suffering from frontal lobe lesion was considered to be useful to obtain information about the functional significance of these brain areas.

This Chapter summarizes the results obtained for true and false recognition in the different experiments. The first section focuses on electrophysiological correlates of familiarity and recollection processes, which are known to be critical for true recognition memory (cf. dual process account of recognition memory, Mandler, 1980; Gardiner & Java, 1993). While both components are reported to be related to the functions of the hippocampal formation (cf. section 3.2.2), a second section focuses on results that are related to the functions of the frontal lobe. The final part of the Chapter will summarize the conclusions and will discuss directions for future research.

8.1 Illusory Familiarity and Recollection

True recognition can result from familiarity assessment as well as from the recollection of a memory trace (dual process theory of recognition memory, Gardiner & Java, 1993, cf. also section 1.1.1). In earlier electrophysiological studies of true recognition the two different components of the dual process account could be associated with two different ERP old/new effects (for an overview cf. Friedman & Johnson, 2000; Mecklinger, 2000). While an early frontal ERP old/new effect is seen as related to familiarity assessment, a parietal ERP old/new effect is assumed to reflect the recollection of item specific information. Given this proposal the question arises whether false recognition is also based on similar dual processes.

The goal of *Experiment 1* was to investigate whether words from different semantic categories are suited to examine false recognition. Prior studies often used words from the Deese paradigm (Deese, 1959), whose rediscovery by Roediger and McDermott in 1995 elicited the systematic investigation of false recognition. In the Deese paradigm, participants are required to learn lists of words. All words from one list have a semantic relation to one non-studied so called LURE word, which is often falsely recognized in a later test of memory (cf. section 2.3). By definition, LURE words share many semantic features with studied words in the respective word list. Moreover, words that had to be studied were chosen due to their associative relation to LURE words, which are the theme words of each list. Consequently, associative relations between different OLD words of a list are smaller than between OLD and LURE words. This could result in differential context effects in the test phase (cf. section 2.6). Doubts about the comparability of the brain activation patterns elicited by the different kinds of words were discussed (cf. Rubin et al., 1999). This problem can be solved by using words from different semantic categories. Such words were expected to be well qualified for a comparison of the electrophysiological correlates of the processes involved in true and false recognition, because OLD and LURE words share similar semantic relationships. Both kinds of words were chosen due to their semantic relation to the category name, which is the theme in these lists. Thus, LURE words in categorical lists should be featured by smaller typicality for the theme than the LURE words from the Deese lists. Furthermore, most important for the interpretation of brain activation patterns, LURE and OLD words in categorical lists are marked by more comparable semantic features than the respective words from the Deese lists.

Rates of false recognition in Experiment 1 were lower than rates obtained for LURE words from the Deese paradigm, resembling other studies using material from different categories (e.g., Seamon et al., 2000). This suggests that smaller rates of false recognition in categorical lists compared to the Deese lists reflect the described different semantic relations between the words in both paradigms.

Lower semantic relations of LURE words in the categorical lists are reflected in lower rates of false recognition (for the influence of strength of semantic relation, e.g., Robinson & Roediger, 1997). However, the rate of false recognition in Experiment 1 was higher than false old responses to non-studied unrelated words. This false recognition effect indicates that also categorical material can be used to study processes associated with false recognition.

To examine the question whether false recognition is also based on familiarity and recollection processes as observed for true recognition, ERP-results were analyzed within the neurocognitive model of recognition memory (Mecklinger, 2000, see also section 3.2.2). In Experiment 1 both true and false recognition elicited an early frontal ERP old/new effect, which is assumed to reflect familiarity assessment. A parietal ERP old/new effect, which is associated with conscious recollection, was obtained for true recognition only. This result is in line with models of false recognition that state that false old responses to semantically related material occur in the recognition test due to the overlap with the general information from the studied words (e.g., Fuzzy trace model, Brainerd et al., 1995a, see also Schacter et al. 1998a and section 2.4). The failure to find parietal ERP old/new effects for false recognition does not support the claim from other models of false recognition, in which it is assumed that LURE words were already activated during encoding via spreading activation in a semantic network (e.g., Underwood, 1965; Roediger & McDermott, 1995, see also Schacter et al. 1998a and section 2.4). However, in Experiment 1 it could not be ruled out that this result was influenced by a large P300 Oddball effect for NEW words. Since it is possible that the different numbers of item types in Experiment 1 were responsible for differential non-retrieval related ERP effects the design was changed in *Experiment 2*.

Results from Experiment 2 replicated the reliable behavioral false recognition effect as well as the early frontal ERP old/new effects for true and false recognition. Furthermore, beside the effect for true recognition there was also a parietal ERP old/new effect for false recognition. This suggests that false recognition arises from familiarity as well as from active recollection processes. The occurrence of a parietal ERP old/new effect for false recognition supports the assumption that LURE words might be already activated during encoding via spreading activation (e.g., Schacter et al., 1998a). This activation resulted in memory traces for non-studied related words. In the later test phase memory traces were reactivated and elicited false old responses and parietal ERP old/new effects. However, the parietal ERP old/new effect was smaller for false than for true recognition indicating that also recollection processes were smaller for false than for true recognition. This result contrasts with prior ERP-studies that reported no differences in brain activity for true and false recognition using words from the Deese lists (Düzel et al., 1997; Johnson et al., 1997). As mentioned before (cf. also section 2.6), LURE words in the Deese paradigm are highly associative to all of the respective OLD words. They are the theme words in the respective list. Consequently, the activation of a LURE word from the Deese lists during encoding is assumed to be more probable than for the LURE words from the categorical lists. This may result in stronger memory traces for LURE words from the Deese lists than for LURE words from the categorical lists. In sum, it was suggested that the degree of recollection is dependent on the strength of the semantic relationship. However, this interpretation was rejected by a group comparison based on the differential rates of false recognition. Participants with high rates of false recognition showed similar ERP old/new effects for true and false recognition resembling ERP-results found for the Deese lists. This was not true for participants with low false recognition rates, where ERPs for false recognition showed no old/new effect at all. Consequently, semantic relations of LURE words are not sufficient to explain the differential ERP effects. Rather, it was assumed that individual differences in the encoding strategy are responsible for the obtained ERP-results. It is suggested that participants making high rates of false recognition use categorical (general) information for the old/new judgement. Instead, participants with smaller false recognition rates are assumed to use more item specific information.

These hypotheses were directly investigated in *Experiment 3* in which the encoding strategy was manipulated. Participants in the Category Group were focused on the general (i,e., categorical) information, while participants in the Item Group were focused on item specific information. Even though false recognition rates were similar for the Category Group and the Item Group, there were differences in the ERP-patterns. In line with the hypotheses, true and false recognition elicited similar ERP old/new effects in the Category Group, while differences between true and false recognition were obtained in the Item Group. More specifically, there were no early ERP old/new effects for false recognition in the Item Group indicating that LURE words did not elicit illusory feelings of familiarity. A parietal ERP old/new effect for false recognition allows the assumption that illusory recollection took place. However, a larger parietal effect for true recognition in the Item Group could indicate that recollection processes were smaller for false than for true recognition. In sum, results from Experiment 3 showed that the encoding strategy influences neuronal activity for false recognition. Moreover, there were electrophysiolocigal correlates of recollection processes for false recognition in both encoding groups. This suggests that LURE words were activated in the study phase independent of the encoding focus. That the activation of semantically related items in the study phase appears for different kinds of encoding processes, is in line with results showing that LURE words are also activated if words in the study phase are presented unconsciously (cf. Seamon et al., 1998). However, there was no electrophysiological marker for familiarity assessment in the Item Group challenging the claim that illusory familiarity is especially involved in the occurrence of false recognition (cf. section 2.4).

To examine directly the relationship between rates of false recognition and illusory familiarity, as reflected by the early frontal ERP old/new effect, the retention delay was manipulated in *Experiment 4*. Responses in different independent study-test blocks with either a short or a long retention delay were required. In line with prior studies (e.g., Friedman, 1990b; Hintzman, 1969), memory performance declined from a short (40 sec) to a long retention delay (80 sec) suggesting that memory traces degrade over time. Moreover, while ERP old/new effects were found for true recognition independent of the delay condition, an early frontal

ERP old/new effect for false recognition was only found after the short retention delay. This result suggested that degraded memory traces in the long delay condition also lead to lower feelings of familiarity for semantically related items. The combined analysis of performance and ERP-measures in Experiment 4 indicates that higher rates of false recognition in the long as compared to the short retention delay do not result from higher reliance on familiarity processes. This suggests that an increase in the rate of false recognition is not always based on illusory familiarity. Rather, degraded memory traces might complicate the differentiation between studied and non-studied related items. More specifically, item specific information from different sources is assumed to be activated in the test phase. Participants were not always able to differentiate correctly in all cases between item specific information from studied words and item specific information from words not studied in the respective block. False item specific information could come from prior study-test blocks of the experiment that interact with the actual block. They could also stem from an internal generation via spreading activation in the study phase of the actual block. Due to the more degraded memory traces for the studied items after the long as compared to the short delay participants made more false old responses to LURE words in the long delay condition.

If it is the recollection of false item specific information that drives false recognition, there should be a parietal ERP old/new effect for false recognition. However, the special design used in Experiment 4 does not allow the investigation of parietal ERP old/new effects. Each NEW word was taken from another semantic category, resulting in larger centro-parietally focused N400 components to NEW words (cf. Kutas & Van Petten, 1994). This does not allow an analyses of the parietal ERP old/new effect. Future studies should examine in more detail recollective aspects of false recognition. As indicated by the results of the different experiments it is assumed that false recollection of item specific information is more often involved in false recognition than familiarity processes.

So far, results from the different experiments show that illusory familiarity as well as illusory recollection can be involved in false recognition. False responses to non-studied but semantically related materials do not only occur due to the overlap of general information. Instead, they are also caused by the recollection of item specific features that were activated and stored during encoding due to spreading activation in a semantic network (cf. Underwood, 1965, see also section 2.4). Familiarity and recollection processes are considered as important for true recognition (cf. dual process account of recognition memory, Gardiner & Java, 1993; Mandler, 1980, see also section 1.1.1). That both components have proved to be involved in false recognition stresses the similarity of the processes underlying true and false recognition. This is in line with reconstructive models of memory (Moscovitch, 1992; Schacter et al., 1998a), in which the occurrence of some errors is supposed to belong to the normal process of retrieval. However, it also could be shown that in addition to the false recognition rate strategic processes during encoding, such as processing conceptual features, are an important factor in determining electrophysiological differences between true and false recognition. So, in a post hoc comparision in Experiment 2 there was no old/new ERP effect for false recognition in a low performance group. ERPs for the Item Group in Experiment 3 showed no early frontal ERP old/new effect, this means that no sign of illusory familiarity. In the Item Group there was only a small parietal old/new effect that is seen as reflecting recollection processes. Furthermore, in Experiment 4, there was no early frontal ERP effect for false recognition in the long retention delay. It was indicated that larger rates of false recognition are not always based on higher feelings of illusory familiarity.

In sum, different manipulations are sufficient to diminish or to reject ERP components for false recognition that are seen as reflecting familiarity and recollection processes. Both processes are seen as dependent of the hippocampal formation, which provide automatic information elicited by a retrieval cue (Moscovitch, 1992). It appears to be the case that some manipulations, as for instance focusing on item specific features in encoding, can influence the automatic output from the hippocampal formation.

As already mentioned, structures of the hippocampal formation are not the only brain structures that are involved in recognition judgements. The automatic output has to be sorted by a frontal component. Such processes point more to the reconstructive characteristics of memory and are described in the next section.

8.2 The Relevance of the Frontal Lobes for False Recognition

Processes involved in memory retrieval are described as mainly reconstructive (cf. section 1.2, 1.3; Moscovitch, 1992; Schacter et al., 1998a). This means that recognition memory involves additional processes beside familiarity and recollection. Moscovitch (1992) and Schacter et al. (1998a) discuss the role of the frontal lobes in strategic or effortful processes implicated in the act of retrieval as well as for monitoring and verification processes following the retrieval decision. In line with this idea, neuroimaging studies consistently demonstrate activation in right prefrontal regions for true recognition (cf. Wagner et al., 1998). Activation in the right frontal lobe was also reported for false recognition. For instance, in a PET study performed by Schacter and colleagues (1996c) right frontal activation appears to be somewhat larger for false recognition than for true recognition. However, no differences were found between the activity at right prefrontal locations for true and false recognition in a fMRI study (Schacter et al., 1997a). As it is already suggested by the frontal activation for true as well as for false recognition, data from patients suffering from frontal lobe lesions also lead to the assumption that the frontal lobes are involved in recognition processes. Moreover, high rates of false recognition found for frontal lobe patients suggest that the frontal lobe is especially involved in the processes that prevent false responses to semantically related but non-studied material (e.g., Delbecq-Derouesne et al., 1990; Parkin et al., 1996; Schacter et al., 1996b). Results from six patients suffering from different frontal lobe lesions in *Experiment 5* suggest that the selective impairment in the correct rejection of semantically related but non-studied words depends on the right posterior fronto-lateral cortex and is not a general characteristic of frontal lobe pathology. It was concluded that this structure is more relevant for the differentiation of item specific information, which is provided by the hippocampal formation (Moscovitch, 1992), than the other frontal regions. Different analyses further imply that enhanced false recognition cannot be explained with a more liberal response criteria. Instead, it is assumed that the impairment is related to an overreliance to general information. However, given the descriptive status of the results (cf. Experiment 5) further studies are necessary to support the assumed relevance of the right posterior fronto-lateral cortex in the processes preventing for false recognition.

An involvement of the frontal lobes in true and false recognition was also suggested by results of the different ERP-studies (cf. Experiment 1-4). Late right frontal ERP effects, which are known to be associated with the function of the frontal lobes (e.g., Ranganath & Paller, 1999, cf. also section 3.2.2), were found for true recognition in nearly all different conditions of the four reported EEG experiments[1]. Furthermore, as illustrated in Table 8.1 (left side) late right frontal effects for false recognition varied across the different studies.

This pattern of results for true and false recognition does not allow an unique conclusion about the functional significance of this effect (cf. section 4.4, 5.5, 6.5). Similar late right frontal ERP old/new effects for true and false recognition found in Experiment 1 and 3 may suggest that the effect reflects some kind of semantic processing related to the studied theme. However, this is raised into question by the results of Experiment 2. Participants with high false recognition rates showed a late right frontal ERP old/new effect only for false but not for true recognition. This result is more in line with the interpretation that the search for and the access of weaker representations in memory may require more retrieval effort and that this might be reflected in the frontal effect (cf. Henson et al., 1999; Schacter et al., 1996a).

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[1] No effect was found for true recognition in the high false recognition group in Experiment 2.

Table 8.1: *Across experiment comparison: Patterns of mean differences of the late ERP effects elicited by true and false recognition in Experiment 1-4.*

	Right frontal positivity		**Parietal negativity**	
	True recognition	**False recognition**	**True recognition**	**False recognition**
Experiment 1				
all participants	+	+	-	+
Experiment 2				
all participants	+	+	-	+
High false rec. Group	-	+	-	-
Low false rec. Group	+	-	-	+
Experiment 3				
Category Group	+	(+)	-	-
Item Group	+	(+)	-	+
Experiment 4				
Short delay	+	-	+	+
Long delay	+	-	(+)	+

Note: rec. = recognition; $'+' = p < 0.05;' (+)' = 0.05 < p < 0.1;' -' = p > 0.1$.

Contrary, a late ERP effect was only found after true recognition for participants with low false recognition rates. This is more in line with the view that the frontal ERP old/new effect may reflect successful retrieval (e.g., Rugg et al., 1996; Wilding & Rugg, 1996). Similar interpretations may account for the results of Experiment 4. A late right frontal ERP effect was only found for true but not for false recognition after both short and long retention delays.

The data suggest that some conditions do not elicit right frontal activation for false recognition. Another possibility might be that differential effects found for the late right frontal ERP old/new effect are associated with differential effects of summation. The logic goes as follows: The frontal lobes are seen to be involved in many different processes important for memory (cf. Shimamura, 1994; Schacter, 1987). It might be that the right frontal ERP old/new effect measured on the scalp reflects different processes working at the same time. Activation associated with these different processes could summate to the late ERP effect. Maybe, a special combination of such activations summates to an ERP effect which is not different to that found for correct rejections to NEW items as it was revealed for some conditions.

However, which additional processes could underly these differential effects for the late right frontal activity? Maybe, the occurrence of another ERP-deflection can give some information about the ongoing processes. Note that in all conditions where there was no late right frontal ERP effect for false recognition there appeared a late parietal negativity. As shown in Table 8.1 (right side) the parietal negativity was observed for the ERPs for false recognition averaged over all participants in Experiment 1 and Experiment 2. After the performance based group comparison in Experiment 2 the effect was only evident for participants with low rates of false recognition. There was no late parietal negativity for participants with high rates of false recognition, which were assumed to use mainly general information for the recognition judgements[2]. Furthermore, a late parietal negativity for false recognition was found for the Item Group in Experiment 3. In Experiment 4 late parietal negativities for false recognition were observed after both retention delays and were also evident for true recognition.

Some previous studies also found similar ERP-deflections (cf. Düzel et al., 1997; Rubin et al., 1999; Wilding & Rugg, 1997), but so far there is no clear interpretation of the effect. However, summarizing the results from Experiment 1-4 the late parietal negativity occurred for false recognition in those conditions for which a higher contribution of item specific information can be assumed. Item specific information should have higher relevance for the recognition decision in

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[2] Although different performance groups were not compared such a performance-based differentiation could also be true for Experiment 1.

the group with low rates of false recognition in Experiment 2 and in the Item Group in Experiment 3. The special design used in Experiment 4, the repeated study-test procedure as well as the short retention delays as compared to Experiment 1-3, also strongly requires the use of item specific information.

FMRI-constrained dipol analyses performed for the low false recognition group in Experiment 2 and the Item Group in Experiment 3 (cf. section 5) suggest that the anterior cingulate cortex (ACC) is involved in the generation of the negative deflection. Because the ACC is considered to be involved in error detection it might be that response-related processes like the Error-Related Negativity (ERN, Gehring et al., 1993) are involved in the late parietal negativity. This hypothesis was supported in Experiment 4, although ERN-like deflections were not only found for false but were also evident for true recognition. It was concluded that this response-related negativity does not necessarily reflect a perceived error per se. Instead, it may reflect the perceived difference between the response and the internal representation of what is the correct response (Coles, Scheffers & Holroyd, 2000).

However, the ERN found for false recognition was larger than the negativity found for true recognition and gave rise to a slightly different topography. It may be that for false recognition the effect does also capture response conflict processes that are caused by an enhanced response uncertainty to non-studied but semantically related words. Such processes might be also reflected in the late parietal negativity for false recognition found for stimulus-related averages.

This interpretation is in line with other studies reporting ACC activation in different cognitive tasks. Neuroimaging studies showed activity in caudal areas of the ACC for cognitive tasks, as for instance in cognitive interference tasks (e.g., Bush et al., 1998) or diveded attention tasks (Corbetta, Miezen, Dobmeyer, Shulman & Petersen, 1991). Given this pattern of activations, a special involvement of the caudal part of the ACC in the processing of conflicts between competing information is assumed.

Furthermore, recent studies suggest that both, the cognitive division of the ACC and areas of the lateral prefrontal cortex, operate together during tasks involving high levels of mental effort. It is assumed that these structures belong to a network of brain regions involved in attention, response selection, motor planing, and motor output (Bush et al., 1998 Dehaene, Kerszberg & Changeux, 1998). Probably, both structures also act in concert for false recognition under conditions where conflicts are high. The ACC may be involved in the detection of cognitive states such as response competition or uncertainty (cf. Carter et al., 2000). In the present experiments conflicts should be higher and should result in ACC activity in conditions where participants focus on item specific information rather than on general information. This is consistent with the pattern of the occurrence of the late parietal negativity (cf. Table 8.1). The frontal lobes might be informed about the cognitive state and might be activated for additional strategic processes to reduce the cognitive state of uncertainty. Maybe, a connection between ACC and right frontal lobe could account for the pattern of late right frontal and parietal ERP effects found for false recognition.

However, these suggestions remain speculative as no direct investigation of ACC activity was provided. Future fMRI studies could provide more direct evidence for the suggestion that ACC and the lateral prefrontal cortex work together to prevent false old responses to semantically related but non-studied material on the basis of analyzing item specific information. The results obtained here do only allow speculations about the role of ACC and right frontal lobes in false recognition. It might be that the ACC is only active under conditions in which the focus is on inconsistent information. This would be in line with the assumption that the ACC is implicated in interference and attention tasks. The lateral prefrontal cortex is supposed to be involved generally in recognition related judgements but can as well interact with ACC activation.

8.3 Conclusion and Future Research

The present work examined behavioral and electrophysiological correlates of true and false recognition from words of different semantic categories. The results indicate that false recognition can be based on illusory familiarity as well as on illusory recollection, supporting models that assume similar processes for the creation of true and false memories by accenting reconstructive processes (cf. section 1.3, see Schacter et al., 1998a; Moscovitch, 1992). Electrophysiological correlates of recollection processes found for false recognition support the idea that memory traces for non-studied material are built already during encoding due to spreading activation in a semantic network (Underwood, 1965; Roediger & McDermott, 1995).

However, it was shown that differences in performance, manipulations of the encoding strategy, as well as manipulations of the retention delay can influence the electrophysiological correlates of familiarity and recollection for false recognition, and can result in neuronal differences between true and false recognition. It was also indicated that false recognition is not always joined with an electrophysiological correlate of familiarity assessment. Beside familiarity and recollection processes, which may be associated with the functions of hippocampal structures, the frontal lobes are considered to be important for recognition memory. This structure is assumed to be especially involved in processes preventing false recognition. This is also in agreement with the fact that amnesics do not show enhanced false memory while some frontal lobe patients do (cf. section 2.6). Results obtained in Experiment 5 imply that the right posterior fronto-lateral cortex is especially relevant for processes preventing pathologically enhanced false recognition. ERP-results also suggest that the frontal lobe is involved in recognition memory. Late right frontal ERP old/new effects were found for true recognition in nearly all conditions in Experiments 1 through 4. However, given the differential ERP-results for false recognition, there is no clear answer to the question which processes are actually reflected. It is suggested that the right frontal ERP old/new effect is not associated with a unitary functional activity. Instead, it reflects different aspects of the retrieval processes, like for instance evaluation or the processing of general information. Furthermore, a late parietal negativity was found for false recognition, interpreted to reflect activity of the ACC. This effect might indicate a high response uncertainty that is associated with the false old response to non-studied but semantically related material. It is assumed that the ACC and the right frontal cortex work together in a network under conditions where conflicts are high. However, future neuroimaging studies should examine in more detail whether both structures are involved in false recognition and under which conditions they are activated.

We do not remember fixed episodes, instead, we remember features that we have to bind together and that we have to verify for their reality (Schacter et al., 1998a). Such processes are prone to errors and can result in false memories. It is proposed that features are activated by processes mediated by the hippocampal structures (Moscovitch, 1992). These processes are involved in the elicitation of the early frontal and the parietal old/new ERP effect, which are seen to be related to familiarity and recollection processes, respectively. Furthermore, the frontal lobes are known to be critical for the strategic processes that are necessary for binding and verification processes. Results of the experiments reported here lead to the assumption that these processes similarly underly true and false recognition. However, the disappearance or the decrease of electrophysiological correlates of familiarity and recollection for false recognition suggests that the output from the hippocampal structure in response to a retrieval cue can be influenced. Furthermore, strategic processes as reflected by the activity of the frontal lobes differ with respect to the given conditions.

The question arises whether also other manipulations can elicit differential electrophysiological effects to false recognition. Can differential ERP old/new effects also be observed if only the retrieval strategy in the test phase is manipulated? After an identical encoding phase participants could be differentially focused on either general or item specific features. For the early frontal ERP old/new effect, assumed to reflect familiarity, similar results as for the encoding manipulation in Experiment 3 should be expected. An early frontal ERP-effect should occur in a group focusing on general information, while no effect should be expected in the item specific information group. A validation of this hypothesis would be further support for the claim that false recognition is not always based on illusory familiarity. Regarding the parietal ERP old/new effect it seems possible that similar activation processes for semantically related items during encoding would result in similar parietal ERP old/new effects for false recognition in both groups.

In the present work categorical lists were used. Such lists were regarded to be better suited for a comparison of electrophysiological activity for true and false recognition than the Deese lists, because OLD and LURE words share similar semantic relations to one another. So, occurring differences are not related to different semantic relations as it is possible for words from the Deese lists. However, a recent study, which used lateralized encoding, showed that it is also possible to find electrophysiological differences between true and false recognition for words from the Deese list which cannot be associated with the differential semantic relationships for the OLD and LURE words (Fabiani, Stadler & Wessels, 2000b). The authors presented word lists from the Deese paradigm to either the right or the left cerebral hemisphere at study. This lateralized encoding led to lateralized brain activity for OLD words in the recognition test, in which words were presented centrally. Such a lateralized brain activity did not occur to LURE words that were falsely judged as studied (false recognition). Consequently, the results indicate that encoding led to sensory signatures and that such signatures can be used to differentiate true and false recognition. Also word lists from the Deese paradigm can be used to reflect differences if special designs are used. This is especially interesting because rates of Remember responses or rates of confidence judgements are nearly similar for OLD and LURE words from the Deese lists. As shown in Experiment 3 this is not the case for OLD and LURE words from the categorical lists.

Consequently, regarding the different advantages and disadvantages of both paradigms, the categorical lists and the Deese lists should be used for further investigations of the processes involved in false recognition. An interesting question would be, for instance, whether the sensoric signatures found by Fabiani et al. (2000) can also be observed after longer retention delays.

Beside such word lists, future research should also focus more on visual imaging or on the use of pictures. One interesting study on this kind of false memory research was recently reported by Gonsalves and Paller (2000). Participants were asked to visualize common objects when they saw the correspondending word. On some study trials a photograph of the object was presented 1800 ms after the word. In a later test participants heard words and were required to indicate whether they had seen a photograph of this word in the study phase or not. The rate of true recognition (75 %) was higher than the rate of false old responses to words that were studied before but for which no photograph was presented (30 %, false recognition). The rate of false recognition was higher than false old responses to new words (9 %). True recognition elicited more positive going waveforms than false recognition at parietal locations between 900 and 1200 ms. This was interpreted as a reflection of the differences in the amount of perceptual detail accompanying true and false recognition.

ERP studies using pictures are also needed to compare correlates of brain activity for verbal false recognition and false recognition of pictures. This is especially interesting because it is proposed that LURE-pictures are less likely to be activated during prior encoding (Koutstaal & Schacter, 1997). An alternative assumption might be that there should be no differences for verbal materials and pictures, because not fixed pictures but only features are stored. Such features have to be bind together in retrieval and, consequently, there should be no difference between the false recognition of verbal materials and false recognition of pictures.

The present studies demonstrated that the investigation of false recognition is useful to get a new kind of insight into the processes involved in memory than the one that is given by the classical work on true recognition. I am convinced that false memories will continue to play an important role in memory research and will improve our knowledge of how memory might be implemented in the brain.

Chapter 9

Deutsche Zusammenfassung

9.1 Theoretischer Hintergrund und Hypothesen

Der Akt des Erinnerns ist ein hauptsächlich rekonstruktiver Prozess. In zahlreichen Untersuchungen zu gedächtnisrelevanten Fragen konnte gezeigt werden, dass für richtige Erinnerungen dabei sowohl Schlussfolgerungen auf der Basis von Vertrautheit als auch die aktive Wiedererinnerung von früher erlebten Episoden eine Rolle spielen (vgl. dual process theory of recognition memory, Mandler, 1980; Gardiner & Java, 1993). Besonders in den letzten Jahren verstärkte sich auch das Interesse an der Frage, welche Prozesse daran beteiligt sind, wenn wir uns an etwas zu erinnern glauben, was tatsächlich nie passiert ist. Viele experimentelle Studien beschäftigen sich mit denjenigen falschen Erinnerungen, die aus einer semantischen Überlappung kritischer nicht gelernter Items (LURE) mit gelernten Items (ALT) entstehen. Oft wird dafür ein spezielles Paradigma benutzt, welches erstmals von Deese (1959) vorgestellt und von Roediger und McDermott (1995) wiederentdeckt und weiterentwickelt wurde: Die Probanden lernen Listen von Wörtern, die jeweils in einer semantischen Beziehung zu einem nicht zu lernenden LURE-Wort stehen. In einem späteren Erinnerungstest sind sich die Probanden oftmals sicher, dass sie das LURE-Wort ebenfalls gelernt haben.

Dies konnte in Wiedergabetests und auch durch die Ergebnisse bei Wiedererkennungstests gezeigt werden. Während bei Tests der Wiedergabe gelernte Items frei erinnert werden sollen, antworten die Probanden bei Tests der Wiedererkennung auf dargebotene Wörter mit einer *alt*-Antwort (Wort in der Lernphase des Experimentes gelernt) oder einer *neu*-Antwort (Wort in der Lernphase des Experimentes nicht gelernt). Verschiedene Studien, die mit den Listen des Deese-Paradigmas durchgeführt wurden, fanden überraschend hohe Raten von *alt*-Antworten auf nicht gelernte LURE-Wörter (falsche Erinnerung). Oft unterschieden sich diese nicht von den Raten richtiger Erinnerungen (z. B., Roediger & McDermott, 1995).

Ein Erklärungsmodell für diesen Befund geht davon aus, dass falsche Erinnerungen durch ein illusorisches Gefühl von Vertrautheit entstehen. Nach diesem Ansatz erscheinen die LURE-Wörter wegen ihrer Übereinstimmung mit den generellen Merkmalen der gelernten Wörter vertraut und werden deswegen als gelernt beurteilt (vgl. Schacter, Norman & Koutstaal, 1998a; Schacter, Isreal & Racine, 1999). Es wird angenommen, dass die Entstehung von falschen Erinnerungen hauptsächlich auf Prozesse zurückgeht, die in der Testphase ablaufen. Im Gegensatz zu richtigen Erinnerungen erfolgt für falsche Erinnerungen keine aktive Wiedererinnerung itemspezifischer Informationen aus einer Gedächtnisspur. Studien, in denen für richtige Erinnerungen ein größerer Anteil an itemspezifischen, detaillierten Merkmalen nachgewiesen werden konnte als für falsche Erinnerungen, unterstützen diesen Ansatz (z. B., Mather, Henkel & Johnson, 1997; McDermott, 1997; Norman & Schacter, 1997).

Ein zweites Modell nimmt dagegen an, dass falsche Erinnerungen ebenso wie richtige Erinnerungen sowohl auf Prozessen der Vertrautheit als auch auf der aktiven Wiedererinnerung von Gedächtnisspuren basieren können. Es wird davon ausgegangen, dass diese Gedächtnisspuren durch eine Aktivierung der kritischen LURE-Wörter in der Lernphase entstehen. In Übereinstimmung mit Underwood (1965) wird postuliert, dass dies beim Lernen von semantisch relatierten Wörtern über eine sich ausbreitende Aktivierung in einem semantischen Netzwerk erfolgt

(Craik & Lockhart, 1972). So kann z. B. das Wort *Arbeit* zur Aktivierung des Wortes *Erfolg* führen. Diese Aktivierung bewirkt, dass auch für LURE-Items eine Gedächtnisspur abgelegt wird, die in der Testphase aktiv wiedererinnert werden kann. Scheitert die Zuordnung dieser Gedächtnisspur zu ihrer Entstehungsart ('intern generiert' oder 'tatsächlich gelernt'?), resultiert eine falsche Erinnerung (vgl., Quellegedächtnis, source memory, Johnson, Hashtroudi & Lindsay, 1993; Johnson & Raye, 1981, vgl. auch Schacter et al., 1998a). Dieses zweite Modell misst damit auch den Prozessen, die in der Lernphase ablaufen, für die Entstehung von falschen Erinnerungen eine hohe Bedeutung zu. Die Annahme, dass es auch bei nicht gelernten Items zu einer aktiven Wiedererinnerung kommen kann, wird u. a. durch die Befunde von Roediger und McDermott (1995) gestützt. In dieser Studie waren die Probanden aufgefordert, für jede *alt*-Antwort anzugeben, ob diese auf dem bewussten *Erinnern* von spezifischen Merkmalen der Lernphase beruht (wie z. B. dem Klang eines Wortes), was den Abruf einer Gedächtnisspur impliziert. Dagegen sollte eine *Wissen*-Antwort abgegeben werden, wenn die Probanden sich lediglich sicher waren, das Wort früher gelernt zu haben. Eine solche Antwort sollte also nur dann erfolgen, wenn eine Entscheidung nicht auf der aktiven Erinnerung von itemspezifischen Merkmalen beruhte, sondern eher auf Vertrautheitsprozesse zurückging (vgl. Remember/Know procedure, Tulving, 1985). Die Autoren berichten ähnliche Raten von *Erinnern*-Antworten für richtige und falsche Erinnerungen, was einen vergeichbaren Anteil von aktiven Erinnerungsprozessen annehmen lässt. Richtigen und falschen Erinnerungen scheinen damit gleiche Prozesse zugrunde zu liegen, was mit rekonstruktiven Ansätzen des Gedächtnisses übereinstimmt (vgl. Constructive Memory Framework, CMF, Schacter et al., 1998a). Dies wurde auch in bisherigen Studien, die neuronale Aktivierungen für richtige und falsche Erinnerungen vergleichen, bestätigt. Ergebnisse aus PET- (Schacter et al., 1996c), fMRI- (Schacter, Buckner, Koutstaal, Dale & Rosen, 1997a) und EKP-Studien (Johnson et al., 1997; Düzel, Yonelinas, Mangun, Heinze & Tulving, 1997) deuten auf ähnliche Aktivierungsmuster für beide Arten von Erinnerungen hin. Tendenzielle Unterschiede, die sich zeigten (Düzel et al., 1997; Schacter et al., 1996c), wurden auf die unterschiedliche semantische Beziehung der LURE- und ALT-Wörter einer Liste zurückgeführt. So nutzte man in diesen früheren Experimenten die Deese-Listen, in denen die ALT-Wörter nur nach ihrer semantischen Beziehung zu den LURE-Wörtern ausgewählt wurden, d. h. auf die semantische Beziehung der zu lernenden Wörter einer Liste untereinander wurde nicht geachtet. Dies kann in der Testphase zu unterschiedlichen Priming-Effekten für die beiden Wortarten führen, was sich wiederum in Unterschieden der Hirnaktivierung ausdrückt. Außerdem nehmen Miller und Wolford (1999) an, dass es aufgrund dieser Unterschiede zwischen den LURE- und ALT-Wörter zu unterschiedlichen Entscheidungskriterien in der Testphase kommen kann (vgl. aber auch Wixted & Stretch, 2000).

In der vorliegenden Arbeit werden falsche Erinnerungen mit Substantiven aus verschiedenen Kategorien untersucht. In diesen Listen wurden alle Wörter über ihre Beziehung zu dem Kategorienamen ausgewählt und nicht in ihrer Beziehung zu einem Wort, welches später als LURE-Wort benutzt wird. Über das Merkmal der Kategorie sind die verschiedenen Items gleichermaßen assoziativ miteinander verbunden. Diese Listen gewährleisten damit eine vergleichbare semantische Beziehung zwischen den ALT- und LURE-Wörtern und sollten deshalb besser für die Untersuchung von Hirnaktivierungsmustern geeignet sein als das Deese-Material.

Mit Hilfe Ereignis-Korrelierter Potentiale (EKP) sollte untersucht werden, ob sich die Mechanismen, die richtigen und falschen Erinnerungen zugrunde liegen, unterscheiden lassen. EKPs stellen elektrophysiologische Korrelate der Hirnaktivität dar, die wegen ihrer hohen zeitlichen Auflösung (im Millisekunden-Bereich) gut dafür geeignet sind, Gedächtnisprozesse zu untersuchen. Frühere EKP-Studien konnten zeigen, dass sich bei Wiedererkennungsaufgaben ein so genannter *alt/neu*-Effekt im EKP ableiten lässt. Richtig wiedererkannte Items generieren im Vergleich zu vorher nicht gelernten, richtig zurückgewiesenen Items mit einer Latenz von circa 300 ms einen positiveren Verlauf im EKP. Dieser *alt/neu*-Effekt lässt sich in wenigstens drei zeitlich und skalptopographisch unterschiedliche Subkomponenten unterteilen (neurocognitive model of recognition memory, Mecklinger, 2000). Basierend auf empirischen Befunden (für einen Überblick vgl., Friedman & Johnson, 2000; Mecklinger, 2000) wird ein *früher frontaler alt/neu-Effekt* im Zeitbereich von 300-500 ms nach der Darbietung des kritischen Wortes in der Testphase mit Vertrautheitsprozessen in Verbindung gebracht. Ein *parietal* mit maximaler Amplitude auftretender *alt/neu*-Effekt im EKP ist mit der bewussten Wiedererkennung von spezifischen Merkmalen der Lernphase assoziiert. *Rechtsfrontale, späte Positivierungen* (ab 800 ms nach der Darbietung des ALT-Items) scheinen die Weiterverarbeitung der abgerufenen Gedächtnisinhalte widerzuspiegeln. Einige Autoren sehen in diesem Effekt eher eine Reflexion erfolgreicher Wiedererinnerung (retrieval success account, z. B. Wilding & Rugg, 1997), während andere von einer Relation zum Erinnerungsaufwand ausgehen (retrieval effort account, z. B. Ullsperger, Mecklinger & Müller, 2000). Eine Vielzahl divergierender Befunde, die u. a. die Rolle von Kontextfaktoren (Wagner, Desmond & Gabrieli, 1998) oder von generellen Erfordernissen der Aufgabe (Düzel et al., 1999) annehmen lassen, haben bisher eine Beschreibung der funktionellen Bedeutungen des Effektes erschwert.

Die vorliegende Arbeit nutzt dieses Modell erinnerungsabhängiger elektrophysiologischer Aktivierung (Mecklinger, 2000). Durch einen Vergleich der zeitlichen und räumlichen Muster der *alt/neu*-Effekte im EKP für richtige und falsche Erinnerungen sollte festgestellt werden, ob den beiden Arten von Erinnerungen gleiche Prozesse zugrundeliegen oder nicht. Beide vorgestellten Erklärungsmodelle falscher Erinnerungen sehen die Entstehung falscher *alt*-Antworten auf nicht gelernte aber semantisch relatierte Items an eine in der Testphase auftretende illusorische Vertrautheit gekoppelt. Diese Vertrautheit sollte sich in einem frühen frontalen *alt/neu*-Effekte für die mit *alt* beantworteten LURE-Items zeigen. Das zweite Erklärungsmodell nimmt zusätzlich itemspezifische Erinnerungsprozesse an, was neben dem frühen frontalen *alt/neu*-Effekt einen etwas später beginnenden parietalen *alt/neu*-Effekt im EKP für falsche Erinnerungen erwarten lässt. Die divergente Befundlage zu dem späten rechtsfrontalen *alt/neu*-Effekt bei richtigen Erinnerungen lässt keine spezifischen Hypothesen für falsche Erinnerungen zu.

Der späte frontale EKP-Effekt wird mit Aktivierungsprozessen, insbesondere des rechten frontalen Kortex in Verbindung gebracht (z. B. Wilding & Rugg, 1996). Da Patienten mit einer Läsion des Frontallappens, trotz normaler Raten richtiger Erinnerungen, pathologisch erhöhte Raten falscher Erinnerungen zeigen (z. B. Curran, Schacter, Norman & Galluccio, 1997; Parkin, Blindschaedler, Harsent & Metzler, 1996), ist eine Involvierung entsprechender Hirnregionen wahrscheinlich. Daher ist auch bei falschen Erinnerungen das Auftreten rechtsfrontaler *alt/neu*-Effekte im EKP von Interesse. Außerdem wurde eine Untersuchung mit Patienten durchgeführt, die unterschiedliche Läsionen im Bereich des frontalen Kortex aufwiesen. Es sollte festgestellt werden, ob pathologisch erhöhte Raten falscher Erinnerungen ein allgemeines Merkmal von Schädigungen des Frontallappens sind.

9.2 Methoden

In fünf Experimenten wurden verschiedene Varianten eines Lern-Test-Paradigmas verwendet, bei denen Substantive aus unterschiedlichen Kategorien als Reizmaterial verwendet wurden. Einer Lernphase, in der die Substantive auditiv dargeboten wurden, folgte nach einem kurzen Zwischenzeitraum ein Wiedererkennungstest. Die Probanden sollten dabei eine *alt/neu* Entscheidung zu visuell dargebotenen Wörtern abgeben. Die Testphase enthielt vorher gelernte Wörter (ALT), nicht gelernte Wörter aus nicht gelernten Kategorien (NEU) sowie nicht gelernte Wörter aus gelernten Kategorien (LURE). Experiment 1, 2 und 3 bestanden aus jeweils einer Lernphase und einer Testphase. Vor der Testphase führten die Probanden ein zehnminütiges Computerspiel durch. In Experiment 4 und 5 wurden mehrere Blöcke von Lernphasen und Testphasen benutzt. Hier folgte die Testphase der Lernphase mit einer variablen Verzögerung von 40 Sekunden oder von 80 Sekunden, in der die Probanden laut rückwärts zählten. Außerdem wurden in den Testphasen der Experimente 1 bis 4, an denen gesunde Studenten der Universität Leipzig teilnahmen, EKPs von 61 Skalpelektroden abgeleitet. In Experiment 5 wurden behaviorale Daten von 6 Patienten mit Läsion des frontalen Kortex sowie 12 gesunde, alters- und bildungsgematchte Kontrollprobanden untersucht.

9.3 Ergebnisse und Diskussion

In Experiment 1 wurden 72.6 % der gelernten Wörter wiedererkannt. Die Probanden gaben auf 11.5 % der NEU-Wörter und auf 30.1 % der LURE-Wörter eine *alt*-Antwort. Der höhere Anteil falscher *alt*-Antworten auf LURE-Items belegt, dass auch Wörter aus verschiedenen Kategorien benutzt werden können, um das Phänomen falscher Erinnerungen zu untersuchen. EKPs für richtige Erinnerungen zeigten gegenüber den EKPs für richtige Zurückweisungen von NEU-Wörtern, übereinstimmend mit früheren Studien (vgl. Mecklinger, 2000), einen frühen frontalen, einen mittleren parietalen sowie einen späten rechts frontalen *alt/neu*-Effekt im EKP. EKPs für falsche Erinnerungen zeigten ebenfalls einen frühen frontalen und einen späten, rechtsfrontal maximalen *alt/neu*-Effekt im EKP. Es trat keine parietale Positivierung gegenüber EKPs für richtige Zurückweisungen von NEU-Wörtern auf. Dies spricht gegen die Annahme itemspezifischer Erinnerungsprozesses bei falschen Erinnerungen, und damit gegen das Vorhandensein von Gedächtnisspuren für LURE-Items.

In Experiment 1 konnte jedoch wegen der geringen Anzahl von nicht gelernten Items aus nicht gelernten Kategorien (NEU-Wörter) ein P300 Effekt für richtige Antworten auf NEU-Items nicht ausgeschlossen werden. Da ein solcher P300 Effekt einen parietalen *alt/neu*-Effekt im EKP für falsche Erinnerungen überlagert haben könnte, wurde in Experiment 2 das Verhältnis der verschiedenen Wortarten angeglichen. In Experiment 2 erkannten die Probanden 77.8 % der studierten Wörter und gaben zu 5.3 % falsche *alt*-Antworten auf NEU-Wörter ab. Die Ergebnisse des Experimentes 1 bestätigend, lag die Fehlerrate bei den LURE-Items mit 26.4 % höher als bei den NEU-Items. *Alt/neu*-Effekte im EKP konnten für richtige und falsche Erinnerungen nachgewiesen werden. Auch falsche Erinnerungen zeigten parietale Positivierungen, die allerdings schwächer waren als die parietalen *alt/neu*-Effekte für richtige Erinnerungen. Gedächtnisspuren scheinen also auch für falsche Erinnerungen vorzuliegen, wobei diese aber schwächer sind als für richtige Erinnerungen. Dieser Befund steht in Kontrast zu den Ergebnissen gleicher EKP-Aktivität bei richtigen und falschen Erinnerungen aus früheren Studien, die mit den Deese-Listen durchgeführt wurden (Johnson et al., 1997; Düzel, Yonelinas, Mangun, Heinze & Tulving, 1997). Eine mögliche Ursache könnte in der unterschiedlichen semantischen Relatiertheit der LURE-Wörter in den Deese-Listen und den Kategorie-Listen liegen. Wie schon beschrieben, weisen die LURE-Wörter der Deese-Listen einen höheren semantischen Bezug zu den ALT-Wörtern auf als in den Kategorie-Listen. So kann angenommen werden, dass LURE-Wörter der Deese-Listen auch häufiger in der Lernphase aktiviert werden als LURE-Wörter der Kategorie-Listen. Dies wiederum führt bei LURE-Wörtern der Deese-Listen zu stärkeren Gedächtnisspuren und damit zu vergleichbaren *alt/neu*-Effekten im EKP für richtige und falsche Erinnerungen. Diese Annahme konnte jedoch nach einer Gruppenanalyse nicht aufrechterhalten werden. Während richtige und falsche Erinnerungen bei Probanden, die viele falsche Erinnerungen zeigten, ähnliche *alt/neu*-Effekte im EKP auslösten, unterschieden sich die EKPs für richtige und falsche Erinnerungen in der Gruppe mit wenigen falschen Erinnerungen.

Die Annahme, dass dieses Ergebnis auf die Benutzung von unterschiedlichen Strategien zurückgeht, wurde in Experiment 3 geprüft. In der Lernphase dieser Studie wurden die Probanden entweder auf die kategorielle (generelle) Information (Kategoriegruppe) oder auf die spezifische Information (Itemgruppe) fokussiert. In einem späteren Wiedererkennungtest zeigten Probanden der Kategoriegruppe und der Itemgruppe ähnliche Raten richtiger Erinnerungen (Kategoriegruppe 70.4 %, Itemgruppe 75,4 %) und falscher Erinnerungen (Kategoriegruppe 34.6 %, Itemgruppe 33.8 %). In der Kategoriegruppe wurden allerdings weniger Fehler auf NEU-Wörter gemacht als in der Itemgruppe (Kategoriegruppe 8.0%, Itemgruppe 16.9%). Dies reflektiert, dass Probanden der Kategoriegruppe die generelle Information über die Kategoriezugehörigkeit stärker benutzten als

Probanden der Itemgruppe, um nicht gelernte Items, die in keiner semantischen Beziehung zu den gelernten Listen stehen, zurückzuweisen. Dieser Strategieunterschied zeigte sich in EKP-Unterschieden der *alt/neu*-Effekte für richtige und falsche Erinnerungen in den beiden Gruppen. Die EKPs für Probanden der Kategoriegruppe zeigten in den drei *alt/neu*-Effekten keinen Unterschied zwischen den richtigen und falschen Erinnerungen. Beide Bedingungen lösten frühe frontale, mittlere parietale und späte rechtsfrontale EKP-Effekte aus. Diese *alt/neu*-Effekte im EKP konnten auch für richtige Erinnerungen in der Itemgruppe nachgewiesen werden. EKPs für falsche Erinnerungen in dieser Gruppe zeigten jedoch keinen frühen frontalen *alt/neu*-Effekt, was die Annahme unterstützt, dass es nicht illusorische Vertrautheit ist, die zu einer falschen *alt*-Antwort führt. Stattdessen lässt ein vorhandener parietaler *alt/neu*-Effekt für falsche Erinnerungen vermuten, dass LURE-Wörter in der Lernphase auch dann aktiviert werden, wenn nicht auf die generelle Information fokussiert wird. In der Itemgruppe war der parietale Effekt für falsche Erinnerungen außerdem kleiner als für richtige Erinnerungen, was die stärkeren itemspezifischen Erinnerungen für die ALT-Wörter unterstreicht.

Zusammenfassend konnte in Experiment 3 gezeigt werden, dass EKP-Effekte für falsche Erinnerungen von den verwendeten Lernstrategien abhängen. Wenn Probanden auf generelle Merkmale der Information, wie z. B. die kategorielle Zugehörigkeit fokussieren, zeigen richtige und falsche Erinnerungen gleiche EKP-Effekte. Die Benutzung von Strategien, die eher auf itemspezifische Merkmale der zu lernenden Wörter ausgerichtet sind, führt dagegen zu einer differentiellen EKP-Aktivität. Die EKPs für falsche Erinnerungen zeigen einen schwächeren parietalen Effekt als die EKPs für richtige Erinnerungen und interessanterweise keinen frühen frontalen Effekt, der mit Vertrautheit assoziiert ist. Beide eingangs beschriebenen Erklärungsmodelle falscher Erinnerungen gehen jedoch von der Bedeutung illusorischer Vertrautheitsprozesse für die Entstehung von falschen Erinnerungen aus. In Experiment 4 sollte deswegen speziell der Zusammenhang zwischen falschen Erinnerungen und illusorischer Vertrautheit mit Hilfe des frühen frontalen Effektes untersucht werden.

Dafür wurde ein Paradigma verwendet, welches die Untersuchung von *alt/neu*-Effekten nach unterschiedlichen Zeitspannen erlaubt. In einer Reihe von Experimenten konnte gezeigt werden, dass der frühe frontale EKP-Effekt nach einem langen Behaltensintervall im Vergleich zu einem kurzen Behaltensintervall an Stärke abnimmt (z. B. Rugg & Nagy, 1989; Chao, Nielson-Bohlman & Knight, 1995). Nach einem längeren Intervall zwischem dem Lernen und dem Testen wird aber auch mit erhöhten Raten falscher Erinnerungen gerechnet. Lassen sich diese beiden Annahmen bestätigen, spricht dies gegen einen direkten Zusammenhang zwischen der Anzahl falscher Erinnerungen und illusorischer Vertrautheit.

Die Probanden zeigten in Experiment 4 bessere behaviorale Leistungen nach dem kurzen als nach dem langen Behaltensintervall. Reaktionszeiten und Fehler in der *alt/neu* Entscheidung nahmen im langen Intervall zu (Raten richtiger Erinnerungen: kurzes Intervall 87.3 %, langes Intervall 85.9 %, Raten falscher Erinnerungen: kurzes Intervall 17.7 %, langes Intervall 21.3 %, Raten falscher *alt*-Antworten auf NEU-Items: kurzes Intervall 1.6 %, langes Intervall 2.0 %). EKPs für richtige Erinnerungen zeigten in beiden Intervallbedingungen frühe frontale EKP-Effekte. Dagegen konnte für falsche Erinnerungen nur im kurzen, nicht aber im langen Behaltensintervall eine frühe frontale Positivierung festgestellt werden. Illusorische Vertrautheitsprozesse scheinen damit im langen Behaltensintervall keine Rolle für die Entstehung von falschen Erinnerungen zu spielen. Dagegen wird angenommen, dass eine Verschlechterung der itemspezifischen Erinnerungsspuren im langen Intervall auch zu einer Abnahme der Vertrautheit führt.

Neben dem frühen frontalen *alt/neu*-Effekt zeigten richtige Erinnerungen in beiden Behaltensintervallen auch späte rechtsfrontale Positivierungen gegenüber richtigen Zurückweisungen von NEU-Wörtern. Obwohl in den vorherigen Experimenten späte rechtsfrontale Effekte auch für falsche Erinnerungen beschrieben wurden (nicht jedoch für die Gruppe der Probanden mit wenig falschen Erinnerungen in Experiment 2), konnte eine solche Positivierung in Experiment 4 nicht nachgewiesen werden. Dagegen zeigte sich eine späte parietale Negativierung für falsche Erinnerungen. Ein ähnlicher Effekt fand sich auch in Experiment 2 für die

Gruppe der Probanden mit wenig falschen Erinnerungen sowie in Experiment 3 für die Itemgruppe. Diese Negativierung konnte in einer Dipolmodelierung mit einer Aktivität im Anterioren Cingularen Cortex (ACC) assoziiert werden, die in vergleichbaren fMRI-Studien für falsche Erinnerungen im Vergleich zu richtigen Zurückweisungen von NEU-Wörtern gefunden wurde.

Da dem ACC u. a. eine wichtige Rolle bei Prozessen der Fehlerentdeckung zugeschrieben wird (Dehaene, Posner & Tucker, 1994) und die parietale Negativierung in Experiment 2 und 3 nur bei fehlerhaften Reaktionen auftrat, ist ein Beitrag reaktionsrelatierter Komponenten wie der fehlerrelatierten Negativität wahrscheinlich (Error-Related Negativity, ERN, Gehring, Goss, Coles, Meyer & Donchin, 1993). Tatsächlich wurden für reaktionsrelatierte EKPs ERN-ähnliche Negativierungen für falsche Erinnerungen gefunden. Etwas schwächer traten diese Negativierungen allerdings auch für richtige Erinnerungen auf. Dies scheint in Übereinstimmung mit neueren Annahmen zur ERN zu stehen. Es wird postuliert, dass in der ERN nicht ein Fehler an sich, sondern der Mismatch zwischen einer internen Vorstellung über die richtige Antwort und der tatsächlichen Antwort reflektiert wird (Coles, Scheffers & Holroyd, 2000; Scheffers & Coles, 2000). Unterschiede in der Topographie und der Amplitude der Negativierung für richtige und falsche Erinnerungen werden außerdem mit erhöhten kognitiven Anforderungen bei der Beurteilung von LURE-Wörtern in Verbindung gebracht.

Dies steht in Übereinstimmung mit neuere Annahmen zur funktionellen Bedeutung des Frontallappens. Diese gehen davon aus, dass der ACC und der rechte frontale Kortex bei kognitiv anstrengenden Aufgaben zusammenarbeiten (Bush et al., 1998; Dehaene, Kerszberg & Changeux, 1998). Die Modelle gehen davon aus, dass diese Strukturen zu einem Netzwerk von Hirnarealen gehören, die mit Prozessen der Aufmerksamkeit, der Reaktionsauswahl sowie der motorischen Planung und Durchführung assoziiert sind. Ergebnisse der Experimente dieser Studie weisen darauf hin, dass der ACC und rechtsfrontale Hirnareale auch bei falschen Erinnerungen zusammenarbeiten. Dies scheint insbesondere dann aufzutreten, wenn die Aufgabe durch eine spezielle Berücksichtigung von itemspezifischer Information aus der Lernphase erschwert wird. Da für nicht gelernte LURE-Wörter nur itemspezifische Informationen aus der internen Generierung vorliegen, nicht jedoch vom tatsächlichen Lernen, sollten unter solchen Bedingungen Anwortkonflikte oder Zustände erhöhter Unsicherheit entstehen. Es wird angenommen, dass diese von dem ACC erkannt und den Strukturen des rechten frontalen Kortex mitgeteilt werden. Diese Areale sind dann für die Implementierung zusätzlicher strategischer Prozesse verantwortlich, um den Zustand der Unsicherheit zu reduzieren. Ein solches Zusammenspiel von ACC und rechtsfrontalen Gehirnstrukturen würde eine mögliche Interpretation für die uneinheitlichen Befunde zu den späten rechtsfrontalen *alt/neu*-Effekten sowie den späten parietalen Effekten bereitstellen. Um diese Annahme zu bestätigen sind allerdings fMRI-Studien notwendig, die eine reliablere Lokalisierung von Aktivierungen im Kortex als EKP-Studien erlauben.

Das Strukturen des rechtsfrontalen Kortex an Prozessen beteiligt sind, die falsche Erinnerungen versuchen zu verhindern, konnte in Experiment 5 bestätigt werden. In dieser Studie wurden Patienten mit Frontallappenläsion unterschiedlicher Topographie untersucht. Patienten mit bi- oder linkslateraler Läsion im frontopolaren Kortexbereich zeigten keinen überproportionalen Anstieg falscher Erinnerungen im Vergleich zu gesunden Kontrollprobanden. Ein solches Ergebnis wurde nur bei einem Patienten beobachtet, der unter einer ausgedehnten rechtshemisphärischen Läsion litt, die den posterioren Anteil des Gyrus frontalis medialis und des Gyrus frontalis inferior einschloss. Diese Gehirnregionen war auch beim Patienten B.G. lädiert, für den ebenfalls hohe Raten falscher Erinnerungen berichtet wurden. Es wird geschlussfolgert, dass pathologisch erhöhte Raten falscher Erinnerungen kein generelles Merkmal von Frontallappenläsionen sind, sondern dass dem rechten posterioren frontolateralen Kortex eine zentrale Rolle bei der Kontrolle des itemspezifischen Erinnerns zukommt.

9.4 Schlussfolgerung

In der vorliegenden Arbeit wurden behaviorale und elektrophysiologische Korrelate falscher Erinnerungen untersucht und zu denen richtiger Erinnerungen in Bezug gesetzt. Als Reizmaterial wurden Substantive aus verschiedenen Kategorien benutzt, die eine bessere Vergleichbarkeit der ALT- und LURE-Wörter gewährleisten als die Items der Deese-Listen. Zusammenfassend lassen die Befunde darauf schließen, dass richtigen und falschen Erinnerungen gleiche Prozesse zugrundeliegen. Dies unterstützt Modelle, die einen rekonstruktiven Charakter des Gedächtnisses postulieren. Es konnte jedoch auch gezeigt werden, dass sich elektrophysiologische Korrelate falscher Erinnerungen unter speziellen Bedingungen von denen richtiger Erinnerungen unterscheiden lassen. Die EKP-Daten legen nahe, dass neben der Rate falscher Erinnerungen die strategischen Prozesse in der Lernphase wichtige Bedingungen für das Entstehen von elektrophysiologischen Unterschieden zwischen richtigen und falschen Erinnerungen sind. Es konnte weiterhin gezeigt werden, dass ein Anstieg der Rate falscher Erinnerungen nicht immer auf einen Anstieg des Gefühls von illusorischer Vertrautheit zurückgeht. Außerdem konnte die Rolle des Frontallappens bei Erinnerungsprozessen bestätigt werden. Besonders wichtig für das itemspezifische Erinnern scheinen der posteriore Anteil des Gyrus frontalis medialis und des Gyrus frontalis inferior zu sein. Weiterhin legen die Befunde eine Involvierung des ACC bei falschen Erinnerungen nahe. Diese Struktur scheint dann innerhalb eines kortikalen Netzwerkes mit rechtsfrontalen Gebieten zusammenzuarbeiten, wenn die Unsicherheit bei den *alt/neu* Entscheidungen erhöht wird.

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Stimulus Material

Thirty lists of different categories were used in the present work. Each list includes 10 German nouns. The words were taken from a categorical word pool. This pool was created in a categorical noun generation experiment performed with 139 undergraduate students at the University of Leipzig (107 female), between 18 and 34 years old (mean = 22) (cf. Ullsperger et al., 2000). Words in each list are ordered with respect of the totalized number of generation by the different participants. The number of generations is given for each word.

Ein Baum	
Eiche	131
Ahorn	97
Tanne	91
Buche	78
Kiefer	73
Fichte	65
Birke	64
Linde	59
Erle	46
Pappel	29

Ein Beruf	
Lehrer	90
Arzt	73
Maurer	51
Verkäufer	42
Maler	41
Bäcker	34
Tischler	28
Friseur	25
Elektriker	19
Klempner	18

Eine Blume	
Rose	119
Tulpe	113
Nelke	103
Narzisse	54
Aster	39
Veilchen	31
Gerbera	30
Margarithe	28
Lilie	22
Orchidee	19

Ein Fahrzeug

Auto	124
Fahrrad	107
Bus	91
Motorrad	83
Zug	60
Moped	55
Schiff	16
Mofa	11
Traktor	10
Kutsche	6

Ein Familienangehöriger

Mutter	138
Vater	138
Onkel	132
Tante	132
Bruder	128
Schwester	128
Oma	114
Opa	114
Cousine	80
Cousin	68

Ein Fisch

Karpfen	93
Forelle	79
Aal	70
Hai	64
Hecht	60
Hering	56
Lachs	46
Barsch	32
Flunder	32
Makrele	32

Eine Frucht

Apfel	128
Birne	108
Banane	99
Kiwi	80
Kirsche	78
Orange	66
Pflaume	65
Ananas	62
Mango	41
Mandarine	38

Eine Fußbekleidung

Stiefel	103
Schuh	96
Sandale	95
Socke	77
Strumpf	69
Pumps	30
Pantoffel	24
Stiefelette	11
Schlappen	7
Mokassin	6

Ein Gebäudeteil

Dach	93
Fenster	85
Tür	83
Keller	65
Balkon	44
Treppe	44
Zimmer	43
Flur	39
Eingang	32
Erker	32

Ein Gemüse

Tomate	76
Gurke	73
Möhren	70
Brokkoli	49
Erbsen	47
Kohlrabi	45
Bohne	39
Kartoffel	34
Zucchini	24
Aubergine	22

Ein Gewürz

Pfeffer	138
Oregano	66
Basilikum	56
Curry	54
Majoran	43
Kümmel	40
Zimt	40
Muskat	35
Anis	26
Thymian	22

Ein Insekt

Biene	114
Fliege	103
Mücke	88
Wespe	77
Ameise	61
Hummel	52
Käfer	44
Hornisse	42
Spinne	42
Libelle	39

Ein Kleidungsstück

Hose	139
Jacke	113
Hemd	94
Rock	78
Pullover	65
Bluse	64
Kleid	53
Mantel	43
Schal	30
Mütze	29

Ein Körperteil

Bein	133
Arm	132
Fuß	118
Kopf	116
Finger	109
Hand	106
Zeh	88
Nase	84
Hals	50
Mund	40

Ein Küchengerät

Mixer	97
Messer	59
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Herd	40
Löffel	38
Gabel	36
Toaster	32
Quirl	30
Pfanne	26
Sieb	16

Ein Metall

Eisen	122
Kupfer	82
Silber	80
Gold	76
Stahl	73
Blei	55
Zink	48
Zinn	33
Platin	29
Nickel	18

Ein militärischer Rang

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Gefreiter	79
General	68
Leutnant	64
Major	54
Soldat	51
Oberst	49
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Ein Möbelstück

Tisch	134
Stuhl	132
Schrank	128
Sessel	99
Bett	89
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Regal	66
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Klavier	101
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Trommel	44
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Eine natürliche Landschaft

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Wiese	57
See	57
Berg	54
Meer	52
Wüste	41
Tal	38
Fluß	28
Feld	20
Steppe	19

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Cola	114
Tee	102
Saft	98
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Kaffee	81
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Papst	103
Priester	79
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Kuh	61
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Ein Spielzeug

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Puzzle	25
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Fink	83
Star	82
Drossel	81
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Elster	38
Taube	36
Rabe	25
Papagei	24

Ein Werkzeug

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Zange	83
Säge	79
Feile	48
Bohrer	45
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Nagel	16
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Selbständigkeitserklärung

Mit der Vorlage dieser Arbeit unterziehe ich mich erstmalig einem Promotionsverfahren. Die vorliegende Arbeit wurde von mir selbständig und ohne unzulässige Hilfe oder Benutzung anderer als der angegebenen Hilfsmittel angefertigt. Die aus anderen Quellen wörtlich oder inhaltlich übernommenen Gedanken wurden in der Arbeit als solche kenntlich gemacht. Insbesondere wurden alle Personen erwähnt, die an der Entstehung der vorliegenden Arbeit beteiligt waren. Ich versichere, dass Dritte von mir weder unmittelbar noch mittelbar geldwerte Leistungen für Arbeiten erhalten haben, die im Zusammenhang mit der vorgelegten Dissertation stehen. Weiterhin versichere ich, dass die vorgelegte Arbeit weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde zum Zwecke einer Promotion oder eines anderen Prüfungsverfahrens vorgelegt wurde.

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